Ecology and Conservation of Avifauna of Some Forested Areas in Gujarat, India

Thesis submitted to

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Doctor of Philosophy in Wildlife Science

By

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CERTIFICATE

I have great pleasure in forwarding the thesis of Mr. Pranav Gautam Trivedi titled "Ecology and conservation of avifauna of some forested areas in Gujarat, India", for accepting the degree of Doctor of Philosophy in Wildlife Science from the Saurashtra University, Rajkot. This study was carried out by Mr. Pranav Trivedi under my supervision and has not been submitted in part or full to any other University /Institute for the award of any degree. He has put in seven terms of research work under my supervision.

Forwarding through,

Head
Department of Biosciences
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V. C. Soni
Guiding Teacher

DECLARATION

The thesis carries the research work carried out by me at the Department of Biosciences, Saurashtra University, Rajkot, is submitted to the Saurashtra University and the results of this work have not been submitted to any other University for the award of Doctor of Philosophy.

Date:

Place: **Pranav Trivedi**

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Dedicated to...

three generations of naturalists, who have touched my life...

Lavkumar Khacher

educationist, guide and philosopher

Mihir Dave

a companion and co-explorer to the world of nature

Aakash & Aroovi

my future hopes, to make a difference to the world....

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Pranav Trivedi (20-06-2006)

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Chapter 1

INTRODUCTION

1.1 AVIAN EXTINCTIONS AND HUMAN ENVIRONMENT

One in eight of the world's birds or 1,211 species out of about 10,000 species found worldwide are globally threatened with extinction (BirdLife International 2004). About 150 species of birds have gone extinct from the earth in the last 500 years - a rate of one species extinction every 3.3 years. At present, 179 species of birds are critically endangered i.e. facing a high risk of extinction in the immediate future (BirdLife International 2004). Extinctions and threatened status of many bird taxa is alarming because these reflect the global trends of human interference in all ecosystems of the world; be it high use of pesticides, global trade in animals and their parts or unsustainable forestry to meet human needs of timber, paper and rubber. Birds are good (though not perfect) indicators of environmental quality and environmental changes such as intensive farming practices, unsustainable forestry and habitat fragmentation (BirdLife International 2004). Birds also play crucial roles in forest ecosystems as seed dispersers, pollinators, regulators of the numbers of potential crop pests such as insects and rodents and as prey of several predatory mammals, birds and some reptiles (see Otvos 1979, Snow 1981, Howe and Smallwood 1982, Herrera 1985, Stiles 1985). Being one of the megadiversity countries (Gadgil and Rao 1998) and harbouring two global biodiversity hotspots and seven endemic bird areas of the world (Grimmett *et al*. 1998), India has about 12 % (1,224 species) of the world's avifaunal richness. Of these, 141 species are endemic to the Indian sub-continent (Grimmett *et al*. 1998) and 50 species are endemic to

India (Dasgupta *et al*. 2002). The process of avian impoverishment has been observed in India too. India's avifaunal richness is in jeopardy as 78 bird species of the country are threatened with extinction, while another 52 are near threatened (Islam and Rahmani 2002).

1.2 BIRD COMMUNITY ECOLOGY: AN INTRODUCTION

Bird community ecology has occupied an important place in mainstream ecological research for several decades. This pursuit has contributed in a major way to the conceptual and theoretical framework of community ecology as a whole (Wiens 1983, Karr 1983). Along side, bird community studies have paved the way for conservation of species and their habitats. Several bird community studies have shown impacts of anthropogenic activities on ecosystem health and avian species (e.g. Temple and Cary 1988, Raman 1995, Mehta 1998, Castellatta *et al*. 2000, Peres 2000, Freemark and Kirk 2001, Raman 2001, Laurance *et al*. 2002, Gutzwiller and Barrow 2003).

Avian community ecology has a fairly long history in the northern hemisphere and some parts of the Neotropics (see Wiens 1989 for a review). But, in the old world tropics such studies are few and relatively recent. Considering the wealth of bird species and the diversity of habitats, studies on forest bird communities are few in India. A review of published literature revealed that these studies were largely confined to the southern Western Ghats and Himalayas, while few were carried out at scattered locations in the peninsular India. Several of these studies focused on small subsets of the communities such as specific guilds/taxa (e.g. Davidar 1979 - nectarivores, Santharam 1995 - woodpeckers, Vijayan 1984 - drongos) and mixed-species flocks (e.g. Robin and Davidar

2002, Sridhar 2005). Others looked at ecological patterns of distribution, abundance and richness of all or several forest-dependent bird species at a location (e.g. Gaston 1978, Rao 1988, Daniels 1989, Worah 1991, Bhushan 1994, Johnsingh and Joshua 1994, Raman 1995, Javed 1996, Singh *et al*. 2000, Raman 2001). There were only a few studies that compared the bird communities of two or more sites (e.g. Worah 1991, Mehta 1998, Raman 2001, Jayson and Mathew 2002, Price *et al*. 2003). Noteworthy bird community studies in the eastern forest belt of Gujarat include those of Worah (1991) and Singh *et al*. (2000) who studied the impacts of forest fragmentation on bird communities in Dangs and overall richness, abundance and distributional patterns of bird species at Vansda National Park respectively.

1.3 GUJARAT: A MAJOR AVIAN AREA

Gujarat is a major avian area of the world (Khacher 1996). It is a major wintering ground for the Demoiselle Crane (*Anthropoides virgo*) and Common Crane (*Grus grus*), important stronghold of the resident Sarus Crane (*Grus antigone*), and a crucial nesting area for the Greater and the Lesser flamingos (*Phoeniconaias* spp.). Its location on the Indus Flyway - an important route for migratory birds and presence of a wide variety of habitats make it an important place on the ornithological map of India. Further, the State boasts of a rich tradition supporting conservation of birds. Together, these factors have shaped a rich avian diversity. The State boasts of nearly 525 species of birds (Parasharya *et al.* 2004). Gujarat also has a rich history of bird watching and ornithology. The rulers of the erstwhile States of Bhavnagar, Jasdan, Kachchh-Bhuj, Jamnagar, Wankaner, Vansda and Baroda took keen interest and contributed greatly in the development of this

field in the State. There are also a large number of amateurs involved in bird watching in different parts of the state, who have documented its avifauna in literature in their respective capacities. Khacher (1996) has provided a review of development of ornithology in the state highlighting the contributions of various sections of the society. He also provided an overview of the avifauna of Gujarat in terms of occurrence and status although for the eastern forest belt (referred to below), the information is sketchy.

1.4 THE 'EASTERN FOREST BELT' AND ITS SIGNIFICANCE

The forested belt from north to south Gujarat, along its eastern side (located roughly between 20^{o} 10' to 24^{o} 31' N and 72^{o} 23' to 74^{o} 12' E), called the "eastern forest belt" (*purva patti*) is the most extensive forest habitat of the State (Khacher 1996, Singh 2001). Four major mountain ranges of India are represented in this area. It has the westernmost parts of the Vindhyas and the Satpuras, southern section of the Aravallis and the northernmost part of the Sahyadris or the Western Ghats. The Western Ghats mountain range is a global biodiversity hotspot (Myers *et al*. 2000). The eastern forest belt of Gujarat also marks the western or northwestern global range boundaries of several moist forest species of the Oriental region (Trivedi and Soni, *in press*). Located in the central highlands, this forest belt is also important for understanding the distribution patterns of patchily distributed forest bird species, as shown by Ali (1950 and 1954-55), who documented range extensions of ten such species through his surveys of Gujarat's eastern forest belt, chiefly in the northernmost Sahyadris and westernmost Satpuras. In spite of all these features, few ornithological studies have been conducted in this region. Thus, from an ornithogeographic and conservation point of view this stretch occupies a high

significance in India. The noteworthy attempts include surveys of Butler (1875, 1876, 1877), Ali (1954-55) and Monga and Naoroji (1983); and studies of Worah (1991), Desai *et al*. (1993) and Singh *et al*. (2000).

1.5 GENESIS OF THE STUDY

Loss, fragmentation and degradation of habitat caused by humans have been regarded as important factors for species extinctions and impoverishment of biota of a region. The eastern forest belt has also witnessed fragmentation and degradation (Singh 2001, Khacher 1996). Singh (2001) showed a loss of 1,782 km^2 of forest area in Gujarat (c. 12 % of the current total forest area of the state) between years 1960 and 2000 to causes such as irrigation projects, agriculture, regularisation of encroachment, mining, road building and industrial purposes. Worah (1991) reported patchy distribution of forests in Dangs with a mean patch size of 28 km^2. She regarded these forests as 'fragmented' due to presence of several teak and bamboo monocultures, many of these fairly young. Organised forestry led to opening up of the forests of Purna Sanctuary and surrounding region through roads and associated anthropogenic disturbances. In the Dangs, between late 19th century to mid 20th century selection felling eliminated large trees and from about 1960s to 1980s, several patches were clear felled and converted into teak monocultures (Anonymous 2001). The forestry operations of thinning and climber cutting removed several associates (with low timber value) of teak as well as lianas (Anonymous 2001). This has led to a change in composition and structure of forests. Tree felling was stopped with a moratorium on green felling in 1987-88 (Anonymous 2001), but harvesting of bamboo on a large scale has continued till date (Trivedi 2003). Worah

(1991) and Singh *et al*. (2000) have also noted local extinctions of Indian Giant Squirrel *Ratufa indica dealbata*, Tiger *Panthera tigris*, Gaur *Bos gaurus*, Smooth-coated Otter *Lutra perspicillata* and Sloth Bear *Melursus ursinus* from the Dangs.

The present study, conducted with this background formed part of two biodiversity studies at Ratanmahal Wildlife Sanctuary (Ratanmahal) and Purna Wildlife Sanctuary (Purna) undertaken by the Gujarat Ecological Education and Research (GEER) Foundation. I visited Ratanmahal (from September 1999 to January 2001) 13 times putting in 32 days of field-work (Trivedi 2001), while 14 visits and 38 days of field-work were put in for Purna from June 2001 to March 2003 (Trivedi 2003). The present study has particular relevance when habitat degradation and fragmentation have been leading to weakening and disruption of ecological services, erosion of human cultural diversity and a general severing of human-nature relationship.

1.6 AIMS OF THE STUDY

The study had following aims.

1. To document and compare the bird communities of the two sites in terms of their structure and organisation.
2. To show distribution patterns of forest avifauna at the study sites, especially with regards to noteworthy species for the state through surveys and intensive study.
3. To determine the status of birds at the study sites, identify susceptible/sensitive taxa, and suggest specific measures for conservation.

1.7 SPECIFIC OBJECTIVES

Specifically I asked the following questions before the study.

- Has the eastern forest belt been explored adequately for bird species records? Can extensive and intensive sampling enlist species not yet documented at the two sites?
- What differences in the bird communities of the two sites can be expected and seen due to differences in forest structure, history and anthropogenic impacts?
- What would determine composition of bird communities at the two sites? Specifically, would these factors be local (competition, vegetation structure and plant species composition, climatic influences etc.) or regional (historical and geographical factors such as barriers, zoogeographic history), or both?
- What are the impacts of forest fragmentation and other anthropogenic influences in terms of avifaunal impoverishment at the two study sites?

1.8 ORGANISATION OF THE THESIS

I have oraganised this thesis in eight chapters, the first being this chapter. The second chapter introduces the two study areas in detail with information on location, climate, geography, significance, vegetation, flora, fauna and human influence. Chapter three deals with the methods employed to collect data in field as well as for analyses. Chapter four concerns the structure and composition of bird communities of the two study sites with reference to species richness, abundance and its consequences, habitat use by birds and guild structure. Chapter five focuses on the composition and structure of mixed-species flocks at the two study sites. The findings of the study in a regional ornithogeographical context are dealt with in chapter six. All the important sightings

including first records, new site records and other noteworthy species encountered during the study have been included in this account. I have also made an attempt to explain the factors affecting distribution of birds in India and particularly in the western part of the country with regards to my data. In chapter seven, I discuss the status of birds, analyse their vulnerability based on ecological and zoogeographic factors, and identify possible local extinctions and sensitive taxa at the two study sites. Finally, in the eighth chapter, I outline threats to bird species and their habitat and propose specific conservation measures.

Chapter 2

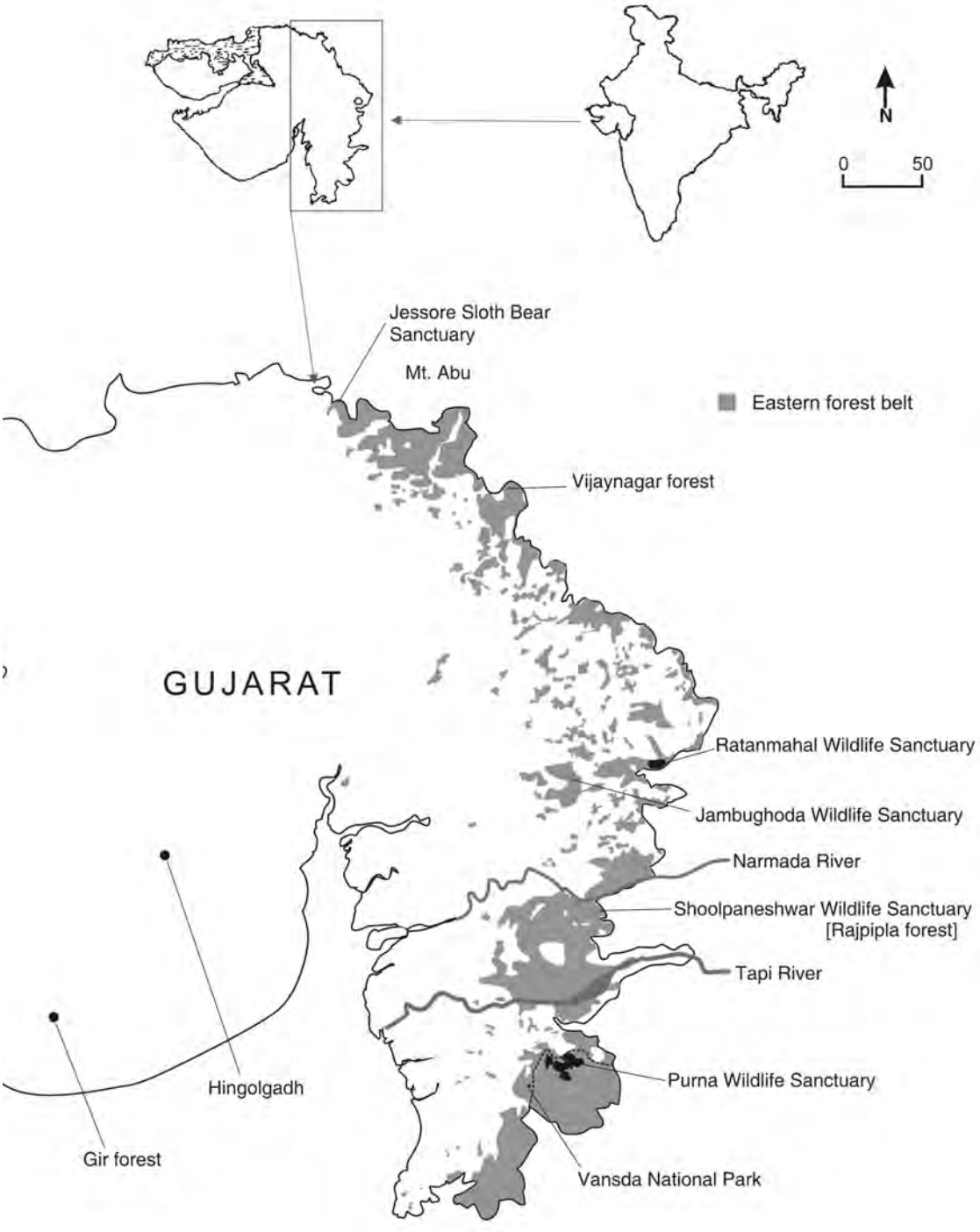
STUDY AREA

Ratanmahal and Purna Wildlife Sanctuaries located in the fragmented eastern forest belt of Gujarat (Figure 2.1) were the study sites, where intensive fieldwork was carried out. Both these forest areas possess significant value in terms of ornithogeography and avifaunal conservation in India (Trivedi 2001, 2003).

2.1 RATANMAHAL WILDLIFE SANCTUARY (RATANMAHAL)

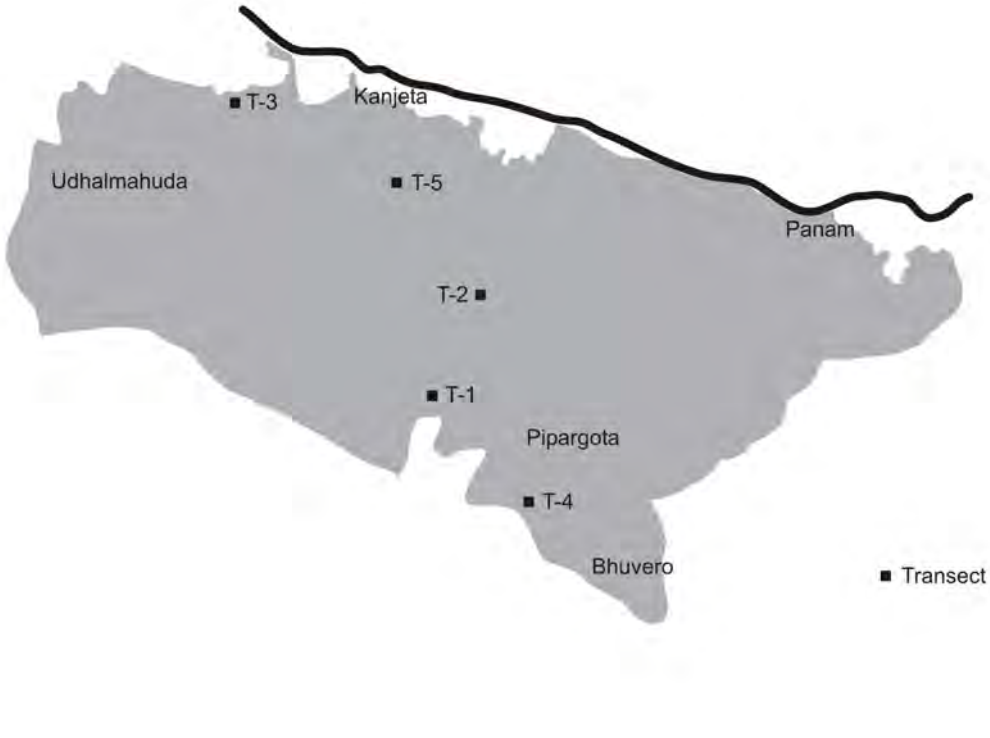
2.1.1 Location and Significance: Ratanmahal (Figure 2.2) lies in Limkheda Taluka of Dahod District along the eastern border of the state of Gujarat. It is located between 74^{o} 03' E to 74^{o} 11' E and 22^{o} 32' N to 22^{o} 53' N. It is spread over an area of 55.65 km^{2}. Its southern and eastern boundaries also form the boundary of the state of Gujarat with the adjoining Madhya Pradesh. Geographically, Ratanmahal lies on the Malwa plateau adjoining the westernmost parts of the Vindhya mountain range. It is located in the Gujarat-Rajwara Biogeographic Zone - 4B as per the classification of Rodgers and Panwar (1988). Ratanmahal is regarded as an important stronghold of a sub-population of the sloth bear (*Melursus ursinus*) - an endangered mammal species of India (Singh *et al*. 2002). Ecologically, its boundaries stretch northwards beyond the Panam River and westwards into the forested hilly tracts of Chhota-Udepur (Vadodara district), Limkheda and Baria talukas. This landscape is dotted with villages and degraded forests. Along its southern and eastern sides are the forests of Jhabua district of Madhya Pradesh state.

Figure 2.1 Locations of Ratanmahal and Purna Wildlife Sanctuaries



2.1.2 History and Land use: Historically, the forests of this region were under the rule of the erstwhile state of Champaner. Under this reign, the local tribal (*Adivasi*) chiefs held on to these forests against the onslaught of the external attacks. Even the British could not exploit the forests of Ratanmahal and its surrounding area as they could in other parts of the state (Singh *et al*. 2002). Until the nineteenth century, the erstwhile state of Devgadh Baria did not take interest in protection and exploitation. With the re-organisation of Devgadh Baria State under the British rule, the Ratanmahal forests were annexed and preserved as a Royal hunting (*Shikaar*) Reserve. The forests were worked according to the Baria State Forest Rules, 1902 (see Singh *et al*. 2002). Some areas were reserved under this and cutting of certain tree species prevented. The forests belonged to two categories viz. reserved blocks and protected blocks. These forests were a major source of revenue in terms of timber, jungle produce, charcoal and miscellaneous produce (Singh *et al*. 2002). To protect this resource, the state had appointed 7 rangers who reported to a superintending inspector. A railway tract was constructed between Piplod and Devgadh Baria to aid in systematic extraction of timber (Singh *et al*. 2002). However, there was no repeated felling owing to the area being a reserve and also because of its inaccessibility. Even before and after the merger of the Devgadh Baria state with the Indian Union, the situation remained more or less same. Further, a scrutiny of past management (historically) reveals that timber exploitation at a commercial scale has not been carried out at Ratanmahal since 1900. Hence the forests have retained a natural character compared to other forests in the same district (Singh *et al*. 2002). A part of these forests were declared a Wildlife Sanctuary in 1982 under the provisions of the Wildlife (Protection) Act, 1972.

Figure 2.2 Ratanmahal Wildlife Sanctuary showing locations of transects



2.1.3 Topography and Geology: Ratanmahal lies at the confluence of Malwa Plateau and Vindhya Ranges. It is characterised by the forested flat-topped hills. The plateaus on hilltops are locally known as 'maal', hence the name Ratanmahal (from original word 'Ratanmaal'). The altitude of the Sanctuary ranges from 230 m to 670 m above MSL. Altitude is lowest in the northern portion where the Panam River abuts the Sanctuary and highest near Pipargota, close to Gujarat-Madhya Pradesh state border. The ridges are rugged and oriented in an east-west direction. Several seasonal streams crisscross the hills; those on the northern slopes leading to the Panam river, while those along the southern slopes flowing into the Orsang river (Singh *et al*. 2002). Ratanmahal thus forms an important catchment for Panam and Orsang rivers. Geologically, the area comprises of pre-Cambrian granites and gneiss with the sedimentary sequence made up of conglomerates and sandstones (mid Cretaceous) covering the eroded surface (Singh *et al.* 2002). The sedimentary rocks are chiefly made up of quartz and rock fragments embedded in sandy and/or clayey matrix. The soil is gravel and depth is high in plains and on hilltops, but low on hill slopes. The pH is either neutral or basic and ranges from 7.3 to 8.2 (Singh *et al*. 2002). The forest soil appears healthy with adequate or good amount of organic carbon and phosphorous and a very high quantity of potash (Singh *et al*. 2002).

2.1.4 Climate: The climate is sub-tropical monsoonal with three distinct seasons viz. winter (November-February), summer (April-June) and monsoon (July-September). The months of March and October mark the transition from winter to summer and monsoon to winter respectively. The temperature ranges from a low of 6.1^{o} C to 44.4^{o} C with the

mean annual temperature being 25.3^{o} C (Singh *et al*. 2002). Mean annual precipitation, mostly in the form of rain is about 1,000 mm. Mist and fog frequently occur during winter and monsoon, particularly in the higher plateau region in southern parts of Ratanmahal. Most rainfall is received through southwest monsoon. In a year, on an average there are about 250 sunny days at Ratanmahal with 10 to 14 hrs a day of solar insolation (Singh *et al*. 2002).

2.1.5 Forest Cover: Dry and moist deciduous forests clothe Ratanmahal. Based on remotely sensed images Singh *et al.* (2002) have identified three major categories of forests based on density of vegetation. In this classification a density of 40 % and above is regarded as *dense forest*, density between 10 and 40 % is *open forest* and that below 10 % is *degraded forest*. The other categories of open habitat include cultivation, water body grass or highly degraded and areas devoid of vegetation. Based on the above (data of 1997), about 68.2 % of the area of Ratanmahal is dense forest, 23 % open forest and 2.7 % degraded forest. Cultivation covers about 5 %. The dense forests lie in Kubero (408 ha), Udhalmahuda (444.8 ha) and Limdi-Mendri (421.6 ha) blocks, while Pipargota (309.3 ha), Bhindol and Panam (less than 200 ha) have less area under such forests (Singh *et al*. 2002).

2.1.6 Vegetation and Flora: The forests of Ratanmahal fall in 4 well-defined sub-types in the classification system of Champion and Seth (1968). These are -

- **Dry teak forests ($5A/C_{1b}$):** Occurs below 400 MSL and more commonly in drier parts of Ratanmahal. Nearly 962 ha of area of Ratanmahal contain this forest sub-type.
- **Southern dry mixed deciduous forests ($5A/C_2$):** A major vegetation type of Ratanmahal and well represented in high hilly regions. *Terminalia crenulata, Lagerstroemia parviflora, Mitragyna parviflora, Tectona grandis, Diospyros melanoxylon, Bassia latifolia, Dalbergia paniculata, Anogeissus latifolia, Butea monosperma, Buchanania lanzan, Alangium salvifolium, Miliusa tomentosa, Syzygium* spp. and bamboo (two species) comprise the chief species.
- **Dry bamboo brakes ($5/E_9$):** On hill slopes, the two bamboo species form congregations known as bamboo brakes. On altitudes beyond 400 MSL, roughly south of an east-west line in the centre of Ratanmahal *Bambusa arundinacea* is found, while in lower and drier portions *Dendrocalamus strictus* is encountered.
- **Southern moist mixed deciduous forests ($3B/C_2$):** At high elevations, this forest sub-type occurs although it is in low proportion. The main tree species include *T. crenulata, Albizzia procera, Adina cordifolia, M. parviflora, D. melanoxylon, Syzygium cumini, Grewia tiliaefolia, Phyllanthes emblica*, and bamboo (*B. arundinacea* as well as *D. strictus*).

Table 2.1 Occurrence of dominant tree species in Ratanmahal

No.	Species	Density (Per ha)	Frequency %	% Composition
1.	*Tectona grandis*	158.1	84.4	19.67
2.	*Lagerstroemia parviflora*	126.2	58.4	15.70
3.	*Terminalia crenulata*	075.7	59.0	09.41
4.	*Diospyros melanoxylon*	061.3	65.3	07.63
5.	*Casearia graveolans*	042.8	42.2	05.32
6.	*Miliusa tomentosa*	042.1	51.4	05.24
7.	*Butea monosperma*	036.6	48.8	04.55
8.	*Anogeissus latifolia*	025.9	36.4	03.23
9.	*Mitragyna parviflora*	022.5	38.4	02.80
10.	*Dalbergia paniculata*	018.2	36.7	02.27
11.	*Cassine glauca*	017.0	26.9	02.11
12.	*Madhuca indica*	016.0	24.9	01.99

(Source: Singh *et al*. 2002)

The floral diversity of Ratanmahal is high with 543 species belonging to 104 families of flowering plants (Singh *et al.* 2002). Of these, 119 are tree species, 40 shrubs, 238 herbs, 48 grasses, 9 orchids and 2 species of partial parasites. The dominant tree species in terms of composition, density and frequency have been shown in Table 2.1. Among shrubs *Holarrhena antidysenterica* dominates, being present in about three fourth of localities surveyed (Singh *et al*. 2002). Other less dominant species with limited frequency (1 to 15 %) and per cent composition (1 to 10 %) are *Zizyphus xylopyra, Helicteris isora, Woodfordia fruticosa, Lantana camara, Carvia callosa and Maytenus emarginata*. Among herbs, *Desmodium laxiflorum, Blumea oxyodonta, Borreria articularis, Cassia tora, Phyllanthes fraternus, Cleome gynandra, Alysicarpus tetragonolobus, Pulicaria wightiana, Blumea lacera, Neuracanthes sphaerostachyus* and

Waltheria indica are the chief elements (Singh *et al*. 2002). Several species of climbers and lianas also occur in the forest. Chief constituents among these are *Hemidesmus indicus, Rhynchosia minima, Dioscorea hispida, Celastrus paniculata, Cissus repanda, Mucuna prurita, Acacia pennata, Combretum ovalifolium, Luffa cylindrica* and *Dolichos trilobus* (Singh *et al*. 2002).

Forest Stratification: The forests of Ratanmahal possess two to three storeys with canopy layer on average being 15 meters and often 20 meters in the moist patches, while in drier parts it is less than 15 meters. Maximum height of some canopy trees reaches beyond 20 meters and in some cases closer to 30 meters (Singh *et al.* 2002). The top canopy is occupied by tree species such *as T. grandis, L. parviflora, T. crenulata, D. melanoxylon, C. graveolens, M. tomentosa, A. latifolia, M. parviflora, D. paniculata, M. indica, Lannea coromandelica, D. latifolia, Garuga pinnata, Ougenia oujeinensis and Garuga pinnata*. The middle storey is made up of medium to small sized trees and woody shrubs; the chief constituents being *Butea monosperma, Wrightia tinctoria, Alangium salvifolium, Cordia gharaf, Xeromphis spinosa* and *Holarrhena antidysenterica*. In the lower storey various shrubs described earlier occur, while the undergrowth was formed by a combination of herbs and grasses. Climbers and lianas are more dominant in moist localities, especially above 400 m. The composition of flora and stratification differed greatly between patches. This has been addressed in some detail under the section of vegetation along transects.

2.1.7 Fauna: Singh *et al*. (2002) have listed 27 species of mammals, 33 species of herpetofauna (10 species of amphibians & 23 species of reptiles) and 176 species of invertebrates including 99 species of spiders and 44 species of butterflies. Sloth Bear (*Melursus ursinus*) - an endangered species is the flagship mammal of Ratanmahal. This area is important in the Malwa landscape for conservation of the species (Singh *et al.* 2002). About ten species of spiders were reported for the first time from this area, while several range extensions including those of some reptile species were also noted (Singh *et al*. 2002). The study showed a high biodiversity potential of Ratanmahal with possibilities of further increase in the list of fauna, particularly among invertebrates.

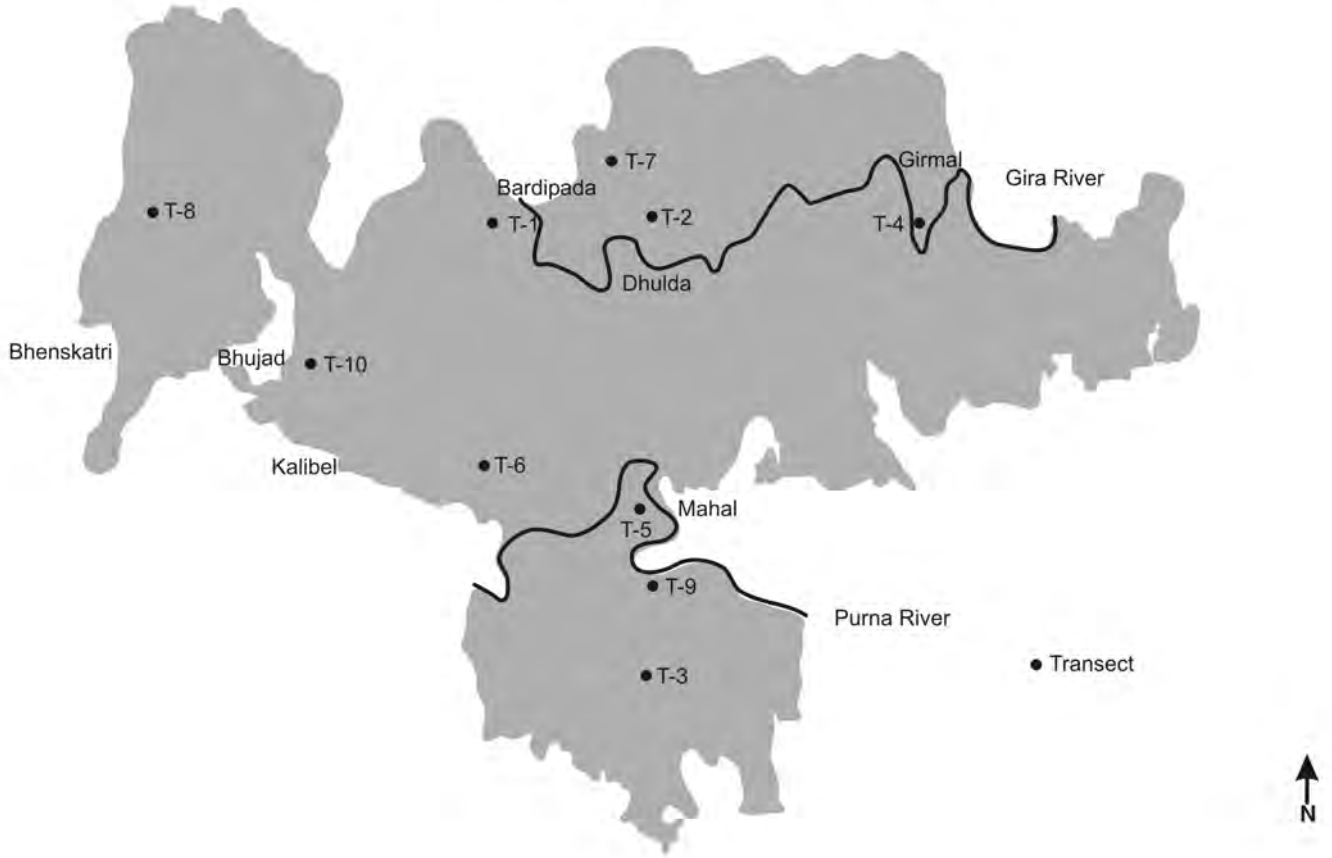
2.1.8 Human Influences: There are 11 villages located within the Sanctuary. Out of these Pipargota, Alindra, Bhuvero, Morai and Kubero are located inside, while Panam, Bhindol, Kanjeta, Limdi-Mendri, Gumli and Udhalmahuda are peripherally located and have some parts within the Sanctuary. About 82 % of the geographical area of Ratanmahal belongs to the Forest Department, while about 15 % is privately owned and the remaining 3 % is classified as communal grazing area (*gaucher*). The tribal population within and around Ratanmahal depends on the forests for several sustenance needs such as fuel wood, fodder, small timber, bamboo for house building and domestic use, fruit, honey and mahuwa (*Madhuca indica*) flowers and seeds. Collection of leaves of *timru* (*D. melanoxylon*) for *bidi* (country cigarette) making is a major activity during summer months. Many local people are involved in it. Most of the population is illiterate and believe in tribal rituals and shaman practices. The major tribe is *bhil* and their sub-castes such as *Rathwa, Koli, Tadvi, Variya, Thanala, Bhuria, Dangi, Parmar, Pawar* and

Nayak (Singh *et al.* 2002). Their main occupation is agriculture, the crops being maize, grams, paddy, millets and groundnut. Except the irrigation reservoir at Udhalmahuda village, there is no irrigation facility in any village, hence agriculture is rain fed. Many people migrate annually as farm labourers to parts of north Gujarat, Saurashtra and Kachchh. The traditional knowledge systems of Ratanmahal are rich and there were several individuals with an in-depth knowledge of plants and animals of the area (*pers. obs.*). People from Bhuvero village are master craftsmen of bamboo-based products. Their bows and arrows, catapults and traditional breweries are reminiscent of a bygone era of a rich agrarian and hunter-gatherer society. About 70 plants with ethno botanical value have been listed by Singh *et al*. (2002). Hunting and poaching of birds and mammals is present, but it is on a low scale.

2.2 PURNA WILDLIFE SANCTUARY (PURNA)

2.2.1 Location and Significance: The Western Ghats have been recognised as a unique and distinct Biogeographic Zone of India (Mani 1974, Rodgers and Panwar 1988). This mountain range along the western edge of the Indian peninsula is of high significance as a global biodiversity hotspot (Myers *et al*. 2000) and an endemic bird area (Grimmett *et al*. 1998). The Western Ghats experience pronounced variation in climate (mainly due to extent of rainfall and dry period), with mean annual rainfall ranging from 2,000 to 7,500 mm (see Raman 2001). The southern Western Ghats receive rains from southwest as well as northeast monsoons (Raman 2001). The northern parts on the other hand have a much longer dry season (almost 7-8 months at Purna, Dangs).

Figure 2.3 Purna Wildlife Sanctuary showing locations of transects



The moister semi evergreen and rainforests are located south of 16^{o} (Raman 2001), while those in extreme northern parts such as Purna (at 20^{o} and 21^{o}) are dry and moist deciduous forests (Champion and Seth 1968). Purna is located between 20^{o} 51' and 21^{o} 01' N and 73^{o} 32' and 73^{o} 48' E in Dangs district of Gujarat (see Figures 2.1 and 2.3) and lies in sub-category 5B (Western Ghat mountains or the *Sahyadris*) of the Western Ghats biogeographic zone (Rodgers and Panwar 1988). It is situated in the northernmost part of this mountain range and lies to the southwest of the westernmost portion of the Satpura mountain range. In biogeographical terms, this has been regarded as a very unique location with the Satpura mountain range believed to have been a pathway for dispersal of Malayan forms to the Western Ghats (Ali 1950). The northern boundary of Purna is also the boundary between Surat and Dangs districts. Purna is bounded to the east, south and west by Protected Forests (PF), revenue areas of several villages and one patch of Reserved Forest (RF). Ecologically, however the area is contiguous in north till the Jhankhri river in Vyara taluka of Surat district, in south till the Khapri river of Dangs district, in West with the Unai range of Navsari district and in east with the hills along Gujarat-Maharashtra state border (Anonymous 2001).

2.2.2 History and Land use: There is a paucity of documentation in terms of history of humans in the Dangs region (Worah 1991). Significant ecological changes seem to have occurred here from early 19th century onwards, following British colonisation as also in case of other parts of the Western Ghats (see Raman 2001). Worah (1991) believed that the *bhils* were the original inhabitants of Dangs with traceable records of their inhabitation from the early 19th century. Hunting and gathering was their means of

survival and settled agriculture was absent. Advent of another tribal group - the *koknis* (arrival year uncertain) brought with it the first agriculture (Patel 1971 quoted in Worah 1991). People of Dangs practiced slash-and-burn agriculture (shifting cultivation) till as late as the end of 19th century (Worah1991). Owing to a low human population of the Dangs district (around 18,000) in 1871 (Worah 1991), it could have been a sustainable system. There were signs by 1891 that the *koknis* were practising settled agriculture. This mainly consisted of lopping the trees within and around the cultivated area, rather than burning or cutting entire trees (Lucas 1892 quoted in Worah 1991).

2.2.3 Forestry and its impacts in Dangs: The forests of Dangs district have a documented history of systematic exploitation in terms of timber since 1800s (see Table 2.2). Between 1818 and 1845 the timber harvesting rights were given out to the merchants from Surat by the *bhil* chiefs through Government timber agent appointed by the then British Government (Anonymous 1996-97). A dearth of means of transport and availability of local labour prevented over exploitation of the forests (Worah 1991). Between 1840s and 1880s heavy exploitation of teak, khair and other trees was carried out mainly under the supervision of the *Bhil* chiefs and the Forest inspectors of the British Government (Anonymous 1996-97). Table 2.2 gives the chronology of forest exploitation in the Dangs. Both unsystematic and systematic harvesting of timber took a heavy toll on the forest with most exploitable sized trees already cut. Silivicultural systems included clear felling (in areas with inferior growing stock), improvement felling and selective felling (Anonymous 1996-97, Anonymous 2001). Planting of teak and other species of commercial importance (i.e. *Acacia catechu* and bamboo) in harvested and

other forest areas has changed the composition of flora and forest structure. As a result, several monocultures exist in Purna. The forestry practices of thinning, climber cutting, girdling and felling of 'inferior' species and selective removal of mature or over-mature (generally defined in forestry terms by GBH or available timber in cubic feet) teak trees have contributed to a negative impact on the physiognomy of the forests (Anonymous 1996-97, *personal observation*). Harvesting of bamboo and climber cutting has been going on since the earliest period of commercial use till date (Anonymous 2001).

Against the many negative impacts, certain benefits also accrued due to forestry operations, especially since 1914 when systematic management practices were adopted. The first and foremost was demarcation of forest boundaries and division of the forests into blocks and compartments facilitating better management and protection (Anonymous 2001). Further, the forests were classified as Reserved Forests (RF) and Protected Forests (PF) with management specifications for the respective categories. The prescription of improvement felling gave rise to uneven aged crop (Anonymous 2001). This was beneficial as it left the regenerating forests in a condition approximating the natural forests in terms of structure and age class composition rather than true plantations. Forests of Purna have undergone the above-described changes as part of forestry operations carried out in Dangs. The forests of Dangs were settled and categorised as reserved and protected in 1889 (Anonymous 2001). According to the agreement between tribal chiefs and the British Government as part of the lease, local people were prevented from cultivating inside reserved forests. Lease amount was also increased to compensate for non-cultivation in these areas (Anonymous 2001).

Table 2.2 History of forest exploitation in the Dangs

Period	Control over Forests	Nature of Exploitaion	Role of Local People
Pre 1800	Bhil Chiefs	Low; limited commercial use, unsystematic	Sole Proprieters & users
1818-45	Bhil chiefs,	Selective; mainly of teak, khair and other commercially useful species, unsystematic	Owners dealing with timber merchants
1842-67	Lease (first) between bhil chiefs and the British Government	- do - (forest inspectors supervised); unsystematic	- do -
1867-89	- do -	- do -	- do -
1890-1902	British Govt. with marginal role of Bhil chiefs	Unsystematic, mainly for road construction & demand for marketeable sized timber; heavy illegal harvesting by locals due to their alienation; both forest categories in Purna valley nearly cleared of good timber	Forest demarcation into Reserved and Protected categories, many restrictions on harvesting by locals
1902-1914	British Govt.	Period of rest from the British Govt.; locals continue abuse through cutting & burning	Locals alienated, even evacuated to suit British Govt.'s exploitation plans
1913 onwards	- do -	First management plan by Marjoribanks, systematic working in forests begins	Marginal role, mainly as labour
1949-1960	Bombay State, Govt. of India	Revised working plan, systematic working	- do -
1960-till date	Gujarat state, Govt. of India	- do -; 1966-66 to 1985-86 Mr. Khanchandani's working plan, complete & systematic division of Dangs in forest blocks & compartments; 1973	Marginal role, subsistence level harvesting, commercial

Period	Control over Forests	Nature of Exploitaion	Role of Local People
		onwards Sanctuaries and National Parks created under the Indian Wildlife (P) Act, 1972; working and felling stopped after moratorium on green felling in 1987-88	harvesting of NTFPs, signs of more involvement, JFM

However, this annoyed the local *bhils* and they took to illicit cutting and burning of forests destroying them in the process for almost a decade till the appointment of a Divisional Forest Officer (DFO) with the powers of a First Class Judicial Magistrate in 1911 (Anonymous 2001). The earlier notifications by the British Government were changed and re-issued following the enactment of Indian Forest Act (1927), and subsequent notifications. Majority of PF have been used for cultivation, while the remaining good forests are mainly under the RF category (Worah 1991, Anonymous 1996-97).

2.2.4 Topography and geology: Purna is located in the hilly catchment region of Gira and Purna rivers. The altitude ranges from 130 m above MSL to 574 m above MSL (Anonymous 2001). The eastern portions are higher with the highest point being the W*alu dungar*. The entire PA is hilly, with most hills being flat-topped. The hills of Purna contain Deccan lava flows that overlie the Archaean rocks (Anonymous 2001). These flows were a result of eruptions that occurred about 65 million years ago and spread over 5,00,000 km^2, cooling into basaltic rock (see Raman 2001). The rock formations at Purna are classified as 'plateau basalts' and are uniform in composition (Worah 1991). At places, the trap contains iron, traces of feldspar, otrivine and hornblende; producing the

sharp, red gravel found on hillsides (Khanchandani 1970 quoted in Worah 1991). The soil is black cotton in valleys and lowlands, while on hills it is red soil (Worah 1991). pH of the soil ranges between 6 and 8, but in most localities it is neutral i.e. 6.5 to 7.2 (Anonymous 2001). Two rivers run east west along the northern (Gira river) and southern (Purna river) boundaries of Purna. Both are perennial, but in peak summer, the rivers contain pools of water rather than continuous flow (Anonymous 2001). Drainage is very good with high level of soil erosion in monsoon (Anonymous 1996-97). Both the rivers and some larger streams carry brown coloured water during June to September due to this reason (*pers obs.*). However, several small forest streams contain clear water even after torrential rains indicating the differential impact of vegetation in the areas of rainfall.

2.2.5 Climate: Purna has three distinct seasons. The monsoon (June to October) is heavy with an annual average rainfall of 2,100 mm. (Anonymous 2001); most of which is received during the southwest monsoon. There could be as many as 80 rainy days (Anonymous 2001) with July being the rainiest month (Worah 1991). There are flash floods during heavy rains during every monsoon. Winter (November to February) is the season with temperatures dropping to a minimum of about 8^{o} c., while summers (March to May) have a high of 40^{o} c (Worah 1991, Anonymous 1996-97, Anonymous 2001). Months of October and March are transition periods of monsoon to winter and winter to summer respectively. December and January are the coldest months; May being the hottest.

2.2.6 Forest cover: Based on remote sensing data of 1988 the forest cover in Purna has been shown in Table 2.3.

Table 2.3 Forest Cover in Purna (Anonymous 2001)

No.	Forest Cover Type	Area (in km^2)	% Area
1.	Closed forest (> 80 % crown density)	95.70	50.47
2.	Open forest (30-80 % crown density)	63.76	33.63
3.	Degraded forest (10-30 % crown density)	29.62	15.62
4.	Blank (< 10 % crown density)	00.53	0.28
	Total	**189.61**	**100**

Worah (1991) carried out aerial survey of the Dangs and documented that in western Dangs (where Purna is located), the forest cover was high and coupled with plantations the area under forest vegetation was nearly 58 % compared to only 35 % in eastern Dangs. The tree cover in different habitat categories given by her is shown table 2.4.

Table 2.4 Land use type vis a vis tree cover in Dangs

Land use type	Tree cover (%)
Natural forest	80
Plantations	59
Temporary fields	44
Permanent fields	14

Source: Worah (1991)

It is interesting to note that temporary fields possessed high tree cover and may still provide contiguity in terms of corridors. However, this classification cannot be applied now since the category 'temporary fields' may no longer be valid. Another feature worth noticing is the difference between tree cover percentages of natural forest and plantations. This is mainly because many plantations are young, lacking the tall tree growth - characteristic of the natural forests, even when these are of secondary nature.

2.2.7 Forest types: Worah (`1991) described the forests of Purna as the largest contiguous patch of Reserved Forest remaining in Dangs consisting mainly of secondary dry and moist deciduous forests interspersed with plantations of teak, khair and bamboo. Based on Champion and Seth (1968), the forests of Purna have been classified as -

- South Indian Moist Deciduous Forests (3B/C1) and
- Southern Dry Deciduous Forests

Under these, there are various sub-types such as -

- Very moist teak forests (3B/C1a)
- Moist teak forests (3B/C1b)
- Slightly moist teak forests (3B/C1c)
- Southern moist mixed deciduous forests (3B/C2)
- Dry teak forests (5A/C1b)
- Dry mixed deciduous forests (5A/C3)
- Dry bamboo brakes (5E9)
- Dry tropical riverine forests (5/1S1)

The above forest sub-types correspond to climatic factors, particularly rainfall, moisture regime and terrain. Besides, several old plantations in various growth stages as well as regenerating patches of natural forests once harvested under the selective/improvement felling system render a high degree of heterogeneity to the vegetation of Purna. Ranging from monocultures of teak (*Tectona grandis*) to pure mixed moist deciduous forests; there is a gradient of luxuriance, physiognomy and richness that gives uniqueness to the vegetation. The better areas of the Reserved forests in Purna possess a nearly unbroken canopy, a high diversity of tree species, luxuriant undergrowth, brakes of bamboo and profusion of lianas (Worah 1991). So, although these are of secondary nature due to past exploitation, their structure and stature is as good as what the original forests' would have been (Worah 1991). However, these forests are patchily distributed, not just due to areas of agriculture but also owing to teak and bamboo plantations. This factor has affected their conservation value (Worah 1991). The average canopy height of the forests of Purna is about 20 meters, though certain species attain a height of over 30 meters at some localities. The forest has three to five layers from the canopy to the undergrowth. The chief floral elements have been described in the Management Plan (2001-2010) of Purna Wildlife Sanctuary (Anonymous 2001).

2.2.8 Vegetation and Flora: 131 species of trees, 38 species of shrubs, 78 of climbers, 250 species of herbs (including 13 species of orchids), 2 partial parasites, 5 species of ferns and 47 species of grasses formed its floral diversity (GEER Foundation, *unpublished data*). This implies a total floral wealth of 551 species including the cultivated plants. The canopy is occupied mainly by *Tectona grandis*, *Terminalia*

crenulata, *Ougenia oojeinensis*, *Mitragyna parviflora*, *Lagerstroemia parviflora*, figs (*Ficus* spp.), *Dalbergia* spp., *Albizzia procera*, *Adina cordifolia*, *Dillenia pentagyna*, *Careya arborea*, *Madhuca indica*, *Lannea coromandelica*, *Anogeissus latifolia*, *Garuga pinnata* and *Terminalia bellirica*. The middle and understorey are occupied by *Wrightia tinctoria, Holarrhoena antidysenterica, Butea monosperma, Diospyros melanoxylon, Phyllanthes emblica, Bauhinia* spp., *Zizyphus mauritiana, Z. xylopyra,* bamboo, *Cassia fistula, Trema orientalis, Mallotus philippensis, Oroxylon indicum* and regenrating trees (small to medium size) of the canopy species. The undergrowth consists of *Helicteris isora*, *Carvia callosa*, *Woodfordia fruticosa*, *Carissa carandus*, *Xeromphis spinosa*, *Flacourtia indica*, *Costus speciosus*, *Uraria picta, Azanza lampas*, *Cassia tora*, *Desmodium* spp. etc.

Ground vegetation chiefly comprises of annuals including grasses. The main species include *Lee aspera*, L*eucas biflora*, *Achyranthes aspera*, *Desmodium trifolium*, wild turmeric (*Corauma aromatica*) and several grasses such as *Spodiopogon rhizophorus*, *Panicum montanum*, *Themeda* spp., *Cynodon dactylo*, *Hetropogon contortus*, *Cymbopogon martinii*, *Vetiveria zizanioides*, *Eleusine* spp., *Chloris* spp. and *Polytoca* spp. A characteristic of the Purna forests is preponderance of climbers, especially lianas in better-preserved tracts. The main elements include - *Milletia racemosa*, *Butea superba*, *Vitis repanda*, *Cryptolepis buchanani*, *Wagatea spicata*, *Tinospora cordifolia*, *Ventilago denticulata*, *Mucuna prurita*, *Acacia intensia*, *Abrus precatorius*, various species of yams (*Dioscorea* spp.) and *Acacia coneina*.

2.2.9 Fauna: With over 3,000 species of insects, about 60 species of amphibians and reptiles, over 150 bird species and 30 species of mammals, Purna is one of the richest areas in terms of faunal wealth in Gujarat (Anonymous 2001). However, the mammalian fauna has been impoverished over the past few decades. Purna has witnessed recent (last two decades) local extinctions of the Surat-Dangs race of the Indian Giant Squirrel (*Ratufa indica dealbata*), tiger (*Panthera tigris*), chital (*Axis axis*) and sambar (*Rusa unicolor*). Mammals such as sloth bear (*Melursus ursinus*), dhole (*Cuon alpinus*), smooth-coated otter (*Lutra perspicillata*) and possibly gaur (*Bos gaurus*) were exterminated from the Dangs much earlier (Singh *et al*. 2000). The present mammalian fauna of Purna includes carnivores such as leopard (*Panthera pardus*), striped hyena (*Hyaena hyaena*), small Indian Civet (*Viverricula indica*), lesser cats (could be *Felis rubiginosa* & *F. chaus* and *Prionailurus bengalensis*, see Worah 1991), and mongooses (*Herpestes edwardsii* and *H. smithi*). Other mammals include bonnet macaque (*Macaca radiata*), rhesus macaque (*M. mulatta*), common langur (*Presbytis entellus*), barking deer (*Muntiacus muntjac*), four-horned antelope (*Tetracerus quadricornis*), hare (*Lepus nigricollis*) and Indian flying fox (*Pteropus giganteus*). Several species of bats and rodents occur, but have not been documented. Most mammals exist at very low densities as shown by direct (vehicle transects & search lighting) as well as indirect methods (Worah 1991).

2.2.10 Human influences: There are 26 villages on the periphery of Purna exerting human impact in various forms such as agricultural practices, livestock grazing, legal as well as illegal removal of timber and non-timber forest produce (NTFP), fishing,

poaching and man-made fires. These villages have a human population of about 14,000 and livestock population of about 11,500 (1991 figures, Anonymous 2001). Considering the average annual growth rate of 2.6 % for Dangs as a whole, the present human population would be close to 20,000 and that of livestock more or less the same. Other villages located farther from Purna also derive parts of their requirements from Purna (*pers obs.*). A village here typically consists of about 70 to 80 households, some being far smaller and few larger. None of the villages use cooking gas, very few have stoves; thus most people collect and use firewood - undoubtedly the largest NTFP being collected from the forest. The old practice of stacking the firewood before monsoon and in general throughout the year is followed till date. Majority of villagers who own land were found engaged in farming. Large farms are rare as a rule probably owing to a combination of terrain and traditional hunting-gathering mode of life. There is no centrally planned irrigation system and all agriculture is rain-fed. Very few farmers have bore wells. Since most people take maximum two crops a year (e.g. paddy and maize/*naagli* – a local millet), they are relatively free of farming related work during October to April when some go as labourers to adjoining Vyara and Songadh areas for sugarcane cultivation. It is also during this period that some people are engaged in harvesting forest resources such as bamboo, NTFP, honey and even poaching. Indeed, it is difficult to find a *Dangi* without axe and catapult. The catapult is mainly used to hunt birds. Fishing is also a major activity although the small size and quantity of fish prevent this from becoming full-time activities. Several unique and indigenous methods are employed for fishing and hunting by the *Dangi* tribals.

The next major impact to wood collection and grazing of livestock is lopping of trees in fields and surrounding forest areas for rab burning. This is a traditional farming practice involving burning of a pile of leaves and twigs of the lopped trees in a small area of the field to facilitate good growth of seedlings of *nagli*. These seedlings are then transplanted. Use of fertilisers or pesticides for farming is virtually non-existent in Dangs. Rather surprising in an industrial state, there is no industry in Dangs except a negligible handicrafts trade. In the present scenario, many *Dangis* have joined the mainstream and taken up Government jobs. Most have reduced or left consumption of country liquor, partly due to the influence of Christian missionaries. Proper schooling coupled with good public transport and health facilities has influenced their way of life and not taken them to cities as compared to other tribal areas.

Chapter 3

METHODS

3.1 RECONNAISSANCE

Reconnaissance has been regarded as a powerful tool to get baseline information (Rodgers 1991) about Protected Areas. I used this method to familiarise myself with the study areas, their environs and anthropogenic activities. The first few visits were used for reconnaissance when I traversed the existing jungle paths that passed through a range of terrain and vegetation types at the study sites and their ecological neighbourhoods. Attention was paid to specific spots along these paths that were known to be rich or unique for wildlife (as informed by the local guides). Precincts of human habitation were also surveyed. Perennial and ephemeral water sources were located with the help of local guides. All the habitats along the tar and dirt roads were surveyed extensively. The reconnaissance helped in obtaining a broad picture of the avian habitats and generated a preliminary checklist of birds. This information was compiled and used as baseline data on which the intensive study was planned.

3.2 INTENSIVE STUDY

Reviewing the existing literature (e.g. Verner 1985, Daniels *et al*. 1990, Raman 2001), considering the aims of the study and hilly terrain, line transects of open width without distance estimates (see Verner 1985) were chosen for the intensive study. Due to large size (for Purna) of the study areas, two other complementary sampling approaches were adopted for intensive study. These approaches - long trails along the existing jungle paths

and visits to specific spots differed in terms of the scale of information that each generated.

3.2.1 Transects: After the initial surveys, transect localities were chosen based on their habitat features and extent of human influences. Besides, feasibility for repeated sampling was also considered for selecting these locations. Five line transects in Ratanmahal, each of 1 km length; and ten line transects at Purna varying in length from 1 to 3.5 km were walked during the study. Salient features of these transects have been outlined in Appendices 3.1 and 3.2. Locations of these transects are shown in figures 2.2 and 2.3. Table 3.1 gives the details of sampling effort at the two sites. At Ratanmahal, four transects (T-1, T-2, T-4 and T-5) were walked six times; while transect T-3 was walked seven times. At Purna, transects T-1 and T-2 were walked six times each; followed by T-3 which was walked five times; T-4, T-5 and T-6 three times each; T-7, T-8 and T-10 two times each and T-9 was walked once.

Table 3.1 Sampling effort through line transects for avifauna study at Ratanmahal and Purna Sanctuaries, Gujarat

Sampling Season	Frequency Ratanmahal	Frequency Purna	Total
Monsoon (July – September)	7	3	10
Winter (October – February)	9	23	32
Summer (March – June)	15	7	22
Total Samples	**31**	**33**	**64**
Total Length (km)	**31**	**53**	**84**

The line transects were walked twice a day i.e. once each between 06:45 to 10:00 hrs. and 16:00 to 18:45 hrs. The exact timings varied based on seasonal changes in light conditions and intensity of bird activity. Transects were walked in all three seasons.

The parameters recorded on transects were-

- Name of the Bird Species
- Time of Sighting
- No. of Birds (Male, Female, Juvenile & Total)
- Habitat (Vegetation category, Edge +/-)
- Vertical location of the bird (s) (in 0-1, 1-3, 3-8, 8-15 & >15 m categories)
- Activity
- Bird calls
- Any other relevant information

Each call was treated as a separate sighting and was considered for data analysis at par with actual sightings. Unless the number of calling birds was clearly discernible, each call was treated as one bird in terms of numbers. Binoculars of 8 X 40 were used during the reconnaissance period. For intensive study, 12 X 50 binoculars were used. Generally, one assistant who was well worse with the area as well as birds accompanied me during the entire study. A pedometer was used to measure the distance walked on trails. The nomenclature (both common and binomial names) and systematic order of bird species and families follows Grimmett *et al*. (1998). Due to difficulty in identification of migratory *Phylloscopus* warblers in flocks to species levels, these were treated as one species (leaf warbler) for the purpose of analysis.

3.2.2 Trails (2 to 8 km length): Existing forest trails/ paths in different parts of the Sanctuary were traversed frequently with a view to increase the sampling effort. This ensured greater coverage of the area, thus allowing access to a wider variety of habitats. The approach generated qualitative data on different bird species seen. Trails were walked in mornings and afternoons, however their duration varied and was generally longer than transects (over three hours for some). At Purna, 11 trails were walked 24 times (75 km length), of which 15 were during morning and the remaining 9 during evening. At Ratanmahal there were eight trails that were walked.

3.2.3 Bird watching at specific spots: This approach comprised of intensive bird watching in a small area (spot) on a regular basis. Spending more time in a small area offered advantages that an extensive study method like trails or transects would not provide. The spots were visited during late mornings, afternoons and late evenings in addition to early morning and evening times. Four such spots were identified at Purna viz. (I) Preservation plot (compt. # 56) (ii) Dhulda old campsite area (compt. # 52) (iii) Borumal (compt. # 60) and (iv) Sawardakasad along Purna river (compt. # 165). These were localities with moist deciduous forest and *katas* bamboo (*Bambusa arundinacea*) that offered potential for sighting species of moist forest areas of the Western Ghats. For Ratanmahal the spots visited on a regular basis were Udhalmahuda Reservoir (for aquatic birds), Pipargota Rest House (RH) precincts (altitude c. 600 m), Kanjeta RH precincts (altitude c. 350 m) and Popatkuwa forest area (altitude c. 550 m).

3.2.4 Nocturnal bird study: For recording nocturnal birds such as owls and nightjars, night trails (by vehicle as well as on foot) were conducted. Intermittent stops were chosen to listen to the sounds of nocturnal birds. Besides, specific spots were visited between 18:30 to 19:30 hrs to listen to their calls. Five nights were spent out in the forest in different areas of Purna. These spots were chosen in compartment numbers 60, 65, 4, 164 and 61. Each spot varied with reference to its topography, moisture conditions, vegetation and flora. I remained at the site from 18:30 hrs to 7:00 hrs next morning. All the calls heard during this period were noted. Intermittently, walks of about 1 km were conducted paying attention to the sounds and looking for movement or bird sightings. At Ratanmahal, owing to safety reasons, instead of night outs, different times of the night were spent at various spots on the plateau and Popatkuwa areas.

3.2.5 Mixed-species flocks: Observations were made along the line transects and during monitoring along existing trails or at specific spots where flocks were opportunistically encountered. When encountered on transects, I recorded all visible individuals of mixed flocks and their vertical location (in categories of 0-1, 1-3, 3-8, 8-15 and >15 m) in vegetation. I did not follow flocks when encountered on transects but some flocks were followed on trails. Behavioural observations were made on flocks opportunistically. The mixed-species flocks of the two areas shared many common features as the study sites lie close to one another and also shared several species of birds (Trivedi 2001, 2003). Hence, I pooled the data of two sites except when discussing specific aspects of the flocks of two areas.

3.2.6 Vegetation study: Floral composition and broad vegetation types were noted along all the transects. Chief tree species were used to denote the vegetation type along with

terrain features. Visual estimation of canopy height, vertical strata in vegetation and luxuriance (based on dry/moist gradient) were also made.

3.3 DATA ANALYSIS

3.3.1 Bird abundance: The abundance of birds was determined based on their encounter rate on transects. Encounter rate was derived by the number of individuals of a species divided by the distance covered. Mean encounter rate was the average of mean encounter rates of each transect at each site for each species. Thus, sample sizes for mean encounter rates were ten and five for Purna and Ratanmahal respectively. Relative abundance (RA) was calculated as the proportion of individuals of a species in the total number of individuals of all species encountered on all transects at a site.

3.3.2 Avifaunal impoverishment and status of birds: To assess changes in the status of forest birds over time at Purna, I used two past data sets: Ali (1954–1955) and Worah (1991). There have been no previous surveys at Ratanmahal, so a detailed assessment of avifaunal changes here was not possible. Instead, I depended on secondary information collected from local residents and on previous observations made by me during 1989–1991. To maximise my chances of detecting rare species, I searched intensively in all habitats and searched specifically for such species. I categorised the distribution (widespread or patchy) and nature of habitat occupancy (forest-interior, edge, open area, etc.) for species using Ali (1969), Worah (1991) and Grimmett et al. (1998). Feeding guilds were assigned based on the literature (Ali 1969, Grimmett et al. 1998, Raol 1998) as well as my own observations in the field. I classified the foraging guilds of all bird

species encountered at the two sites based on existing literature (Ali 1954-55, Ali 1969, Grimmett et al. 1998, Raol 1998) as well as my own observations. Bird species susceptible to forest alteration and loss were identified primarily based on rarity (mean encounter rates <0.5 individual/km) and habitat specificity (forest-interior species and species preferring moist deciduous forest). This information was compared with published literature documenting susceptible taxa in the Oriental region (e.g. Johns 1986, Worah 1991, Mitra and Sheldon 1993, Raman 1995, Datta 2000, Castelletta et al. 2000, Raman 2001).

3.3.3 Mixed-species flocks: Flocking propensities were calculated as the percent times (sightings/occurrences) a species was found in mixed flocks out of the total number of its occurrences on transects or were derived by using number of individuals in place of number of sightings/occurrences.

3.3.4 Statistical analyses: Since the data collected varied in scale and frequency distribution, more stress was laid on using non-parametric tests to detect the statistical significance of observed patterns. Further, I carried out exploratory data analyses to detect patterns. I used Siegel (1956) for all non-parametric statistical tests. Microsoft Excel was used for preliminary data analysis. I used the software packages PRIMER 5, STATISTICA 6 and EcoSim for various analyses. All the statistical tests were carried out using Microsoft Excel (correlations), STATISTICA 6 (non-parametric tests) and PRIMER 5 (cluster analysis and MDS). All correlations have been made using Pearson's corrletaion co-efficient.

Owing to unequal sampling effort and the resultant differences in the number of individuals obtained on different transects, I carried out rarefaction (see James and Rathbun 1981) for all transects using the software ECOSIM (Gottelli and Entsminger 2006). Rarefaction gives the expected species richness for a uniform and predetermined sample of individuals against observed species richness, which is affected by the number of individuals encountered (sampling effort).

Two exploratory techniques for interpretation of relationships in the data - cluster analysis and multi-dimensional scaling (MDS) were performed using the software package PRIMER 5. Cluster analysis sorts objects into different groups such that if these belong to the same group, they have high association than if they belong to different groups. The resultant structure is expressed as a chart called dendrogram. MDS helps identify underlying dimensions based on observed similarities or dissimilarities between the objects. In this way, it is similar to factor analysis except that the latter uses correlation matrix as a similarity measure, where as the former can use any kind of similarity or distance measure. The MDS analysis produces a diagram in two-dimensional (or three-dimensional) space with objects lying according to the distance between them. A point represents each object and the points are arranged in this space based on the similarities among the pairs of objects. Thus, objects lying closer to each other are more similar than those occurring farther.

For both the above analyses, I used the data set containing total abundance of bird species on all 15 transects to determine similarities in species composition. For mixed-species

flocks also I used similar information for cluster analysis and to assess similarities between regular flocking species, I used their occurrence patterns. Bray-curtis similarity was used as it has several features suitable for ecological data including independence from the scale of measurement and joint absences (see Clarke 1993). I then square-rooted the raw abundances and standardized the data to produce a similarity matrix. This matrix was used for cluster analysis and MDS. For the former, I used group average clustering.

For testing the influence of specific factors on similarity of species composition on transects, I used analysis of similarity (ANOSIM) using the package PRIMER 5. This is a non-parametric measure similar to ANOVA. It provides a way to test statistically whether there is a significant difference between two or more groups of sampling units. ANOSIM procedure generates the R-statistic value. This is a relative measure of separation of the prior defined groups. An R-value of zero (0) indicates that there is no difference among groups, while a value of one (1) shows that samples within groups are more similar than between groups. ANOSIM was used to assess the influence of the species of bamboo present, moisture gradient and location to explore this aspect.

Chapter 4

COMPOSITION AND ORGANISATION OF BIRD COMMUNITIES

4.1 BIOTIC COMMUNITIES: AN INTRODUCTION

The term community has been variously defined and interpreted in the past. Ecologists have perceived communities as either 'organised' units or chance assemblages (see Clements 1916, Gleason 1917,1926) with the former view regarding communities are discrete, repeatable assemblages of species that are closely integrated and possess properties similar to those of individual organisms and the latter view considering communities as no more than fortuitous coincidences or random assemblages (Wiens 1989). Elton (1927) defined animal community as a characteristic and interacting set of animals found in a habitat. Whittaker regarded a natural community as 'a distinctive living system with its own composition, structure, environmental relations, development and function' (see Southwood 1987). Landres and MacMahon (1980) described community as 'groups of interacting populations, among which no gene exchange is taking place, but whose demography or gene pools are affected by the interaction'. Southwood (1987) defined community as "a group of organisms (generally of wide taxonomic affinities) occurring together in a location; many of them will directly interact with each other within a framework of both horizontal and vertical linkages." Communities have also been defined on the basis of habitat or microhabitat units (e.g.

rocky intertidal communities, a tree), life forms (e.g. tree or herbaceous communities), and taxonomic groups viz. bird or lizard communities (Wiens 1989).

Biotic communities are characterized by two properties, structure or organisation (called *patterns*) and function or dynamics (called *processes*). The former includes distribution of species in communities, their variety and abundance and the trophic structure, which connects different components of a community. The latter entails causal processes such as colonisation, competition, predation, parasitism, climate, history, and chance events (Southwood 1987).

4.2 AVIAN COMMUNITY ECOLOGY: CONTEXT OF THE PRESENT STUDY

4.2.1 Introduction: The focus of bird community ecology has been on identifying patterns that characterise natural assemblages of species and processes that cause these patterns (Wiens 1989). A pattern is 'a particular configuration of properties of the system under examination' and the process is the 'underlying causes' or 'factors that produce a particular relationship among observations' (Wiens 1989). The major focus of development in bird community ecology has been finding the 'true nature, stability and predictability of community structure' (Raman 2001). Based on this pursuit, there are three prevalent views of community structure. These are referred to as equilibrium, non-equilibrium and dynamic equilibrium states (Raman 2001). The processes that shape or influence the communities have been categorized as deterministic (predictable) and stochastic (chance) processes (Raman 2001). The important aspects addressed in the study of bird communities include patterns of bird species richness, distribution and

abundance in an area and factors affecting these parameters. These include bird species-habitat relationships, mechanisms of species co-existence (e.g. resource partitioning, foraging guilds and mixed-species flocks) and impacts of anthropogenic/natural disturbances on bird communities. Wiens (1989) has provided a detailed chronological account of development of bird community ecology.

4.2.2 Determinism and local influences: In the early phase of community ecology, local ecological processes (intrinsic factors) were mainly regarded of significance in determining the richness and composition of communities. Competition and habitat (mainly vegetation structure) were regarded as the driving forces of community organisation. Higher vertical heterogeneity and productivity of tropical forests coupled with availability of specific resources was regarded to be responsible for high bird species richness of the tropics (MacArthur and MacArthur 1961, Orians 1969, Terborgh and Robinson 1986). This relationship between bird species diversity and habitat features (e.g. MacArthur *et al*. 1966, Pearson 1975, Roth 1979, Cody 1981, James and Wamer 1982, Terborgh 1985, Wiens *et al*. 1987) was a central theme seeking deterministic processes underlying the observed patterns. Major ideas to emerge from such studies were that structural features of vegetation (vertical layers of vegetation, canopy characteristics, heterogeneity etc.) determine the composition of bird communities. However, this relationship was shown not to remain constant temporally or spatially as shown by the influence of scale of the study on the conclusions drawn (Wiens *et al*. 1987). This brought in the role of scale and regional factors in understanding composition and organisation of bird communities. Further, relationship between birds and habitat

structure has been shown to be complex and variable in tropical areas with absence of any consistent pattern, especially in terms of relationship between BSD and habitat structure (see Katti 1989, Raman 1995, Javed 1996, Jayapal 1997).

Most studies concerned with organisation of communities considered the role of competition central in shaping these communities (MacArthur and MacArthur 1961, Terborgh 1985, also see Wiens 1989 for a review). Species co-existence was treated as an extension of the classical Darwinian perspective of survival by natural selection. The chief mechanisms considered responsible were morphological differences (bill size, wing length etc.), habitat segregation (including altitudinal segregation), foraging mode and diet differences. These were regarded as the outcomes of competition between species in the past. However, the competition paradigm had its limitations, especially in the light of studies showing the importance of other factors as well as a collective role of several factors including chance and history (i.e. stochastic factors).

4.2.3 Regional influences – the role of history and geography: As more studies were conducted at different scales (from a habitat type to landscape and regional) and on different continents, it became apparent that species composition of communities was also influenced by regional (geographical, evolutionary and historical) factors (see Ricklefs and Schluter 1993). For instance, very high bird diversity in certain parts of the Neotropics was explained on the basis of 'refugia hypothesis' in which historical (geological) processes were largely responsible for shaping the unusually rich species pools of some sites in the region (Haffer 1969). A balance between immigration and local

extinctions contributes to species richness on the islands connected by land bridges with mainland in geological past. For such islands, Terborgh (1974) regarded the size of island as an important determinant of bird species richness with bigger islands possessing higher richness due to lower extinction rates. Wilcox (1978) showed that time since isolation was an important criterion in determining local species richness in lizard communities although larger islands experienced fewer extinctions than smaller. Diamond (1972) showed the effect of disruption of faunal inflow through submergence of land bridges in reducing the species pool of islands of the southwest Pacific.

The foregoing suggests that the communities need to be viewed at hierarchical scales beginning from local habitat patch to a landscape containing several habitats to a region and finally the continents (Ricklefs and Schluter 1993). Hence, the scale at which a community is being viewed would provide *that* perspective on composition and organisation. This would change as one goes lower or higher in the hierarchy. Wiens *et al*. (1987) showed how the relative importance of patterns and processes changed with change in scale at which these were viewed. Translating these observations to my study, Ratanmahal and Purna could be viewed as two patches in a larger regional context. These patches in turn contain several smaller habitat patches. Some vegetation types are similar between the two sites, while several different vegetation types exist within each site. One would expect that if only local factors were important, similar vegetation types at the two sites would have more similar bird communities than different vegetation types at the same site. However, if regional factors were also involved, the pattern would vary as per the influence of geographical barriers, history etc.

4.3 RESULTS

4.3.1 Overall Species Richness: In all, 191 species belonging to 51 families were recorded at the two study sites (see Appendix 4.1). Of these, 95 species (49.7 %) and 37 families (72.5 %) were common between the two sites. Fifty-two and 44 species were exclusive of the 147 species of birds at Ratanmahal and 139 at Purna respectively. Seven families each were exclusive to the two sites. More migratory species were recorded at Ratanmahal than Purna; the latter though had a higher proportion of resident species (Table 4.1). Proportions of arboreal and ground-dwelling species were different between the two sites (Table 4.1).

Table 4.1 Bird species richness of Ratanmahal and Purna Sanctuaries, Gujarat

Parameter	Ratanmahal	Purna
No. of families	44	43
No. of Species	147	139
Resident species	99 (67.3)	110 (79.1)
Migrant species *	48 (32.7)	29 (20.9)
Aquatic species	31 (21.1)	18 (13)
Terrestrial species	116 (78.9)	121 (87)
Arboreal species **	81 (69.8)	93 (76.8)
Ground-dwelling species **	21 (18.1)	12 (10.0)
Species with mixed niche **	14 (12.1)	16 (13.2)

Figures in parentheses show percentages * includes extralimital as well as local migrants ** % of terrestrial spp.

Overall, there were 20 families (39.2%) with only one species. Nine families each had two, three and between four and ten species respectively, while four families (7.8%) had more than 10 species. The ten most dominant families included over half (58.1%) of the total species encountered at the two sites (Table 4.2). When the two aquatic families

(Ardeidae and Scolopacidae) were removed from these ten, the remaining families still contributed 98 species (51.3 %). Among the seven exclusive families at Purna, four (Bucerotidae, Trogonidae, Pittidae & Sittidae) were of forest birds; while for Ratanmahal all except one out of the seven exclusive families were of aquatic non-forest dependent species and one family was of open area birds (e.g. Alaudidae). It was thus clear that Purna was richer than Ratanmahal in terms of forest bird species. Excepting Passeridae of which Ratanmahal had five species more and Muscicapidae (in which the two sites had equal number of species); Purna was richer in all the other dominant families of terrestrial birds. Purna had much higher number of species than Ratanmahal in families Accipitridae (raptors), Picidae (woodpeckers) and Strigidae, of which there were 24 species at Purna as against 16 at Ratanmahal.

Table 4.2. Species richness of dominant bird families at Ratanmahal and Purna

Family	**Species number**		
	Total	**Ratanmahal**	**Purna**
Corvidae	21	17	19
Muscicapidae	14	12	12
Passeridae	14	12	7
Sylviidae	14	9	11
Accipitridae	10	7	9
Picidae	10	5	9
Strigidae	8	4	6
Ardeidae	7	6	5
Columbidae	7	6	6
Scolopacidae	6	6	2
Total Species	**111**	**84**	**86**

4.3.2 Species richness and composition patterns on transects

Rarefied species richness: Of the 191 species encountered, 106 species (80 species at Ratanmahal and 89 species at Purna) were encountered on transects (Appendix 4.2).

Table 4.3 Rarefied species richness of sampling units at Purna and Ratanmahal

N (no. of individuals)	T10 Rupgadh	T1 Borumal	T2 Dhulda	T3 Mahal Kot	T4 Girmal	T5 Mahal	T6 Bhalkhet	T7 Waghdarda	T8 Bhenskatri	T9 Sawarda
10	8.36	8.86	8.30	8.14	7.73	8.59	8.42	8.37	8.94	4.62
20	14.16	15.69	14.42	13.59	12.76	14.81	14.27	14.47	15.96	7.22
30	18.51	21.04	19.40	17.60	16.58	19.51	18.58	19.31	21.60	9.15
40	21.99	25.32	23.61	20.76	19.69	23.23	21.90	23.26	26.21	10.64
50	24.93	28.81	27.24	23.34	22.31	26.27	24.58	26.54	30.06	11.80
60	27.51	31.71	30.42	25.52	24.57	28.83	26.80	29.28	33.31	12.00
75	28.00	35.22	34.51	28.25	27.45	32.05	29.56	32.60	37.34	12.00
100	28.00	39.61	39.98	31.79	31.28	36.34	33.14	36.60	42.46	12.00
150	28.00	45.43	47.68	36.44	36.53	42.68	38.19	41.28	48.97	12.00
200	28.00	49.36	52.83	38.00	37.00	44.00	41.00	42.00	51.00	12.00
250	28.00	52.37	56.51	38.00	37.00	44.00	41.00	42.00	51.00	12.00
300	28.00	54.79	59.26	38.00	37.00	44.00	41.00	42.00	51.00	12.00
350	28.00	56.00	61.38	38.00	37.00	44.00	41.00	42.00	51.00	12.00
400	28.00	56.00	63.06	38.00	37.00	44.00	41.00	42.00	51.00	12.00

N (no. of individuals)	**T1 - Kotda**	**T2 - Popatkuwa**	**T3 - Mendri**	**T4- Bhuvero**	**T5- Kanjeta**
10	7.83	8.71	8.10	7.18	7.98
20	13.00	15.30	13.55	11.67	13.34
30	16.99	20.54	17.67	15.17	17.46
40	20.30	24.81	21.03	18.05	20.83
50	23.14	**28.39**	23.86	20.47	23.67
60	25.62	31.42	26.30	22.55	26.12
75	28.82	35.20	29.43	25.20	29.21
100	33.16	40.02	33.61	28.69	33.27
150	39.56	46.34	39.57	33.62	38.95
200	44.24	50.22	43.73	36.96	42.94
250	47.91	52.77	46.87	39.36	45.98
300	50.87	54.53	49.35	41.17	47.00
350	53.28	55.79	51.00	42.60	47.00
400	55.24	56.71	51.00	43.00	47.00

Rarefied species richness for 15 transects at the two sites (Table 4.3) shows that Bhenskatri (T-8), Borumal (T-1) and Dhulda (T-2) at Purna and Popatkuwa (T-2) at Ratanmahal were the richest transects. Bhuvero (T-4) at Ratanmahal and Sawardakasad (T-9) at Purna were the poorest in terms of species richness. However, since T-9 and T-10 (at Purna) were sampled only once and twice respectively, I considered the rarefied richness of other 13 transects for a sample of 150 individuals. The results did not change and the same transects showed the highest and lowest richness (Table 4.3). When only five transects of Ratanmahal were compared for their species richness (250 individuals), Popatkuwa (T-2) emerged as the richest and Bhuvero (T-4) the poorest. Kotda (T-1) was the second richest and Mendri (T-3) and Kanjeta (T-5) had intermediate species richness. When transects at Purna only were compared (excluding T-9 and T-10), the earlier results still remained true. Thus, with increasing number of individuals the gradient of bird species richness of sampling units changed only marginally.

Most transects with the lowest species richness had dry deciduous forest with some having young monocultures of teak and few like Bhuvero (T-4) had extensive bamboo brakes. These transects had low (<15 meters) and variable canopy, two to three vertical strata and fewer edges (Trivedi 2001 and 2003, also see Appendices 3.1 and 3.2). Besides, high occurrence of fire and absence of undergrowth or its ephemeral nature were also features associated with these transects (Trivedi 2001 and 2003). Preponderance of bamboo brakes at Bhuvero (T-4) led to a reduction in availability of well-defined strata in vegetation as compared to other diverse habitats. The Rupgadh transect (T-10) with the lowest bird species richness at Purna had a large portion covered by young teak

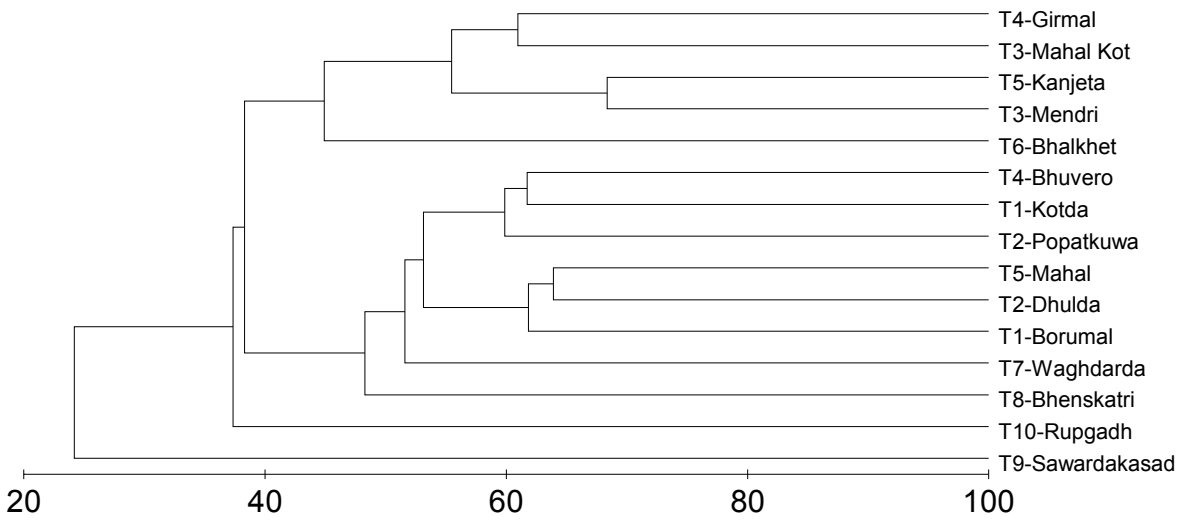
plantation with impoverished flora and vertical strata. Sawardakasad (T-9) transect appeared poor but it was sampled only once. Data gathered on trails and through casual observations showed that T-9 was a rich area containing bamboo brakes interspersed with teak and secondary moist forest habitat possessing 45 bird species, many of which were Western Ghat and/or forest-interior species. Since the latter two transects were sampled on one and two instances, these have not been included in further discussion of species richness and composition.

The species-rich transects had mixed or moist deciduous forests (generally the most mature within the site), with or without bamboo, more than three vertical strata and a canopy beyond 15 meters (see Appendices 3.1 and 3.2). Two species rich transects at Purna (T-2 and T-8) also had a high number of edges due to their proximity to human habitation and riverine forest in case of T-2. T-8 was the only transect with dry deciduous forest and *D. strictus* showing high species richness. Popatkuwa (T-2) – the richest transect at Ratanmahal was located almost equidistance from the moist area and dry area transects. It shared a high number of observed bird species (from 67 % to 80 %) with all the other transects at Ratanmahal. Besides, it also had patches of riverine forest, bamboo and abandoned crop fields (at one site) providing high habitat heterogeneity. Presence of a variety of vegetation types such as moist mixed forests, moist teak forests, secondary moist forest, preponderance of *B. arundinacea,* higher vertical heterogeneity and availability of perennial water sources made T-2 and T-1 good habitats for birds at Purna. Although the two differed in terrain features (see Appendix 3.2) and to some extent also in bird species composition, they were more similar to each other than other transects.

Transects with intermediate richness had low habitat and vertical heterogeneity, drier forests and too much or too less of bamboo. Transects T-3 to T-7 at Purna and T-1, T-3 and T-5 at Ratanmahal were in this category.

Species composition patterns: To investigate these trends further, I conducted exploratory analysis - cluster analysis and multi dimensional scaling (MDS), which represented similarity in species composition of transects through a dendrogram and two-dimensional plots (Figures 4.1 and 4.2). Figures 4.1 and 4.2 show the arrangement of sampling units with respect to species similarity matrix.

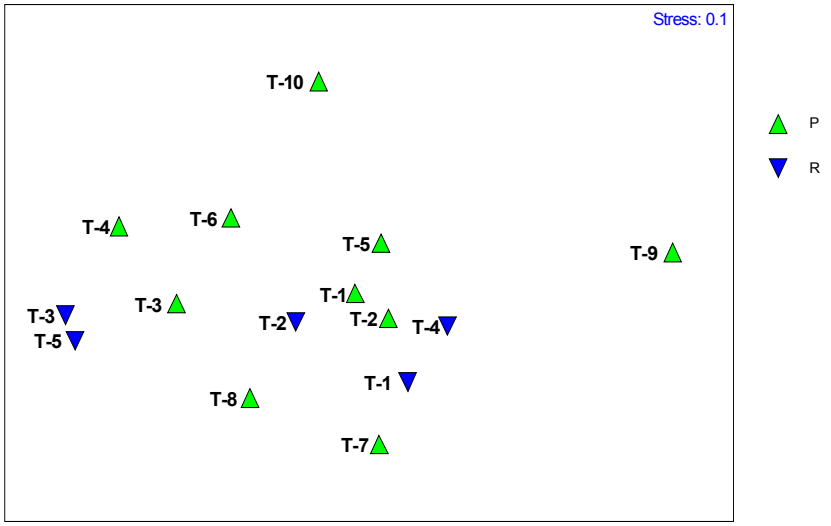
Figure 4.1 Dendrogram showing similarity in species composition of transects



The clusters in Figure 4.1 indicate two distinct sets and two outliers. The outliers are T-9 and T-10 of Purna, for which the least sampling effort was put in. The two distinct clusters include one with five transects and the other with eight transects. The former represents the dry deciduous zone transects, while the latter contains the moist and semi-

moist transition zone transects. A noticeable aspect is that transects of both sites are present in each cluster. The dry zone transect cluster contains three transects from Purna and two from Ratanmahal, while the other cluster has five transects from Purna and three from Ratanmahal. MDS analysis in figure 4.2 reveals the two outliers and two sets of sites as also seen in Figure 4.1. However, within the second cluster Waghdarda (T-7) and Bhenskatri (T-8) are farther from the cluster containing moist zone transects (figure 4.2). It is evident that the sampling units of two sites do not lie as per their physical distance from one another; rather the pattern appears to show a moisture gradient and concomitant forest structure.

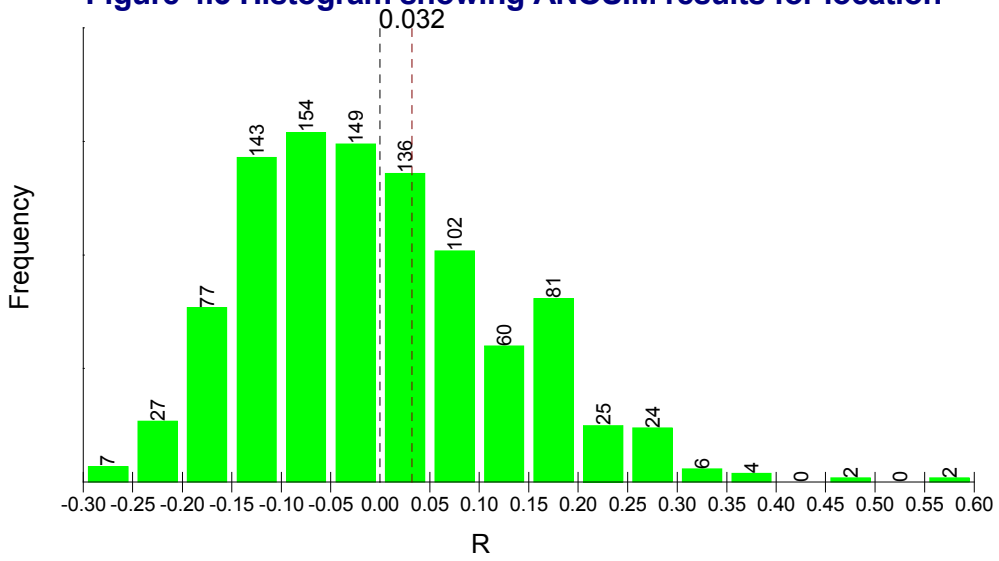
Figure 4.2 Similarity in species composition of transects based on MDS



Dry area transects Mendri (T–3) and Kanjeta (T–5) showed marked differences in their flora, yet their mutual similarity in species composition was higher than that with the moist zone transects. Both were also poor in terms of species richness. Transects T–3

and T-4 at Ratanmahal were the extremes on a moisture and elevation gradient, which contributed to the observed high dissimilarity between their bird species. To identify the likely role of distance effects, I categorized transects based on their location within Purna or Ratanmahal and looked at the similarity (ANOSIM) in their bird species composition. As hypothesized, location did not account for similarity (Figure 4.3, R=0.032, p>0.1) implying that differences in bird communities within a site were greater than those between the sites. Thus, location (distances) between transects did not have significant effect in influencing the similarity in bird species composition.

Figure 4.3 Histogram showing ANOSIM results for location



Bird-habitat relations: As shown in Table 4.4, riverine and mixed forests at Ratanmahal and riverine and teak mixed forests at Purna had the highest number of bird sightings respectively. The lowest number of sightings occurred in cultivation and open areas. The rest of habitats had intermediate sightings. Ecotonal (categorized as areas lying within 25 m from the next transition in vegetation) areas were highly (over 50 % sightings at both sites) used. Preponderance of teak at both sites should have led to high

number of sightings in teak mixed and teak forests had the birds used vegetation types in proportion to their availability, but this did not seem to be the case, especially at Ratanmahal (Table 4.4). On the contrary, forests with non-teak tree species (mixed forests) and bamboo showed high occurrence of birds at both the sites (Trivedi 2001, 2003). Teak forests and plantations (classified as TF) were used less. Young plantations, which were poor in both vegetation structure and plant species richness had low bird species richness as seen on Rupgadh (T-10) transect. Transects at Mahal kot (T-4) at Purna and Kanjeta (T-5)at Ratanmahal also had such composition and subsequently impoverished bird species richness.

Table 4.4 Habitat use by birds at Purna and Ratanmahal

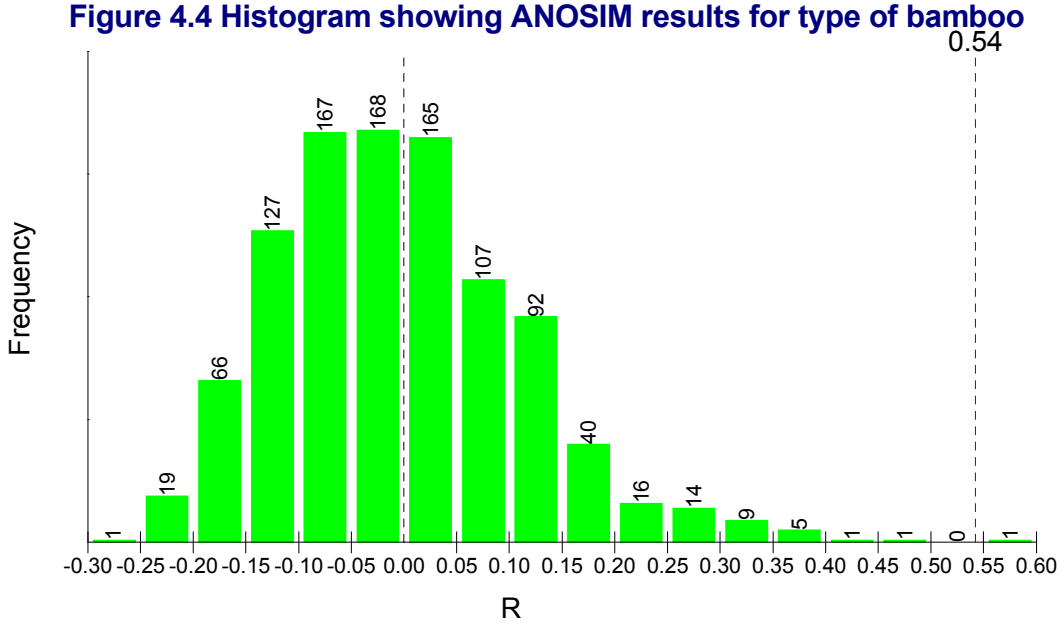
Sr. No.	Habitat Type	No. of Sightings (%) Ratanmahal (n=914)*	No. of Sightings (%) Purna (n=882)
1.	Riverine Forest (RF)	**360 (39.4)**	**192 (21.7)**
2.	Mixed Forest (MF)	**286 (31.3)**	151 (17.1)
3.	Mixed Forest Hill (MFH)	140 (15.3)	**
4.	Teak Mixed Forest (TMF)	116 (12.7)	**193 (21.9)**
5.	Cultivation (C)	**86 (09.4)**	42 (4.7)
6.	Open Area (OP)	169 (18.3)	**20 (2.2)**
7.	Plateau (P)	95 (10.4)	**
8.	Bamboo (B)	173 (18.9)	152 (17.2)
9.	Teak Forest (TF)	**	132 (15.0)
10.	Edge / Ecotone (E)	**513 (56.1)**	**584 (66.0)**

* includes the sightings of edges i.e. numbers not mutually exclusive ** categories not applicable

At both sites, a high number of sightings were obtained in bamboo brakes. Bamboo, due to its unique structural features offered perching sites and escape cover for many species. Birds used habitats with *Bambusa arundinacea* – a tall, thorny, moist area bamboo more than those with *Dendrocalamus strictus* – a dry deciduous forest species

(Trivedi 2001, 2003). Some of the bird species that remained partial to the former included Brown-cheeked Fulvetta, Rusty-cheeked Scimitar Babbler, White-rumped Shama, Blue-headed Rock Thrush, Orange-headed Thrush and Rufous Woodpecker. To explore the influence of bamboo as a factor playing a role in similarity of bird species composition, I categorized all transects in terms of presence of one of the two species of bamboo and conducted the analysis of similarity (ANOSIM). The results were highly significant (Figure 4.4, R=0.54, p<0.001) indicating that the transects with the same species of bamboo were likely to have more similar species composition in bird communities.

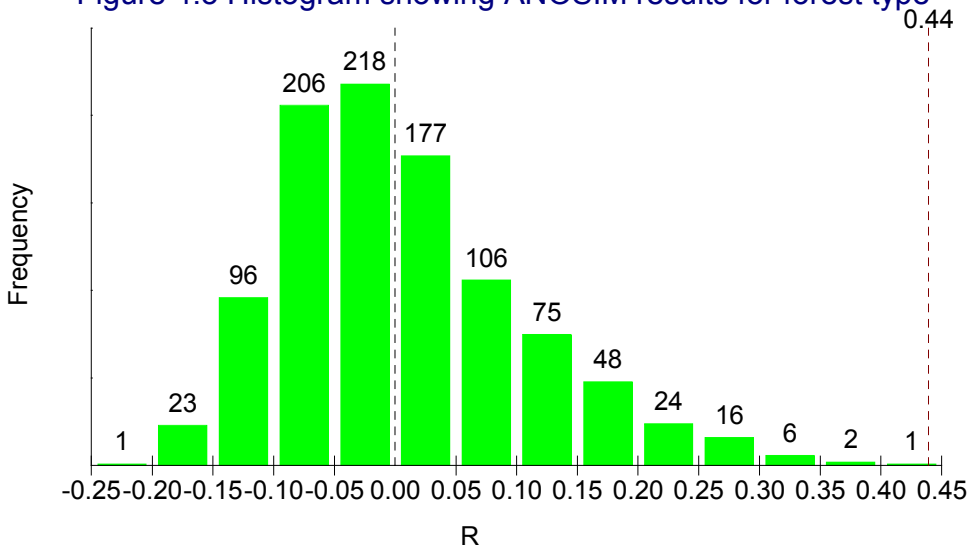
Figure 4.4 Histogram showing ANOSIM results for type of bamboo



This result, however, needs to be regarded as a rather qualitative one since it was the visual dominance/presence of bamboo that was taken into consideration. Further, when I categorized transects based on a dry, semi-moist and moist gradient based on luxuriance of vegetation and species composition, the results showed a significant influence of this factor on species similarity (Figure 4.5, R=0.44, p<0.001). Thus, it becomes apparent that similarities

(and differences) in bird species composition were largely influenced by the structure and composition of vegetation.

Figure 4.5 Histogram showing ANOSIM results for forest type



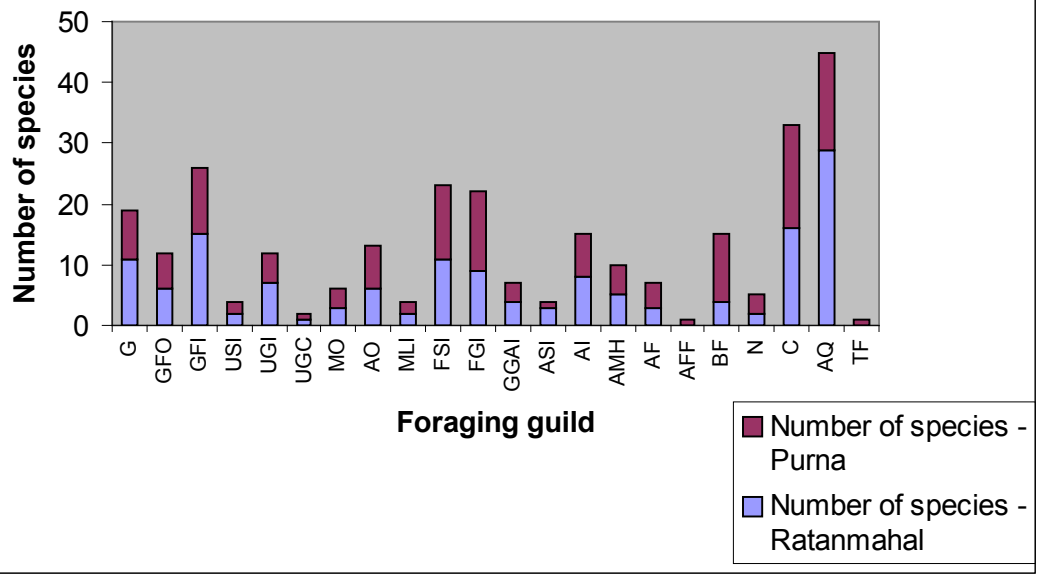
Use of Forest Strata: Vertical layers of vegetation have been considered important in avian ecology for foraging and nesting requirements of bird species (MacArthur & MacArthur 1961, Anderson 1981, Cody 1981, Daniels *et al*. 1990). The highest number of sightings at both the sites occurred in 3-8 and 8-15 metres (Table 4.5) reflecting that foliage was the most used part of the forest. A low number of sightings at the ground level was intriguing as I recorded several species that foraged on ground (see section on guilds). This could be because such species were observed during non-foraging activity when they used the higher strata (to perch). Since birds were recorded at all levels in vegetation from ground to above 15 meters based on their foraging niches, vertical heterogeneity was important in increasing bird diversity.

Table 4.5 Use of vertical vegetation strata by birds in Ratanmahal and Purna Sanctuaries, Gujarat

Height in Meters	No. of Sightings Ratanmahal (%)	No. of Sightings Purna (%)
0-1	37 (**3.52**)	68 (**7.71**)
1-3	191 (18.19)	79 (8.96)
3-8	387 (36.86)	288 (32.65)
8-15	435 (**41.43**)	317 (**35.94**)
>15	--	130 (14.74)
Total	**1,050**	**882**

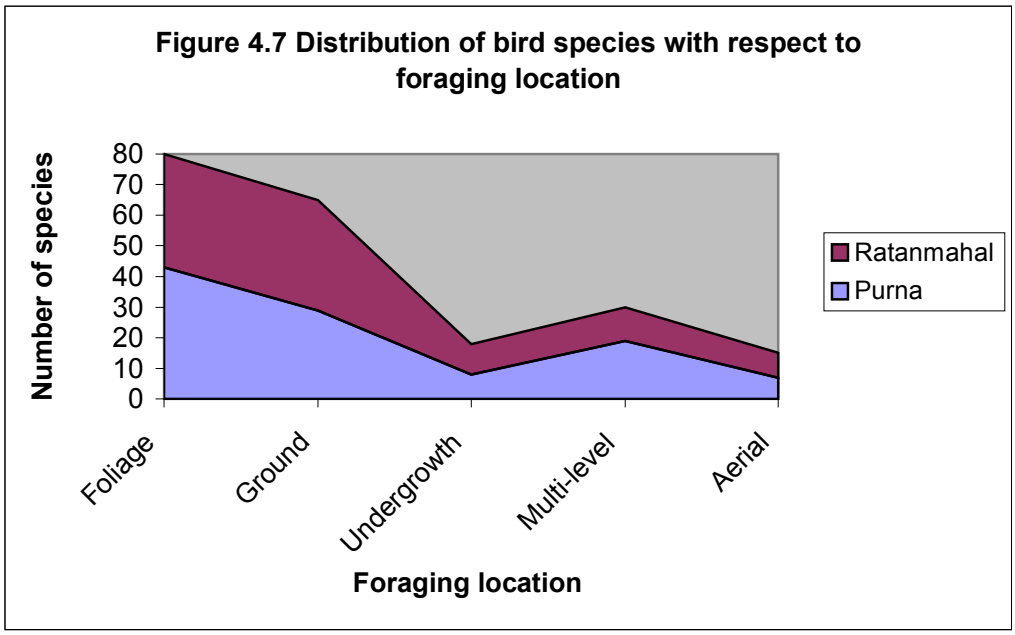
4.3.3 Foraging guilds: There were 22 foraging guilds at Purna and 20 at Ratanmahal. Sixty-five species (44.21%) at Ratanmahal and 67 species (48.2%) at Purna belonged to the insectivore guild that contained the largest number of species. Carnivores and omnivores had higher number of species at both sites compared to granivores and other herbivores (including frugivores) (Figure 4.6).

Figure 4.6 Guild organisation of Purna and Ratanmahal birds



The lowest number of species belonged to the nectarivore guild. Aquatic species though in good numbers belonged mainly to non-forest dependent category. Foliage foraging (gleaning and sallying) and ground foraging insectivores, carnivore, granivore and bark foraging guilds dominated the two bird communities. The guilds absent from Ratanmahal were arboreal frugivore-faunivores (e.g. Indian Grey Hornbill) and terrestrial frugivores (e.g. Emerald Dove). Indian Grey Hornbill has possibly gone extinct from Ratanmahal (Trivedi and Soni, *in press*), while the latter was absent from Ratanmahal. Six guilds had the same number of species at both the sites. Among the guilds that had higher number of species at Ratanmahal, four (granivores, ground foraging insectivores, undergrowth gleaning insectivores and arboreal sallying insectivores) showed a notable difference. Purna showed considerably higher richness in bark foraging and foliage-gleaning guilds compared to Ratanmahal.

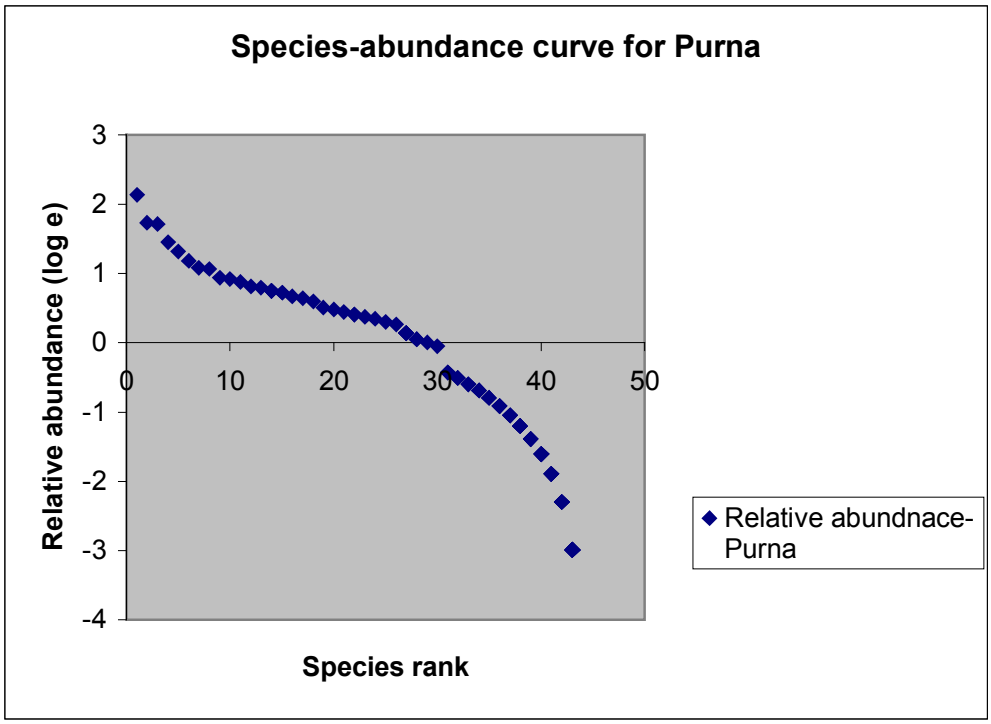
When guilds were viewed in the light of the vertical strata that they occupied to forage in the forest (see figure 4.7), species using foliage topped with 37 such species at Ratanmahal and 43 at Purna followed by species that forage on the ground (36 species at Ratanmahal and 29 species at Purna). Multi-level foraging guilds were represented by 11 species at Ratanmahal and 19 species at Purna respectively. The lowest number of species belonged to undergrowth foraging and aerial guilds (10 and 8 species for Ratanmahal; 8 and 7 species for Purna). Species belonging to the carnivore and aquatic guilds were not taken into account for this analysis.

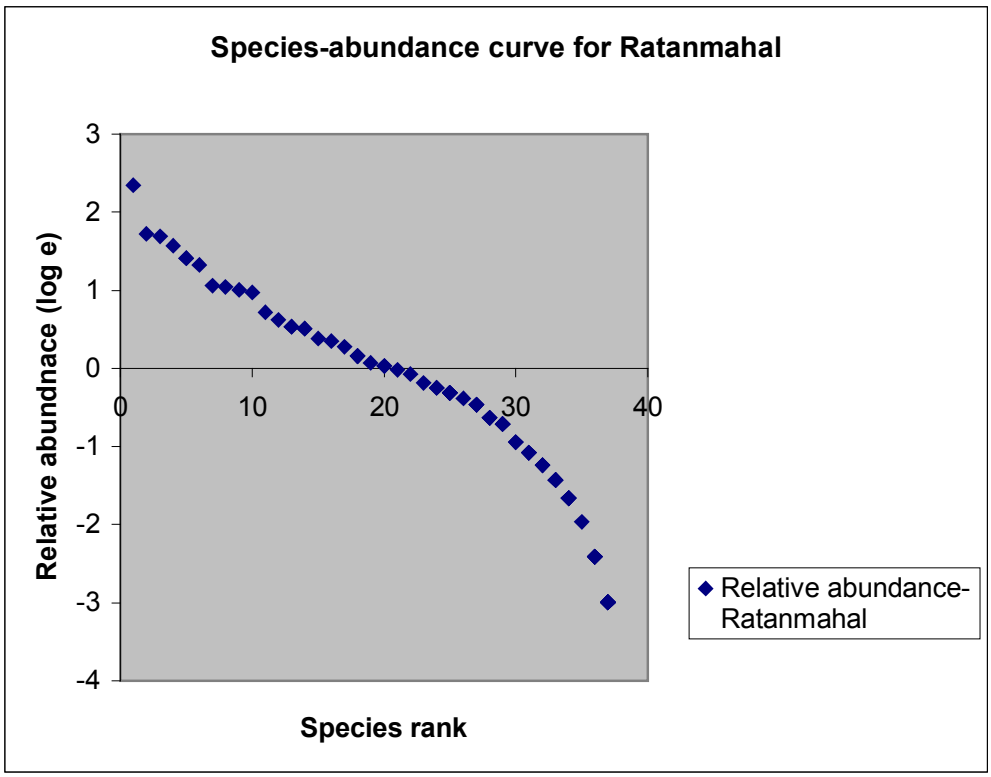


4.3.5 Species abundance patterns: In terms of relative abundance, only a few species had very high abundances, but several species had low and intermediate abundance values (see Appendices 4.3 and 4.4). The species-abundance curves (Figure 4.8) appeared to show a lognormal pattern of distribution for both sites though for Ratanmahal, it assumed a superficial resemblance with the broken-stick model of species-abundance distribution.

In terms of relative abundances (RA), 12 species at Ratanmahal and 14 species at Purna accounted for 50% of the individuals encountered on transects. Six species among these were common between the two sites. These were Jungle Babbler *Turdoides striatus*, Chestnut-shouldered Petronia *Petronia xanthocollis*, Leaf Warbler *Phylloscopus* spp., Large-billed Crow *Corvus macrorhynchos*, Plum-headed Parakeet *Psittacula cyanocephala* and Common Tailor Bird *Orthotomus sutorius*. All the six are widespread species. Jungle Babbler was the most abundant species at both the sites

Figure 4.8 Species-abundance curves for Purna and Ratanmahal





followed by leaf warbler and Chestnut-shouldered Petronia. Eleven species at Ratanmahal and 14 species at Purna were rare (RA between 0.5 to 0.25 %), of which two species (Black Redstart and Common Hawk Cuckoo) were common between the two sites. Among the 24 and 31 very rare species (RA < 0.25) at Ratanmahal and Purna respectively, 14 were common between the two areas. The common species belonging to both the above categories were non-forest specialist species with wide distribution or migrants. Thirty-three species at Ratanmahal and 26 species at Purna had intermediate abundances (0.5 to 2.0 %), with 12 species being common. Twelve and 18 species respectively had high relative abundances (> 2.0 %) with eight species being common between the sites. In all, 36 species at both the sites had similar abundance ratings.

4.4 DISCUSSION

4.4.1 Overall species richness

Within the eastern forest belt, species richness of Ratanmahal and Purna was lower than Shoolpaneshwar Sanctuary (173 species, Desai *et al*. 1993) and Jessore Sanctuary (212 species, Trivedi 2005); but higher than Jambughoda Sanctuary (c. 135 species, Pandya and Oza 1998) and Vansda National Park (115 species, Singh *et al*. 2000). The checklist of birds of Jessore was an exception as nearly one third of its avifauna consisted of aquatic species (Trivedi 2005). When only terrestrial species were considered, the area had about 142 species. Considering the overall documented species richness of Purna (including check-lists of Ali 1954-55, Shull 1962, Worah 1991 and present study), the number of species recorded is close to 180. Thus, Purna could be considered as one of the richest areas in the eastern forest belt of the state in terms of bird species richness. It

should be kept in mind that this is not the current richness pattern at Purna (also see chapter 7).

The avifauna of the two areas showed many similarities, though there were important differences in species composition. For instance, Purna had four exclusive families of forest birds containing one species each. Of these four species, three (Indian Grey Hornbill, Malabar Trogon, Velvet-fronted Nuthatch) that did not occur at Ratanmahal were forest-interior species. Of these, no records exist for Malabar Trogon even historically, but the other two species have possibly gone extinct there (Trivedi and Soni, *in press*). The three families with higher species number at Purna (Accipitridae, Picidae and Strigidae) also had species that possibly did not occur at Ratanmahal historically. These included White-bellied Woodpecker, Heart-spotted Woodpecker, Rufous Woodpecker, Lesser Yellownape, Greater Flameback, Brown Wood Owl and Brown Hawk Owl. Ten out of 24 families that had one or more exclusive species at Purna were of forest birds. In contrast, out of the 28 families with one or more exclusive species at Ratanmahal, only two were of forest birds and majority were of aquatic species. Thus in terms of overall richness of forest dependent avifauna, Purna had more species. Whether this trend was a result of historical factors or impoverishment in recent past was difficult to deduce.

4.4.2 Correlates of species richness and composition: There appeared to be an ascending bird species richness gradient from young plantations (i.e. monocultures) and dry deciduous forests to mature mixed and moist deciduous forest habitats. Similar

results were shown by several studies in India. Worah (1991) studied the impacts of fragmentation on bird communities in Dangs and documented the highest species richness in the largest patch of natural forest i.e. Purna Wildlife Sanctuary (Purna), while the lowest richness was found in isolated plantation remnant. More forest-interior species were found at Purna, while the isolated plantation had no forest-interior species. Forestry practices, particularly monocultures of teak were shown to be curtailing species diversity. Rao (1988) showed similar results in the tropical dry evergreen forest at Sriharikota in southeast India, where he found that *Casuarina* monoculture had the least species, while regenerating mixed forest and dry evergreen forest (climax vegetation) had the highest species richness. In contrast, Daniels (1989) found higher species richness in moist deciduous forests (185 species) and disturbed rainforests (165 species) compared to coastal habitat (130 species), dry deciduous forests (160 species) and evergreen forests (111 species). However, there were differences in species composition with forest interior and endemic species preferring the tropical rainforest habitat. This was also true for my study as several species of moist forest habitats such as White-bellied Woodpecker, Rufous Woodpecker, Lesser Yellownape, Malabar Trogon, Heart-spotted Woodpecker, Orange-headed Thrush and Blue-capped Rock Thrush were encountered only on transects with moist deciduous forests. Jayson and Mathew (2002) showed a marginally higher richness at rainforests of Silent Valley over moist deciduous forests of Mukkali. However, they also noted several endemic rainforest species at the former site that were absent at the latter, a trend also documented by Daniels (1989). Katti (1989) indicated that structurally more complex habitats had higher bird species diversity (BSD) at Dachigam in the Kashmir Himalaya.

Figures 4.1 and 4.2 indicated that transects arranged chiefly along a moisture gradient. Grouping of transects in two distinct clusters was a result of such pattern of habitat occupancy by birds. The basic unit that contributed to similarity in bird species composition thus appeared to be vegetation. Hence, two transects nearer to each other were more likely to have similar bird species if they also had similar vegetation than if they had different vegetation. Similarly, two transects with similar vegetation showed higher similarity in their bird species composition even if these were separated by large distances (c. 200 km) as in case of several transect pairs showing similarity of species composition in both areas (see Figures 4.1 and 4.2). How could such patterns arise? Over 30 % species at both sites occurred on only two transects. Although rarity and passive sampling could have had their influence, such a patchy distribution pattern was shown even by some of the most abundant species such as Jungle Babbler, Greater Racket-tailed Drongo and Plum-headed Parakeet. The Kanjeta (T-5) transect that had repeated incidences of dry season fires showed absence (at least temporary) of some species such as Jungle Babbler, Red-throated Flycatcher and Asian Paradise-flycatcher (Trivedi 2001). This could be due to loss of leaf litter and reduced undergrowth leading to reduced availability of food, foraging sites and cover for ground and undergrowth foraging birds. On the same transect, complete absence of leaf warblers was noted as it showed the longest 'leafless' period that co-incided with winter when these migrant birds are present here (Trivedi 2001).

The above patterns indicated that the patchy distributions on transects were brought about by differences in vegetation. Similar results were shown by Raman (2001), who

highlighted the role of vegetation structure compared to physical distance as a determinant of bird species composition in fragmented rainforest habitat of southern Western Ghats. Worah (1991) documented that in Dangs, protected forest areas and plantations showed two different clusters grouping together areas with similar vegetation features. She showed that small forest patches of good quality beyond a size threshold had higher bird abundance than a larger forest area with low quality habitat, thus habitat structure compensated for area. BSD was significantly correlated with structural and tree species diversity (Worah 1991). Javed (1996) carried out a study of the bird communities of terai forest and grasslands in Dudhwa National Park, northern India. Using Principal Components Analysis (PCA), he documented the importance of vegetation structure (height, number of strata) along with other key factors such as foraging behaviour and body size of the birds in determining the guild and community structure of the area. Jayapal (1997) found no linear correlation between BSD and FHD and limited evidence for positive correlation between BSD and plant species diversity at Pench National Park in central Indian highlands. A significant difference was found between guild composition of different habitat types (Jayapal 1997).

An important question in the present study was to assess whether the observed differences in species richness and composition were brought about by the factors considered above or there were other factors involved. There have been few attempts to document differences in bird communities of two sites in India. In one such study, Price *et al*. (2003) attributed the observed differences in avifaunal composition of two sites (Manali and Overa sanctuaries) separated by 250 km in the Himalayas to replacement by

similar sized congeners, specific habitat requirements (e.g. presence of particular tree species), patchy distribution and unexplained patterns. They however, did not consider the role of climatic and structural variations in the habitat in detail, but indicated the likely role of vegetation in these observed differences. In another study, Jayson and Mathew (2002) attributed differences in bird species composition between rainforest and moist deciduous forest at two sites separated by 20 km in southern Western Ghats to variation in vegetation, mainly high diversity index. At their sites the bird species richness did not show great variation, but species composition varied. The two sites shared only about 40 % of species despite their proximity. Considering this and the differences in species composition (with rainforest species being absent from moist deciduous forest patch), the role of vegetation (local level) seemed more important than distance effects in the observed patterns.

Despite the apparent role of vegetation at local level, the possible role of history needs to be considered for species composition of bird communities at my study sites. For instance, I was unable to account for the absence of the typical moist forest species such as Emerald Dove, Malabar Trogon, several woodpecker species, White-rumped Shama, Bar-winged Flycatcher-shrike and Scarlet Minivet from Ratanmahal. Since these species do not occur further north, except in the moist forests of the lower Himalaya, Purna and forests to its immediate north should be regarded as range boundaries for such species. Historical factors such as prevention of successful colonization due to habitat unsuitability and stochasticity, loss of moist forest habitats due to changes in climatic conditions (see Ripley and Beehler 1990), presence of barriers (e.g. discontinuity

between the Western Ghats and other mountain ranges to its north) and impoverishment of species pool due to local extinctions could have played a role in absence of these species at Ratanmahal. I have dealt with this point in detail in chapter 6. A thorough study of the communities of the remaining forest patches in the eastern forest belt from Purna to Ratanmahal can throw more light on this aspect.

Bird-habitat relations: Differential use by bird species of moist and dry forests (including the species of bamboo present) at Ratanmahal and Purna provided evidence in favour of vegetation features being of high significance for the observed differences and similarities in bird communities. It is indeed well known that *B. arundinacea* is a moist deciduous forest species, while *D. strictus* is mainly a dry deciduous bamboo (see Champion and Seth 1968). Higher use of riverine and mixed forests could be due to higher productivity and floral richness of these vegetation types. Edges are known to increase diversity and this has been documented with many groups of animals including birds (Harris 1988). High use of riverine forests that shared many edges with other habitats owing to their strip like nature could also be due to this reason. Worah (1991) also showed a positive relationship between floral diversity and bird diversity in Dangs. In particular, she documented a low diversity of birds in teak plantations.

Use of vertical strata: Javed (1996) showed two main divisions in the guild structure at Dudhwa in the terai belt of northern India - canopy foragers and ground foragers or foragers of the lower vegetation strata. My data set also identified these two predominant guilds. The higher levels of vegetation with foliage seemed to offer more insect biomass

for birds as indicated by a higher number of species observed in the higher strata. A vast majority of sightings obtained in the three to eight meter category were generally in the above five meter level (*personal observation*). Development of good undergrowth at many sites could have facilitated a high number of ground and undergrowth foraging species. Foliage in the middle and upper stories including the canopy seemed important for most species in the bird communities of the two sites.

4.4.3 Foraging guilds: A guild is defined as a set of 'species that exploits the same class of environmental resources in a similar way' (Root 1967 in Wiens 1989). Guilds have high functional utility in understanding the organisation of communities (Terborgh and Robinson 1986). The guild signatures of my study sites did not vary much on the whole except few noticeable differences among some guilds. Both sites had few specialized guilds indicating lack of great differences in guild composition. There were six guilds that had the same number of species at both the sites. Due to the presence of an irrigation reservoir at Ratanmahal, it had a higher number of species in the aquatic guild as compared to Purna, which lacked any reservoir. My observation of gleaning insectivores dominating the communities at two sites along with sallying insectivores was in accordance with observations of Javed (1996) and Rao (1988) in terai belt and dry evergreen forests of southeast India respectively. Karr (1980) compared guild signatures of tropical forest undergrowth avifaunas of three continents and pointed at the preponderance of foliage gleaning insectivore guild. He stressed the roles of biogeographic and evolutionary history, but also outlined the influence of geographic proximity, climate and specific biotic factors in shaping the guild signatures. Landres and

MacMahon (1980) considered similarities in guilds between their oak woodland sites in western North America to similarities in vegetation structure (tree structure) and differences in the same were attributed to behavioural flexibility of species in response to prey. Pearson (1975) pointed at the likely role of history, foliage and body size relationships and role of other taxa (in terms of competition) in community composition of three Amazonian forest sites. Differences in guild signatures of the two sites largely pointed at the structural and floristic differences in vegetation of the two sites. Purna had a much higher canopy than Ratanmahal leading to more vertical layers in the forest on most transects (Singh *et al*. 2002, Trivedi 2003). Ratanmahal lacked this luxuriance except in the moist deciduous patches at Kotda (T-1) and to some extent at Popatkuwa (T-2). This factor in turn could be an influence of the biogeographic history of the two sites and/or higher rainfall (almost twice the rainfall at Ratanmahal) at Purna. The other factor that could have played a role was the presence of several stages of vegetation at Purna approximating natural successional stages (from a young monoculture to a climax moist deciduous forest). This probably contributed to high richness of the bark-foraging guild that was dominated by woodpeckers at Purna. Since occurrence of several woodpecker species indicates properties of dynamic forested landscape and their distribution reflects anthropogenic influences on the habitats (Mikusinski *et al*. 2000), their high richness at Purna is of high conservation significance.

4.4.4 Species Abundance – Correlates of Commonness and Rarity: The trends of species abundance indicated a high similarity between the patterns observed in the bird communities of the two sites. The distribution-abundance curves showed that both the sites possessed highly even bird communities (see Terborgh *et al*. 1990). Although

distribution of abundance has not received much attention at regional and continental scales, many local and habitat scale studies have focused on this aspect. Three models depicting local patterns of distribution of species abundances have been described. These are geometric, lognormal and broken stick (see Wiens 1989). Magurran (1988) has discussed their ecological relevance though there is considerable debate and discussion regarding the ecological implications and validity of these models, particularly the commonest - lognormal model (see Magurran 1988). The distribution observed in the bird communities of both study sites is a universal feature among communities of varying taxa and in sizes ranging from diatometer slides to continents (Sugihara 1980). Though there is no agreement on whether this is a mathematical artifact or has a biological basis, Sugihara (1980) explained this pattern in terms of a hierarchical community structure represented by a sequentially divided niche space.

It appears that several species in communities are rare and that rarity has different connotations. For instance, Karr (1977) studied rarity in rainforest birds in Panama. He described five forms of rarity that included species associated with other habitats, species which could not be sampled well (i.e. canopy species, nocturnal species), species showing seasonal movements, species visiting the area for specialized resources and unknown form of rarity. He indicated that some species exhibited more than one form of rarity and in all 62 % of the species were rare in his study area. Terborgh *et al*. (1990), while documenting the Amazonian bird community found about 42 % of species to be rare using Karr's criteria. They re-interpreted Karr's work to reduce rarity to two chief forms - local rarity and inherent or constitutional rarity. The latter type includes species

that are habitat specialists, the largest sized species within certain guilds, woodpeckers, raptors and owls. Such species are more vulnerable to changes in habitats (Terborgh *et al*. 1990) and require more attention from the conservation point of view. In their study, 10 % of the species showed such rarity.

Close to half the species (45.2%) encountered on transects at the two study sites were rare or very rare. Among these, species common to both sites (33.3%) belonged to the category of 'common elsewhere' i.e. in other habitats as shown by Terborgh *et al*. (1990) or these were migrants. My results showed that there were 16 constitutively rare species of forest birds (for both sites combined) on transects. This category did not include migratory species. Six species among these occurred at range extremities (five at Purna and one at Ratanmahal). Hence, their rarity at my study sites could also be called 'biogeographic rarity'. Two of these species - Malabar Trogon and White-cheeked Barbet are endemic to the Western Ghats (see Grimmett *et al*. 1998). The above indicates that patchy distribution of bird species and their apparent rarity are normal for tropical forest bird communities. However, such species need to be viewed in light of factors such as their habitat specificity, body size, guilds and endemism for conservation purposes.

Chapter 5

COMPOSITION AND ORGANISATION OF MIXED-SPECIES FLOCKS

5.1 INTRODUCTION

Mixed-species foraging flocks of birds show a convergent community level pattern across the continents and a range of ecosystems (Diamond 1981) although there is a remarkable gradient in their organization from temporary associations to cohesive, permanent, territory-defending units (Munn and Terborgh 1979). Several studies have addressed questions pertaining to structure, organization and evolution of mixed-species bird flocks (e.g. Winterbottom 1949, Moynihan 1962, Vuilleumier 1967, Morse 1970, Buskirk 1976, Herrera 1979, Munn and Terborgh 1979, Powell 1989, Jullien and Clobert 2000). Mixed-species flocks carry important implications at population and community levels in terms of reduced intraspecific and interspecific competition (Munn and Terborgh 1979, Powell 1979), increased species richness of communities (Powell 1989, Graves and Gottelli 1993) and evenness of abundance of species (Terborgh *et al.* 1990, Hino 2002). Avoidance of predation and foraging facilitation are the two major hypotheses to explain mixed-species flocking. Jullien and Clobert (2000) have shown that survival rates of obligate flock members are significantly higher compared to solitary and facultative flocking species.

Species participating in flocks have been classified as 'nuclear' and 'attendant' (see Winterbottom 1949, Moynihan 1962, Vuilleumier 1967) depending on the roles of these species in terms of flock formation and cohesion. Herrera (1979) classified species as 'flock-positive' and 'flock-negative' based on life history and behavioural traits. Flock-negative species are of lower body weight, fairly specialised in their morphology and substrate use and less capable of copying foraging locations of other species. Flock-positive species, on the other hand, are large-bodied, less specialized in morphology and substrate use and capable of copying foraging locations of other species. Both groups are probably equally vulnerable to predation (Herrera 1979). Morse (1970), Munn and Terborgh (1979) and Dolby and Grubb (1999) pointed out that flock members derive differential benefits by joining mixed flocks. Research has shown that nuclear species seem to derive foraging benefits in terms of kleptoparasitism and copying of foraging locations, while most other species gain anti-predatory advantages by joining flocks.

Various factors have been shown to play a role in influencing species composition of flocks. Local species pools and distribution patterns were regarded to play a major role in composition of mixed flocks of Southeast Asia (McClure 1967), central and south America (Hutto 1987, Gram 1998) and southern India (Sridhar 2005). Studies on mixed-species flocks in the Neotropics, the Caribbean and Madagascar showed positive association between relative abundance of a species and its flocking propensity (Hutto 1994, Latta and Wunderle 1996, Hino 2002). Presence of sympatric congeneric species affects flock participation as shown by checkerboard patterns of flock participation of such species pairs in the Neotropics (Graves and Gottelli 1993). Presence/absence of

nuclear species has also been shown to influence flock composition (Buskirk *et al*. 1972, Powell 1979). Habitat fragmentation and the nature of surrounding matrix also influence species composition of mixed-species flocks (Stouffer and Bierregaard 1995, Maldonado-Coelho and Marini 2000).

There have been several studies of mixed flocks in the Oriental region (e.g. McClure 1967, Croxall 1976, Partridge and Ashcroft 1978, Vijayan 1989, King and Rappole 2001a, Robin and Davidar 2001 and 2002, Kotagama and Goodale 2004, Goodale and Kotagama 2005, Sridhar 2005), with a majority focusing on rainforest flocks. There is a paucity of information from most parts of India on mixed-species flocks, especially so for the deciduous forests in the central highlands. Here, I document the composition and organisation of mixed-species flocks at Purna and Ratanmahal wildlife sanctuaries located in the fragmented eastern forest belt of Gujarat. I specifically sought answers for these questions –

1. What are the factors that govern species composition of flocks?
2. Are there patterns in co occurrence of species, if yes, which factors favour/prevent it?
3. Which species do not join flocks and why?

5.2 RESULTS

5.2.1 Species richness and flock size: I encountered 61 mixed-species flocks at the two study sites, 36 flocks were met with on transects and the rest while walking on trails or during casual observations. Thirty-two flocks were recorded at Ratanmahal and 29 flocks at Purna.

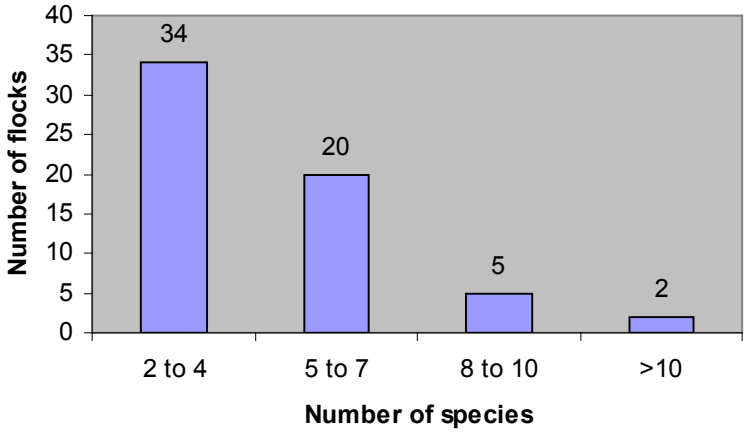
Table 5.1 Species encountered in mixed flocks and their frequency of occurrence at Ratanmahal and Purna

No.	Species	Acronym	Status	Guild	Frequency (n=61)
	Ashy Drongo *Dicrurus leucopheus*	AD	M	FSI	7
	Asian Paradise-flycatcher *Terpsiphone paradisae*	APF	M?	FSI	12
	Black Drongo *Dicrurus macrocercus*	BD	R	FSI	2
	Black-hooded Oriole *Oriolus xanthornus*	BHO	R	AO	12
	Black-naped Monarch *Hypothymis azurea*	BNM	R	FSI	7
	Black-rumped Flameback *Dinopium benghalense*	BRF	R	BF	16
	Blue-winged Leafbird *Chloropsis cochinchinensis*	BWL	R	AO	2
	Brown-capped Pygmy Woodpecker *Dendrocopus nanus*	BCPW	R	BF	5
	Brown-headed Barbet *Megalaima zeylanica*	BHB	R	AFR	2
	Chestnut-shouldered Petronia *Petronia xanthocollis*	CSP	R	MO	2
	Common Hawk-cuckoo *Hierococcyx varius*	CHC	M	FGI	1
	Common Iora *Aegithina tiphia*	CI	R	FGI	3
	Common Tailor Bird *Orthotomus sutorius*	CTB	R	UGI	4
	Common Woodshrike *Tephrodornis pondicerianus*	CWS	R	FGI	18
	Crimson Sunbird *Aethopyga siparaja*	CS	R?	N	1
	Golden-fronted Leafbird *Chloropsis aurifrons*	GFL	R	AO	11
	Great Tit *Parus major*	GT	R	FGI	8
	Greater Coucal *Centropus sinensis*	GC	R	UGC	1
	Greater Flameback *Chrysocolaptes lucidus*	GFB	R	BF	3
	Greater Racket-tailed Drongo *Dicrurus paradiseus*	GRTD	R	FSI	34
	Green Bee-eater *Merops orientalis*	GBE	R	ASI	1
	Jungle Babbler *Turdoides striatus*	JB	R	MLI	36
	Large Cuckooshrike *Coracina macei*	LCS	R	FGI	1
	Large-billed Crow *Corvus macrorhynchos*	LBC	R	MO	1
	Leaf Warbler *Phylloscopus* spp.	LW	M	FGI	5
	Orange-headed Thrush *Zoothera citrina*	OHT	M	GFI	1
	Oriental Magpie Robin *Copsychus saularis*	OMR	R	GFI	4
	Oriental White-eye *Zosterops palpebrosa*	OWE	R	FGI	4
	Puff-throated Babbler *Pellorneum ruficeps*	PTB	R	GFI	1
	Purple Sunbird *Nectarinia asiatica*	PS	R	N	1
	Purple-rumped Sunbird *Nectarinia zeylonica*	PRS	R?	N	1
	Red-vented Bulbul *Pycnonotus cafer*	RVB	R	AO	5
	Rufous Treepie *Dendrocitta vagabunda*	RTP	R	AO	17
	Rufous Woodpecker *Celeus brachyurus*	RWP	R	BF	1
	Scarlet Minivet *Pericrocotus flammeus*	SCM	R	FGI	2
	Small Minivet *Pericrocotus cinnamomeus*	SM	R	FGI	3
	Spotted Dove *Streptopelia chinensis*	SD	R	G	3
	Tawny-bellied Babbler *Dumetia hyperyhtra*	TBB	R	UGI	1

No.	Species	Acronym	Status	Guild	Frequency (n=61)
	Tickell's Blue Flycatcher *Ficedula tickelliae*	TBF	R	USI	2
	Tree Pipit *Anthus trivialis*	TP	M	GFI	1
	White-bellied Drongo *Dicrurus caerulescens*	WBD	R	FSI	31
	White-browed Fantail *Rhipidura aureola*	WBF	R	FSI	5
	Yellow-crowned Woodpecker *Dendrocopus maharattensis*	YCW	R	BF	2

A total of 283 occurrences and 545 individuals were recorded. Of these, 165 occurrences and 391 individuals were obtained on transects. Forty-three bird species participated in mixed flocks; 32 species (27.6% of the 116 terrestrial species) at Ratanmahal and 31 species (25.6% of the 121 terrestrial species) at Purna (Table 5.1). Nineteen species were common to the flocks of the two sites. No species was exclusive to mixed flocks. The number of species encountered in a single flock ranged from 2 to 13 with most flocks (88.5%) having seven or fewer species (see Figure 5.1). The flocks in which all individuals of participating species were recorded (n = 46) ranged from three to 35.

Figure 5.1 Species richness wise frequency of occurrence of flocks



The number of individuals in the smallest flock was three and four for Ratanmahal and Purna respectively, while the largest flocks consisted of 30 and 35 individuals for the two sites respectively. Most flocks (80.4 %) had less than 15 individuals and only three flocks (6.5 %) contained more than 20 individuals (see Table 5.2). Only one species – Jungle Babbler contributed nearly 85 to 90 percent individuals in two such flocks, while Small Minivet contributed 50 percent individuals in the third flock. Median flock size at Ratanmahal was 8 individuals (mean flock size=10.5, n=23, SD=6.51) and at Purna it was 9 individuals (mean flock size=11.3, n=23, SD=8.09). Median flock size over all was 9 individuals (mean flock size=10.9, n=46, SD= 7.36).

Table 5.2 Number of individuals per flock in mixed-species flocks at Purna and Ratanmahal (n=46)

Flock size (number of individuals)	Number of Flocks		
	Ratanmahal	**Purna**	**Total**
0-5	7	5	12
6-10	7	10	17
11-15	4	4	8
16-20	4	2	6
>20	1	2	3
Total	23	23	46

The flock sizes are likely to be underestimated in some instances where all individuals in a flock were not detected. This was particularly true for Jungle Babbler, which is a gregarious species and forages at all levels from middle storey to ground level. Median flock sizes were the lowest for flocks with three species (five individuals, n=8) and

highest for flocks with seven or more species (14.5 individuals, n=6). There was a significant positive correlation between number of species in a flock and mean flock size (r=0.85, df =4, p<0.05). There was some seasonality observed in flocking with low flocking observed during breeding season (April to July and October-November) of major species (especially likely nuclear species). However, since my sampling was not uniform each month, it is a tentative inference.

5.2.2 Flock Composition: Jungle Babbler, Greater Racket-tailed Drongo and White-bellied Drongo (all scientific names in Table 5.1) were present in more than half of the 61 flocks encountered. These three species along with Common Woodshrike, Rufous Treepie and Black-rumped Flameback were found in more than 25 percent flocks and regarded as regular participants. Six species were encountered in 10 to 25 per cent flocks (major attendants). Thirty-one species joined less than 10% flocks (irregular attendants), of which 13 species (accidental participants) were present in only one flock each. Fifty-four flocks contained at least one species of drongo, 15 flocks had two species; while four flocks had three species of drongo. Over all, there were 50 flocks with either Jungle Babbler or Common Woodshrike, or both. Of the rest 11 flocks (eight in Ratanmahal, three in Purna), eight had at least one species of drongo, mainly Greater racket-tailed Drongo and White-bellied Drongo. Jungle Babbler alone contributed nearly half (47 %) of the total number of individuals found in flocks encountered on transects (n=36). In 20 flocks out of the 36 met with on transects, it had a mean group size of 9.2 individuals (range-2 to 30 individuals). No species was exclusive to mixed flocks and all flocking species were met with on transects (within or outside mixed flocks) during sampling. Six

migratory species (13.95 %) were met with in flocks (Table 5.2), the rest being resident species. Interestingly, the extra-limital migrants had a very low presence in flocks. The only migrants observed frequently in flocks were Asian Paradise-flycatcher and Ashy Drongo. These were local migrants.

Table 5.3 Flocking propensities of mixed flocking species at Purna and Ratanmahal based on their numbers within and outside flocks (*n*=36)

No.	Species	Guild	Body size (cm)	Number overall[1]	Number MSF overall[2]	FP-R	FP-P	Flocking propensity (%) #
1	**AD**	FSI	29	(8, 26) 34	(0, 3) 3	0	11.53	8.82
2	**APF**	FSI	20	(16, 31) 47	(4, 5) 9	**25**	16.12	19.14
3	**BCPW**	BF	13	(24, 10) 34	(3, 1) 4	12.5	10	11.76
4	**BD**	FSI	28	(4, 4) 8	(2, 0) 2	**50**	0	**25**
5	**BHB**	AFR	27	(34, 59) 93	(0, 1) 1	0	1.69	1.07
6	**BHO**	AO	25	(38, 45) 83	(3, 2) 5	7.89	4.44	6.02
7	**BNM**	FSI	16	(20, 27) 47	(4, 2) 6	20	7.4	12.76
8	**BRF**	BF	26	(15, 21) 36	(4, 5) 9	**26.66**	23.8	**25**
9	**BWL**	AO	20	(4, 4) 8	(1, 1) 2	**25**	**25**	**25**
10	**CHC**	FGI	34	(8, 6) 14	0	0	0	0
11	**CI**	FGI	14	(15, 10) 25	(4, 0) 4	**26.66**	0	16
12	**CS**	N	11	(7, 42) 49	(0, 1) 1	0	2.38	2.04
13	**CSP**	MO	13.5	(111, 112) 223	(4, 0) 4	3.6	0	1.79
14	**CTB**	UGI	13	(58, 48) 106	0	0	0	0
15	**CWS**	FGI	18	(84, 41) 125	(14, 10) 24	16.66	24.39	19.2
16	**GBE**	ASI	16	(17, 11) 28	(1, 1) 2	5.88	9.09	7.14
17	**GC**	UGC	48	(15, 23) 38	0	0	0	0
18	**GFB ***	BF	33	(0, 23) 23	(0, 4) 4	0	17.39	17.39
19	**GFL**	AO	19	(11, 51) 62	(4, 4) 8	**36.36**	7.84	12.9
20	**GRTD**	FSI	32	(29, 58) 87	(8, 16) 24	**27.58**	**27.58**	**27.58**
21	**GT**	FGI	14	(19, 33) 52	(7, 5) 12	**36.84**	15.15	23.07
22	**JB**	MLI	25	(213, 169) 382	(72, 112) 184	**33.8**	**66.27**	**48.16**
23	**LBC**	MO	46	(98, 65) 163	0	0	0	0
24	**LCS**	FGI	30	(24, 30) 54	(1, 1) 2	4.16	3.33	3.70
25	**LW**	FGI	10	(114, 110) 224	(5, 0) 5	4.38	0	2.23
26	**OHT**	GFI	21	(2, 11) 13	(0, 1) 1	0	9.09	7.69
27	**OMR**	GFI	23	(16, 12) 28	(2, 0) 2	12.5	0	7.14
28	**OWE**	FGI	10	(27, 29) 56	(5, 0) 5	18.51	0	8.92
29	**PRS ***	N	10	(0, 2) 2	(0, 1) 1	0	**50**	**50**
30	**PS**	N	10	(34, 41) 75	(0, 1) 1	0	2.43	1.33

No.	Species	Guild	Body size (cm)	Number overall[1]	Number MSF overall[2]	FP-R	FP-P	Flocking propensity (%) #
31	**PTB**	GFI	15	(2, 19) 21	0	0	0	0
32	**RTP**	AO	46	(59, 42) 101	(10, 4) 14	16.94	9.52	13.86
33	**RVB**	AO	20	(35, 42) 77	(2, 2) 4	5.71	4.76	5.19
34	**RWP ***	BF	25	(0, 3) 3	(0, 1) 1	0	**33.33**	**33.33**
35	**SCM ***	FGI	20	(0, 23) 23	(0, 4) 4	0	17.39	17.39
36	**SD**	G	30	(84, 39) 123	(2, 0) 2	2.38	0	1.62
37	**SM**	FGI	16	(42, 6) 48	(1, 0) 1	2.38	0	2.08
38	**TBB**	UGI	13	(2, 4) 6	0	0	0	0
39	**TBF**	UGI	14	(35, 50) 85	0	0	0	0
40	**TP**	GFI	15	(13, 28) 41	0	0	0	0
41	**WBD**	FSI	24	(77, 38) 115	(21, 8) 29	**27.27**	21.05	**25.21**
42	**WBF ***	FSI	18	(24, 0) 24	(5, 0) 5	20.83	0	20.83
43	**YCW**	BF	17	(5, 5) 10	(2, 0) 2	**40**	0	20

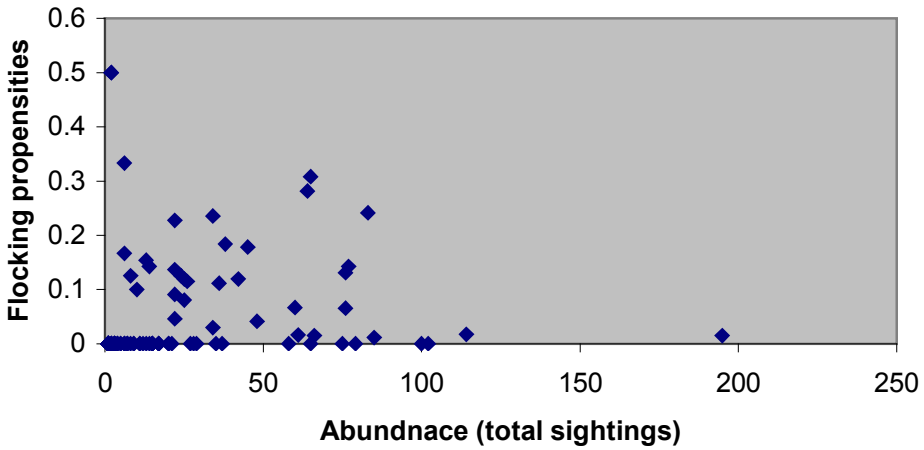
number of individuals in flocks out of total number of individuals of a species, 1 & 2 - figures in parenthesis denote numbers at Ratanmahal and Purna respectively

5.2.3 Flocking propensities: Of the 106 species encountered on transects at both sites during the study, 35 species (33 %) were recorded in mixed flocks. Table 5.3 gives flocking propensities of these species at both the sites. When data for both sites was combined, eight species showed 25 % and above flocking propensities. Of these, high propensities of Purple-rumped Sunbird and Rufous Woodpecker seemed to be a result of few individuals being met with and not considered significant. Twelve species showed between 10 and 25 %; while 23 species had less than 10 % flocking propensities. Flocking propensities of 11 species were above 25 % at Ratanmahal compared to five such species at Purna. A Wilcoxon matched pairs test showed that the flocking propensities of the species at two sites were significantly different (T=104, n=30, z=2.254, p=0.024). Since five species were absent from either of the sites and eight species did not occur in flocks, flocking propensities of 30 species only were compared. Of these, 20 species showed significantly high flocking propensities at Ratanmahal

(Wilcoxon matched pairs test, T=0, n=20, z=3.919, p =0.00008). Eight species showed higher flocking propensities at Purna, while two species had identical flocking propensities. Eight species (40 %) with higher flocking propensities at Ratanmahal belonged to size class >20 cm, while among those showing higher flocking propensities in this size class at Purna, there were two species (25 %).

Abundance and flocking propensity: Total number of sightings of all species met with on transects in both communities (n=106) and their flocking propensities (percent times that a species occurred in mixed flocks out of total occurrences on transects) were positively correlated, but this correlation was not statistically significant (r=0.12, df=104, p>0.1). However, examination of data (see Figure 5.2) revealed that presence of many rare species, guild distribution and several other factors (discussed later) could have obscured the true nature of this relationship.

Figure 5.2 Correlation between total sightings and flocking propensities of species found on transcets



For instance, rare and migratory insectivores such as Verditer Flycatcher and Grey-headed Canary Flycatcher (rare at both sites, P. Trivedi, *unpublished data*) did not participate in flocks. On the contrary there were several insectivorous species with high mean encounter rates (at both or one of the two sites) such as leaf warblers *Phylloscopus* spp., Red-throated Flycatcher *Ficedula parva*, Oriental White-eye *Zosterops palpebrosa*, Tickell's Blue Flycatcher *Cyornis tickelliae*, Large Cuckooshrike *Coracina macei*, Small Minivet and Scarlet Minivet (P. Trivedi, *unpublished data*) that did not show high flocking propensities. Besides, some species with low mean encounter rates (e.g. Oriental Magpie-Robin *Copsychus saularis*, Black-rumped Flameback) were frequent flock participants.

Guilds and their propensities: Species belonging to 10 foraging guilds were present in mixed flocks out of a total of 15 foraging guilds recorded at the two sites (Table 5.4).

Table 5.4 Guild representation in mixed flocks at Purna and Ratanmahal

Guild	Number of species - total	Number of Species in mixed flocks
Arboreal insectivore	35	17
Undergrowth insectivore	10	3
Multilayer insectivore	2	1
Bark foraging insectivore	11	5
Ground foraging insectivore	17	4
Granivore	14	1
Nectarivore	3	3
Arboreal omnivore	7	5
Other omnivore	12	2
Carnivore	24	1
Frugivore (arboreal & terrestrial)	5	1
Arboreal frugivore-faunivore	1	0
Arboreal herbivore	5	0
Aerial insectivore	12	0

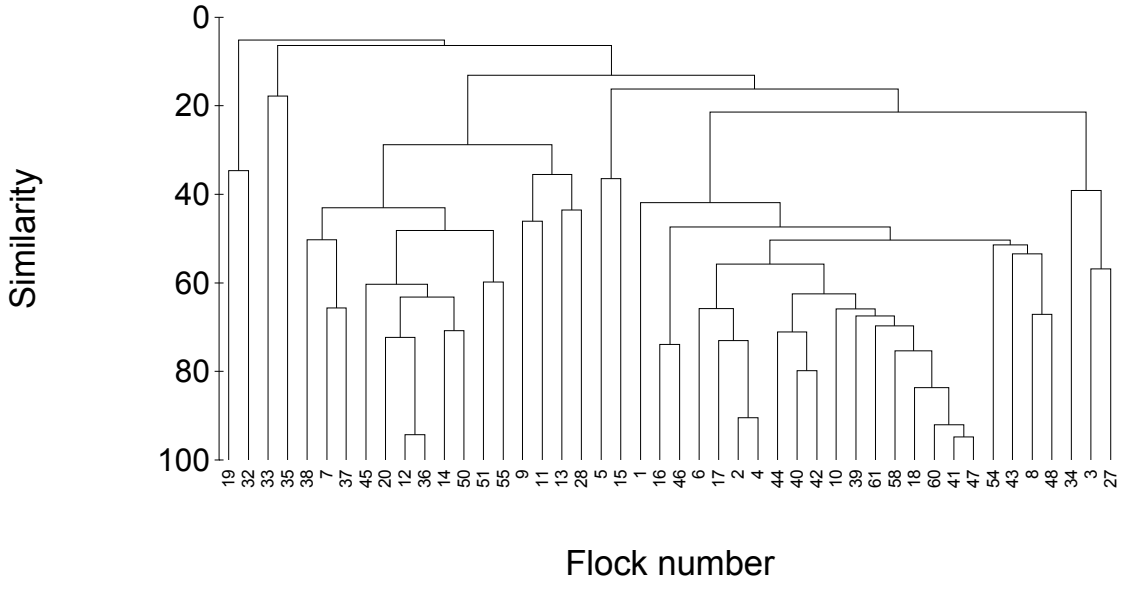
Aquatic	33	0
Total	**191**	**43**

Thirty species were predominantly insectivorous with the foliage sallying and gleaning insectivores dominating, followed by arboreal omnivores and bark foragers. Of the six regular species, five were insectivores and one omnivore; while of the six major attendants, four were insectivores and two omnivores. Thus, nine species out of the 12 major species were insectivores. The remaining 31 species of irregular and accidental attendants had 21 species of insectivores.

When I compared the guild wise number of species (13 guilds excluding aquatic and aerial insectivore guilds) present in mixed flocks versus those not found in flocks from the total species belonging to these guilds found at the two sites; their occurrence was significantly different than expected by chance (x^2=35.8, *df*=12, p<0.001). Hence, some guilds participated more and others less than expected by chance. Mean flocking propensity of insectivores was the highest (mean=13.65, n=30, SD=11.87), followed by herbivores (mean=11.21, n=5, SD=21.68), omnivores (mean=9.25, n=7, SD=8.66) and carnivores (0, n=1). The last guild was absent from flocks on transects. The guilds not encountered in flocks were aquatic, arboreal frugivore-faunivore (hornbills), aerial insectivore (swallows, swifts) and arboreal herbivores (parakeets, flowerpeckers). Carnivores, granivores and frugivores were among the common guilds in the community that were represented by one or two species in mixed flocks. Some of the absent or low represented species and guilds had high relative abundances in the bird communities at my study sites (*unpublished data*). However, my data set is limited to draw further conclusions as for some guilds there have been very few observations.

5.2.4 Species Co-occurrence Patterns: Using the data of 46 flocks in which abundance for all species were known, I derived a similarity matrix for flocks. The resulting dendrogram has been shown in Figure 5.3. The flocks lying adjacent to each other are more closely related than those lying at distance. Although distinct clusters were not obtained, there were two major sets of clusters – those containing Jungle Babbler (22 flocks, flock 1 to 48 in Figure 5.3) and those with White-bellied Drongo and Common Woodshrike (15 flocks, flock 38 to 28), with nine flocks being heterogeneous species groupings (flock 19 to 35, 5 and 15 and 34 to 27) mostly lacking Jungle Babbler and White-bellied Drongo.

Figure 5.3. Dendrogram showing similarity between mixed-species flocks



Jungle Babbler flocks mainly had medium sized species (≥21 cm) viz. Greater Racket-tailed Drongo, White-bellied Drongo, Rufous Treepie, Black-rumped Flameback and Black-hooded Oriole. Most members were. White-bellied Drongo-Common Woodshrike

flocks mainly had small species (all ≤20 cm) including Golden-fronted Leafbird and Great Tit as major associates with other members being Brown-capped Pygmy Woodpecker, Yellow-crowned Woodpecker, White-browed Fantail. Rufous Treepie was a large sized species present in these flocks. Two flocks also had Jungle Babbler, but it had a very low abundance in these flocks. The heterogeneous flocks mainly consisted of small species (<20 cm) - Small Minivet, Oriental White-eye, White-browed Fantail, Black-naped Monarch, Asian Paradise-flycatcher and Leaf warblers. Black-rumped Flameback (two flocks), Greater Racket-tailed Drongo (four flocks) and White-bellied Drongo (one flock) were present infrequently in heterogeneous flocks, while Jungle Babbler was absent.

Table 5.5 shows an association matrix of the 12 regular participants and major attendants (present in >10% flocks overall). On further exploring for size-based association patterns among these species (for the ones with higher flocking propensities), it was apparent that larger species such as Jungle Babbler, Greater Racket-tailed Drongo and White-bellied Drongo associated more with species in the size category ≥21 cm and less with species below 20 cm size class. Similarly, smaller species such as Common Woodshrike associated with species below 20 cm size such as Golden-fronted leafbird and Great Tit. However, this relationship did not hold true for Golden-fronted leafbird that associated with larger species more often than with smaller species. Thus size based flock co-occurrence was observed frequently, however, there were other factors such as guilds of the flock associates which could have influenced the co-occurrence patterns of regular flocking species. For instance, a species pair showing high occurrence – Jungle Babbler

and Greater Racket-tailed Drongo showed similar distribution pattern at Purna and Ratanmhal with the latter being absent from transects on which the former was absent or showed a very low encounter rate there (*unpublished data*). Greater Racket-tailed Drongo was associated with Jungle Babbler in 28 flocks of the total 34 in which it occurred (see Table 5.5). Another species-pair, Jungle Babbler and Common Woodshrike also showed a partially checkered distribution pattern. The latter occurred in more flocks (six out of nine flocks) on transects without Jungle Babbler and in fewer flocks (five out of twenty seven flocks) where Jungle Babbler was present. This difference was statistically significant (x^2=7.37, *df*=1, p<0.01).

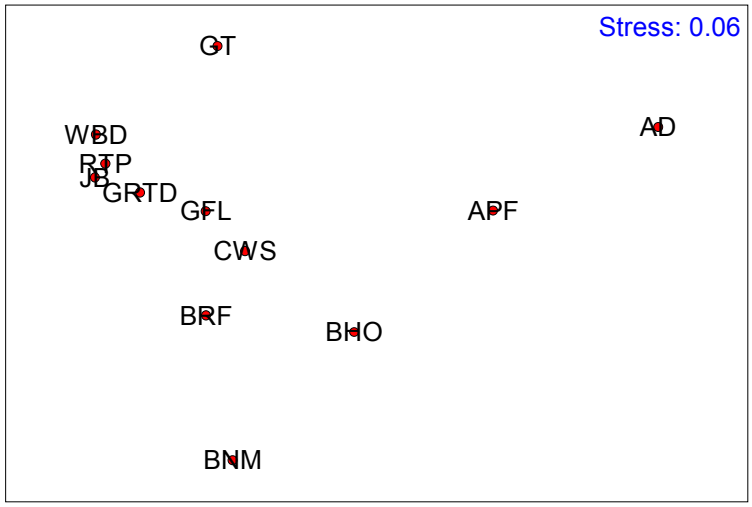
Table 5.5 Association Matrix of Common species (> 10% occurrence) in mixed flocks (n=61)

	Tr	**AD**	**APF**	**BHO**	**BNM**	**BRF**	**CWS**	**GFL**	**GRTD**	**GT**	**JB**	**RTP**	**WBD**
AD	**7**	--	5	1	--	2	2	3	4	1	3	3	4
APF	**12**		--	3	2	1	3	3	7	1	5	4	7
BHO	**12**			--	2	5	3	6	8	1	7	5	5
BNM	**7**				--	2	1	1	6	--	4	2	2
BRF	**16**					--	1	2	12	--	12	5	7
CWS	**18**						--	6	5	6	3	3	13
GFL	**11**							--	4	1	2	5	5
GRTD	**34**								--	1	28	12	13
GT	**8**									--	2	2	5
JB	**36**										--	12	18
RTP	**17**											--	10
WBD	**31**												--

Tr = total records, other abbreviations as per Table 5.1

Using the information in Table 5.5, I carried out a multidimensional scaling analysis (MDS, see Figure 5.4) showing distances between these species in a two-dimensional space. Ashy Drongo and Asian Paradise-flycatcher were outliers, so were Black-naped Monarch, Great Tit and Black-hooded Oriole. Great Tit-Black-naped Monarch and Black-naped Monarch-Ashy Drongo were the farthest distanced species pairs. The species that formed a distinct cluster were Greater Racket-tailed Drongo, Jungle Babbler, Rufous Treepie and White-bellied Drongo. Common Woodshrike and Golden-fronted Leafbird formed another cluster and were closer to Black-rumped Flameback. Great Tit occurred closer to the Jungle Babbler-drongo cluster, so did Black-hooded oriole for Common Woodshrike cluster.

Figure 5.4 MDS diagram showing similarity matrix of species in >10% flocks



Most congeneric species-pairs (Golden-fronted Leafbird/Blue-winged Leafbird, Scarlet Minivet/Small Minivet and Brown-capped Pigmy Woodpecker/Yellow-crowned Woodpecker) were never found in the same flock. These species either showed checkerboard distributions with respect to dry-moist/flat-hilly habitats or had varying

abundances when sympatric. The congeneric species that co-occurred were the three species each of drongos and sunbirds. White-bellied Drongo associated with Greater Racket-tailed Drongo in 13 flocks, of which three were at Purna and 10 at Ratanmahal (see Table 5.6). Ashy Drongo associated with both White-bellied Drongo and Greater Racket-tailed Drongo once each; and with both species in a single flock on three occasions. The three species of sunbirds – Purple Sunbird, Purple-rumped Sunbird and Crimson Sunbird were found in a single flock once. Abundances and presence of nuclear species appeared important for drongos since White-bellied Drongo showed higher flocking propensity at Ratanmahal, where its abundance was much higher.

Table 5.6 Participation by two drongo species in mixed flocks at Ratanmahal and Purna*

Species	**Ratanmahal**							**Purna**						
	T-1	**T-2**	**T-3**	**T-4**	**T-5**	**NT**	**T**	**T-1**	**T-2**	**T-3**	**T-4**	**T-7**	**NT**	**T**
GRTD	2	1	0	1	0	2	**6**	1	5	1	0	1	7	**15**
WBD	3	2	4	1	1	1	**12**	0	0	1	2	0	3	**6**
Both	1	1	0	1	0	7	**10**	0	1	1	0	1	0	**3**
Total	**6**	**4**	**4**	**3**	**1**	**10**	**28**	**1**	**6**	**3**	**2**	**2**	**10**	**24**

* Abbreviations in Table 1. NT=Non-transect flocks, T=Total number of flocks

5.2.5 Flock organisation

Basic/core flocks: I analysed all the 12 flocks containing only two species considering these to be 'basic flocks' consisting of nuclear species that were in the process of recruiting more species and individuals. In all, 10 species were found in such flocks. Only one among these - Ashy Drongo was a non-resident species. Jungle Babbler was

present in eight out of 12 flocks followed by Greater Racket-tailed Drongo (four flocks), White-bellied Drongo (three flocks), Golden-fronted Leafbird and Rufous Treepie (two flocks each) and Ashy Drongo, Black-rumped Flameback, Common Woodshrike, Small Minivet and Oriental White-eye (one flock each). Jungle Babbler was found in association with drongos in six of the eight flocks. It also associated with Black-rumped Flameback and Rufous Treepie once each. Greater Racket-tailed Drongo was present with Jungle Babbler in all four flocks in which it occurred. Any one species of drongo was present in eight flocks. I did not come across any two-species flock containing two species of drongo. Except one flock containing Ashy Drongo and Golden-fronted Leafbird, no flock had a combination of species belonging to >20 and <20 size classes. This indicated a strong size-based core component of flocks. Except one flock consisting of Oriental White-eye and Small Minivet, none of the flocks consisted of identical guilds. Most combinations involved a species each of arboreal omnivore and gleaning or sallying insectivore or a species each of gleaning and sallying insectivores.

Table 5.7 Species richness, presence of basic/core flocking species and nestedness

Type of flock	Number of flocks encountered	Total species richness	Cumulative species richness	Number of basic/core species	Percent nestedness*
2-species	12	10	10	10	--
3-species	10	13	17	6	60
4-species	13	15	23	9	61.5
5-species	8	21	27	8	70.6
6-species	9	28	39	7	57.1
7-species and more	9	32	43	10	75

* percent species present in the three-species flock out of those occurring intwo-species flocks and so on for other flcok species richness categories

Since I did not observe the fate of all two-species flocks, I was interested in assessing whether the flocks with three or more species (*n*=49) were extensions of the two-species flocks. To do this, I explored species composition of such flocks (see Table 7). All flocks had at least one of these ten species; in the four flocks that contained only one such species, Asian Paradise-flycatcher was always present. Five species viz. Jungle Babbler, Greater Racket-tailed Drongo, White-bellied Drongo, Black-rumped Flameback and Golden-fronted Leafbird were present in all categories of flocks given in Table 7. Ashy Drongo and Common Woodshrike were present in four of the five categories, while Rufous Treepie and Oriental White-eye were present in three and Small Minivet in two. This aspect showed that all flocks with more than two-species contained a basic/core (nuclear) and an extended (attendant) component. Close to 60 % species of each flock category was present in the higher species richness category, this figure being the highest for the transition between six-species to seven and above species flocks. This trend was indicative of a partial nested subset kind of distribution of species in flocks.

Species roles: Of the 10 species present in the 'basic' flocks, four species (three species of drongo and Golden-fronted Leafbird) were good mimics. Except Black-rumped Flameback, Small Minivet and Oriental White-eye, the rest seven species were observed mobbing the avian predators. The 'basic' or 'core' species thus seemed to be those with certain characteristics vital to facilitate flocking. Jungle Babbler qualified as a nuclear species as it was intraspecifically gregarious, conspicuous due to active foraging behaviour and vocalisations, had high abundance and flocking propensities. It was a year-round resident and regular participant in mixed flocks. Others, which qualified as nuclear

species were Greater Racket-tailed Drongo, White-bellied Drongo, Common Woodshrike and Golden-fronted Leafbird. All were conspicuously active, had loud vocalizations, mobbed prey and participated in flocks regularly. Three species had mimicking abilities, while the drongos gave loud alarm calls. Only one species – Common Woodshrike was intraspecifically gregarious. I also observed drongos leading the flocks in many instances. Species composition of two-species flocks (basic flocks), over all frequency of occurrence and abundance in flocks (as well as instances of leading the flocks) suggested that excepting Black-rumped Flameback, the other nine species were potential nuclear species.

5.3 DISCUSSION

5.3.1 Species richness and flock size: The flock richness and flock sizes of the two sites were similar and low. Studies in the tropics have reported the mean number of species per flock between 2.5 to 18.6 and mean number of individuals per flock between 2.5 and 41.3 (McClure 1967, Croxall 1976, Greig-smith 1978, Munn and Terborgh 1979, Hutto 1987, Latta and Wunderle 1996, Gram 1998, King and Rappole 2001a, Kotagama and Goodale 2004, Sridhar 2005). Thus, compared to several tropical flocks, median/mean species richness per flock was low in the present study, but it was higher than flocks of Madagascar (Hino 2002), the Mediterranean (Herrera 1979), and North America (Austin and Smith 1972, Morrison *et al*. 1987). Mean flock sizes of my sites were also low compared to many other tropical flocks. In terms of total number of species participating in flocks, my sites had much lower richness compared to 87 species reported by Sridhar (2005), 61 species by Robin and Davidar (2002), 59 species by Kotagama and Goodale

(2004), 52 species by King and Rappole (2001a), 56 species by Greig-Smith (1978), 41 species by Croxall (1976), 66 species by Gram (1998) and 75 to 102 by McClure (1967). Amazonian flocks also showed much higher overall species richness. However, flocks at my sites showed higher overall richness than those recorded by Hino (2002) at Madagascar and several flocks of the northern hemisphere.

In the permanent understorey flocks of the Neotropics, flock size and membership were primarily influenced by intraspecific social organisation throughout the year (Munn and Terborgh 1979, Powell 1979). Presence of Palearctic/Nearctic migrants was shown to play an important role in increased species richness in some regions (McClure 1967, Hutto 1987, Latta and Wunderle 1996, Gram 1998, Sridhar 2005). As discussed earlier, these factors did not play a major role in determining flock size and richness at my study sites. Rather, availability of resources seemed to have exerted an upper limit on flock richness and size with optimum species richness being in the range of four to seven and optimum flock size between 10 and 15 individuals. Species richness of flocks has been found to be a reflection of the available species pool in a habitat (Latta and Wunderle 1996, Hutto 1994, Gram 1998, Sridhar 2005). Although there was an indication of higher species richness in the flocks found on transects with high species richness, small sample size prevented me from drawing conclusions in this regard.

5.3.2 Flock composition: In terms of species composition, the mixed flocks encountered by me at the two sites were similar although there were striking differences in flocking propensities and flock composition, which I discuss later in this paper. Jungle Babbler,

Greater racket-tailed Drongo and White-bellied Drongo dominated the flocks at my sites. Preponderance of drongos reported by me has been observed in mixed flocks of Africa and Asia (Winterbottom 1949, Croxall 1976, Greig-smith 1978, Vijayan 1989, Robin and Davidar 2001, Hino 2002). My observation of the occurrence of most species as solitary individuals or pairs in mixed flocks reflected a pantropical pattern observed in mixed flocks (Buskirk *et al*. 1972, Munn and Terborgh 1979, King and Rappole 2001a, Hino 2002). However, one species - Jungle Babbler had a high number of individuals in flocks. This and the likely nuclear role of the species (discussed later) are probably being reported for the first time.

It is known that there is higher variability in species composition of tropical flocks as compared to temperate flocks (Austin and Smith 1972). The flocks observed at my sites had some resemblance with those of the southern Western Ghats of India and to some extent with rainforest flocks of Sri Lanka. Jungle Babbler, Greater Racket-tailed Drongo, White-bellied Drongo, Black-rumped Flameback and Great Tit were among the commonest flocking species at Parambikulam in southern India (Robin and Davidar 2001). Vijayan (1989) also observed high participation of Greater Racket-tailed Drongo, White-bellied Drongo, Asian Paradise-flycatcher, Black-rumped Flameback and Black-hooded Oriole in southern India. My observation of high participation and abundance of Jungle Babbler in mixed flocks, being reported for the first time from this region was similar to high abundance of Orange-billed Babbler *Turdoides rufescens* (a congeneric of Jungle Babbler) reported by Kotagama and Goodale (2004) in rainforest flocks of Sri Lanka. They also reported high occurrence of Greater Racket-tailed Drongo in their

mixed flocks. Low presence of Palearctic long-distance migrants in flocks of my area was also similar to that reported by Robin and Davidar (2001) and Kotagama and Goodale (2004). However, the high occurrence of Scarlet Minivet and Small Minivet reported by the above three studies was not recorded at my study sites. Flocks reported by Sridhar (2005) from rainforest fragments in the Anamalai hills of the southern Western Ghats were different in terms of species composition from the flocks reported by me. There the flocks were dominated by smaller species such as Brown-cheeked Fulvetta, Black-lored Tit, Oriental White-eye, Bar-winged Flycatcher-shrike, leaf warblers, Asian Paradise-flycatcher and Velvet-fronted Nuthatch. However, drongos (Greater Racket-tailed Drongo, Bronzed Drongo and Ashy Drongo) played prominent role in these flocks too (see Sridhar 2005).

5.3.3 Correlates of flocking propensities: Although over one-fourth of terrestrial species joined flocks at both sites, over all flocking propensities were low for most species. High degree of evenness in bird communities has been attributed to participation in mixed flocks by birds (Terborgh *et al*. 1990, Hino 2002). However, I recorded low flocking propensities in spite of a high degree of evenness of abundance among the bird communities of the two sites (*unpublished data*). In contrast to a majority of earlier studies of mixed flocks in tropical areas (Hutto 1994, King and Rappole 2001a), I found most participant species outside flocks more often than within. The trend observed in this study of no species having flocking propensities above 50 % and only few species with 25 % or more flocking propensities was a departure from other tropical flocks of India where more species participated in flocks and with higher flocking propensities (see

Robin and Davidar 2001, Kotagama and Goodale 2004, Sridhar 2005). For instance, against only eight species joining more than 25 % flocks at my sites, there were 19 such species reported by Kotagama and Goodale (2004) and 43 species by Sridhar (2005). Such low flocking propensities documented by me could be inherent for deciduous forests with their lower biomass and fewer niches than rainforests. Alternately, this could be a manifestation of various factors described below.

Abundance of species: Positive relationship between abundance and flocking propensities of species has been shown in flocks of Mexico, Hispaniola and Madagascar (Hutto 1994, Latta and Wunderle 1996, Hino 2002). My data show that though abundance seems to be an important factor influencing flocking propensities of species, it is not the only aspect. Hence, not all differences in abundance of species at the two sites led to observable differences in flocking propensities. It has been shown that intraspecific factors promote flocking (Munn and Terborgh 1979, Powell 1979, Fernandez-Juricic 2002). Accordingly, it is likely that flocking is triggered beyond certain abundance due to intraspecific competition or that increasing abundance of conspecifics stimulates flock joining by other members (Powell 1979, Fernandez-Juricic 2002). Hence, rarity of several species such as Bar-winged Flycatcher-shrike, Velvet-fronted Nuthatch, Yellow-crowned Woodpecker, Verditer Flycatcher, Grey-headed Canary Flycatcher and Black-lored Tit was a likely reason for their low flocking propensities or lack of flocking.

I observed low abundance of several forest species found at their range boundaries at Purna and Ratanmahal (Trivedi and Soni, *in press*). Many of these such as Malabar Trogon, Rufous Woodpecker, White-bellied Woodpecker, Lesser Yellownape, Heart-

spotted Woodpecker, Scarlet Minivet, Golden-fronted Leafbird and Velvet-fronted Nuthatch are known to join mixed-species flocks regularly (Partridge and Ashcroft 1978, King and Rappole 2001a, Robin and Davidar 2001, Kotagama and Goodale 2004, Sridhar 2005). Their rarity due to edge-of-the-range distribution could have led to reduced flocking or a total absence of it. In case of congeneric species that were sympatric at a site, species with higher abundance participated more often in flocks. For instance, Greater Racket-tailed Drongo was encountered in more flocks at Purna than at Ratanmahal and vice versa for White-bellied Drongo (Table ?). Similarly, for the two woodpecker species (e.g. Brown-capped Pygmy and Yellow-crowned woodpeckers), higher encounter rate determined which of the two would participate in a mixed flock.

Dilution of species pool due to local extinctions: Trivedi and Soni (*in press*) reported avifaunal impoverishment (including eight likely local extinctions) from these two sites. Some of these species such as Large Woodshrike, Black-lored Tit and White-throated Fantail have been reported as nuclear or important flocking species (Vijayan 1989, Robin and Davidar 2001, Yahya 2001, Sridhar 2005). These extinctions were reported from Purna, where most species had low flocking propensities compared to Ratanmahal, which has not experienced such impoverishment (Trivedi and Soni, *in press*). Disappearance of nuclear species known to cause disintegration of flocks (Botero 2002) could have led to similar consequences at Purna. However, my data is not adequate to address this question nor are there comparable studies from other deciduous forest habitats in India.

Foraging guilds: The guild organisation of mixed flocks at my study sites was characterised by higher participation by arboreal (sallying and gleaning) insectivores and bark foragers; reflecting a trend shown by many earlier studies (Munn and Terborgh 1979, Kotagama and Goodale 2004, Sridhar 2005). However, a high proportion of arboreal omnivorous species was a variance from usual dominance of insectivores. This was also partly due to differences in the way I classified the guilds of leafbirds, bulbuls etc. High mean flocking propensities of insectivores highlighted the advantage of foraging improvement compared to other guilds. However, several insectivores showed low or no flocking, which was intriguing and in case of abundant species difficult to explain. The guilds that did not participate in flocks were not compatible due to ground/aerial foraging modes or were tied to certain foraging substrates (i.e. perch sites for Indian Roller and shrikes). Some guilds of ground and undergrowth foraging birds (Red-throated Flycatcher, Tickell's Blue Flycatcher) did not join flocks or showed low propensity owing to low vulnerability to avian predators (see Buskirk 1976, Herrera 1979).

Other factors: In some specific cases, none of the above factors could explain the observed pattern of flocking. For instance, Greater Flameback showed less flocking propensities than the sympatric Black-rumped Flameback despite a higher relative abundance at Purna (*unpublished data*). Robin and Davidar (2002) and Kotagama and Goodale (2004) also reported low flocking by Greater Flameback. Unlike Black-rumped Flameback, which was frequently kleptoparasitised by Greater Racket-tailed Drongo, White-bellied Drongo, Jungle Babbler and Red-vented Bulbul; Greater Flameback

prevented other bird species from kleptoparasitising it (Santharam 2003). This behaviour possibly led to lower flocking by the latter species. Territoriality was another important factor that could have led to low flocking, especially in the migrant species. This was the likely reason for low flocking by leaf warblers and Red-throated Flycatcher – migrants with high abundances. These species could have established territories and joined flocks only when a flock passed through it as reported from the Neotropics and Southeast Asia (Powell 1979, Munn and Terborgh 1979, King and Rappole 2001a). Species such as Oriental White-eye and minivets possibly formed mono-specific flocks, hence showing low flocking in mixed parties.

5.3.4 Species co-occurrence patterns: Likely causes

Local species pools and habitat distributions: Mixed-species flocks have been shown to reflect available species pools (Hutto 1994, Latta and Wunderle 1996, Gram 1998, Sridhar 2005). These trends are believed to be an outcome of habitat related influences such as vegetation types, altitude and patch dynamics (see McClure 1967, Hutto 1994, Sridhar 2005). Patchy distributions of a majority of bird species in the tropics (Wiens 1989) that produce varying species pools in a small area (Terborgh *et al*. 1990) give rise to variable associations of species in mixed flocks. Small sample sizes prevented me from analyzing whether local species pools (at transect level) determined species richness locally. However, I found that most bird species were patchily distributed at my sites (P. Trivedi, *unpublished data*). This distribution was reflected in the species co-occurrence patterns documented in Table 5 and Figure 4. The examples of distribution based co-occurrence patterns of Jungle Babbler and Greater Racket-tailed Drongo/Common

Woodshrike illustrated that habitat distributions play an important role in flock composition.

Two or more small sized congeners have been shown to co-exist through segregation at micro-habitat scale in the same flock by Munn and Terborgh (1979) and Powell (1989). Graves and Gottelli (1993), however, documented a checkerboard pattern of participation in mixed flocks for several pairs of congeneric species. At my study sites, both trends were encountered. For congeneric species-pairs that did not co-occur in a single flock, pattern of distribution seemed to be an important factor. From the leafbird species-pair, Golden-fronted Leafbird showed high flocking possibly on account of being more abundant. Co-occurrence of two or more congeneric species such as four species of drongo was made possible by differential use of vertical strata, differential mode of prey capture and prey size as documented by Vijayan (1989). Variation in abundance and associate species, as shown earlier also played a role. However, I were unable to explain why Greater Racket-tailed Drongo and White-bellied Drongo co-occurred more often at Ratanmahal than at Purna.

Body size: Body size has been regarded as an important ecological trait of species. My data suggested that the associations of regular flocking species with one another were influenced by body size. Sridhar (2005) referred to such a possibility in the flocks of southern Western Ghats. Body size related flock formation could have been a mechanism to prevent high costs incurred by smaller species due to copying of foraging locations or kleptoparasitism by larger species. It could also be due to inability of the former to

exploit the latter through these means. I are not aware of specific work pertaining to body size influences in mixed flocks and feel that this aspect needs further study.

Presence of nuclear species: Hutto (1994) regarded availability of nuclear species as the most important factor for flock composition followed by habitat distribution and abundance of attendant species. I found evidence in favour of this, however, it was difficult to rule out the possibility that 'attendant' species showed some 'choice' in terms of nuclear species to associate with. Body size related factors and presence of congeneric species could also have played a role in this context.

5.3.5 Flock Organisation

Importance of basic/core flocks: On exploring the two-species flocks in my study area, I found that Moynihan's (1962) assumption that the initial mechanism of interspecific flocking was a one-way social bond between two species seemed to be partly true. This was because there appeared to be mutual benefit in most associations. It appears likely therefore, that the initial flocking mechanism could have involved a 'two-way' social bond, which then got extended to include several species to form a mixed-species flock. Vuilleumier (1967), pointed out three important criteria which determine the formation of a mixed flock –

- a nuclear species which is equally gregarious outside as well as within the mixed flocks
- tendency of the nuclear species to be socially indifferent to other species and
- follower species that are found most often in flocks

Since Jungle Babbler was not a socially indifferent species, it appeared that this role was played not by the 'primary nuclear species', but by the 'sentinel-nuclear' species – generally a drongo in case of flocks observed by me. Social indifference of drongos to non-predatory birds is well known. Several species of birds nest close to a Black Drongo's nest, some even in the same tree (*personal observation*). Thus, drongos are 'facilitators' and it seems that such species have been a pre-requisite in the evolution of mixed-species flocks. In this regard, Croxall's observation about drongo being the 'catalyst' species could be most apt. Such 'facilitator' species could then be expected to even lead flocks in absence of 'primary nuclear species', which was observed in eight instances (when neither JB nor CWS were present) at my study sites. It was observed that the likely 'facilitator' species had a range of vocalisations including mimicking abilities. More work on exploring individual species roles in mixed flocks would probably help clarify these assumptions. The partial nested subset kind of species composition of flocks documented by me indicated that species rich flocks arise out of basic combinations of fewer species. However, since more species got added in successive flocks with higher richness, larger species pool (due to increasing area) and habitat distribution of participants seemed to come into play.

Species roles: The flocks I observed were chiefly organized around the nuclear gleaning/sallying species, sentinels and mobbing species. Most regular flocking species were involved in all or one of these three major roles. Regular participants and major attendants played crucial roles of sentinels and/or mobbers. Most species that participated in less than 10 % flocks did not seem to play any significant functional role in mixed

flocks.There is evidence from observations of earlier studies to regard Jungle Babbler and Common Woodshrike as nuclear species. Ali (1954-55, 1969) hinted at the role of Jungle Babbler as a nucleus of mixed flocks of forest birds. Jungle Babbler is known to show sentinel behaviour (Gaston 1978), generally attributed to nuclear species. Kotagama and Goodale (2004) considered Orange-billed Babbler – a congeneric of Jungle Babbler as a possible nuclear species in Sri Lankan rainforest flocks. Jungle Babbler showed diverse foraging modes such as gleaning, bark foraging, hawking, and copying of foraging locations. Such flexibility in foraging modes has been attributed to nuclear species (Morse 1970). King and Rappole (2001a) classified one group of flocks in dipterocarp forests of Myanmar as Common Woodshrike flocks. Its congeneric - Large Woodshrike was regarded as a nuclear species by Vijayan (1989).

The sallying species – Greater Racket-tailed Drongo and White-bellied Drongo performed the role of sentinels in mixed flocks and were also other likely nuclear species. Presumably Ashy Drongo also played this role, but I lack observations to confirm this. Sentinel behaviour is a highly evolved form of vigilance. Such species give out loud and unambiguous alarm calls; hence, their nuclear role appears a natural fall-out (Munn and Terborgh 1979, Goodale and Kotagama 2005). Goodale and Kotagama (2005) showed that alarm calls of Jungle Babbler were less reliable than those of Greater Racket-tailed Drongo. Further, since the drongos perch higher and give loud alarm calls, babblers also use this behaviour for predator detection (Goodale and Kotagama 2005). Preponderance of drongos has already been shown in the Oriental and African mixed-flocks (e.g. Winterbottom 1949, Croxall 1976, Greig-smith 1978, Robin and Davidar 2001, Hino

2002; but also see McClure 1967, King and Rappole 2001a). Greater Racket-tailed Drongo and White-bellied Drongo occurred in more than 50% of flocks at my study sites. Both species also possess an elaborate vocal repertoire including mimicking abilities. Thus, despite the ambiguity regarding the role of drongos in mixed flocks (see Winterbottom 1949, Croxall 1976, Greig-smith 1978, King and Rappole 2001b, Styring and Ickes 2001, Robin and Davidar 2001), the nuclear status of these two species as sentinels in mixed flocks seems likely (also see Kotagama and Goodale 2004). The arboreal omnivores reported to be absent or having a marginal role in several studies of mixed flocks (Buskirk 1976, Munn and Terborgh 1979, King and Rappole 2001a, Kotagama and Goodale 2004) were important as mobbing species at my study sites. I also observed several regular and other irregular flocking species such as Black-hooded Oriole, Asian Paradise-flycatcher, and White-browed Fantail mobbing the raptors.

Chapter 6

DISTRIBUTION PATTERNS

"The crisp edge of a standard field-guide range map often translates in the real world into a very fuzzy distributional boundary, where neither the presence nor the absence of a species is certain." ***- Robert MacArthur (1978)***

6.1 INTRODUCTION

6.1.1 Bird distribution records in central Indian highlands: As mentioned earlier in Chapter 4, very few studies of forest avifauna have been carried out in the central Indian highlands of the Indian peninsula. The existing information from the region dates back to pre-independence era and needs to be reviewed in the present context. Thus, information on bird species of this area with three major mountain ranges (Satpura, Vindhya and Western Ghats) is of high significance to understand Indian ornithogeograohy. Since Purna is located in the northernmost section of the Western Ghats and Ratanmahal in the Vindhya-Malwa Plateau junction, information on presence/absence as well as abundance of forest bird species can provide vital information in this regard. Further, avifauna of Ratanmahal has also not been surveyed in the past. Most importantly, Ratanmahal and Purna form the westernmost patches of moist deciduous forests in the Indian peninsula, marking the global range boundaries of several species of forest birds (Trivedi and Soni, in press). Thus, it was one of the aims of the study to document the avifauna of these two sites to improve knowledge on bird distribution in India.

6.1.2 Patchy distribution of forest avifauna in India: It is well known that bird species have patchy distributions at both local and regional scales (Wiens 1989). Tropical bird species in particular show highly patchy distribution (Diamond 1980, Vuilleumier and Simberloff 1980, Terborgh et al. 1990). This has been attributed to tighter species packing through narrow habitat choices and heterogeneity of habitats (Diamond 1980, Terborgh et al. 1990). In India too, many species of forest birds show disjunct ranges (see Mani 1974). In most cases of range disjunction among forest avifauna of India, species show two distinct areas of occurrence – first, the forest belt extending from the western lower Himalayas to northeastern India and second, the peninsular hills, mainly the Western Ghats but also the Eastern Ghats. Mani (1974) argued that the range discontinuity is apparently there for Indochinese and Malayan forms only (forest species), this phenomenon being absent for Mediterranean and Ethiopean forms. He also added that the observed pattern of discontinuous distribution of Indo-chinese and Malayan derivatives is of relatively recent origin and at least with such mammals, it is a relict of former continuous distribution (also see Kurup 1974). Surveys and studies of Ali (1954-55), Monga and Naoroji (1983), Desai *et al*. (1993) and Worah (1991) showed that several bird species having patchy distribution in India occur in the eastern forest belt of the state, however, most occur only in the Western Ghats and few go beyond. However, since much of the eastern forest belt is now fragmented, these protected areas occur as patches in a matrix dominated by agriculture. Hence, documenting and monitoring the occurrence and status of these species in the eastern forest belt is crucial for their conservation.

6.1.2 Distribution-abundance relationship: It has been shown for birds that their abundance generally rises as one moves from the edges of their ranges towards the center of distribution (Brown 1984, Brown *et al*. 1995). In several cases, there are many such locations (hotspots) where these species show the highest abundance (see Brown *et al*. 1995). Emlen *et al*. (1986), Scott *et a*l. (1986) and Root (1988) evaluated such patterns for birds of central USA, Hawaiian islands and North America respectively. They found unimodal, multimodal and sharply truncated abundance-distribution relationships among various taxa, thus ruling out any single pattern for such a relationship among tropical and temperate birds. In the present study, there was a scope for exploring this pattern for some bird species, which showed range boundaries at Ratanmahal or Purna. Apparently, many such species are also patchily distributed in India.

In this chapter, I document and discuss the status of the noteworthy species including first records for Gujarat and for the two study sites. I also explore the pattern of abundance of species at Ratanmahal, Purna and Kalakkad in southern Western Ghats. I analyse the presence/absence information on patchily distributed forest bird species at three locations in the eastern forest belt. Based on this information, I then look at the factors responsible for the observed distribution patterns. Specifically, I differentiate between historical factors and recent range dynamics (or both) that have played a role in present day distribution patterns of forest bird species. Based on my observations at Purna and Ratanmahal, I draw tentative conclusions about these patterns.

I intensively surveyed the two areas for new species not yet documented from the state or from either of the two study areas. Throughout the sampling, stress was laid on forest bird species with patchy, disjunct and unexplained distribution patterns in India or with documented sensitivity to habitat fragmentation and other anthropogenic changes. My interest was in exploring how far have the species showing patchy distribution gone beyond the Western Ghats and why. Here, I depict the presence/absence and status data for these species at Ratanmahal (the last patch of moist forest), Shoolpaneshwar Sanctuary (a patch between Purna and Ratnmahal) and Purna. Finally, I consider the historical factors likely to be responsible for the observed patterns.

6.2 RESULTS

I recorded two bird taxa for the first time from Gujarat and added six other new site records of forest avifauna together for Ratanmahal and Purna. I also document the status and abundance of 11 other noteworthy species.

6.2.1 New records for Gujarat: Two species, Large-tailed Nightjar *Caprimulgus macrourus* and Brown Wood Owl *Strix leptogrammica*, were recorded for the first time from the state. Neither species was recorded by earlier surveys or listed in checklists for Gujarat (Ali 1954–1955, Khacher 1996, ZSI 2000, Khacher and Raol undated).

BROWN WOOD OWL *Strix leptogrammica*

This species was seen at Purna in moist deciduous forest consisting of teak, *Adina cordifolia, Terminalia crenulata* and extensive brakes of *Bambusa arundinacea* (Trivedi

2003). Three sightings were obtained at Dhulda in Bardipada range during daylight on 22 March 2002 (one sighting) and 30 April 2002 (two sightings). Two sightings involved a pair (presumably the same pair), while the third was of a solitary individual. The pair was found perched in a bamboo clump and, when disturbed, flew a short distance within the middle storey and settled at a low height. The absence of concentric barring on the facial disks and the dark coloration clearly distinguished this species from the congeneric Mottled Wood Owl *S. ocellata*. Ali and Ripley (1983) described the distribution of the species as 'dense moist deciduous to semi-evergreen and evergreen biotopes at suitable locations throughout the country', while Grimmett *et al*. (1998) described it as inhabiting the Himalayas, northeast India, Eastern and Western Ghats. Its northernmost record in the Western Ghats is from the Sanjay Gandhi National Park (Mumbai), Maharashtra (Prasad 2003). Thus our record is a northerly extension of the known range of this species by over 150 km.

LARGE-TAILED NIGHTJAR *Caprimulgus macrourus*

During surveys for nocturnal birds at Ratanmahal, a distinct 'chaunk...chaunk...' call was heard on the plateau at the Ratanmahal temple near the Gujarat-Madhya Pradesh border during 19:00 to 19:30 hrs. on 3 March 2000 and 17 march 2000. Based on the frequency of notes as well as on their long-drawn nature as compared with the 'chunk...chunk…' call of the Grey Nightjar *C. indicus*, these calls were identified as belonging to the Large-tailed Nightjar. No visual observations were made. Ali (1969) noted that *C. macrorus* is difficult to distinguish by sight in field, but its call is diagnostic. The closest prior records are by D'Abreau (1935), who described this species as breeding in densely shaded

ravines of the former Central Provinces (presently Madhya Pradesh and Chhattisgarh states), and by Grimmett *et al*. (1998) from eastern Madhya Pradesh. Our record at Ratanmahal extends the known range of the species considerably to the west.

6.2.2 New records for Purna and Ratanmahal

BLACK EAGLE *Ictinaetus malayensis*

This species was sighted twice (on 20 August 2001 and 22 December 2001) at Purna (the first records for this site) and was also seen at Jambughoda Wildlife Sanctuary (hereafter Jambughoda) in January 2002, 2003, 2004 and 2005. The species was identified by its characteristic upward-angled primaries in flight, dark coloration, yellow cere and feet and, most notably, its behaviour of gliding low over the forest canopy. In Gujarat, this species has been reported from Jambughoda forest (Ali 1954–1955) and Gir forest (Dharmakumarsinhji 1985). In neighbouring states, Mashru (2004) recorded it from Mt Abu in Rajasthan and D'Abreau (1935) reported it from Madhya Pradesh.

ASHY WOODSWALLOW *Artamus fuscus*

We found c.10 individuals of this species at Ratanmahal on 10 September 2000. They were perched on telegraph wires and an adjacent tree while making aerial sallies to hawk insects. This species was not recorded by Ali (1954–1955) from Gujarat, but Khacher (1996) reported a sighting from the Rajpipla area (Narmada district, Satpura mountain range) and Worah (1991) recorded it in the Dangs district. Our record extends the known range of the species by c.75 km north.

GREATER RACKET-TAILED DRONGO *Dicrurus paradiseus*

This species was sighted 24 times (involving 29 individuals) in the months of January, March, April, May, July and December at Ratanmahal and on 40 occasions (involving 58 individuals) in the months of January, February, March, April, June and December at Purna. The mean encounter rate of the species was 0.97 birds/km (SD=0.83) at Ratanmahal and 0.91 birds/km (SD=0.69) at Purna. It was found to be a sentinel species (and possibly an 'active-nuclear' species) in mixed-species flocks at both Ratanmahal and Purna, and it probably plays a key role in such flocks. Ali (1954–1955) reported this species to be common in bamboo and mixed deciduous forests south of the Narmada river, while Monga and Naoroji (1983) and Desai *et al*. (1993) recorded it from Rajpipla forests (now Shoolpaneshwar Wildlife Sanctuary), south of the Narmada. Ratanmahal appears to be the northernmost limit of this species in India and possibly the westernmost boundary of its global range.

BLUE-CAPPED ROCK THRUSH *Monticola cinclorhynchus*

We recorded three sightings (of singles individuals) of this species, one in Purna (22 March 2002) and two in Ratanmahal (on the plateau at the Ratanmahal temple near the Gujarat-Madhya Pradesh border on 19 and 30 January 2000). These were the first records at Ratanmahal. At Purna the species was not sighted on transects, while at Ratanmahal, it was sighted on one transect once, with a mean encounter rate of 0.03 birds/km (SD=0.08). All three birds were in dense bamboo brakes in moist deciduous forest. The species is reported to over-winter mainly in the Western Ghats (Grimmett *et al*. 1998) and in Gujurat it has been reported from Hingolgadh (Khacher 1996), Rajpipla forests

(Monga and Naoroji 1983) and Dangs district (singly or in pairs in very small numbers during February and March: Ali 1954–1955).

ORANGE-HEADED THRUSH *Zoothera citrina*

At Ratanmahal, two sightings of this species were made: two individuals on a transect on 23 July 2000 (Trivedi 2001) and one on 22 July 2000, while at Purna it was sighted on nine occasions (involving 11 individuals) on two transects during June of 2002 . Its mean encounter rate was 0.07 birds/km (SD=0.15) at Ratanmahal and 0.19 birds/km (SD=0.40) at Purna. The race was identified as *Z. c. cyanotus* based on the presence of two vertical black stripes across the white ear coverts and throat. In Gujurat, the species has been reported previously only from south of the Narmada river (Monga and Naoroji 1983, Ali 1954–1955). Our records from Ratanmahal extend its known range to c.75 km north of the Narmada river. The species appears to be a summer visitor and possibly breeds at both sites.

CRIMSON SUNBIRD *Aethopyga siparaja*

This species was sighted at Purna and Ratanmahal, and was fairly common in teak and mixed moist forest with *Bambusa arundinacea*. Five sightings (involving seven individuals) were made at Ratanmahal and 29 sightings (involving 42 individuals) were made at Purna. Its mean encounter rate was 0.23 birds/km (SD=0.34) at Ratanmahal and 0.74 birds/km (SD=0.94) at Purna. The race observed at both sanctuaries was *A. s. vigorsii* of the Western Ghats. In Gujarat, Ali (1954–1955) recorded the species south of river Narmada at Rajpipla forest. It has also been reported from Shoolpaneshwar

Sanctuary in Narmada district (Monga and Naoroji 1983, Desai *et al*. 1993). Our records at Ratanmahal extend its known range by about 75 km and the site is the northernmost for the species in Gujarat.

6.2.3 Noteworthy species: There were 11 such species, most of which are forest-interior (see Worah 1991) and show a documented vulnerability to forest fragmentation and alteration (see Raman 2001, Castelletta *et al*. 2002).

GREY JUNGLEFOWL *Gallus sonneratii*

This galliform was heard in Purna at only two localities, but was seen as well as heard on four occasions (eight birds) in Ratanmahal. It appears to have been persecuted beyond recovery in many areas of its former distribution (e.g. Jessore Sloth Bear Sanctuary, Trivedi 2005). Pheasants are sensitive to changes in forest composition (Johns 1986, Castelletta *et al*. 2000, Datta 2000) as well as hunting. Hunting may be a severe problem for this species as ground-dwelling birds are vulnerable to passive methods of trapping, and this species depends on concealment rather than flight for escape.

RUFOUS WOODPECKER *Celeus brachyurus*

This woodpecker was encountered only at Purna, where it was uncommon and appeared to be partial to bamboo brakes in moist deciduous forest. It was reported previously from Dangs district and Vansda National Park (Ali 1954–1955, Worah 1991, Bhatt 2004), but not elsewhere from Gujarat; hence Purna appears to be the northwesterly limit of its

distribution. The species is peculiar in its habit of nesting in the nests of *Crematogaster* ants (Ali 1969).

WHITE-BELLIED WOODPECKER *Dryocopus javensis*

We recorded the species three times in Purna at two localities. Purna is the northernmost site for the species in India and the westernmost limit of its global range. This population of White-bellied Woodpecker is isolated, with the nearest neighbouring population at a distance of c.350 km in Melghat Tiger Reserve, Maharashtra (Prasad 2003). The largest woodpecker of peninsular India, this is a bird of primary moist deciduous forest and secondary forest and is also seen in tropical evergreen and semi-evergreen forests (Ali and Ripley 1983, Grimmett *et al*. 1998). In Gujarat, it was reported earlier from Dangs district and adjoining areas of Navsari district (Ali 1954–1955, Worah 1991, Singh *et al*. 2000, Santharam 2003). In the Western Ghats of Maharashtra, the species is extremely rare and has a fragmented distribution (Prasad 2003). Furthermore, its preferred habitat, primary moist deciduous forest, is rare in Gujarat, having been replaced by either secondary forests or plantations (Worah 1991, Santharam 2003). This has resulted in a reduced availability of suitable nesting trees (Santharam 2003). Ali (1954–1955) reported that the tribals hunted this species in Dangs. These factors suggest that the species may be more susceptible to local extinction. Castelletta *et al*. (2000) reached a similar conclusion for the species in Singapore, where only one pair was found surviving after the loss of a large area of rainforest.

HEART-SPOTTED WOODPECKER *Hemicircus canente*

This species was recorded on transects on four instances (seven individuals) in Purna (mean encounter rate: 0.11 birds/km, SD=0.23), where it was confined to moist deciduous forest with bamboo. It has been reported from the same localities in Gujarat as White-bellied Woodpecker, with additional records further north from Rajpipla forests (Monga and Naoroji 1983). Santharam (1995) described it as a specialist based on its foraging mode. Prasad (2003) considered it rare in western Maharashtra.

LESSER YELLOWNAPE *Picus chlorophus*

This was a rare species, being sighted on only four occasions at three localities in Purna. It was reported earlier by Ali (1954–1955) and Worah (1991) from Dangs district and from Vansda National Park (Bhatt 2004) and inhabits moist deciduous forests with bamboo (Trivedi 2003). There are no records of the species from other parts of Gujarat. In western Maharashtra, the species is rare with a restricted range (Prasad 2003).

WHITE-CHEEKED BARBET *Megalaima viridis*

The occurrence of this species was confirmed on only one occasion in Purna based on its call. This represents the northernmost extent of the distribution of this Western Ghats endemic. The congeneric Brown-headed Barbet *M. zeylanica* was common at Ratanmahal and Purna.

MALABAR TROGON *Harpactes fasciatus*

This species was sighted only in Purna at three localities. While Ali (1954–1955) reported it to be 'fairly common' in Dangs district, the present study showed it to be uncommon. Ali (1954–1955) mentioned one of the locations of the species as Ajwa (in present day Vadodara district), situated more than 150 km northwest of the Dangs district. This appears to be a typographical error with 'Ajwa' being printed instead of 'Ahwa' (the capital of Dangs district). I suspect this because, although a record at Ajwa would be unusual and noteworthy, Ali (1954–1955) does not refer to this locality or emphasise the importance of this record in his annotations to the sites where this species was collected. Malabar Trogon has also been reported from Vansda National Park (Singh *et al*. 2000). It is found in moist deciduous forest with bamboo and secondary growth (Ali 1954–1955). The species has been found sensitive to forest fragmentation and alteration in the southern Western Ghats in India (Raman 2001) as have its congeners elsewhere in the Orient (e.g. Johns 1986, Castelletta *et al*. 2000).

CRESTED TREESWIFT *Hemiprocne coronata*

This species was sighted only in Purna (only off transects) and Ratanmahal (eight sightings including 30 individuals on transects). Its mean encounter rate at Ratanmahal was 0.86 individuals/km (SD=1.83). Ali (1954–1955) encountered it only in Rajpipla forests (see also Monga and Naoroji 1983) and Dangs district. It has also been reported from the Gir forest (Khacher 1996). I found it in forest with *Lannea coromandelica, Boswellia serrata* and *Anogeissus latifolia* on boulder-studded dry hills. Crested Treeswift may be sensitive to forest loss and degradation, as Castelletta *et al*. (2000)

recorded the local extinction of the congeneric Whiskered Treeswift *H. comata* in Singapore.

BAR-WINGED FLYCATCHER-SHRIKE *Hemipus picatus*

A rare resident, this species was seen only once on transects (23 June 2002) in Bhenskatri range in Purna. Both Ali (1954–1955) and Worah (1991) reported the species earlier from Dangs district, but Singh *et al*. (2000) did not record it from the nearby Vansda National Park. It is easily overlooked owing to its rarity, inconspicuous colouration and small size. Prasad (2003) reported it as an uncommon, localised resident in western Maharashtra, while placing it among the species affected by loss of forests. Johns (1986) and Castelletta *et al*. (2000) also regarded the genus *Hemipus* to be sensitive to forest degradation.

MALABAR WHISTLING THRUSH *Myophonus horsfieldii*

This species was sighted only once (on 24 December 2001), on a stream bank in moist deciduous forest at Purna. Although it is known for its melodious song, we never heard it during the study period. Ali (1954–1955) recorded it as resident in Dangs district, but not common. It is a terrestrial omnivore, known to forage along streams for a variety of invertebrates, including aquatic insects (Ali 1969). Its rarity could conceivably have resulted from changes in hydrology caused by the building of check-dams, perhaps affecting prey availability.

WHITE-RUMPED SHAMA *Copsychus malabaricus*

I saw this species only at Purna where it was confined to moist deciduous forest and bamboo patches, and was usually seen rummaging among leaf litter in search of insects. It was reported from Dangs (Ali 1954–1955, Worah 1991) and from Vansda National Park (Singh *et al*. 2000), but not from elsewhere in Gujarat. It has a patchy distribution in India (Grimmett *et al*. 1998), and belongs to the terrestrial insectivore guild, which is susceptible to forest fragmentation (Raman 2001).

Table 6.1 Patchily distributed bird species in the eastern forest belt of Gujarat

Species	Ratanmahal	Shoolpanshwar	Purna	Presence at number of sites	Remarks
Rufous Woodpecker	A	A	P	1	No historical record
Greater Flameback	A	P	P	2	No historical record
White-bellied Woodpecker	A	A	P	1	No historical record
Heart-spotted Woodpecker	A	P	P	2	No historical record
Malabar Trogon	A	A	P	1	No historical record
Brown Wood Owl	A	A	P	1	No historical record
Black Eagle	A?	A	P	1	Doubtful occurrence
Scarlet Minivet	A	A	P	1	No historical record
Bar-winged Flycatcher-shrike	A	P?	P	1	No historical record?
Large Woodshrike	A	A	P?	1?	Locally extinct?
Malabar Whistling Thrush	A	P	P	2	Doubtful occurrence
Orange-headed Thrush	P	P	P	3	Present in all
White-rumped Shama	A	A	P	1	No historical record
Velvet-fronted Nuthatch	P?	P	P	2	Locally extinct?
Black-lored Tit	P	P	P?	2	Locally extinct?
Puff-throated Babbler	P	P	P	3	Present in all
Crimson Sunbird	P	P	P	3	Present in all

[Data for Purna: Worah 1991, Trivedi, present study; Ratanmahal: Trivedi, present study; Shoolpaneshwar: Desai *et al*. 1993]

6.2.4 Patchily distributed species: There were 16 species of forest birds encountered during the study, which showed a patchy distribution in India (Table 6.1, see Grimmett *et al*. 1998). Of these species, Greater Flameback, Scarlet Minivet, Puff-throated Babbler and Crimson Sunbird were not rare. In terms of presence, only three species were present at all three sites; two of these were presumably local migrants. Of the other 14 species, eight species occurred only at Purna, while four species occurred at one more site besides Purna. Black-lored Tit was present at Ratanmahal and Shoolpanshwar, but not at Purna from where it had possibly gone extinct locally (see Chapter 7). I failed to get any sightings of Large Woodshrike that was reported earlier by Ali (1954-55). Hence, this species also appeared to have suffered a local extinction (see Chapter 7).

6.2.5 Geographical variation in abundances: As presence or absence of a species is considered to evaluate its distribution pattern, it is tempting to draw conclusions regarding avian distribution patterns in Gujarat based on above information. However, it is also important to consider the geographical variation in the abundance of species over its range to better understand the patchy distribution pattern (MacArthur 1972, Vuilleumier and Simberloff 1980). Hence, I chose six forest bird species, which had their range boundaries at Ratanmahal or Purna. Of these, three species also showed a patchy distribution (see Table 6.1). When I compared the encounter rates of these species at extremities (Ratanmahal or Purna) and other parts (southern Western Ghats, Kalakkad) of their range (Table 6.2).

Table 6.2 Geographical variation in abundance of some patchily distributed species in India

Species	Mean encounter rate		
	Ratanmahal	Purna	Kalakkad*
Golden-fronted Leafbird	0.37	0.79	UA
Greater Racket-tailed Drongo	0.97	0.91	3.7
Puff-throated Babbler	0.07	0.31	3.9
Crimson Sunbird	0.23	0.74	UA
White-cheeked Barbet	UA	0.02	4.7
Scarlet Minivet	UA	0.27	5.0

* Raman (2001), UA = Unavailable

Mean encounter rates of all the species were less at Ratanmahal than at Purna, except in the case of Greater Racket-tailed Drongo. However, its relative abundance was almost half at Ratanmahal compared to Purna. A comparison between encounter rates of four bird species (two other species were present, but their encounter rates were not available) at Purna and Kalakad, a similar trend of very low abundances at Purna was seen. This trend indicated that abundances of all species decreased towards their range boundaries. The end-of-range kind of situations of several species at Ratanmahal and Purna make them vulnerable to stochastic factors and local extinctions. This makes it imperative for prioritization of conservation around such susceptible species.

6.2.6 Temporal perspective in species occurrence - sampling effects or range dynamics: On comparing my results with the two earlier studies conducted on the avifauna of Dangs (e.g. Ali 1954-55, Worah 1991), I recorded 13 new taxa, either missed

by Ali (1954-55) or Worah (1991). In comparison, they recorded 19 taxa, which I did not encounter.

Table 6.3 Comparison of bird records at Purna/Dangs between 1940s and 2001-03

No.	Species A	Source	No.	Species B
1	Large Woodshrike	A, W	1	Barred Buttonquail
2	Forest Wagtail	A, W	2	Indian Cuckoo
3	White-Necked Stork	A, W	3	Pied Cuckoo
4	Red Spurfowl	A, W	4	Common Hoopoe
5	Ashy Swallow-Shrike	W	5	Black-Headed Cuckooshrike
6	Brown Flycatcher	A, W	6	White-Browed Fantail
7	Ultramarine Flycatcher	W	7	Purple-Rumped Sunbird
8	Jungle Bush Quail	A, W	8	Brown Fish Owl
9	White-Browed Bulbul	W	9	Brown Wood Owl
10	Mottled Wood Owl	A, W	10	Collared Scops Owl
11	Eurasian Sparrow-Hawk	A	11	Black Eagle
12	Changeable Hawk Eagle	A	12	Indian Nightjar
13	Short-Toed Snake Eagle	A, W	13	Spotted Owlet
14	Eurasian Eagle Owl	A, W		
15	Short-Eared Owl	A		
16	Stork-Billed Kingfisher	A		
17	Eurasian Blackbird	A		
18	Black-Lored Tit	A		
19	White-Throated Fantail	A		

Species A - seen by A=Ali (1954-55) & W=Worah (1991), Species B - seen in Present study, but not sighted by A / W

The missing species fell under various categories such as raptors, nocturnal birds, migratory species and possibly locally extinct species. Species that were added through the present study in most cases (eight species) were open area and edge species. For Ratanmahal, such a comparison was not possible due to lack of earlier studies or reliable checklists.

6.3 DISCUSSION

6.3.1 Overall trends of occurrence: Addition of two species for the state as a whole and several new site records showed inadequacy of sampling effort at a local scale. For the two new records for the state, Gujarat appeared to be their western or northwestern range extremity. Their very low abundance and nocturnal nature together could have accounted for their not being detected till date. It could also be that these species colonised the two forest areas in recent past. Three factors seemed important for differences in species occurrence recorded between 1940s and 2001-03 at Purna. First, the species missed by either of the three observers were rare, so that it was likely to miss them by chance alone. This could be a possibility for many species considering these were nocturnal, migratory or included raptors (see Karr 1982). Second, sampling was not adequate to detect these species. This did not appear to be the case as species-accumulation curves for the two sites (see Chapter 7) reached asymptote indicating adequate sampling. Third, the species were absent at the time of sampling owing to local extinction (range dynamics), or they had colonised Purna in the recent past due to advantages provided by degradation and/or fragmentation of forest caused by human disturbances.

It was clear that most species showing patchiness in distribution were rare and only few were encountered beyond the Western Ghats. For most species occurring only at Purna, there were no historical records of distribution at the other two sites (see Ali 1954-55). Ali (1954-55) reported the presence of some of these species in the Songadh forests, an area which is severely deforested and degraded today. Further, species such as Large Woodshrike recorded in the past at Purna had possibly gone extinct locally. Although the

data based on six species shows fall in abundance as one moves from core area of the range to the edges, its application is limited owing to small sample size. Besides, unavailability of reliable abundance estimates across their ranges makes the task more difficult. One also needs to consider that species distributions are not static and the ranges show much higher flux at extremities (Bown *et al*. 1995). So, the data presented here could provide a baseline for evaluating range dynamics in future as suggested by Wiens (1989).

6.3.2 Distribution records of forest avifauna – chance vs. history: What could have caused the observed patterns of distribution of forest birds at the two study sites? Even though Ratanmahal is only 200 km from Purna and contains patches of moist deciduous forest, most species showing patchy distribution and found at Purna were not recorded there. Shoolpaneshwar – a larger forest area lying closer to Purna had a higher number of such species than Ratanmahal though this area too had less than half of the species showing patchy ranges. Since Purna is part of the Western Ghats, which appears to be the only source of birds of moist forest for Ratanmahal; I considered the latter as an island and former as mainland to examine likely ecological and evolutionary (stochastic or historical) factors influencing a low species pool at Ratanmahal. Karr (1982) summarized seven factors to explain the causes of impoverished avifauna of Barro Colorado island in Panama. These included biogeographic access, founder effect, competition, predation, successional habitat changes, island size and environmental heterogeneity and habitat mosaic.

Of these, biogeographic access could have played a role as the gaps between the Western Ghats (Purna) and the Satpura ranges as well as between the latter and the Vindhya-Malwa system (Ratanmahal) are large (both c. 75 km). These are wider than the Palghat gap considered to be an important barrier for distribution of fauna in the Western Ghats (see Raman 2001). Founder effect is the influence of isolation of an island from the mainland. If the island carried fewer species at that instance, it is unlikely that it would receive more species later. This probably does not apply to Ratanmahal as in the past the entire eastern forest belt was in most likelihood a contiguous stretch of forests. However, at least in present circumstances several moist forest species under consideration are either rare at Purna or suffered local extinctions. Hence, the source pool is also impoverished partly.

Competition, predation (by mesopredator release on islands) and successional changes do not seem to have influenced avifaunal composition at Ratanmahal. However, based on the species-area theory, its size and particularly that of the moist forest patches could have had a bearing on the avifaunal richness. Finally, environmental heterogeneity almost certainly seems to have influenced the avifaunal richness with Ratanmahal having half of mean annual rainfall than Purna. This would influence productivity, forest structure, flora and a host of other aspects, which could be called the habitat mosaic. Cody (1983) and Wiens (1989) regarded the role of unsuitable habitat and resource availability in determining range boundaries of bird species. Worah (1991) showed that contiguous moist deciduous forests had higher relative abundance of forest-interior species compared to plantations and smaller forest fragments in Dangs. My results (see Chapter 4) also

point at the important role of habitat structure in species composition over distance effects. Absence of four moist forest woodpecker species and other forest-interior birds from Ratanmahal suggested the role of structural differences in vegetation between the two sites including forest stratification. Discontinuity in moist forest habitats and their composition (e.g. *Tectona grandis, Bambusa arundinacea*) could be major influences at a regional scale (see Wiens 1989). It appears that the distinct boundaries shown by different forest taxa at least in part reflect their dispersal ability and sensitivity to forest structure and composition (including fragmentation, see Chapter 7). Hence, most species sensitive to such changes have not gone beyond Purna. One cannot rule out though that in historical past, these species could have occurred at Ratanmahal or beyond, but stochastic factors and habitat changes could have led to their local extinctions.

Chapter 7

AVIFAUNAL IMPOVERISHMENT

"Biogeographically India may largely be described, as a land of vanishing relicts."

– M. S. Mani

7.1 INTRODUCTION

7.1.1 Background: The study of species-area relations is one of the oldest areas of interest in plant and animal ecology. This association between the size of sampled area and number of species implied that a certain rise in the sampled area would lead to a corresponding increase in the number of species recorded. Conversely, reduction in the extent of area should lead to loss of species. The theory of 'Island Biogeography' (MacArthur and Wilson 1967) was a fall-out of species-area relation studies. The relationship between number of species and the extent of area is expressed by the equation $S=cA^z$, where S is the number of species, A is area and c and z are constants. This theory, initially based on the study of colonisation of islands by main land taxa was later extended to 'habitat islands' in a terrestrial context. In this way, it found utility in planning the design and management of nature reserves (Diamond 1975). Discussion of this aspect generated a debate popularly called SLOSS (Single Large or Several Small). The debate is still not settled, but studies have shown that both large and small areas are of importance for conservation (Fischer and Lindenmayer 2002).

7.1.2 Impacts of habitat fragmentation and loss on avifauna: Loss, fragmentation and degradation of habitat caused by humans have been regarded as important factors for

species extinctions and impoverishment of biota of a region. Several studies have been conducted to assess the impacts of fragmentation on birds (see Lovejoy *et a*l. 1986, Laurence *et al*. 2002, Lindenmayer *et al*. 2002). Debinski and Holt (2000) have reviewed studies involving experiments on impacts of habitat fragmentation and concluded that there was a 'remarkable lack of consistency' in results, the results were taxa-specific and short-term studies missed patterns, which the long-term studies documented. In spite of the discrepancies and variations in the results, a clear indication is that fragmentation leads to impoverishment of the local species pool of birds. For instance, Castelletta *et al*. (2000) documented a loss of close to 67 % species of forest-dependent birds in 75 years due to a loss of 95 % of original forest habitat in Singapore. Stratford and Stouffer (1999) showed local extinctions ranging from 31 to 100 % in rainforest fragments in the Amazon ranging from 1 to 100 ha. Brooks *et al*. (1999) predicted a loss of over half (50 %) species from tropical forest fragments of 1000 ha in Africa. Renjifo (1999) documented loss of about 30 % bird species from the fragments in the forests of Colombian Andes.

The above results though often interpreted as species-area effects, have been shown through more detailed analyses to be likely effects of several factors such as extent and quality of habitat types, resource availability within the fragments and effects of the surrounding matrix including hunting (Laurance *et al*. 2002). Wethred and Lawes (2003) for instance, showed that nature of the surrounding matrix affected grassland and forest bird species richness and abundance in South Africa. Lindenmayer *et al*. (2002) also showed influence of the matrix on bird assemblages in a heterogeneous landscape in Australia. A significant fall-out of the process of fragmentation is a group of changes and

factors collectively termed as ‘edge effects’ (see Harris 1988). These include increased exposure to nest predation and nest parasitism (Temple and Cary 1988), microclimate change, ingress of edge-tolerant or edge-favouring species and creation of dispersal barriers. Forest-interior species have been shown to be most susceptible to edge effects (Temple and Cary 1988, Dale *et al*. 2000, Beier *et al*. 2002).

Although influences of habitat size and quality, nature of the matrix and isolation are important; not all bird species respond in similar fashion to these factors. Evidence points at the role of several ecological and biogeographic traits of bird species such as body size, foraging guild, habitat specificity, rarity and endemism, population size and population dynamics in determining vulnerability of species to fragmentation (see Henle *et al*. 2004 for review). Besides, there is a time lag before the responses to fragmentation are manifested. This time lag between fragmentation and extinction (relaxation time) has been shown to be roughly 25 to 75 years for loss of 50 % of local bird species pool (see Brooks *et al*. 1999, Castelletta *et al*. 2000). The effects of fragmentation vary temporally between species. This means that patches do not lose all species, but some species go early, others in medium time frame and some species do not disappear. This effect caused by a nested subset pattern of occurrence in which successively larger fragments contain all species occurring in the smaller fragments (see Patterson 1987). On the other hand, edge-favouring or edge-tolerant species colonise the area and the resultant species pool is a diluted version of the original pool of the area.

7.1.3 Forest fragmentation and habitat degradation in the eastern forest belt: The eastern forest belt has witnessed fragmentation and degradation (Khacher 1996, Singh 2001). Singh (2001) showed a loss of 1,782 km^2 of forest area in Gujarat (c. 12 % of the total forest area of the state) between years 1960 and 2000 to causes such as irrigation projects, agriculture, regularisation of encroachment, mining, road building and industrial purposes. Worah (1991) reported patchy distribution of forests in Dangs with a mean patch size of 28 km^2. She regarded these forests as 'fragmented' due to presence of several teak and bamboo monocultures, many of these fairly young. Organised forestry led to opening up of the forests of Purna Sanctuary and surrounding region through roads and associated anthropogenic disturbances. In the Dangs, between late 19th century to mid 20th century selection felling eliminated large trees and from about 1960s to 1980s, several patches were clear felled and converted into teak monocultures (Anonymous 2001). The forestry operations of thinning and climber cutting removed several associates (with low timber value) of teak as well as lianas (Anonymous 2001). This has led to a change in composition and structure of forests. Tree felling was stopped with a moratorium on green felling in 1987-88 (Anonymous 2001), but harvesting of bamboo on a large scale continues even today (*personal observation*). Worah (1991) and Singh *et al*. (2000) have also noted local extinctions of Indian Giant Squirrel *Ratufa indica dealbata*, Tiger *Panthera tigris*, Gaur *Bos gaurus*, Smooth-coated Otter *Lutra perspicillata* and Sloth Bear *Melursus ursinus* from the Dangs. In the analysis presented below, species sensitive to these changes are identified and local extinctions of eight species suspected due to processes operating within and outside the protected areas.

7.2 RESULTS

7.2.1 Species susceptible to habitat loss and degradation: We used encounter rates and information from the literature and from personal observations on the habitat specificity of species to identify those that we considered likely to be susceptible to forest loss and degradation at the two sanctuaries. At Purna, we found 64 species that had a mean encounter rate of ≤0.5 individuals/km, while at Ratanmahal there were 47 such species. The total number of rare species was 83 with 28 species in this category being common to both the sites. Among these, we did not consider 53 widespread species (including raptors) and 17 migrants. The remaining 13 species included Grey Junglefowl, Rufous Woodpecker, Heart-spotted Woodpecker, Lesser Yellownape, White-cheeked Barbet, Indian Grey Hornbill, Malabar Trogon, Black Eagle, Bar-winged Flycatcher-shrike, White-throated Fantail *Rhipidura albicollis*, White-rumped Shama, Velvet-fronted Nuthatch *Sitta frontalis* and Black-lored Tit *Parus xanthogenys*. Indian Peafowl *Pavo cristatus,* though widespread in India was considered to be susceptible due to its rarity at the two sites and vulnerability to hunting. Two additional species that were only encountered off transects, White-bellied Woodpecker and Malabar Whistling Thrush, were also considered susceptible. Further, we suspect the local extinction of eight species based on an absence of sightings during our study: six from Purna and two from Ratanmahal (Table 7.1).

Table 7.1 Possible local extinctions of birds in Purna and Ratanmahal Wildlife Sanctuaries.

SPECIES	Extinct At	Past Status	Source
JUNGLE BUSH QUAIL *Perdicula asiatica*	Purna	Common	Ali (1954–1955)
RED SPURFOWL *Galloperdix spadicea*	Purna	Common	Ali (1954–1955)
INDIAN GREY HORNBILL *Ocyceros birostris*	Ratanmahal	Unknown	Local assistant & other residents (*pers comm.*)
STORK-BILLED KINGFISHER *Halcyon capensis*	Purna, Ratanmahal	Not uncommon	Ali (1954–1955)
WHITE-THROATED FANTAIL *Rhipidura albicollis*	Purna	Not stated	Ali (1954–1955)
LARGE WOODSHRIKE *Tephrodornis gularis*	Purna	Rare? 1 specimen procured	Ali (1954–1955)
VELVET-FRONTED NUTHATCH *Sitta frontalis*	Ratanmahal	Rare, 1 sighting	Personal observations 1989–1991
BLACK-LORED TIT *Parus xanthogenys*	Purna	Not uncommon	Ali (1954–1955)

Velvet-fronted Nuthatch and White-throated Fantail occurred in both categories as the former was locally extinct at Ratanmahal and rare at Purna, while the latter was suspected as extinct from Purna and rare at Ratanmahal. In all, we identified 22 species as likely to be 'susceptible' to forest degradation and loss at the two study sites (Table 7.2).

Table 7.2 Species susceptible to forest loss and degradation in Purna and Ratanmahal Wildlife Sanctuaries.

Species[a]	Distribution in India	Guild[b]	Habitat occupancy	Occurrence
LARGE WOODSHRIKE *Tephrodornis gularis*	Patchy	FGI	Forest interior	Purna
RED SPURFOWL *Galloperdix spadicea**	Widespread	GFO	Forest interior	Purna
JUNGLE BUSH QUAIL *Perdicula asiatica**	Patchy	GFO	Forest edge	Purna
STORK-BILLED KINGFISHER *Halcyon capensis*	Widespread	AQC	Forest edge	Purna, Ratanmahal
BLACK-LORED TIT *Parus xanthogenys**	Patchy	FGI	Forest interior	Purna
WHITE-THROATED FANTAIL *Rhipidura albicollis*	Patchy	FSI	Forest edge	Purna
VELVET-FRONTED NUTHATCH *Sitta frontalis*	Patchy	BF	Forest interior	Ratanmahal

Species[a]	Distribution in India	Guild[b]	Habitat occupancy	Occurrence
INDIAN GREY HORNBILL *Ocyceros birostris**	Widespread	AFO	Forest interior	Ratanmahal
MALABAR TROGON *Harpactes fasciatus**	Patchy	FSI	Forest interior	Purna
MALABAR WHISTLING THRUSH *Myophonus horsfieldii**	Patchy	GFO	Forest interior	Purna
WHITE-BELLIED WOODPECKER *Dryocopus javensis*	Patchy	BF	Forest interior	Purna
HEART-SPOTTED WOODPECKER *Hemicircus canente*	Patchy	BF	Forest interior	Purna
LESSER YELLOWNAPE *Picus chlorophus*	Patchy	BF	Forest interior	Purna
WHITE-RUMPED SHAMA *Copsychus malabaricus*	Patchy	GFI	Forest interior	Purna
RUFOUS WOODPECKER *Celeus brachyurus*	Patchy	BF	Forest interior	Purna
WHITE-CHEEKED BARBET *Megalaima viridis**	Patchy	AFR	Forest interior	Purna
BROWN WOOD OWL *Strix leptogrammica*	Patchy	C	Forest interior	Purna
BAR-WINGED FLYCATCHER-SHRIKE *Hemipus picatus*	Patchy	FSI	Forest interior	Purna
LARGE-TAILED NIGHTJAR *Caprimulgus macrourus*	Patchy	HI	Forest interior	Ratanmahal
BLACK EAGLE *Ictinaetus malayensis*	Patchy	C	Forest interior	Purna
INDIAN PEAFOWL *Pavo cristatus**	Widespread	GFO	Forest interior	Ratanmahal, Purna
GREY JUNGLEFOWL *Gallus sonneratii**	Widespread	GFO	Forest interior	Purna

[a]* = endemic to India

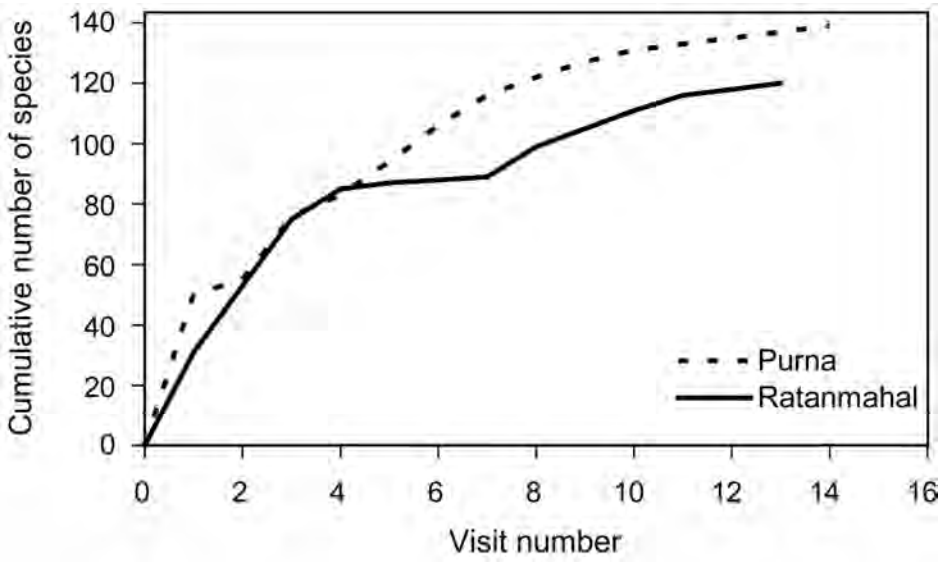
[b] AFO = Arboreal frugivore-omnivore; AFR = Arboreal frugivore; BF = Bark-forager; C = Carnivore; AQC = Aquatic carnivore; FGI = Foliage-gleaning insectivore; FSI = Foliage-sallying insectivore; GFI = Ground-foraging insectivore; GFO = Ground-foraging omnivore; HI = Hawking insectivore

7.3 DISCUSSION

7.3.1 Search efforts for species: Inferences about local extinctions require that sufficient effort be expended in searching for species. The species accumulation curves obtained for Purna and Ratanmahal (Figure 7.1) reached asymptotes roughly at the eleventh visit. At Purna, the four species added on the last two visits included three nocturnal species (two

owls and one nightjar) recorded after intensive night monitoring. These two graphs suggest that our sampling effort was adequate, although it is almost impossible to record all species owing to the dynamic nature of forest avifaunas (Johns 1986).

Figure 7.1 Bird species accumulation curves for Purna and Ratanmahal Wildlife Sanctuaries, Gujarat, India.



7.3.2 Temporal change in status: We identified 22 species that we considered to be likely to be susceptible to habitat change. The status of most of these has changed from 'common' or 'not uncommon' to rare or locally extinct (Table 7.3). For one species, Stork-billed Kingfisher *Halcyon capensis*, there has been no recent record from any part of Gujarat. The six species that appeared to be extinct at Purna were seen by Ali (1954–1955) but not by Worah (1991), supporting our conclusion. Others, like Large Woodshrike *Tephrodornis gularis*, Black-lored Tit *Parus xanthogenys*, Stork-billed Kingfisher *Halcyon capensis*, White-throated Fantail *Rhipidura albicollis* and Indian

Grey Hornbill *Ocyceros birostris*, are known to be vocal and conspicuous, so these are also likely to be genuinely extinct now at these sites.

Table 7.3 Abundance of species susceptible to forest loss and degradation remaining extant in Purna Wildlife Sanctuary

Species	Past status		Current status		
	Ali (1954–1955)	Worah (1991)[a]	Sightings on transects	Relative abundance[b]	Encounter rate[c]
GREY JUNGLEFOWL *Gallus sonneratii*	Not uncommon	0.036	2	0.001	0.05±0.16
INDIAN PEAFOWL *Pavo cristatus*	Common in Gujarat	—	1	0.0015	0.06±0.19
RUFOUS WOODPECKER *Celeus brachyurus*	Rare?	—	2	0.0015	0.03±0.08
WHITE-BELLIED WOODPECKER *Dryocopus javensis*	3 specimens collected in 1 week	0.012	*	*	*
HEART-SPOTTED WOODPECKER *Hemicircus canente*	Not uncommon	0.024	4	0.0035	0.11±0.23
LESSER YELLOWNAPE *Picus chlorophus*	Not uncommon	—	1	0.0005	0.03±0.08
WHITE-CHEEKED BARBET *Megalaima viridis*	Not uncommon	0.012	1	0.0005	0.02±0.05
***INDIAN GREY HORNBILL* Ocyceros birostris**	Not uncommon	0.012	7	0.0065	0.20±0.29
MALABAR TROGON *Harpactes fasciatus*	Fairly common	0.145	1	0.0005	0.01±0.04
BROWN WOOD OWL *Strix leptogrammica*	—	—	*	*	*
BAR-WINGED FLYCATCHER-SHRIKE *Hemipus picatus*	Not common	0.012	1	0.0005	0.02±0.06
MALABAR WHISTLING THRUSH *Myophonus horsfieldii*	Not common	0.072	*	*	*
WHITE-RUMPED SHAMA *Copsychus malabaricus*	Few individuals	0.024	7	0.0035	0.12±0.17
VELVET-FRONTED NUTHATCH *Sitta frontalis*	Fairly common	—	1	0.0005	0.01±0.04

[a]Relative abundance based on point counts (number of birds in highest count divided by total number of points)
[b]Number of individuals of each species divided by number of individuals of all species recorded on all transects (n=10 transects)
[c]Mean±SD individuals/km (n=10 transects) *species not detected on transects

7.3.3 Ecological and zoogeographic correlates of susceptibility: Nineteen of the 22 susceptible species are characteristically forest-interior species. Such species show reduced fecundity near forest edges and their populations decline as fragment sizes reduce unless immigration from larger forest patches occurs (Temple and Cary 1988). Terborgh *et al*. (1990) recognised two types of rarity among birds in the Amazon rainforests of Peru: species that were locally rare (i.e. in the surveyed locality or habitat) and species that were constitutively rare. They considered the latter as truly rare and vulnerable to human intervention; these included large birds with low population densities (< 1 pair/km^2) such as raptors, parrots, woodpeckers and a few other species that were among the largest members of their respective guilds. In our study, the White-bellied Woodpecker as well as some other woodpeckers (see Tables 7.2 and 7.3) and the Stork-billed Kingfisher showed the latter kind of rarity, whereas the other susceptible species were locally rare. The replacement of primary moist deciduous forest either by secondary forest or by plantations at Purna has lead to fragmentation of the habitat (Worah 1991, Santharam 2003) and is a likely reason for the reduced abundance of such species in this sanctuary (Worah 1991).

Other ecological traits were associated with some of the species we identified as susceptible. These were ground-foraging and bark-foraging guilds, large body size, endemism and edge-of-range distribution. As suggested by Henle *et al*. (2004), these traits probably operate synergistically. Ground-foraging (six species) and bark-foraging guilds (five species) represented 50% of the susceptible species. These two guilds constituted only 18.84 % (36 species) of all the 191 species recorded in both sanctuaries.

Hence, ground and bark-foraging guilds were significantly more likely to be susceptible (x^2 =15.77, *df*=1, $p<0.001$). Ground-foraging birds have been found susceptible to forest fragmentation in the southern Western Ghats (Raman 2001), and bark-foraging birds are known to be susceptible to changes in micro-climate and foraging substrate resulting from logging (Johns 1986), forest loss and fragmentation (Castelletta *et al*. 2000, Raman 2001).

Stork-billed Kingfisher is likely to be susceptible on account of its large body size. Ali (1954–1955) regarded it as 'not uncommon on forest streams' in the eastern forest belt of the state. However, Khacher (1996) called for a special investigation to ascertain its status in relation to the limnological changes, which have taken place in forest streams. The species presumably feeds on relatively large fish as is suggested by its much larger bill (84–93 mm long) and body size compared with the congeneric White-throated Kingfisher (bill length: 60–67 mm) (Ali 1954–1955). We suspect that degradation of the lotic ecosystems by siltation (Khacher 1996), over-fishing and construction of check-dams has adversely affected the availability of the size and/or species of fish favoured by Stork-billed Kingfisher. In addition, competition with the White-throated Kingfisher *Halcyon smyrnensis*, a widespread, open-area species with a varied diet (Khacher 1996) that has colonised Purna in recent years, could also have affected its abundance.

Gaston (1985), Daniels *et al*. (1990) and Raman (2001) showed that endemic bird species in the Indian peninsula and Western Ghats were more vulnerable to habitat loss than non-endemic species. In the Atlantic forest fragments of Brazil, Ribon *et al*. (2003) found that

endemic species were more likely to go locally extinct than non-endemics. 23 out of 191 species (12.04 %) were endemic to the Indian sub-continent. There were 9 endemic species among the 22 susceptible species (40.9%; Table 3), which is significantly higher than expected (x^2 =19.56, *df*=1, p<0.001).

Populations found at the peripheries of a species' distributional range tend to occur at lower densities (Hengeveld and Haeck 1982) and hence be more vulnerable to extinction (Lawton 1995) than those in the core parts of its distribution. Of the 22 susceptible species we identified, 14 have their westernmost distributional limits in Gujarat's eastern forest belt (see Grimmett *et al.* 1998). The species for which Purna marks the northern, western or northwestern distributional limit are Large Woodshrike, White-bellied Woodpecker, Rufous Woodpecker, Lesser Yellownape, Brown Wood Owl, Malabar Trogon and White-cheeked Barbet. Ratanmahal is probably the northernmost distributional limit for Velvet-fronted Nuthatch and westernmost boundary for Large-tailed Nightjar. It is notable that Large Woodshrike was also reported locally extinct in Singapore (Castelletta *et al*. 2000), which is near its southernmost range limit.

7.3.4 Other factors: Poaching may also influence forest avifaunas (Castelletta *et al*. 2000, Henle *et al*. 2004). For example, phasianids are popular game birds and have been hunted to extinction from several areas in Gujarat (Trivedi 2005, *personal observations*). The effect of hunting on Indian Peafowl is particularly clear. In most parts of Gujarat, where there is a taboo against hunting this species, it is common, occurring in very high abundance at Gir forest (Trivedi 1993) and in several human-inhabited areas. However,

in the region populated by tribal groups where Ratanmahal and Purna are located, there is no hunting taboo and the species is extremely rare (Trivedi 2001, 2003).

Forest fragmentation may act synergistically with anthropogenic activities such as hunting and logging (Laurance *et al*. 2002). We encountered eight widespread species at Purna that are known to favour edges or open areas (Ali 1954–1955, Grimmett *et al*. 1998), but were not recorded by earlier studies: Barred Buttonquail *Turnix suscitator*, Common Hoopoe *Upupa epops*, Black-headed Cuckooshrike *Coracina melanoptera*, Common Myna *Acridotheres tristis*, White-browed Fantail *Rhipidura aureola*, Purple-rumped Sunbird *Nectarinia zeylonica*, Spotted Owlet *Athene brama* and White-throated Kingfisher *Halcyon smyrnensis*. Colonisation by these species has possibly been facilitated by the road-building and habitat degradation that accompanied forestry operations (also see Johns 1986). Whether these species have played a role in the impoverishment of forest avifauna could not be ascertained, although instances of edge-tolerant or edge-favouring competitor species causing a decline of forest-interior or rare species have been reported elsewhere (see Harris 1988, Laurance *et al*. 2002, Henle *et al*. 2004).

7.3.5 Conclusion: Gujarat's forest avifauna is in a fragile situation. While intensive surveys are adding species to the state's checklist, there are indications of avifaunal impoverishment and local extinctions. Ratanmahal and Purna are among the last remaining patches of moist deciduous forest in Gujarat and hence mark the global distributional limits for several forest birds. As a result of past forestry operations, the

habitat at Purna is more fragmented than that at Ratanmahal, however it has a higher richness of forest bird species. This has a bearing on future avifaunal impoverishment and conservation in the state. The situation is made worse by the increased isolation of bird populations in forest patches. Intensive surveys should be carried out in all forested regions of the state, including existing and potential forest corridors. Studies on the ecology of susceptible forest birds and the impacts of anthropogenic activities also need to be undertaken.

Chapter 8

CONSERVATION OF AVIFAUNA

8.1 INTRODUCTION

From the foregoing it is clear that Ratanmahal and Purna Sanctuaries are of high conservation significance for several forest bird species as the last remaining patches of moist deciduous forest in Gujarat. This is particularly so from the viewpoint of moist forest bird species showing disjunct and restricted ranges in India. These species are susceptible to changes in habitat structure and its floristic composition. Purna was found to be more fragmented habitat due to forestry practices of the past compared to Ratanmahal, which has a bearing on future avifaunal impoverishment and conservation. The anthropogenic activities (major threats) that could affect the avifauna of the two sites include poaching and over-fishing, some forestry practices, forest fires, unsustainable and careless harvesting of resources, construction of more roads and increasing vehicular traffic on these roads; overgrazing, and harmful agricultural practices.

8.2 THREATS TO AVIFAUNA

8.2.1 Poaching/Hunting: On many occasions, I encountered people who had entered the sanctuaries to hunt wildlife. At Purna, I came across hunters on over 15 occasions, while at Ratanmahal, I chanced upon them on three instances - all were during the daylight hours. There were differences in the methods of hunting between the two sites and this I believe was also responsible for differential hunting pressure on the target taxa. At Purna,

the commonest method was using catapults to hunt birds and squirrels. This was done mainly by youth - single individuals or twosomes. The other method that was also commonly used at Ratanmahal was hunting with the help of dogs. This was specifically targeted to hunt hares. At Ratanmahal, I also came across people carrying bows-arrows and firearms. These were probably used to kill macaques, monkeys and other large mammals. At Purna, people also hunt other mammals such as wild pig and four-horned antelope and game birds (junglefowl, spurfowl), which are rare (*personal observation*), possibly with the help of firearms. Thus, most hunting was directed at mammals, small passerines and game birds.

Hunting of birds such as White-bellied Woodpecker and Indian Grey Hornbill has been reported in the past (Ali 1954-55) though I could not get any evidence of the same. Keeping catapults and hunting is an integral part of the cultural milieu of Dangs (Worah 1991, Anonymous 2001). Interviewing these locals (12 groups/individuals) revealed that birds and lesser mammals such as hare, flying squirrel and palm squirrels were their prime targets. Several times, I asked hunters to show the contents of their 'catch'. Their unwillingness to do so explained the reasons. On one occasion, when I could inspect the contents of a hunter's '*jhola*' (cloth bag), I found a hare. On interviewing one willing hunter in detail, I found that not all birds are killed. Birds not hunted as a taboo included the two species of crows, members of the cuckoo family (Asian Koel, Greater Coucal and Common Hawk Cuckoo), Black Ibis, egrets and birds of prey including vultures and owls. Generally, small passerines were the targets. The aiming skills of local people with catapults were very high. In many instances, birds hunted are also consumed in the forest.

Although I did not carry out a survey of hunting, my observations and encounters indicated that few people were involved in hunting and that too not as a major subsistence activity or as occupation. Rather, most people did it seasonally (in late winter to summer when there were no standing crops and farm related work was wanting) or in absence of employment (labour in this case). Most people interviewed at Purna were not afraid of carrying the catapult or talking about hunting and showing their aiming skills, though some tried to hide the weapons and most did so for their catch. Some were aware of poaching being prohibited at Purna. I did not come across any hunter carrying firearms at Purna although several people living around are known to possess the same (Anonymous 2001).

Since livestock grazing is present throughout both the sanctuaries, this provides an opportunity for locals to hunt birds with ease. Besides, RWS shares its southern and eastern boundaries with Madhya Pradesh, a state in which hunting is more common and widespread. Hence, areas adjoining the inter-state border appear more prone to this problem. Poaching is a very serious and direct threat, although its extent and impact has not been quantified in the present study. Lack of patrolling has led to its preponderance in some areas. However, effect of hunting on birds is expected to be higher at Purna compared to Ratanmahal.

8.2.2 Fishing: Fishing is widespread throughout Purna throughout the year. Crabs and bivalves are also taken. There are many indigenous methods for fishing, but the most

common method at Purna was using bamboo barriers. I seldom came across fish that was larger than a human finger. Fish caught were either fried or dried and used later. Hunting was exclusively carried out by men, but women were involved in fishing and in catching crabs. The pressure of fishing is high and widespread. It is likely that this has led to reduction in average size of fish caught – a sign of ecological overfishing. This could have negative impact on the whole aquatic ecosystem in general and piscivorous birds in particular. I have attributed this to be the likely cause of local extinction of Stork-billed Kingfisher (*Halcyon capensis*) at Purna. At Ratanmahal, fishing was restricted to Udhalmahuda reservoir as streams within the sanctuary were ephemeral. At Udhalmahuda though fishing was carried out on a commercial scale using nets. Fishing and hunting did not have a commercial angle at Purna.

8.2.3 Forest Fires: Data of fire incidences of last ten years at Purna showed that 1 to 6 per cent of the total area experienced fire every year (Anonymous 2001). Bardipada and Bhenskatri ranges were more prone and lost large areas of forest. Most fires were man-made and often intentional. Most parts of Ratanmahal (mainly the dry zone) were also susceptible to forest fires owing to their predominantly dry nature and presence of *Dendrocalamus* bamboo. I observed forest fires on a number of occasions in different areas from March to May and found evidence of their occurrence in June. These fires were mainly affecting the leaf litter and undergrowth, both important habitats for birds. Fire destroyed ground vegetation, bamboo and regeneration. Ground-nesting and terrestrial birds are vulnerable to fires, particularly because the highest occurrence of fire coincides with nesting season of these birds. In addition, the fires would also reduce the

availability food resources such as insects and lizards in the pinch period. Repeated fires could also prevent regeneration of important plant species and kill the young trees. This may alter forest structure with more hardy species surviving and dominating the vegetation. Transect T–5 was a striking example of such an effect. All areas of Purna and Ratanmahal affected by fire showed reduced bird richness. Specific studies on the impacts of fire on bird diversity in the two areas could prove useful in revealing its impacts.

8.2.4 Agricultural Practices: Agriculture in Dangs at one time was in the form of slash-and-burn or shifting cultivation (Worah 1991). It was gradually replaced by settled but non-intensive agriculture. The Dangi people practice rab burning (locally called *chhindni*), in which they lop and burn the branches and twigs of tress standing in their fields. In case, there are no trees on the farm, rab is procured from the nearby forest. This material is burnt in a small area, before the rains. After the first showers, seeds are sown and seedlings later transplanted to the field. This method has been criticised as wasteful and destructive by Singh *et al.* (2000) for Vansda National Park. Worah (1991) however argued that it was the optimal way to get good production. She showed rab-burning and burning of manure to be important for increase in yield and also for keeping weeds under check. This practice caused crown distortion and leafless canopies for three to four months in the pinch period i.e. April-June (*personal observation*). With trees on fields decreasing, pressure on forests for rab collection would also increase. A less laborious but expensive alternative - use of fertilizers may reduce this impact, but have other consequences. However, the use of pesticides or chemical fertilizers is low or non-

existent at present in the entire Dangs district, but its spread could be harmful as over half the bird species of Purna are insectivorous. Such impact elsewhere has led to local extinction and endangerment of birds. Like Purna, Ratanmahal too had non-intensive agriculture without (or little) chemical inputs. Farm holdings being small and crops diverse, danger to birds appeared low from this factor.

8.2.5 Past forestry practices: In the past, logging was carried out in all areas of Purna. Timber was obtained mainly through clear felling and selection felling systems (see Anonymous 2001). The target species were teak and to some extent *Acacia catechu* and bamboo. This led to extensive teak monocultures and TKB plantations (Teak-Khair-Bamboo). These plantations were maintained regularly by operations such as climber cutting, thinning and removal of 'inferior' (= economically inferior) species. Bamboo was also harvested regularly in large quantities. These forestry operations led to change in the quality of forests in terms of reduced plant diversity, vertical heterogeneity and micro-habitats therein. Mature forests have been virtually replaced by plantations (of various age classes) and secondary moist forests. It is beyond doubt that such changes in the structure and floristic composition of the forests at Purna have affected its bird life. Selective felling of mature trees adopted at Purna in the past was a harmful practice for forest-interior and cavity-nesting bird species as could be seen by low occurrence of species such as White-bellied Woodpecker *Dryocopus javensis*. Maintenance operations such as thinning and climber cutting in commercial plantations could affect the habitat and prevent plantations from turning into good bird habitats. Owing to a moratorium on

tree felling in Protected Areas, some recovery has occurred. Thinning was also discontinued in late eighties (Anonymous 2001).

8.2.6 Harvesting of non-timber forest produces: The current practices include firewood collection, bamboo extraction, collection of non-timber forest produce (NTFP) such as fruits, medicinal plants and *tendu* leaves. Every year nearly 8,000 tonnes of firewood and lakhs of rupees worth of NTFP is collected (Anonymous 2001). Such large-scale collection of forest produce could affect the health of the forests with target species suffering the consequences of improper or indiscriminate harvesting. Further, movement of vehicles and a large number of people for harvesting bamboo and tendu leaves causes physical disturbance. Instances of fire and poaching also occur. A number of people of the villages inside Ratanmahal and other peripheral villages were engaged in the collection of *Diospyros melanoxylon* (*Tendu*) leaves during April and May. This directly disturbed the birds as there was widespread human presence throughout the sanctuary. The collection method was also damaging and wasteful as people were knocking off the small branches and then collecting suitable leaves from these fallen branches. This meant that there was often more wastage than usage. I found many *D. melanoxylon* trees with damaged crowns; causing loss or distortion in the canopy/middle storey and leading to alterations in microhabitat used by birds. Collection of leaves of many other species, which included climbers (locally called *dudhi*) and trees such as Schleichera (*Kusum*), *Terminalia* (*Sadad*), and *Butea* (*Khakharo*) was observed from the later part of the dry period i.e. during May to July. Bamboo leaves were also collected. People of the peripheral villages were involved in this and the leaves were collected as forage for

livestock. The pressure was more owing to inadequate rains during the year 2000. Impact of all these changes though not studied on a long-term basis needs to be viewed seriously. Worah (1991) has shown a strong positive correlation between the extent of anthropogenic disturbance and quality of habitat in Dangs. Observations made during the present study emphasise the point further.

8.2.7 Disturbance by Roads & Vehicular Traffic: At Purna as well as its surrounding forest areas, the roads passing through the Sanctuary have uncontrolled vehicular traffic. All types of vehicles including heavy transport ply on these roads throughout the day and even at night. This causes tremendous disturbance to the area. The roads which cause more disturbance and are located in sensitive/core areas include –

- Mahal-Chikhla-Bhalkhet
- Bardipada-Dhulda-Mahal
- Mahal-Ahwa
- Bardipada-Sawarkhadi

Of these, Dhulda-Mahal road is located in one of the best habitat patches with high bird species richness and remnants of good moist deciduous forest and bamboo brakes. This road literally bisects the 'core' area. Although there appears to be marginal direct impact of this traffic on birds, it causes many indirect effects such as habitat degradation and fire.

At Ratanmahal, only one road runs through the Sanctuary area and is not usable in monsoon. However, in fair weather several vehicles with loads of tourists or pilgrims

who are mostly day visitors move on the road. This causes heavy disturbance, especially during festivals such as *shivaraatri*. The other roads with heavy traffic include Kanjeta-Kevdi; abutting the Sanctuary boundary and effectively causing disturbance even at night. One such possibility, which could jeopardize the future of wildlife at Ratanmahal is construction of a mettle road connecting Kanjeta and Pipargota. At present, the dirt road prevents many associated anthropogenic activities such as tourism and keeps the traffic to minimum. Illegal activities also are curbed to some extent due to this. The other side however is that it could make the communication faster and patrolling easier. A solution to this possibility needs to be worked out in such a way that it does not disturb wildlife.

8.2.8 Grazing by Livestock: Livestock grazing was present in both the sanctuaries. Buffaloes, sheep, goats and cows were the chief livestock. They caused damage to vegetation, especially the regenerating saplings. Anonymous (undated) has stated that people residing in and around Ratanmahal tend to keep more heads of livestock due to low productivity of these animals. Since all the animals are grazed in a free-ranging system, it compounds the pressure. Further, past schemes of the State Government of encouraging tribal people to keep goats has contributed to habitat degradation, particularly at Ratanmahal.

8.2.9 Hydrological changes: The two perennial rivers Purna and Gira and streams that drain into these rivers at Purna have witnessed dramatic changes in the hydrological regime in the past decade or so. At Ratanmahal too, extensive efforts have been made to

build check-dams. This has undoubtedly helped in moisture conservation (*personal observation*), but presumably it has caused subtle hydrological changes that could adversely affect the dynamics of this freshwater system. The latest management plan of Purna (Anonymous 2001) suggested creation of 200 check-dams in coming ten years. These changes could have an impact on the plant communities and fish population ultimately affecting birds in a negative way. Kingfishers and other aquatic bird species would be affected in this case as shown by the disappearance of the Stork-billed Kingfisher from both the sites. An increasing number of bore-wells in the peripheral farmlands of the two protected areas could also lead to changes with long-term implications on the water table and moisture conditions.

8.3 RECOMMENDATIONS

8.3.1 General measures:

1. There is a need to review the possibilities of increasing the area of PWS. The management plan of 2002-2011 suggests an increase of about 100 km^2 to make the Sanctuary area 260 km^2.
2. Give high priority to development and strengthening of the corridor between PWS and Vansda N.P. The contiguous forested stretch of roughly 15 to 20 km length needs to be declared a Protected Area, thus making the entire ecological unit of about 500 km^2. The PA would thus cover over 11 % of the Western Ghats of State. This would ensure long-term viability of the populations of moist area bird species affiliated to the Western Ghats.

3. In addition to the above two options, there is a need to consider setting up of satellite Protected Areas. These areas could be small forest areas, but should be rich in their flora and fauna. Barda forest patch to southeast of PWS is one such important area (Worah 1991). Such patches of PA would help as refugia for avian diversity and also help in their dispersal (Worah 1991, Raman 2001).
4. The entire Borumal hill (T-1) and its ramifications should be made into a Ntaional Park with no human interference. After five years, its success should be measured and more areas from other parts of PWS can be selected for similar treatment. Areas of moist deciduous forest adjoining Gira and Purna rivers and other typical habitats should be given high priority for preservation of forest-interior bird species.
5. The Preservation Plot in Bardipada Range should be maintained with strictest enforcement. No human activity except research should be allowed within it. More area should be added to it. Other 5 to 20 hectare patches of mature forest, bamboo brakes or good secondary forest in PWS could also be protected as Preservation Plots, thereby protecting the diversity of habitat and bird species.
6. Although rich in its avian life, the area of RWS is of little ecological significance. Any small PA of this size has little scope to be viable as per the island biogeography theory. Its potential would improve only if the adjoining forest areas are merged with the existing RWS and given the same state of protection.
7. Since poaching occurs in remote areas adjoining the M.P. border and in interior areas of RWS, patrolling becomes an urgent need. Regular presence of the Forest Department staff in such areas only would eliminate this direct threat to wildlife.

8.3.2 Habitat improvement measures:

1. The unregulated traffic in PWS needs a check. Closing the Sanctuary for traffic at night hours (e.g. on Mahal-Chikhla-Bhalkhet, Bardipada-Dhulda-Mahal, and Bardipada-Sawarkhadi road would help in immense way. All the roads located in the Purna-Vansda corridor should be surveyed for traffic and the same diverted in such a way to cause minimum disturbance to wildlife. Night traffic needs to be gradually stopped on these roads too. One or two roads causing less disturbance should be exempted in this regard.
2. Bamboo should not be viewed as a weed or as a commercial commodity. It is rather an integral and important component of PWS habitat. Bamboo harvesting therefore needs to be controlled and conducted in a phased manner. The entire area of PWS need not be subjected to bamboo harvesting every year. *B. arundinacea* harvesting should be more regulated than that of *D. strictus* as the former is more important as a habitat component for bird. The operations need to last for less time so that there is reduction in disturbance. Similarly, *Timru* leaf collection should not be allowed inside Protected Areas.
3. Forest fires are probably going to remain a part and parcel of PWS, but good prevention measures and early detection-action mechanism could reduce the damage considerably. A "fire detection and alert" mechanism is absent and unless fires are detected early, extinguishing the same is extremely difficult looking at the terrain involved. Provision of specially trained man power, creation of fire lines and a regular watch on fire prone areas is required. There is also a need to assess the impact

of fires. Areas that have experienced fire in the past two decades should be surveyed for regeneration and recovery of habitat as well as changes in faunal richness.

4. Plantations should consist of mixed species, so as to make them suitable bird habitats. Large plantations of single species should be avoided at all costs. Forestry operations of climber cutting and thinning in single species plantations should not be undertaken. Allowing regeneration in plantations would help in establishment of other species of trees thus enhancing the habitat diversity.
5. All schemes that promote use of chemical fertilisers, pesticides and building of check-dams need to be scrutinised before approval and implementation. The ongoing initiatives of such kind need to be assessed for their success in achieving the desired outcomes.
6. Due to erratic rainfall, topography and soil type, RWS faces water shortage every year. Years 1999 and 2000 were poor in terms of rainfall and this resulted in scarcity of water from November to June with only 8 to 10 waterholes holding water. Check dams on the streams have been successful only in conserving moisture to some extent, but only natural waterholes were observed to be holding water perennially. Strengthening the existing natural waterhole system may prove to be more effective than building guzzlers along roadsides or at places where perennial streams do not exist. A network of permanent waterholes along the perennial streams (or along the same streams, which have permanent waterholes) might increase water availability. Care should be taken to monitor whether such a change would cause clumping of wildlife and degradation of food resources in the area.

8.3.3 Measures involving public support:

1. Since hunting and fishing have their roots in both cultural and subsistence needs of the locals, the same cannot be stopped outright. A village level poultry initiative to supply the families with a pre-determined number of poultry should be thought of. Families would manage the birds and obtain their protein needs from the same. A simultaneous awareness programme on hunting and its impacts should be devised to make people aware. Fishing is a more difficult activity to deal with. However, changes in mesh size, identification and demarcation of fishing zones and heavy fines on destructive fishing such as blasting could be tried.
2. Local people need to be taken into confidence for all the above actions as it would increase the success rate of all the measures. Otherwise, it could even nullify the efforts of the Forest Department.
3. More children from local communities should be introduced to nature through nature education camps. They should be encouraged to become volunteers for such programmes and contribute to protection of the forests.

8.3.4 Specific measures:

1. The bird species identified as sensitive/susceptible in chapter seven, need to be monitored on a regular basis. Besides, periodic monitoring of avifauna of the two forest areas could be assigned to local bird-watching groups. These in turn could train local youth to carry out this activity.

2. To prevent the negative impacts of rab burning, farmers need to be encouraged to grow more trees on farms, or in strips along fields and on forest/farm lands lying fallow. The forest department nurseries could provide sapling for this purpose.
3. Tree species providing key resources such as *B. monosperma, F. benghalensis, Erythrina suberosa, Bombax ceiba, Lannea coromandelica* and *Casearia* spp. need special attention in terms of regeneration, control on harvesting by humans and illicit felling.
4. Conducting intensive surveys in all the forested regions of the state, including existing and potential forest corridors and studies on the biology and ecology of vulnerable taxa of forest birds need to be undertaken for conservation of forest avifauna in Gujarat.

REFERENCES

Ali, S. 1950. The Gujarat Satpuras in Indian Ornithogeography: The Highway of Malayan forms to the Western Ghats. *Prakriti* 9 (1&2): 9-23.

Ali, S. 1954-55. The Birds of Gujarat - I and II. *Journal Bombay Natural History Society* 52: 374-458 and 735-802.

Ali, S. 1969. Birds of Kerala. The second edition of The Birds of Travancore and Cochin. Oxford University Press.

Ali, S. and Ripley, S. D. 1983. A Pictorial Guide to the Birds of the Indian Subcontinent. BNHS Centenary Publication. Oxford University Press, Delhi.

Anderson, S. H. 1981. Correlating habitat variables and birds. *Studies in Avian Biology* No. 6: 538-542.

Anonymous. (*undated*). Ratanmahal Wildlife Sanctuary. Forest Division, Baria (Gujarat State).

Anonymous. 1996-97. Working Plan for Dangs Forests. Forest Department, Gujarat.

Anonymous. 2001. Management Plan of Purna Wildlife Sanctuary (2002-2011). 2 Volumes. Forest Department, Gujarat State.

Austin, G. T. and Smith, E. L. 1972. Winter foraging ecology of mixed insectivorous bird flocks in oak woodland in southern Arizona. *Condor* 74: 17-24.

Bedi, S. J. 1968. Floristic study of Ratan Mahal and surrounding hills. Ph.D. thesis submitted to M.S. University, Baroda.

Beier, P., Drielen, M. V., and Kankam, B. O. 2002. Avifaunal collapse in West African forest fragments. *Conservation Biology* 16(4): 1097-1111.

Bhatt, M. 2004. Bird-watching in Vansda National Park. *Vihang* 21: 9-10 (*in Gujarati*).

Bhushan, B. 1994. Ornithology of the Eastern Ghats. Ph.D. thesis submitted to Bombay University.

BirdLife International. 2004. State of the world's birds 2004: indicators for our changing world. Cambridge, UK: BirdLife International.

Botero, C. A. 2002. Is the White-flanked Antwren (Formicariidae: *Myrmotherula axillaries*) a nuclear species in mixed-species flocks ? A field experiment. *J. Field Ornithol*. 73 (1): 74-81.

Brooks, T. M., Pimm, S. L. and Oyugi, J. O. 1999. Time lag between deforestation and bird extinction in tropical forest fragments. 13: 1140-1150.

Brown, J. H. 1984. On the relationship between abundance and distribution of species. *The American Naturalist* 124(2): 255-279.

Brown, J. H., Mehlman, D. W. and Stevens, G. C. 1995. Spatial variation in abundance. *Ecology* 76(7): 2028-2043.

Buskirk, W. H. 1976. Social systems in a tropical forest avifauna. *The American Naturalist* 110 (972): 293-310.

Buskirk, W. H., Powell, G. V. N., Wittenberger, J. F., Buskirk, R. E. and Powell, T. U. 1972. Inter specific bird flocks in tropical highland Panama. *Auk* 89: 612-624.

Butler, E. A. 1875. Notes on the avifauna of Mount Aboo and Northern Guzerat. *Stray Feathers* 3: 437-500.

Butler, E. A. 1876. Notes on the avifauna of Mount Aboo and Northern Guzerat. *Stray Feathers* 4: 1-41.

Butler, E. A. 1877. Notes on the avifauna of Mount Aboo and Northern Guzerat. *Stray Feathers* 5 (3 & 4): 207-236.

Castelletta, M., Sodhi, N. S. and Subaraj, R. 2000. Heavy extinctions of forest avifauna in Singapore: Lessons for biodiversity conservation in Southeast Asia. *Conservation Biology* 14 (6): 1870-1880.

Champion, H. G. and Seth, P. K. 1968. A revised survey of the forest types of India. Manager of Publications, Delhi.

Clarke, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. *Aust. J. Ecol.* 18: 117–143.

Clements, F. E. 1916. Plant succession: an analysis of the development of vegetation. *Publication no.* 242, Washington, D.C.: Carnegie Institute.

Cody, M. L. 1981. Habitat selection in birds: the roles of vegetation structure, competitors and productivity. *Bioscience* 31 (2): 107-113.

Cody, M. L. 1983. Bird diversity and density in South African forests. *Oecologia* 59: 201-215.

Crooks, K. R., Suarez, A. V., Bolger, D. T. and Soule, M. E. 2001. Extinction and colonization of birds on habitat islands. *Conservation Biology* 15(1): 159-172.

Croxall, J. P. 1976. The composition and behaviour of some mixed-species bird flocks in Sarawak. *Ibis* 118: 333-346.

D'Abreau, E. A. 1935. A list of the birds of the Central Provinces. *Journal Bombay Natural History Society* 38: 95-116.

Dale, S., Mork, K., Solvang, R. and Plumptre, A.J. 2000. Edge effects on the understorey bird community in a logged forest in Uganda. *Conservation Biology* 14(1): 265-276.

Daniels, R. J. R. 1989. A conservation strategy for the birds of Uttar Kannada district, south India. Ph. D. thesis submitted to the Indian Institute of Science, Bangalore, India.

Daniels, R. J. R., Hegde, M., and Gadgil, M. 1990. Birds of the man-made ecosystems: The plantations. *Proc. Indian Acad. Sci. (Anim. Sci.),* Vol. 99 (1): 79-89.

Dasgupta, J. M., Roy, S. B. and Datta, B. K. 2002. Endemic birds of India, *Rec. zool. Surv. India, Occasional Paper No.* 200: 1-44. Director, Zoological Survey of India, Calcutta.

Datta, A. 2000. Pheasent abundance in selectively logged and unlogged forests of Western Arunachal Pradesh, northeast India. *Journal Bombay Natural History Society* 97(2): 177-183.

Davidar, P. (1979) Synecological studies on the specialised nectar-feeding birds and bird-flowers in the Nilgiris. Ph. D. dissertation submitted to Bombay University.

Debinski, D. M. and Holt, R. D. 2000. A survey and overview of habitat fragmentation experiments. *Conservation Biology* 14(2): 342-355.

Desai, I. V., Suresh, B., and Pilo, B. 1993. Birds of Shoolpaneshwar Wildlife Sanctuary. *Pavo* 31 (1&2): 55-72.

Desai, I. V., Suresh, B., and Pilo, B. 1993. Birds of Shoolpaneshwar Wildlife Sanctuary. *Pavo* 31 (1&2): 55-72.

Dharmakumarsinhji, K. S. 1985. The Black Eagle *Ictinaetus malayensis* TEMM. and LAUG at Sawai Madhopur (Rajasthan). *Journal Bombay Natural History Society* 82(3): 655.

Diamond, J. M. 1972. Biogeographic kinetics: Estimation of relaxation times for avifaunas of Southwest Pacific Islands. *Proc. Natl. Acad. Sci. USA*. 69: 3199-3202.

Diamond, J. M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. *Biological Conservation* 7: 129-145.

Diamond, J. M. 1980. Patchy distributions of tropical birds. In: Conservation Biology. *Ed*. Soule, M. E. and Wilcox, B. A. Sinauer Associates Inc. Massachusetts.

Diamond, J. M. 1981. Mixed-species foraging groups. *Nature* 292: 408-409.

Dolby, A. S. & Grubb, T. C. Jr. 1999. Functional roles in mixed-species foraging flocks: a field manipulation. *Auk* 116 (2): 557-559.

Elton, C. 1927. Animal Ecology. London: Sidgwick and Jackson.

Emlen, J. T., DeJong, M. J., Jaeger, M. J., Moermond, T. C., Rusterholz, K. A. and White, R. P. 1986. Density trends and range boundary constraints of forest birds along a latitudinal gradient. *Auk* 103: 791-803.

Fernandez-Juricic, E. 2002. Nested patterns of species distribution and winter flock occurrence of insectivorous birds in a fragmented landscape. *Ecoscience* 9(4): 450-458

Fischer, J. and Lindenmayer, D. B. 2002. Small patches can be valuable for biodiversity conservation: two case studies on birds in southeastern Australia. *Biological Conservation* 106(2002): 129-136.

Freemark, K. E. and Kirk, D. A. 2001. Birds on organic and conventional farms in Ontario: partitioning effects of habitat and practices on species composition and abundance. *Biological Conservation* 101(2001): 337-350.

Gadgil, M. and Rao, P. R. S. 1998. Nurturing Biodiversity: An Indian Agenda. Environment and Development series. Centre for Environment Education, Ahmedabad.

Gaston, A. J. 1978. Distribution of birds in relation to vegetation on the New Delhi ridge. *Journal Bombay Natural History Society* 75 (2): 257-265.

Gaston, A. J. 1985. Is habitat destruction in India and Pakistan beginning to affect the status of endemic passerine birds? *Journal Bombay Natural History Society* 81(3): 636-641.

Gleason, H. A. 1917. The structure and development of the plant association. *Bulletin of the Torrey Botanical Club* 44: 463-481.

Gleason, H. A. 1926. The individualistic concept of plant association. *Bulletin of the Torrey Botanical Club* 53: 7-26.

Goodale, E. & Kotagama, S. W. 2005. Alarm calling in Sri Lankan mixed-species bird flocks. *Auk* 122 (1): 108-120.

Gotelli, N.J. and Entsminger, G. L. 2006. EcoSim: Null models software for ecology. Version 7. Acquired Intelligence Inc. & Kesey-Bear. Jericho, VT 05465.

Gram, W. K. 1998. Winter participation by Neotropical migrant and resident birds in mixed-species flocks in northeastern Mexico. *Condor* 100: 44-53.

Graves, G. R. & Gotelli, N. J. 1993. Assembly of avian mixed-species flocks in Amazonia. *Proc. Natl. Acad. Sci*. USA 90: 1388-1391.

Greig-smith, P. W. 1978. The formation, structure and function of mixed-species insectivorous bird flocks in west African savanna woodland. *Ibis* 120: 284-295.

Grimmett, R., Inskipp, C. and Inskipp, T. 1998. Birds of the Indian Subcontinent. Oxford University Press, New Delhi.

Gutzwiller, K. J. and Barrow, W. C. 2003. Influences of roads and development on bird communities in protected Chihuahuan Desert landscapes. *Biological Conservation* 113(2003): 225-237.

Haffer, J. 1969. Speciation in Amazonian forest birds. *Science* 165: 131-137.

Harris, L. D. 1988 Edge effects and conservation of biodiversity. *Conservation Biology* 2 (4): 330-332.

Harris, L. D. 1988. Edge effects and conservation of biotic diversity. *Consrevation Biology* 2(4): 330-332.

Hengeveld, R., and Haeck, J. 1982. The distribution of abundance - I measurements. *Journal of Biogeography* 9: 303-316.

Henle, K., Davies, K. F., Kleyer, M., Margules, C. and Settele, J. 2004. Predictors of species sensitivity to fragmentation. *Biodiversity and Conservation* 13: 207-251.

Herrera, C. M. 1979. Ecological aspects of heterospecific flock formation in a Mediterramean passerine bird community. *Oikos* 33: 85-96.

Herrera, C. M. 1984. A study of avian frugivores, bird-dispersed plants, and their interaction in Mediterranean scrublands. *Ecological Monographs* 54(1): 1-23.

Hino, T. 2002. Breeding bird community and mixed-species flocking in a deciduous broad-leaved forest in western Madagascar. *Ornithol. Sci.*1: 111-116.

Howe, H. F. and Smallwood, J. 1982. Ecology of seed dispersal. *Annual Review of Ecology and Systematics* 13: 201-228.

Hutto, R. L. 1987. A description of mixed-species insectivorous bird flocks in western Mexico. *Condor* 89: 282-292.

Hutto, R. L. 1994. The composition and social organization of mixed-species flocks in a tropical deciduous forest in western Mexico. *Condor* 96: 105-117.

Islam, M. Z. and Rahmani, A. R. 2002. Threatened Birds of India. *Buceros* 7 (1 & 2), Compiled from Threatened Birds of Asia. BirdLife International Red data Book 2001.

James, F. C. and Rathbun, S. 1981. Rarefaction, relative abundance, and diversity of avian communities. *Auk* 98: 785-800.

James, F. C. and Wamer, N. O. 1982. Relationships between temperate forest bird communities and vegetation structure. *Ecology* 63: 159-171.

Javed, S. 1996. Study on bird community structure of terai forest in Dudhwa national Park. Ph. D. dissertation, Aligarh Muslim University.

Jayapal, R. 1997. A study on bird communities-habitat structure relationships in Pench National Park, M.P. M.Sc. Dissertation. Saurashtra University

Jayson, E. A., and Mathew, D. N. 2002. Structure and composition of two bird communities in the southern Western Ghats. *Journal Bombay Natural History Society* 99 (1): 8-25.

Johns, A. D. 1986. Effects of selective logging on the ecological organization of a peninsular Malaysian rainforest avifauna. *Forktail* 1: 65-79.

Johns, A. D. 1989. Recovery of a peninsular Malaysian rainforest avifauna following selective timber logging: the first twelve years. *Forktail* 4: 89-106.

Johnsingh, A. J. T. and Joshua, J. 1994. Avifauna in three vegetation types on Mundanthurai Plateau, South India. *Journal of Tropical Ecology* 10: 323-335.

Jullien, M. and Clobert, J. 2000. The survival value of flocking in Neotropical birds: reality of fiction? *Ecology* 81 (12): 3416-3430.

Karr, J. R. 1977. Ecological correlates of rarity in a tropical forest bird community. *Auk* 94: 240-247.

Karr, J. R. 1980. Geographical variation in the avifaunas of tropical forest undergrowth. *Auk* 97: 283-298.

Karr, J. R. 1982. Avian extinction on Barro Colorado Island, Panama: a reassessment. *The American Naturalist* 119: 220-239.

Karr, J. R. 1983. Commentary. In: *Perspectives in Ornithology* ed. Brush, A. H. & Clark, G. A. Jr. pp. 403-410. Cambridge: Cambridge University Press.

Katti, M. V. 1989. Bird communities in lower Dachigam Valley, Kashmir. M.Sc. Dissertation. Saurashtra University.

Khacher, L. 1996 The Birds of Gujarat - A Salim Ali centenarary Year Overview. *Journal Bombay Natural History Society* 93(3): 331-373.

Khacher, L. and Raol, L. M. (*undated*) [Checklist of birds of Gujarat.] Compilation based on separate accounts serially published in *Chatak* - Newsletter of WWF-India, Gujarat State Office. (*in Gujarati*)

Khanchandani, M. S. 1970. Working plan for Dangs forests. Vol. I & II. Government Press, Baroda.

King, D. I. & Rappole, J. H. 2001a. Mixed-species bird flocks in dipterocarp forest of north-central Burma (Myanmar). *Ibis* 143: 380-390.

King, D. & Rappole, J. H. 2001b. Kleptoparasitism of laughingthrushes *Garrulax* by Greater Racket-tailed Drongo *Dicrurus paradiseus* in Myanmar. *Forktail* 17: 121-122.

Kotagama, S. H. & Goodale, E. 2004. The composition and spatial organisation of mixed-species flocks in a Sri Lankan rainforest. *Forktail* 20 (2004): 63-70.

Kurup, G. U. 1974. Mammals of Assam and the mammal-geography of India. In: Ecology and biogeography in India. *Ed*. Mani M. S. Dr. W. Junk b.v. Publishers, The Hague.

Lacy, R. C. and Bock, C. E. 1986. The correlation between range size and local abundance of some north American birds. *Ecology* 67(1): 258-260.

Landers, P. B. and MacMahon, J. A. 1980. Guilds and community organization: analysis of an oak woodland avifauna in Sonora, Mexico. *Auk* 97: 351-365.

Latta, S. C. & Wunderle, J. M. Jr. 1996. The composition and foraging ecology of mixed-species flocks in pine forests of Hispaniola. *Condor* 98: 595-607.

Laurance, W. F., Lovejoy, T. E., Vasconcelos, H. L., Bruna, E. M., Didham, R. K., Stouffer, P. C., Gascon, C., Bierregaard, R. O., Laurance, S. G. and Sampaio, E. 2002. Ecosystem decay of Amazonian forest fragments: A 22-year investigation. *Conservation Biology* 16 (3): 605-618.

Lawton, J. H. 1995. Population dynamic principles. In: Lawton, J. H. and May, R. M. (eds.), Extinction rates. Oxford University Press, Oxford, pp. 147-163.

Lindenmayer, D. B., Cunningham, R. B., Donnelly, C. F., Nix, H. and Lindenmayer, B. D. 2002. Effects of forest fragmentation on bird assemblages in a novel landscape context. *Ecological Monographs* 72(1): 1–18.

Lovejoy, T. E., Bierregaard, R. O. Jr., Rylands, A. B., and others 1986. Edge and other effects of isolation in Amazon forest fragments. Pp. 257-285. In: Conservation Biology: the science of scarcity and rarity. Ed. Soule, M. E. Sinaeur, Sunderland, Massachusetts.

Lucas, A. 1892. Forest conservancy in the Dangs. Revenue Department. Pub. No. 982. Bombay.

MacArthur, R. H. and MacArthur, J. W. 1961. On bird species diversity. *Ecology* 42 (3): 594-598.

MacArthur, R. H. and Wilson, E. O. 1967. The Theory of Island Biogeography. Princeton: Princeton University Press.

MacArthur, R. H., Recher, H. and Cody, M. 1966. On the relation between habitat selection and species diversity. The American naturalist 100: 319-332.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton.

Maldonado-Coelho, M. & Marini, M. A. 2000. Effects of forest fragment size and successional stage on mixed-species bird flocks in southeastern Brazil. *Condor* 102: 585-594.

Mani M. S. ed. 1974. Ecology and biogeography in India. Dr. W. Junk b.v. Publishers, The Hague.

Mashru, A. 2004. Black Eagle in Mount Abu, Rajasthan. *Vihang* 22: 5-6. (*in Gujarati*).

McClure, H. E. 1967. The composition of mixed species flocks in lowland and sub-montane forests of Malaya. *Wilson Bull*. 79 (2): 131-154.

Mehta, P. 1998. The effect of forestry practices on bird species diversity in Satpura hill ranges. Ph. D. thesis submitted to Saurashtra University, Rajkot.

Mikusinski**,** G., Gromadzki, M. and Chylarecki, P. 2000. Woodpeckers as indicators of forest bird diversity. *Conservation Biology* 2000: 208-217.

Mitra, S. S and Sheldon, F. H. 1993. Use of an exotic tree plantation by Bornean lowland forest birds. *Auk* 110(3): 529-540.

Monga, S. G., and Naoroji, R. K. 1983. Birds of the Rajpipla Forest - South Gujarat. *Journal Bombay Natural History Society* 80 (3): 575-612.

Morrison, M. L., With, K. A., Timossi, I. C., and Milne, K. A. 1987. Composition and temporal variation of flocks in the Sierra Nevada. *Condor* 89: 739-745.

Morse, D. H. 1970. Ecological aspects of some mixed-species foraging flocks of birds. *Ecol. Monogr*. 40 (1): 119-168.

Moynihan, M. 1962. The organization and probable evolution of some mixed species flocks of Neotropical birds. *Smithson. Misc. Collect.* 143: 1-140.

Munn, C. A. and Terborgh, J. W. 1979. Multi-species territoriality in Neotropical foraging flocks. *Condor* 81: 338-347.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A. B., Kent, J. 2000. Biodiversity hotspots for prioritizing conservation. *Nature* 203: 853-858.

Orians, G. H. 1969. The number of bird species in some tropical forests. *Ecology* 50: 783-801.

Otvos. I. S. 1979. The effects of insectivorous bird activities in forest ecosystems: an evaluation. In: Dickson, J. G., Conner, R. N., Fleet, R. R., Kroll, J. C. and Jackson, J.

A. (Eds.) The role of insectivorous birds in forest ecosystems. Proceedings of the symposium. Academic Press, New York.

Pandya, T. M., and Oza, G. M. 1998 Bioregion Common Property Resource Management Studies. INSONA, Vadodara.

Parasharya, B. M., Borad, C. K. and Rank, D. N. (2004) A checklist of the birds of Gujarat. Bird Conservation Society, Gujarat.

Partridge, L. & ashcroft, R. 1976. Mixed-species flocks of birds in hill forests of Ceylon. *Condor* 78: 449-453.

Patel, R. I. 1971. Forest Flora of Gujarat State. Forest Department, Baroda.

Patterson, B. D. 1987. The principle of nested subsets and its implications for biological conservation. Conservation Biology 1:323-334.

Pearman, P. B. 2002. The scale of community structure: habitat variation and avian guilds in tropical forest understorey. *Ecological Monographs* 72(1): 19-39.

Pearson, D. L. 1975. The relation of foliage complexity to ecological diversity of three Amazonian bird communities. *Condor* 77: 453-466.

Pearson, D. L. 1977. A pantropical comparison of bird community structure on six lowland forest sites. *Condor* 79: 232-244.

Peres, C. 2000. Synergistic effects of subsistence hunting and habitat fragmentation on Amazonian forest vertebrates. *Conservation Biology* 15 (6): 1490-1505.

Pileou, E. C. 1979. Biogeography. John Wiley & Sons, New York.

Powell, G. V. N. 1979. Structure and dynamics of interspecific flocks in a Neotropical mid-elevation forest. *Auk* 96: 375-390.

Powell, G. V. N. 1989. On the possible contribution of mixed species flocks to species richness in neotropical avifaunas. *Behavioural Ecology and Sociobiology* 24: 387-393.

Prasad, A. 2003. Annotated checklist of the birds of Western Maharashtra. *Buceros* 8 (2&3): 1-174.

Price, T., Zee, J., Jamdar, K. and Jamdar, N. 2003. Bird species diversity along the Himalaya: A comparison of Himachal Pradesh with Kashmir. *Journal Bombay Natural History Society* 100 (2 & 3): 394-410.

Raman, T. R. S. 1995. Shifting cultivation and conservation of tropical forest bird communities in Mizoram, northeast India. M. Sc. Dissertation submitted to Saurashtra University. Wildlife Institute of India.

Raman, T. R. S. 2001. Community ecology and conservation of tropical rainforest birds in the southern Western Ghats, India. Ph. D. thesis. Indian Institute of Science.

Raman, T. R. S. 2001. Community ecology and conservation of tropical rainforest birds in the southern Western Ghats, India. Ph. D. thesis submitted to Indian Institute of Science.

Rao. P. 1988. Bird communities of the tropical dry-evergreen forests of Sriharikota. Ph. D. dissertation, Bombay University.

Raol, L. M. 1998. *Van Upvanna Pankhi.* [Birds of forest and garden.], Centre for Environment Education, Ahmedabad. (*in Gujarati*)

Renjifo, L. M. 1999. Composition changes in a Subandean avifauna after long-term forest fragmentation. *Conservation Biology* 13: 1124-1139.

Ribon, R., Simon, J. E. and De Mattos, G. T. 2003. Bird extinctions in Atlantic forest fragments of the Vicosa region, southeastern Brazil. *Conservation Biology* 17(6): 1827–1839.

Ricklefs, R. E. and Schluter, D. 1993. Species Diversity in Ecological Communities: Historical and Geographical Perspectives. The University of Chicago Press, Chicago.

Ripley, S. D. and Beehler, B. F. 1990. Patterns of speciation in Indian birds. *Journal of Biogeography* 17: 639-648.

Robin, V. V. & Davidar, P. 2001. Species composition and associations of birds in mixed-species flocks at Parambikulam, south India. pp. 711-715. In: Tropical Ecosystems: Structure, Diversity and Human Welfare. Proceedings of the International Conference on Tropical Ecosystems. (*Eds*.) K. N. Ganeshaiah, R. Uma Shanker and K. S. Bawa. Oxford-IBH, New Delhi.

Robin, V. V. & Davidar, P. 2002. The vertical stratification of birds in mixed species flocks at Parambikulam, south India: a comparison between two habitats. *Journal Bombay Natural History Society* 99 (3): 389-399.

Rodgers, W. A. 1991. Techniques for Wildlife census in India: A Field Manual. Wildlife Institute of India, Dehradun.

Rodgers, W. A. and Panwar, H. S. 1988. Planning a Protected Area Network in India. 2 volumes. Wildlife Institute of India, Dehradun.

Rodgers, W. A., Panwar, H. S. and Mathur, V. B. 2000. Wildlife Protected area Network in India: A Review, Executive summary. Wildlife Institute of India, Dehradun.

Root, R. B. 1967. The niche exploitation pattern of the Blue-gray Gnatcatcher. *Ecological Monographs* 37: 317-350.

Root, T. 1988. Environmental factors associated with avian distributional boundaries. Journal of Biogeography 15: 489-505.

Roth, R. R. 1978. Vegetation as a determinant in avian ecology. *Proc. First Welder Wildlife Foundation Symposium*, pp. 162-174.

Santharam, V. 1995. Ecology of sympatric woodpecker species of Western Ghats, India. Ph. D. thesis submitted to Pondicherry University.

Santharam, V. 2003. Distribution, ecology and conservation of the White-bellied Woodpecker *Dryocopus javensis* in the Western Ghats, India. *Forktail* 19 2003. 31-38.

Scott, J. M., Mountainspring, S., Ramsey, F. L., and Kepler, C. B. 1986. Forest bird communities of Hawaii an Islands: their dynamics, ecology, and conservation. *Studies in Avian Biology* 9: 1-431.

Short, L. L. 1961. Interspecific flocking of birds of montane forest in Oaxaca, Mexico. *Wilson Bull*etin 73 (4): 341-347.

Shull, E. M. 1962. Supplementary notes on 'The birds of Gujarat' from birds collected in Surat Dangs. *Journal Bombay Natural History Society* 59: 658-660.

Siegel, S. 1956. Non Parametric Statistics for the Behavioural Sciences. New York. McGraw Hill.

Simberloff, D. 1985. Habitat fragmentation and population extinction of birds. *Ibis* 137: S105-S111.

Singh, H. S. 2001. Natural Heritage of Gujarat (Forests and Wildlife). GEER Foundation, Gandhinagar.

Singh, H. S., Raval, B. R., Patel, B. H., Tatu, K., Patel, D., Vyas, R. and Patel, B. H. 2000. Biodiversity study on Vansda National Park. A comprehensive ecological and socio-economic study. GEER Foundation, Gandhinagar.

Singh, H. S., Patel, B. H., Trivedi, P., Raval, B. R., Pawar, J. S., Vyas, R. and Patel, B. H. 2002. Biodiversity study in Ratanmahals Wildlife Sanctuary (A comprehensive ecological and socio-economic study). GEER Foundation, Gandhinagar.

Snow, D. W. 1981. Tropical frugivorous birds and their food plants: A world survey. *Biotropica* 13(1): 1-14.

Southwood, T. R. E. 1987. The concept and nature of the community. In: Organization of communities: past and present (Ed.) Gee, J. H. R. & Giller, P. S. 27th Symposium of the British Ecological Society, Aberystwyth 1986. Blackwell Scientific Publications.

Sridhar, H. 2005. Patterns in mixed-species flocking of birds in rainforest fragments of the southern Western Ghats. M.Sc. Dissertation, Saurshtra University, Rajkot. 66 pp.

STATISTICA Version 6. 2004. StatSoft Inc. P.O. Box 225, NL-8070 AE Nunspeet, The Netherlands.

Stiles, F. G. 1985. On the role of birds in the dynamics of Neotropical forests. In: Conservation of Tropical forest Birds. Eds. Diamond, A. W. and Lovejoy, T. E. Proceedings of a workshop and symposium held at the XVIII World Conference of the International Council for Bird Presrevation. Cambridge, England.

Stouffer, P. C. and Bierregaard, R. O. 1995. Use of Amazonian forest fragments by understory insectivorous birds. *Ecology* 76: 2429-2445.

Stratford, J. A. and Stouffer, P. C. 1999. Local extinctions of terrestrial insectivorous birds in a fragmented landscape near Manaus, Brazil. *Conservation Biology* 13(6): 1416-1423.

Styring, A. R. & Ickes, K. 2001. Interactions between the Greater racket-tailed Drongo Dicrurus paradiseus and woodpeckers in a lowland Malaysian rainforest. *Forktail* 17: 119-120.

Su, J. C., Debinski, D. M., Jakubauskas, M. E. and Kindscher, K. 2004. Beyond species richness: community similarity as a measure of cross-taxon congruence for coarse-filter conservation. *Conservation Biology* 18 (1): 167-173.

Sugihara, G. 1980. Minimal community structure: an explanation of species-abundance patterns. *The American Naturalist* 116(6): 770-787.

Sullivan, K. 1985. Selective alarm calling by Downy Woodpeckers in mixed-species flocks. *Auk* 102: 184-187.

Temple, S. A. and Cary, J. R. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. *Conservation Biology* 2(4): 340-347.

Terborgh, J. 1985. Habitat selection in Amazonian birds. In: Habitat Selection in Birds. *Ed*. Cody, M. L. pp. 311-338. Academic Press, New York.

Terborgh, J. 1990. Mixed flocks and polyspecific associations: costs and benefits of mixed groups to birds and monkeys. *American Journal of Primatology* 21: 87-100.

Terborgh, J. and Robinson, S. K. 1986. Guilds and their utility in ecology. In: Community Ecology: Pattern and Process. *Eds*. Kikkawa, J. & Anderson, D. J. pp. 65-90. Blackwell Scientific Publications.

Terborgh, J. H. 1974. Preservation of natural diversity: the problem of extinction prone species. *Bioscience* 24: 715-722.

Terborgh, J. W., Robinson, S. K., Parker, T. A., Munn, C. A., and Pierpont, N. 1990. Structure and organization of an Amazonian forest bird community. *Ecological Monographs* 60 (2): 213-238.

Trivedi, P. 2001. Biodiversity Study: Ratanmahal Wildlife Sanctuary. Bird Study: Interim Report II (*unpubl.*). Submitted to GEER Foundation, Gandhinagar. 31 pp.

Trivedi, P. 2003. Bird Study of Purna Wildlife Sanctuary, Dangs under Biodiversity Study of Purna Wildlife Sanctuary. Final report (*unpubl*.) submitted to GEER Foundation, Gandhinagar. 38 pp.

Trivedi, P. 2005. Avifauna Study of Jessore Wildlife Sanctuary. Final Report (*unpubl*.) submitted to GEER Foundation Gnadhinagar

Trivedi, P. and Soni, V. C. (*in press*) Significant bird records and local extinctions in Purna and Ratanmahal Wildlife Sanctuaries, Gujarat, India. *Forktail* 22 (2006): 39-48.

Verner, J. 1985. Assessment of counting techniques. In: Current Ornithology Vol. 2 (ed.) Richard F. Johnston. Plenum Press, New York.

Vijayan, L. 1984. Comparative biology of drongos (Family Dicruridae, Class Aves) with special reference to ecological isolation. Ph. D. dissertation, Bombay University.

Vuilleumier, F. 1967. Mixed species flocks in Patagonian forests, with remarks on interspecies flock formation. *Condor* 69: 400-404.

Vuilleumier, F. and Simberloff, D. 1980. Ecology versus history as determinants of patchy and insular distributions in high Andean birds. *Evolutionary Biology* 12: 235-379.

Waite, T. A. & Grubb, T. C. 1988. Copying of foraging locations in mixed-species flocks of temperate-deciduous woodland birds: an experimental study. *Condor* 90: 132-140.

Walburg, L. K. 1992. Flocking and frugivory: the effect of social groupings on resource use in the Common Bush-tanager. *Condor* 94: 358-363.

Wethred, R. and Lawes, M. J. 2003. Matrix effects on bird assemblages in fragmented Afromontane forests in South Africa. *Biological Conservation* 114(2003): 327-340.

Wiens, J. A. 1983. Avian community ecology: An iconoclastic view. In: *Perspectives in Ornithology* ed. Brush, A. H. & Clark, G. A. Jr. pp. 355-403. Cambridge: Cambridge University Press.

Wiens, J. A. 1989. The ecology of bird communities. 2 volumes. Cambridge University Press, Cambridge.

Wiens, J. A., Rotenberry, J. T. and Horne, B. N. 1987. Habitat occupancy patterns of North American shrubsteppe birds: the effects of spatial scale. *Oikos* 48: 132-147.

Wilcox, B. A. 1978. Supersaturated island faunas: A species-area relationship for lizards on post-Pleistocene land-bridge islands. *Science* 199: 996-998.

Winterbottom, J. M. 1949. Mixed bird parties in the tropics, with special reference to northern Rhodesia. *Auk* 66: 258-263.

Worah, S. 1991. The ecology and management of a fragmented forest in south Gujarat India: The Dangs. Ph. D. thesis submitted the University of Poona, Pune.

Yahya, H. S. A. 2001. Biology of Indian Barbets. Authorspress & Aligarh Muslim University, India.

ZSI 2000. State Fauna Series 8: Fauna of Gujarat, Part - I: Aves, pp. 85-241. Zoological Survey of India, Calcutta.

Appendix 3.1 Salient features of line transects for bird study at Ratanmahal

Transect	Location	Vegetation & Flora	Terrain	Unique Features
T–1	Pipargota	Mixed Forest (with Bamboo), Cultivation-Plateau mosaic, negligible Teak	Flat to undulating	Many edges, 75 % points on ecotones, less undergrowth, perennial stream present
T–2	Popat Kuwa	Mixed Forest, patches of abandoned cultivation, less Bamboo, Teak common	Hilly & undulating	Mature mixed forest with tall trees, less undergrowth, seasonal stream present
T-3	Mendri	Dry Open Mixed Forest Hill, no Teak	Hilly	No Bamboo, few edges, dense undergrowth, perennial stream present
T–4	Bhuvero	Bamboo (*B. arundinacea*) brakes with Mixed Forest species, no Teak	Undulating to Hilly	Few edges, lush tall Bamboo, moist locality, less undergrowth, perennial water hole present
T-5	Kanjeta	Dry Teak Mixed & Mixed Forest, *D. strictus* frequent	Hilly, seldom undulating	Adjacent to a seasonal stream often traversing it, poor undergrowth, high occurrence of fire

Appendix 3.2 Salient features of line transects for bird study at Purna

No.	Name	No. of Walks	Distance Walked (km)	Habitat Features
T-1	Borumal	6	08.0	Hilly area; Moist mixed forest, moist teak forest, secondary forest, bamboo brakes (both species); Canopy > 20 meters, 4-5 vertical strata, good undergrowth; Perennial water sources present
T-2	Dhulda	6	11.5	Valley, Flat terrain; Moist Teak forest, Secondary forest, Teak Plantations, *B. arundinacea* brakes, Riverine forest; Canopy height > 15 meters, 3-4 vertical strata; Perennial water source (Gira river) present
T-3	Mahal Kot	5	06.5	Hilly area descending to flat mid-elevation valley; Dry deciduous mixed and teak forest, Young teak plantation, D. strictus present; Canopy low < 15 meters, 2-3 strata, good undergrowth in monsoon & early winter; No perennial water source
T-4	Girmal	3	04.0	Hilly area; Dry deciduous mixed and teak forest with *Wrightia, A. catechu* and *Lannea*, *D. strictus* present; Canopy low < 15 meters, poor undergrowth, 2-3 strata; Perennial water source present (Gira river)
T-5	Mahal Camp-Site	3	04.5	Flat valley area; Moist *B. arundinacea* brakes interpsersed with mixed forest and teak plantations; Canopy > 15 metres, poor undergrowth, 2-4 strata; Perennial water source present (Purna river)
T-6	Bhalkhet	3	05.0	Flat to undulating valley; Dry locality but along seasonal stream, Riverine forest, different aged teak–bamboo plantations, Secondary forest elements; Canopy variable, good undergrowth, 2-4 strata; Perennial water source present (depends on rainfall, yes in good year)
T-7	Waghdarda	2	04.0	Flat broad valley; Moist mixed and

No.	Name	No. of Walks	Distance Walked (km)	Habitat Features
				teak forest with extensive *B. arundinacea,* young teak plantations; Canopy > 15 meters, moderate undergrowth, 3-4 strata; Perennial water available (depends on rainfall, yes in good year)
T-8	Bhenskatri	2	05.0	Flat to undulating; Dry deciduous teak forests mixed with extensive *D. strictus* brakes (plantations), mixed forest; Canopy low < 15 meters, moderate undergrowth, 2-4 strata; Perennial water available at some places
T-9	Sawardakasad	1	01.5	Hilly; Moist area Riverine forest, *B. arundinacea* dominated area with mixed, secondary and teak forest; Canopy variable, mostly > 15 meters, moderate undergrowth, 3-4 strata; Perennial water available (Purna river)
T-10	Rupgadh	2	02.0	Hilly to undulating; Dry secondary mixed forest and young teak plantations, *D. strictus* present in low number; Canopy low < 10 metres, good undergrowth, 2-3 strata; Perennial water source present

Appendix 4.1 Checklist of birds encountered at Ratanmahal and Purna during present study

No.	Common Name	Purna	Ratanmahal	Status	Guild
1	Alexandrine Parakeet (*Psittacula eupatria*)	1	1	R	AMH
2	Alpine Swift (*Cypsiurus balasiensis*)	1	1	RM	AI
3	Ashy Drongo (*Dicrurus leucophaeus*)	1	1	RM	FSI
4	Ashy Prinia (*Prinia socialis*)	1	1	R	UGI
5	Ashy Woodswallow (*Artamus fuscus*)	0	1	R	ASI
6	Ashy-crowned Sparrow Lark (*Eremopterix grisea*)	0	1	R	G
7	Asian Koel (*Eudynamys scolopacea*)	1	1	R	AO
8	Asian Openbill (*Anastomus oscitans*)	0	1	R	AQ
9	Asian Palm Swift (*Cypsiurus balasiensis*)	0	1	R	AI
10	Asian Paradise-flycatcher (*Terpsiphone paradisi*)	1	1	RM	FSI
11	Barn Owl (*Tyto alba*)	0	1	R	C
12	Barn Swallow (*Hirundo rustica*)	0	1	RM	AI
13	Barred Buttonquail (*Turnix suscitator*)	1	0	R	GFO
14	Bar-winged Flycatcher-shrike (*Hemipus picatus*)	1	0	R	FSI
15	Baya Weaver (*Ploceus philippinus*)	0	1	R	G
16	Bay-backed Shrike (*Lanius vittatus*)	0	1	R	GGAI
17	Black Drongo (*Dicrurus macrocercus*)	1	1	R	FSI
18	Black Eagle (*Ictinaetus malayensis*)	1	0	R	C
19	Black Ibis (*Pseudibis papillosa*)	1	1	R	AQ
20	Black Kite (*Milvus migrans*)	0	1	R	C
21	Black redstart (*Phoenicurus ohruros*)	1	1	RM	GFI
22	Black-headed Cuckooshrike (*Coracina melanoptera*)	1	1	R	FSI
23	Black-hooded Oriole (*Oriolus xanthornus*)	1	1	R	AO
24	Black-lored Tit (*Parus xanthogenys*)	0	1	R	FGI
25	Black-naped Monarch (*Hypothymis azurea*)	1	1	R	FSI
26	Black-rumped Flameback (*Dinopium benghalense*)	1	1	R	BF
27	Black-shouldered Kite (*Elanus caeruleus*)	1	1	R	C
28	Black-winged Stilt (*Himantopus himantopus*)	0	1	R	AQ
29	Blue Rock Thrush (*Monticola solitarius*)	1	1	RM	GFI
30	Blue-capped Rock Thrush (*Monticola cinchlorhynchus*)	1	1	M	GFI
31	Blue-cheeked Bee-eater (*Merops persicus*)	0	1	C	ASI
32	Blue-winged Leafbird (*Chloropsis cochinchinensis*)	1	1	R	AO
33	Brahminy Starling(*Sturnus pagodarum*)	0	1	R	MO
34	Brown Fish Owl (*Ketupa zeylonensis*)	1	1	R	C
35	Brown Hawk Owl (*Ninox scutulata*)	1	0	R	C

No.	Common Name	Purna	Ratanmahal	Status	Guild
36	Brown Shrike (*Lanius cristatus*)	1	0	M	GGAI
37	Brown Wood Owl (*Strix leptogrammica*)	1	0	R	C
38	Brown-capped Pygmy Woodpecker (*Dendrocopus nanus*)	1	1	R	BF
39	Brown-cheeked Fulvetta (*Alcippe poioicephala*)	1	0	R	FGI
40	Brown-headed Barbet (*Megalaima zeylaynica*)	1	1	R	AF
41	Cattle egret (*Bubulcus ibis*)	1	1	RM	GFO
42	Chestnut-shouldered Petronia (*Petronia xanthocollis*)	1	1	R	MO
43	Citrine Wagtail (*Motacilla citreola*)	1	0	M	AQ
44	Collared Scops Owl (*Otus bakkamoena*)	1	0	R	C
45	Common Chiffchaff (*Phylloscopus collybita*)	1	1	M	MLI
46	Common Greenshank (*Tringa nebularia*)	0	1	M	AQ
47	Common Hawk Cuckoo (*Hierococcyx varius*)	1	1	R	FGI
48	Common Hoopoe (*Upupa epops*)	1	1	R	GFI
49	Common Iora (*Aegithina tiphia*)	1	1	R	FGI
50	Common Kestrel (*Falco tinnunculus*)	1	1	RM	C
51	Common Kingfisher (*Alcedo atthis*)	1	1	R	C
52	Common Myna (*Acridotheres tristis*)	1	1	R	GFO
53	Common Rosefinch (*Carpodacus erythrinus*)	1	0	M	G
54	Common Sandpiper (*Tringa hypoleucos*)	1	1	RM	AQ
55	Common Tailorbird (*Orthotomus sutorius*)	1	1	R	UGI
56	Common Teal (*Anas crecca*)	0	1	M	AQ
57	Common Woodshrike (*Tephrodornis pondicerianus*)	1	1	R	FGI
58	Coppersmith Barbet (*Megalaima haemacephala*)	1	1	R	AF
59	Crested Serpent eagle (*Spilornis cheela*)	1	1	R	C
60	Crested Treeswift (*Hemiprocne coronata*)	1	1	R	AI
61	Crimson Sunbird (*Aethopyga siparaja*)	1	1	R	N
62	Desert Wheatear (*Oenanthe deserti*)	0	1	RM	GFI
63	Eurasian Blackbird (*Turdus merula*)	0	1	RM	GFO
64	Dusky crag Martin (*Hirundo concolor*)	1	0	R	AI
65	Emerald Dove (*Chalcophaps indica*)	1	0	R	TF
66	Eurasian Eagle Owl (*Bubo bubo*)	0	1	R	C
67	Eurasian Thick-knee (*Burhinus oedicnemus*)	0	1	R	GFI
68	Eurasian Wryneck (*Jynx torquilla*)	0	1	M	GFI
69	Eurasian Collared Dove (*Streptopelia decaocto*)	1	1	R	G
70	Eurasian Crag Martin (*Hirundo rupestris*)	1	0	R	GGAI
71	European Roller (*Coracias garrulous*)	0	1	RM	GGAI
72	Eurasian Golden Oriole (*Oriolus oriolus*)	1	0	RM	AO
73	Eurasian Hobby (*Falco subbuteo*)	1	0	RM	C
74	Golden-Fronted Leafbird (*Chloropsis aurifrons*)	1	1	R	AO
75	Great Cormorant (*Phalacrocorax carbo*)	0	1	RM	AQ
76	Great Egret (*Casmerodius albus*)	0	1	RM	AQ

No.	Common Name	Purna	Ratanmahal	Status	Guild
77	Great Tit (*Parus major*)	1	1	R	FGI
78	Greater Coucal (*Centropus sinensis*)	1	1	R	UGC
79	Greater Flameback (*Chrysocolaptes lucidus*)	1	0	R	BF
80	Greater Racket-tailed Drongo (*Dicrurus paradiseus*)	1	1	R	FSI
81	Green Bee-eater (*Merops orientalis*)	1	1	R	ASI
82	Green Sandpiper (*Tringa ohropus*)	1	1	M	AQ
83	Greenish Warbler (*Phylloscopus trochiloides*)	1	1	M	FGI
84	Grey Heron (*Ardea cinerea*)	0	1	RM	AQ
85	Grey Junglefowl (*Gallus sonneratii*)	1	1	R	GFO
86	Grey Nightjar (*Caprimulgus indicus*)	1	0	R	AI
87	Grey Wagtail (*Motacilla cinerea*)	1	1	M	AQ
88	Grey-breasted Prinia (*Prinia hodgsonii*)	1	1	R	UGI
89	Grey-headed Canary Flyctacher (*Culicicapa ceylonensis*)	1	1	R	FSI
90	Heart-spotted Woodpecker (*Hemicircus canente*)	1	0	R	BF
91	House Crow (*Corvus splendens*)	1	0	R	MO
92	House Sparrow (*Passer domesticus*)	1	1	R	G
93	House Swift (*Apus affinis*)	0	1	RM	AI
94	Indian Cuckoo (*Cuculus micropterus*)	1	0	R	FGI
95	Indian Grey Hornbill (*Ocyceros birostris*)	1	0	R	AFF
96	Indian Nightjar (*Caprimulgus asiaticus*)	1	0	R	AI
97	Indian Peafowl (*Pavo cristatus*)	1	1	R	GFO
98	Indian Pitta (*Pitta brachyura*)	1	0	R	GFI
99	Indian Pond heron (*Ardeola grayii*)	1	1	R	AQ
100	Indian Robin (*Saxicoloides fulicata*)	1	1	R	GFI
101	Indian Roller (*Coracias benghalensis*)	1	1	R	GGAI
102	Indian Scimitar Babbler (*Pomatorhinus horsfieldii*)	1	0	R	UGI
103	Indian Silverbill (*Lonchura malabarica*)	0	1	R	G
104	Intermediate Egret (*Mesophoyx intermedia*)	1	1	RM	AQ
105	Jungle Babbler (*Turdoides striatus*)	1	1	R	MLI
106	Jungle Owlet (*Glaucidium radiatum*)	1	1	R	C
107	Kentish Plover (*Charadrius alexandrinus*)	0	1	RM	AQ
108	Large Cuckooshrike (*Coracina macei*)	1	1	R	FGI
109	Large Grey Babbler (*Turdoides malcolmi*)	0	1	R	GFI
110	Large-billed Crow (*Corvus macrorhynchos*)	1	1	R	MO
111	Large-tailed Nightjar (*Caprimulgus macrurus*)	0	1	RM	AI
112	Laughing Dove (*Streptopelia senegalensis*)	0	1	R	G
113	Lesser Whitethroat (*Sylvia curruca*)	0	1	M	UGI
114	Lesser Yellownape (*Picus chlorolophus*)	1	0	R	BF
115	Little Cormorant (*Phalacrocorax niger*)	1	1	RM	AQ
116	Little Egret (*Egretta garzetta*)	1	1	R	AQ
117	Little Grebe (*Tachybaptus ruficollis*)	1	0	R	AQ

No.	Common Name	Purna	Ratanmahal	Status	Guild
118	Little Heron (*Butoridea striatus*)	1	0	R	AQ
119	Little Ringed Plover (*Charadrius dubius*)	0	1	RM	AQ
120	Little Stint (*Calidris minuta*)	0	1	M	AQ
121	Long-billed Vulture (*Gyps indicus*)	1	1	R	C
122	Long-tailed Shrike (*Lanius schach*)	1	1	R	GGAI
123	Malabar Trogon (*Harpactes fasciatus*)	1	0	R	FSI
124	Malabar Whistling Thrush (*Myophonus horsfieldi*)	1	0	R	GFO
125	Marsh Sandpiper (*Tringa stagnatilis*)	0	1	M	AQ
126	Mottled Wood Owl (*Strix ocellata*)	0	1	R	C
127	Northern Pintail (*Anas acuta*)	0	1	M	AQ
128	Orange-headed Thrush (*Zoothera citrina*)	1	1	RM	GFI
129	Oriental Honey-buzzard (*Pernis ptilorhyncus*)	1	1	RM	C
130	Oriental Magpie Robin (*Copsychus saularis*)	1	1	R	GFI
131	Oriental Skylark (*Alauda gulgula*)	0	1	R	GFO
132	Oriental Turtle Dove (*Streptopelia orientalis*)	1	1	RM	G
133	Oriental White-eye (*Zosterops palpebrosus*)	1	1	R	FGI
134	Painted Frankolin (*Frankolinus pictus*)	1	0	R	G
135	Pale-billed Flowerpecker (*Dicaeum erythrorhynchos*)	1	1	R	AMH
136	Pied Kingfisher (*Ceryle rudis*)	0	1	R	C
137	Plain Prinia (*Prinia inornata*)	0	1	R	UGI
138	Plum-headed Parakeet (*Psittacula cyanocephala*)	1	1	R	AMH
139	Puff-throated Babbler (*Pellorneum ruficeps*)	1	1	R	GFI
140	Purple Sunbird (*Nectarinia asiatica*)	1	1	R	N
141	Purple-rumped Sunbird (*Nectarinia zeylonica*)	1	0	R	N
142	Red Avadavat (*Amandava amandava*)	0	1	R	G
143	Red-rumped Swallow (*Hirundo daurica*)	1	1	R	AI
144	Red-throated Flycatcher (*Ficedula parva*)	1	1	M	USI
145	Red-vented Bulbul (*Pycnonotus cafer*)	1	1	R	AO
146	Red-wattled Lapwing (*Vanellus indicus*)	1	1	R	AQ
147	River Tern (*Sterna aurantia*)	0	1	R	AQ
148	Rock Pigeon (*Columba livia*)	1	1	R	G
149	Rose-ringed Parakeet (*Psittacula krameri*)	1	1	R	AMH
150	Ruddy Shelduck (*Tedorna ferruginea*)	0	1	RM	AQ
151	Rufous Treepie (*Dendrocitta vagabunda*)	1	1	R	AO
152	Rufous Woodpecker (*Celeus brachyurus*)	1	0	R	BF
153	Scarlet Minivet (*Pericrocotus flammeus*)	1	0	R	FGI
154	Scaly-breasted Munia (*Lonchura punctulata*)	0	1	R	G
155	Shikra (*Accipiter badius*)	1	1	R	C
156	Small Minivet (*Pericrocotus cinnamomeus*)	1	1	R	FGI
157	Spotted Dove (*Streptopelia chinensis*)	1	1	R	G
158	Spotted Owlet (*Athene brama*)	1	0	R	C

No.	Common Name	Purna	Ratanmahal	Status	Guild
159	Sulphur-bellied Warbler (*Phylloscopus griseolus*)	1	0	RM	BF
160	Tawny Eagle (*Aquila rapax*)	1	0	R	C
161	Tawny Pipit (*Anthus campestris*)	0	1	M	GFI
162	Tawny-bellied Babbler (*Dumetia hyperythra*)	1	1	R	UGI
163	Temminck's Stint (*Calidris temminckii*)	0	1	M	AQ
164	Thick-billed Flowerpecker (*Dicaeum agile*)	1	1	R	AMH
165	Tickell's Blue Flycatcher (*Cyornis tickelliae*)	1	1	R	USI
166	Tree Pipit (*Anthus trivialis*)	1	1	M	GFI
167	Velvet-fronted Nuthatch (*Sitta frontalis*)	1	0	R	BF
168	Verditer Flycatcher (*Eumyias thalassina*)	1	1	R	FSI
169	Western Crowned Warbler (*Phylloscopus occipitalis*)	1	0	M	FGI
170	White Wagtail (*Motacilla alba*)	1	1	RM	AQ
171	White-bellied Drongo (*Dicrurus caerulescens*)	1	1	R	FSI
172	White-bellied Woodpecker (*Dryocopus javensis*)	1	0	R	BF
173	White-breasted Waterhen (*Amaurornis phoenicurus*)	1	1	R	AQ
174	White-browed Fantail (*Rhipidura aureola*)	1	1	R	FSI
175	White-browed Wagtail (*Motacilla maderaspatensis*)	0	1	R	AQ
176	White-cheeked Barbet (*Megalaima viridis*)	1	0	R	AF
177	White-eyed Buzzard (*Butastur teesa*)	1	1	R	C
178	White-naped Woodpecker (*Chrysocolaptes festivus*)	1	1	R	BF
179	White-rumped Munia (*Lonchura striata*)	1	0	R	G
180	White-rumped Shama (*Copsychus malabaricus*)	1	0	R	GFI
181	White-rumped Vulture (*Gyps bengalensis*)	1	0	R	C
182	White-throated Fantail (*Rhipidura albicollis*)	0	1	R	FSI
183	White-throated Kingfisher (*Halcyon smyrnensis*)	1	1	R	AQ
184	Wire-tailed Swallow (*Hirundo smithii*)	0	1	R	AI
185	Woolly-necked Stork (*Ciconia episcopus*)	0	1	R	AQ
186	Yellow-browed Warbler (*Phylloscopus inornatus*)	1	0	RM	FGI
187	Yellow-crowned Woodpecker (*Dendrocopus mahrattensis*)	1	1	R	BF
188	Yellow-footed Green Pigeon (*Treron phoenicoptera*)	1	1	R	AF
189	Yellow Wagtail (*Motacilla flava*)	0	1	RM	AQ
190	Yellow-eyed Babbler (*Chrysomma sinense*)	0	1	R	UGI
191	Yellow-wattled Lapwing (*Vanellus malabaricus*)	0	1	R	GFI

R= Resident, M=Migratory, RM=Migrant with resident population

GFI-Ground foraging insectivore
GFO-Ground foraging omnivore
TF: Terrestrial frugivore
G: Granivore
GGAI: Ground gleaning arboreal insectivore
UGC: Undergrowth carnivore
UGI: Undergrowth gleaning insectivore
USI: Undergrowth sallying insectivore
MO: Mixed omnivore
AO: Arboreal omnivore
AF: Arboreal frugivore
AFF: Arboreal frugivore-faunivore
FSI: Foliage sallying insectivore
FGI-Foliage gleaning insectivore
AI: Aerial insectivore
ASI: Arboreal sallying insectivore
BF: Bark forager (Probe+Glean)
AMH: Arboreal mixed herbivore
MLI: Multi-layered insectivore
C: Carnivores (including owls, piscivores excluding kingfishers)
N: Nectarivore
AQ: Aquatic

Appendix 4.2 Frequency of encounters and abundance of bird species sighted on transects at Purna and Ratanmahal Wildlife Sanctuaries

No.	Species Name	Ratanmahal		Purna	
		Frequency	Number	Frequency	Number
1	Alexandrine Parakeet	8	10	20	32
2	Ashy Drongo	7	8	17	26
3	Asian Koel	11	11	9	9
4	Asian Palm Swift	5	15	0	0
5	Asian Paradise-flycatcher	14	16	31	31
6	Barred Bustard-quail	0	0	1	1
7	Bar-winged Flycatcher-shrike	0	0	1	1
8	Bay-backed Shrike	1	1	0	0
9	Black Drongo	2	4	4	4
10	Black Eagle	0	0	1	1
11	Black Ibis	0	0	2	2
12	Black Redstart	7	7	5	6
13	Black-headed Cuckooshrike	1	1	0	0
14	Black-hooded Oriole	34	38	42	45
15	Black-lored Tit	3	6	0	0
16	Black-naped Monarch	12	20	24	27
17	Black-rumped Flameback	15	15	19	21
18	Black-shouldered Kite	0	0	1	1
19	Blue-capped Rock Thrush	1	1	0	0
20	Blue-winged Leafbird	3	4	3	4
21	Brown Fish Owl	3	5	0	0
22	Brown-capped Pygmy Woodpecker	16	24	9	10
23	Brown-cheeked Fulvetta	0	0	13	30
24	Brown-headed Barbet	30	34	55	59
25	Cattle Egret	7	54	8	23
26	Chestnut-shouldered Petronia	44	111	70	112
27	Common Hawk Cuckoo	8	8	6	6
28	Common Iora	13	15	9	10
29	Common Myna	2	4	4	5
30	Common Rosefinch	0	0	1	1
31	Common Tailor Bird	54	58	48	48
32	Common Woodshrike	47	84	30	41
33	Coppersmith Barbet	6	10	21	21
34	Crested Honey-buzzard	0	0	2	2
35	Crested Serpent Eagle	4	4	7	7
36	Crested Treeswift	8	30	0	0
37	Crimson Sunbird	5	7	29	42
38	Emerald Dove	0	0	5	6

No.	Species Name	Ratanmahal		Purna	
		Frequency	Number	Frequency	Number
39	Gold-fronted Leafbird	8	11	34	51
40	Great Tit	13	19	25	33
41	Greater Coucal	14	15	21	23
42	Greater Flameback	0	0	14	23
43	Greater Racket-tailed Drongo	24	29	40	58
44	Green Bee-eater	13	17	9	11
45	Grey Junglefowl	0	0	2	2
46	Grey Wagtail	1	1	5	5
47	Grey-breasted Prinia	2	5	7	12
48	Grey-headed Canary Flycatcher	13	13	4	4
49	Heart-spotted Woodpecker	0	0	4	7
50	House Swift	1	10	0	0
51	Indian Cuckoo	0	0	1	1
52	Indian Grey Hornbill	0	0	7	13
53	Indian Peafowl	1	1	1	3
54	Indian Pitta	0	0	3	4
55	Indian Pond Heron	1	1	2	3
56	Indian Robin	3	6	0	0
57	Indian Roller	20	21	1	1
58	Indian Scimitar Babbler	0	0	11	13
59	Jungle Babbler	42	213	23	169
60	Jungle Owlet	9	11	8	8
61	Kestrel	1	1	0	0
62	Large Cuckooshrike	22	24	26	30
63	Large-billed Crow	48	98	52	65
64	Leaf Warbler	95	114	100	110
65	Lesser Whitethroat	4	6	0	0
66	Lesser Yellownape	0	0	1	1
67	Little Egret	0	0	4	4
68	Long-tailed Shrike	1	1	0	0
69	Malabar Trogon	0	0	1	1
70	Mottled Wood Owl	3	5	0	0
71	Orange-headed Thrush	1	2	9	11
72	Oriental Magpie Robin	14	16	11	12
73	Oriental Turtle Dove	0	0	1	1
74	Oriental White-eye	14	27	12	29
75	Pale-Billed Flowerpecker	20	21	17	20
76	Plum-headed Parakeet	38	56	37	74
77	Puff-throated Babbler	1	2	16	19
78	Purple Sunbird	28	34	33	41
79	Purple-rumped Sunbird	0	0	2	2
80	Red-rumped Swallow	2	4	0	0
81	Red-throated Flycatcher	23	24	42	44

No.	Species Name	Ratanmahal		Purna	
		Frequency	Number	Frequency	Number
82	Red-vented Bulbul	26	35	34	42
83	Red-wattled Lapwing	1	2	0	0
84	Rose-ringed Parakeet	15	22	43	85
85	Rufous Treepie	42	59	34	42
86	Rufous Woodpecker	0	0	2	3
87	Scarlet Minivet	0	0	13	23
88	Shikra	13	14	7	8
89	Small Minivet	20	42	2	6
90	Spotted Dove	31	84	35	39
91	Tawny-bellied Babbler	2	2	1	4
92	Thick-billed Flowerpecker	20	24	9	9
93	Tickell's Blue Flycatcher	32	35	47	50
94	Tree Pipit	8	13	7	28
95	Velvet-fronted Nuthatch	0	0	1	1
96	Verditer Flycatcher	1	2	5	5
97	White-bellied Drongo	51	77	32	38
98	White-browed Fantail	22	24	0	0
99	White-cheeked Barbet	0	0	1	1
100	White-eyed Buzzard	12	13	3	3
101	White-naped Woodpecker	2	3	5	8
102	White-rumped Shama	0	0	7	7
103	White-spotted Fantail	1	1	0	0
104	White-throated Kingfisher	7	7	2	2
105	Yellow-crowned Woodpecker	4	5	4	5
106	Yellow-footed Green Pigeon	5	15	10	36
	TOTALS	**1166**	**1892**	**1387**	**1987**

Appendix 4.3
Relative Abundance of Species in Purna and Ratanmahal Wildlife Sanctuaries

	Ratanmahal		Purna	
No.	**Species**	**Relative Abundance %**	**Species**	**Relative Abundance %**
1	Jungle Babbler	10.44	Jungle Babbler	8.50
2	Leaf Warbler	5.59	Chestnut-shouldered Petronia	5.63
3	Chestnut-shouldered Petronia	5.44	Leaf Warbler	5.53
4	Large-billed Crow	4.80	Rose-ringed Parakeet	4.27
5	Common Woodshrike	4.11	Plum-headed Parakeet	3.72
6	Spotted Dove	4.11	Large-billed Crow	3.27
7	White-bellied Drongo	3.77	Brown-headed Barbet	2.96
8	Rufous Treepie	2.89	Greater Racket-tailed Drongo	2.91
9	Common Tailor Bird	2.84	Golden-fronted Leafbird	2.56
10	Plum-headed Parakeet	2.74	Tickell's Blue Flycatcher	2.51
11	Cattle Egret	2.64	Common Tailor Bird	2.41
12	Small Minivet	2.05	Black-hooded Oriole	2.26
13	Black-hooded Oriole	1.86	Red-throated Flycatcher	2.21
14	Red-vented Bulbul	1.71	Crimson Sunbird	2.11
15	Tickell's Blue Flycatcher	1.71	Red-vented Bulbul	2.11
16	Brown-headed Barbet	1.66	Rufous Treepie	2.11
17	Purple Sunbird	1.66	Common Woodshrike	2.06
18	Crested Treeswift	1.47	Purple Sunbird	2.06
19	Greater Racket-tailed Drongo	1.42	Spotted Dove	1.96
20	Oriental White-eye	1.32	White-bellied Drongo	1.91
21	Brown-capped Pygmy Woodpecker	1.17	Yellow-footed Green Pigeon	1.81
22	Large Cuckooshrike	1.17	Great Tit	1.66
23	Red-throated Flycatcher	1.17	Alexandrine Parakeet	1.61
24	Thick-billed Flowerpecker	1.17	Asian Paradise-flycatcher	1.56
25	White-browed Fantail	1.17	Brown-cheeked Fulvetta	1.51
26	Rose-ringed Parakeet	1.07	Large Cuckooshrike	1.51
27	Indian Roller	1.03	Oriental White-eye	1.45
28	Pale-billed Flowerpecker	1.03	Tree Pipit	1.41
29	Black-naped Monarch	0.98	Black-naped Monarch	1.35
30	Great Tit	0.93	Ashy Drongo	1.3
31	Green Bee-eater	0.83	Cattle Egret	1.15
32	Asian Paradise-flycatcher	0.78	Greater Coucal	1.15
33	Oriental Magpie Robin	0.78	Greater Flameback	1.15
34	Asian Palm Swift	0.73	Scarlet Minivet	1.15
35	Black-rumped Flameback	0.73	Black-rumped Flameback	1.05
36	Common Iora	0.73	Coppersmith Barbet	1.05

	Ratanmahal		Purna	
No.	**Species**	**Relative Abundance %**	**Species**	**Relative Abundance %**
37	Greater Coucal	0.73	Pale-billed Flowerpecker	1.00
38	Yellow-footed Green Pigeon	0.73	Puff-throated Babbler	0.95
39	Shikra	0.68	Indian Grey Hornbill	0.65
40	Grey-headed Canary Flycatcher	0.63	Indian Scimitar Babbler	0.65
41	Tree Pipit	0.63	Grey-breasted Prinia	0.60
42	White-eyed Buzzard	0.63	Oriental Magpie Robin	0.60
43	Asian Koel	0.53	Green Bee-eater	0.55
44	Gold-fronted Leafbird	0.53	Orange-headed Thrush	0.55
45	Jungle Owlet	0.53	Brown-capped Pygmy Woodpecker	0.50
46	Alexandrine Parakeet	0.49	Common Iora	0.50
47	Coppersmith Barbet	0.49	Asian Koel	0.45
48	House Swift	0.49	Thick-billed Flowerpecker	0.45
49	Ashy Drongo	0.39	Jungle Owlet	0.40
50	Common Hawk Cuckoo	0.39	Shikra	0.40
51	Black Redstart	0.34	White-naped Woodpecker	0.40
52	Crimson Sunbird	0.34	Crested Serpent Eagle	0.35
53	White-throated Kingfisher	0.34	Heart-spotted Woodpecker	0.35
54	Black-lored Tit	0.29	White-rumped Shama	0.35
55	Indian Robin	0.29	Black Redstart	0.30
56	Lesser Whitethroat	0.29	Common Hawk Cuckoo	0.30
57	Brown Fish Owl	0.24	Emerald Dove	0.30
58	Grey-breasted Prinia	0.24	Small Minivet	0.30
59	Mottled Wood Owl	0.24	Common Myna	0.25
60	Yellow-crowned Woodpecker	0.24	Grey Wagtail	0.25
61	Black Drongo	0.19	Verditer Flycatcher	0.25
62	Blue-winged Leafbird	0.19	Yellow-crowned Woodpecker	0.25
63	Common Myna	0.19	Black Drongo	0.20
64	Crested Serpent Eagle	0.19	Blue-winged Leafbird	0.20
65	Red-rumped Swallow	0.19	Grey-headed Canary Flycatcher	0.20
66	White-naped Woodpecker	0.14	Indian Pitta	0.20
67	Orange-headed Thrush	0.09	Little Egret	0.20
68	Puff-throated Babbler	0.09	Tawny-bellied Babbler	0.20
69	Red-wattled Lapwing	0.09	Indian Peafowl	0.15
70	Tawny-bellied Babbler	0.09	Indian Pond Heron	0.15
71	Verditer Flycatcher	0.09	Rufous Woodpecker	0.15
72	Bay-backed Shrike	0.05	White-eyed Buzzard	0.15
73	Black-headed Cuckooshrike	0.05	Black Ibis	0.10
74	Blue-capped Rock Thrush	0.05	Crested Honey-buzzard	0.10
75	Grey Wagtail	0.05	Grey Junglefowl	0.10
76	Indian Peafowl	0.05	Purple-rumped Sunbird	0.10

	Ratanmahal		Purna	
No.	**Species**	**Relative Abundance %**	**Species**	**Relative Abundance %**
77	Indian Pond Heron	0.05	White-throated Kingfisher	0.10
78	Kestrel	0.05	Barred Bustard-quail	0.05
79	Long-tailed Shrike	0.05	Bar-winged Flycatcher-shrike	0.05
80	White-spotted Fantail	0.05	Black Eagle	0.05
81			Black-shouldered Kite	0.05
82			Common Rosefinch	0.05
83			Indian Cuckoo	0.05
84			Indian Roller	0.05
85			Lesser Yellownape	0.05
86			Malabar Trogon	0.05
87			Oriental Turtle Dove	0.05
88			Velvet-fronted Nuthatch	0.05
89			White-cheeked Barbet	0.05

Appendix 4.4
Encounter rates of species met with on transects at Ratanmahal and Purna Wildlife Sanctuaries

	Ratanmahal			Purna		
No.	**Species**	**Mean ER**	**Std D**	**Species**	**Mean ER**	**Std D**
1	JUNGLE BABBLER	7.10	7.06	JUNGLE BABBLER	3.79	6.33
2	LEAF WARBLER	3.78	3.75	CHESTNUT-SHOULDERED PETRONIA	2.13	2.24
3	CHESTNUT-SHOULDERED PETRONIA	3.50	1.88	LEAF WARBLER	2.09	1.26
4	LARGE-BILLED CROW	3.20	2.30	ROSE-RINGED PARAKEET	1.55	1.12
5	SPOTTED DOVE	2.79	3.86	PLUM-HEADED PARAKEET	1.53	1.39
6	COMMON WOODSHRIKE	2.60	1.29	LARGE-BILLED CROW	1.26	1.07
7	WHITE-BELLIED DRONGO	2.51	0.93	RED-THROATED FLYCATCHER	1.03	1.21
8	RUFOUS TREEPIE	1.93	0.86	GREATER RACKET-TAILED DRONGO	0.91	0.69
9	COMMON TAILOR BIRD	1.91	1.42	COMMON TAILOR BIRD	0.91	0.68
10	CATTLE EGRET	1.80	4.02	BROWN-HEADED BARBET	0.90	0.68
11	PLUM-HEADED PARAKEET	1.69	2.14	PURPLE SUNBIRD	0.82	0.71
12	SMALL MINIVET	1.32	1.47	TICKELL'S BLUE FLYCATCHER	0.82	0.54
13	BLACK-HOODED ORIOLE	1.24	0.43	BLACK-HOODED ORIOLE	0.81	0.60
14	TICKELL'S BLUE FLYCATCHER	1.16	1.10	RED-VENTED BULBUL	0.80	0.65
15	RED-VENTED BULBUL	1.13	0.55	GOLDEN-FRONTED LEAFBIRD	0.79	0.66
16	BROWN-HEADED BARBET	1.13	1.11	RUFOUS TREEPIE	0.79	0.41
17	PURPLE SUNBIRD	1.08	0.56	COMMON WOODSHRIKE	0.77	0.71
18	GREATER RACKET-TAILED DRONGO	0.97	0.83	YELLOW-FOOTED GREEN PIGEON	0.77	1.18
19	ORIENTAL WHITE-EYE	0.88	0.65	CRIMSON SUNBIRD	0.74	0.94
20	CRESTED TREESWIFT	0.86	1.83	SPOTTED DOVE	0.72	0.58
21	RED-THROATED FLYCATCHER	0.80	0.68	WHITE-BELLIED DRONGO	0.67	0.43
22	LARGE CUCKOOSHRIKE	0.79	0.45	BROWN-CHEEKED FULVETTA	0.64	0.92
23	WHITE-BROWED FANTAIL	0.77	0.50	ASIAN PARADISE-FLYCATCHER	0.59	0.52
24	BROWN-CAPPED PYGMY WOODPECKER	0.76	0.48	GREAT TIT	0.57	0.58
25	THICK-BILLED FLOWERPECKER	0.69	0.51	ALEXANDRINE PARAKEET	0.56	0.54
26	INDIAN ROLLER	0.69	0.53	ORIENTAL WHITE-EYE	0.50	0.60
27	ROSE-RINGED PARAKEET	0.68	0.86	LARGE CUCKOOSHRIKE	0.50	0.46
28	PALE-BILLED FLOWERPECKER	0.67	0.43	ASHY DRONGO	0.48	0.67
29	BLACK-NAPED MONARCH	0.67	0.64	GREATER FLAMEBACK	0.47	0.38
30	GREAT TIT	0.61	0.63	COPPERSMITH BARBET	0.44	0.42
31	ASIAN PARADISE-FLYCATCHER	0.53	0.62	BLACK-NAPED MONARCH	0.44	0.44
32	GREEN BEE-EATER	0.53	0.49	GREATER COUCAL	0.42	0.50

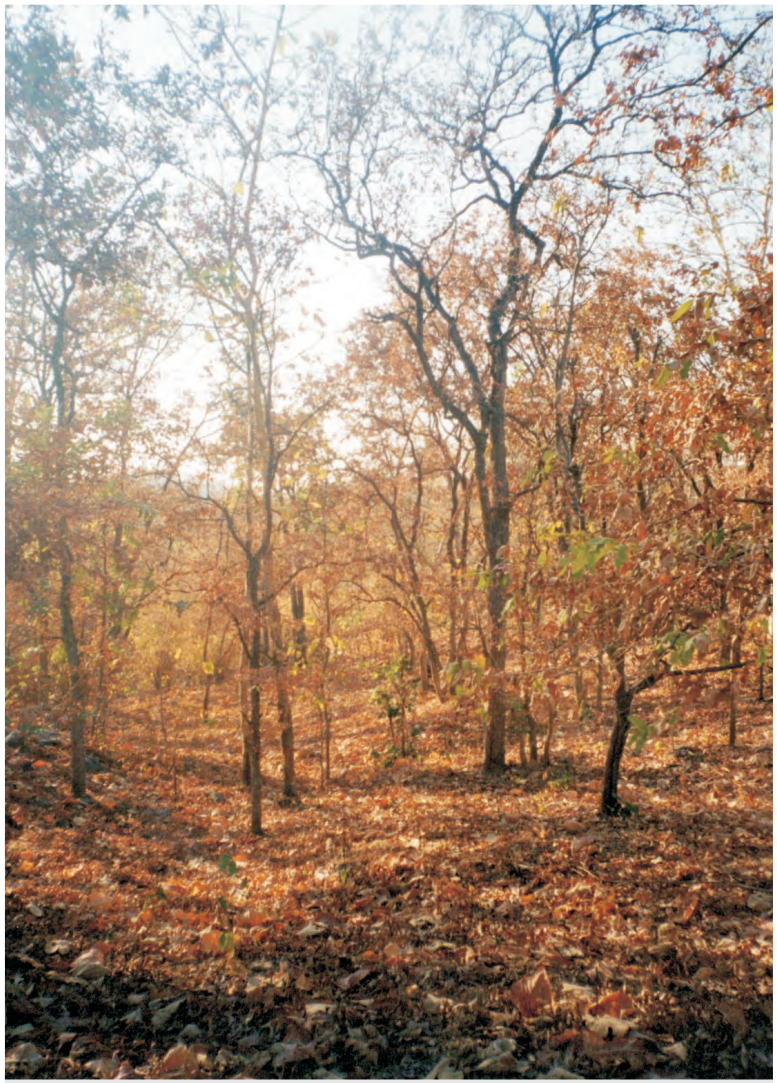
33	ORIENTAL MAGPIE ROBIN	0.52	0.19	BLACK-RUMPED FLAMEBACK	0.42	0.45
34	GREATER COUCAL	0.50	0.55	TREE PIPIT	0.36	0.70
35	ASIAN PALM SWIFT	0.50	0.94	PALE-BILLED FLOWERPECKER	0.34	0.33
36	YELLOW-FOOTED GREEN PIGEON Total	0.49	0.69	PUFF-THROATED BABBLER	0.31	0.32
37	COMMON IORA	0.49	0.58	SCARLET MINIVET	0.27	0.43
38	BLACK-RUMPED FLAMEBACK	0.48	0.21	CATTLE EGRET	0.25	0.54
39	SHIKRA	0.45	0.31	INDIAN SCIMITAR BABBLER	0.23	0.38
40	TREE PIPIT	0.43	0.40	GREEN BEE-EATER	0.20	0.27
41	GREY-HEADED CANARY FLYCATCHER	0.42	0.29	GREY-BREASTED PRINIA	0.20	0.24
42	WHITE-EYED BUZZARD	0.41	0.26	INDIAN GREY HORNBILL	0.20	0.29
43	GOLDEN-FRONTED LEAFBIRD	0.37	0.30	JUNGLE OWLET	0.19	0.23
44	ASIAN KOEL	0.36	0.28	ORANGE-HEADED THRUSH	0.19	0.40
45	JUNGLE OWLET	0.36	0.46	ASIAN KOEL	0.18	0.24
46	HOUSE SWIFT	0.33	0.75	ORIENTAL MAGPIE ROBIN	0.18	0.21
47	COPPERSMITH BARBET	0.33	0.39	BROWN-CAPPED PYGMY WOODPECKER	0.17	0.21
48	BLACK REDSTART	0.27	0.19	BLACK DRONGO	0.15	0.24
49	COMMON HAWK CUCKOO	0.26	0.15	WHITE-EYED BUZZARD	0.15	0.34
50	ASHY DRONGO	0.26	0.15	THICK-BILLED FLOWERPECKER	0.14	0.18
51	ALEXANDRINE PARAKEET	0.26	0.26	SMALL MINIVET	0.14	0.33
52	CRIMSON SUNBIRD	0.23	0.34	COMMON IORA	0.14	0.22
53	WHITE-THROATED KINGFISHER	0.23	0.19	SHIKRA	0.13	0.26
54	LESSER WHITETHROAT	0.20	0.22	GREY WAGTAIL	0.13	0.19
55	BLACK-LORED TIT	0.20	0.22	LITTLE EGRET	0.12	0.31
56	INDIAN ROBIN	0.17	0.38	BLACK REDSTART	0.12	0.38
57	YELLOW-CROWNED WOODPECKER Total	0.17	0.29	CRESTED SERPENT EAGLE	0.12	0.11
58	GREY-BREASTED PRINIA	0.17	0.24	WHITE-RUMPED SHAMA	0.12	0.17
59	MOTTLED WOOD OWL	0.15	0.18	COMMON HAWK CUCKOO	0.12	0.19
60	BROWN FISH OWL	0.15	0.25	HEART-SPOTTED WOODPECKER	0.11	0.23
61	COMMON MYNA	0.13	0.30	WHITE-NAPED WOODPECKER	0.11	0.18
62	BLUE-WINGED LEAFBIRD	0.13	0.22	VERDITER FLYCATCHER	0.10	0.21
63	BLACK DRONGO	0.13	0.30	YELLOW-CROWNED WOODPECKER	0.08	0.12
64	CRESTED SERPENT EAGLE	0.13	0.14	EMERALD DOVE	0.08	0.14
65	RED-RUMPED SWALLOW	0.12	0.17	TAWNY-BELLIED BABBLER	0.08	0.25
66	WHITE-NAPED WOODPECKER	0.09	0.15	COMMON MYNA	0.08	0.15
67	TAWNY-BELLIED BABBLER	0.07	0.09	INDIAN PITTA	0.07	0.19
68	VERDITER FLYCATCHER	0.07	0.15	ORIENTAL HONEY-BUZZARD	0.07	0.16
69	RED-WATTLED LAPWING	0.07	0.15	INDIAN PEAFOWL	0.06	0.19
70	PUFF-THROATED BABBLER	0.07	0.15	BLACK EAGLE	0.05	0.16
71	ORANGE-HEADED THRUSH	0.07	0.15	GREY JUNGLEFOWL	0.05	0.16
72	WHITE-THROATED FANTAIL	0.03	0.08	BLUE-WINGED LEAFBIRD	0.05	0.10
73	LONG-TAILED SHRIKE	0.03	0.08	INDIAN POND HERON	0.04	0.08

74	INDIAN PEAFOWL	0.03	0.08	GREY-HEADED CANARY FLYCATCHER	0.04	0.09
75	GREY WAGTAIL	0.03	0.08	PURPLE-RUMPED SUNBIRD	0.03	0.07
76	BLUE-CAPPED ROCK THRUSH	0.03	0.08	WHITE-THROATED KINGFISHER	0.03	0.07
77	BLACK-HEADED CUCKOOSHRIKE	0.03	0.08	RUFOUS WOODPECKER	0.03	0.08
78	BAY-BACKED SHRIKE	0.03	0.08	INDIAN CUCKOO	0.03	0.08
79	KESTREL	0.03	0.06	LESSER YELLOWNAPE	0.03	0.08
80	INDIAN POND HERON	0.03	0.06	BAR-WINGED FLYCATCHER-SHRIKE	0.02	0.06
81				COMMON ROSEFINCH	0.02	0.06
82				ORIENTAL TURTLE DOVE	0.02	0.06
83				BLACK IBIS	0.02	0.05
84				WHITE-CHEEKED BARBET	0.02	0.05
85				MALABAR TROGON	0.01	0.04
86				VELVET-FRONTED NUTHATCH	0.01	0.04
87				BARRED BUSTARD-QUAIL	0.01	0.03
88				BLACK-SHOULDERED KITE	0.01	0.03
89				INDIAN ROLLER	0.01	0.03

ER=Encounter rate, Std D=Standard deviation

Ratanmahal forest

Ratanmahal forest - interior view



Dry deciduous forest on Trasnect at Mendri T-3

Dry deciduous teak dominated forest
at Ratanmahal T-5

Forest on Ratanmahal plateau - Transect-1 at Kotda

Forest on Ratanmahal plateau - Transect-1 at Kotda during monsoon

Luxuriance of moist forest at Ratanmahal

Bhuvero T-4 transect - dominated by bamboo

Collection of bamboo leaves as fodder for livestock

Collection of leaves during the dry season at Ratanmahal

Collection of tendu *(Diospyros melanoxylon)* leaves at Ratanmahal affects the forest canopy

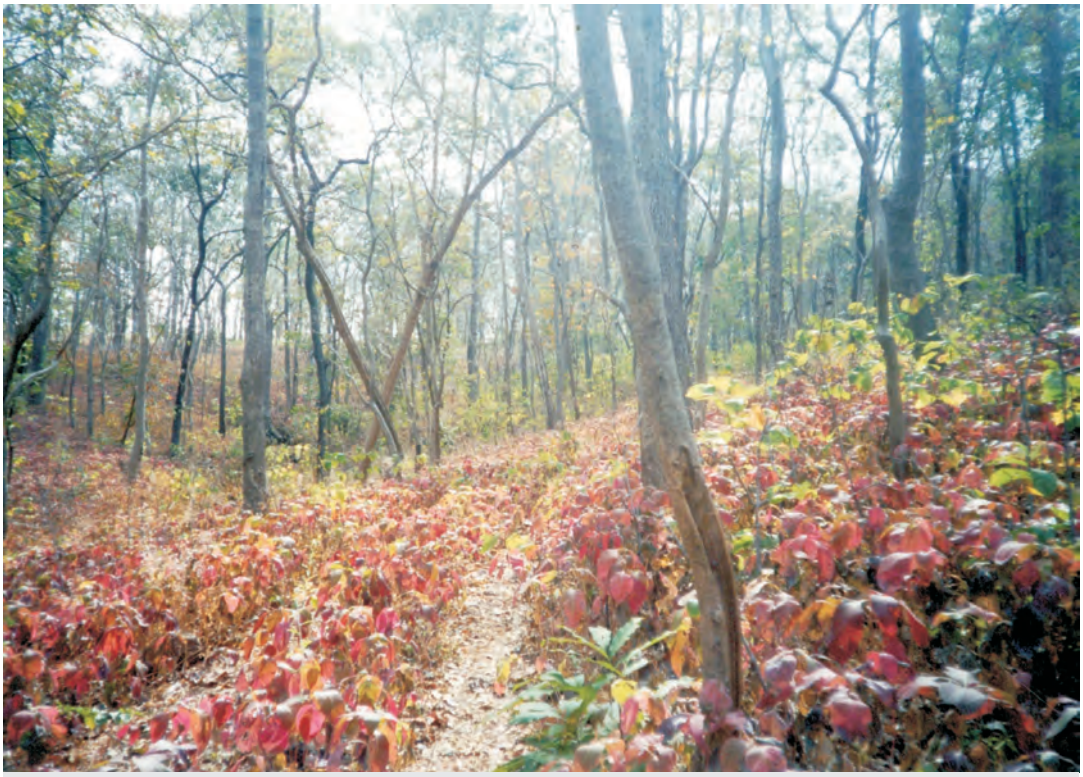
Habitation inside Ratanmahal - Pipargota village

One of the most luxuriant moist forest patches at Purna near Borumal

Dhulda transect at Purna - dominated by teak and bamboo

Luxuriant moist bamboo brakes at Mahal transect T-5 at Purna

Bamboo harvesting at Purna



Dry deciduous forest with impoverished vertical stratification at Purna

Mahal kot transect T-3 at Purna

Purna river drains the sanctuary; lopped trees in the background

Hunting is a direct threat for birds at Purna

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Significant bird records and local extinctions in Purna and Ratanmahal Wildlife Sanctuaries, Gujarat, India

PRANAV TRIVEDI and V. C. SONI

We carried out fieldwork in Purna Wildlife Sanctuary and Ratanmahal Wildlife Sanctuary in the fragmented eastern forest belt, Gujarat, India, between September 1999 and March 2003, and made occasional observations in the area during 1989–2004. We documented the first records of Brown Wood Owl *Strix leptogrammica* and Large-tailed Nightjar *Caprimulgus macrourus* in Gujarat, and recorded six species new for the reserves and eleven other noteworthy species. We identify eight species that may be locally extinct and 14 other species that may be susceptible to forest loss and degradation owing to their rarity, habitat specificity, foraging guild, body size, endemism, and/or edge-of-range distribution. Hunting and biotic homogenisation may also be contributing to local avifaunal impoverishment.

INTRODUCTION

Gujarat, the westernmost state of India, owes its rich avifauna to its diverse range of habitats, geographical location along the Indus flyway, and tradition of conservation (Khacher 1996). The diversity of habitats includes deciduous and thorn forests, grasslands, wetlands, marine intertidal areas, scrublands and saline deserts (Singh 2001). The eastern part of Gujarat harbours about 50% of the state's forests. These are mainly found along the four major mountain ranges: the Aravallis, the Vindhyas, the Satpuras and the Western Ghats. These forests contain the westernmost moist deciduous forest patches in the Indian peninsula and they mark the westernmost limits of several species of forest plants (e.g. teak *Tectona grandis*) and animals (e.g. tiger *Panthera tigris* and sloth bear *Melursus ursinus*) in India. In addition, the state also includes the easternmost range limits of several arid and semi-arid zone species (e.g. Asiatic lion *Panthera leo persica*). Ali (1950) suggested that the Satpura mountain range has played an important role in the dispersal of Indomalayan forms to the Western Ghats, a global biodiversity hotspot. Thus, with respect to Indian ornithogeography, eastern Gujarat is an important region. Considering this, relatively few studies have been carried out to document the avifauna of the region (Table 1).

Large-scale habitat change has taken place since the survey of Ali (1954–1955), and once-contiguous forests are today severely fragmented and disturbed by human activity (Khacher 1996, Singh 2001). For many forest areas in this region, even basic presence/absence data on bird species is unavailable. Such gaps in information hamper the assessment of the status of the forest avifauna and hinder effective conservation planning. This is especially true in the light of documented impacts of habitat loss, fragmentation, degradation and other anthropogenic factors on forest avifauna across the globe in the past two decades (e.g. Simberloff 1985, Newton 1995, Laurance *et al.* 2002). These impacts do not necessarily affect all birds equally: several studies have found that certain groups are more vulnerable than others (see Lindenmayer *et al.* 2002, Henle *et al.* 2004 for reviews). Our study was carried out in part to document the occurrence and abundance of such sensitive forest bird species to facilitate their conservation.

STUDY SITES

Intensive studies were carried out at Purna Wildlife Sanctuary (hereafter Purna) and Ratanmahal Wildlife Sanctuary (hereafter Ratanmahal). Purna (161 km^2) is located between 20°51′N 73°32′E and 21°31′N 73°48′E. It lies in Dangs district, located in the northernmost part of the Western Ghats biogeographic zone. The Western Ghats have been identified as a global biodiversity hotspot and an Endemic Bird Area (Stattersfield *et al.* 1998, Myers *et al.* 2000). Purna has moist and dry deciduous forests with bamboo brakes and extensive teak, 'khair' *Acacia catechu* and bamboo *Dendrocalamus strictus* and *Bambusa*

Table 1. Avifaunal studies in the eastern forest belt of Gujarat (WLS = Wildlife Sanctuary, NP = National Park).

Area	Survey period	Reference
Dangs (including present Purna WLS and Vansda NP)	1946 and 1948 (1 month each)	Ali (1954–1955)
Jambughoda Forest (now WLS)	1944–1948	Ali (1954–1955)
Rajpipla forests (now partly Shoolpaneshwar WLS)	1944–1948	Ali (1954–1955)
Balaram forest, Palanpur (now Balaram-Ambaji WLS)	1944–1948	Ali (1954–1955)
Rajpipla forests	July 1981–January 1983	Monga and Naoroji (1983)
Shoolpaneshwar WLS	December 1989–March 1992	Desai *et al.* (1993)
Dangs forests (including Purna)	1988–1990	Worah (1991)
Vansda NP	April 1998–August 2000	Singh *et al.* (2000)
Ratanmahal WLS	September 1999–January 2001	Present study (Trivedi 2001)
Purna WLS	June 2001–March 2003	Present study (Trivedi 2003)

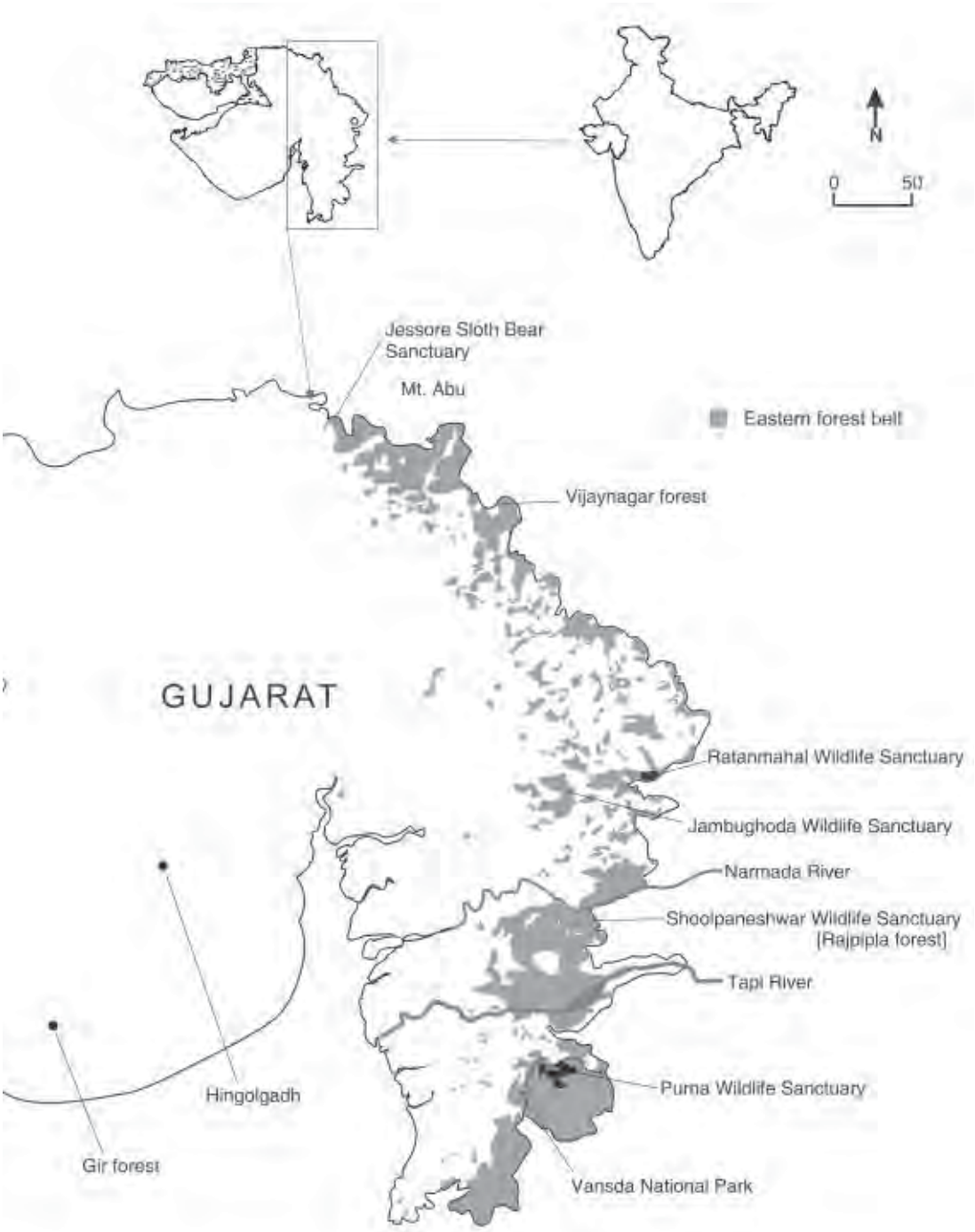

Figure 1. Location of Purna and Ratanmahal Wildlife Sanctuaries, Gujarat, India.

arundinacea plantations (Worah 1991). The average annual rainfall is c.2,100 mm (Anon. 2001). Ratanmahal is located between 20°32′N 74°03′E and 20°35′N 74°11′E. It lies at the confluence of the Vindhya Range and Malwa Plateau adjoining the state of Madhya Pradesh. With an average annual precipitation of c.1,000 mm, it harbours dry deciduous forests dominated by teak, and some patches of moist deciduous biotopes with very little or no teak and with luxuriant bamboo brakes (Singh 2001, Trivedi 2001). Ratanmahal also has preponderance of 'mahuwa' *Madhuca indica* trees.

Most of the precipitation in these two protected areas occurs during the south-west monsoon, i.e., June–October, with July and August being the rainiest months. The terrain in both areas is hilly and rugged, with the highest altitude being 574 m in Purna and 670 m in Ratanmahal. Both areas are rich in their flora (Bedi 1968, Singh *et al.* 2002) and possess high within-habitat heterogeneity (Trivedi 2001, 2003). Purna is free from human habitation (except one village located within the sanctuary), but Ratanmahal has several villages and their crop-fields within the sanctuary. Various other human activities, including moderate-to-heavy livestock grazing, wood cutting, fuelwood collection, collection of leaves (particularly of 'tendu' *Diospyros melanoxylon*), and the harvesting of bamboo and other non-wood forest produce occur in both sanctuaries, as do poaching and fishing (Singh *et al.* 2002, Trivedi 2003). Other areas referred to in the text are either dry deciduous forests with plantations or degraded forests in the eastern forest belt of Gujarat (see Fig. 1).

Habitat loss and fragmentation

The loss, fragmentation and degradation of habitat caused by humans has been regarded as an important driver of species extinctions and of the impoverishment of regional biota. In the eastern forest belt of Gujarat, both fragmentation and complete loss of forests have been reported. Singh (2001) estimated that 1,782 km^2 of forest area in Gujarat (c.12% of the current total forest area of the state) was lost between 1960 and 2000 as a result of irrigation projects, agriculture, mining, road building, industry and the legalisation of encroachments. Purna has a long (c.100-year) history of systematic forestry (Worah 1991), whereas Ratanmahal has remained virtually free of intensive forestry practices (Singh *et al.* 2002). Worah (1991) reported a patchy distribution of forests in Dangs district (in which Purna is located), with a mean patch size of 28 km^2. She regarded these forests as 'fragmented' owing to presence of several teak and bamboo monocultures, many of which were fairly young. Organised forestry has opened up the forests of Purna and surrounding regions through roads and associated anthropogenic disturbances. This has also led to habitat fragmentation. In Dangs district, selective felling between the late nineteenth and mid-twentieth centuries eliminated large trees. Between the 1960s and 1980s, several forest patches were clear-felled and converted into teak monocultures (Anon. 2001). Forestry operations of thinning and climber-cutting removed lianas as well as several species of low timber value associated with teak (Anon. 2001). This has changed the composition and structure of several forest patches, especially in accessible areas. Tree felling was stopped with a moratorium in 1987–1988 (Anon. 2001). However, the harvesting of bamboo on a large scale continues even today (Trivedi 2003). The habitat at Purna thus consists of a mosaic of plantations (mainly of teak) of various ages, secondary forests, and few patches of primary moist and dry deciduous forest. Worah (1991) and Singh *et al.* (2000) reported local extinctions of several mammals from Dangs district, including Indian giant squirrel *Ratufa indica dealbata*, tiger, gaur *Bos gaurus*, smooth-coated otter *Lutra perspicillata* and sloth bear.

METHODS

In total, 70 days were spent in the field at the two sanctuaries (38 at Purna and 32 at Ratanmahal) during all seasons between September 1999 and March 2003. To prepare inventories of bird species we carried out extensive surveys over all terrain and vegetation types within the two sanctuaries. Line transects (without distance estimation) and intensive birdwatching along existing trails were used to obtain information on encounter rates, status and habitat use. For nocturnal species, we noted calls at selected locations by keeping vigil on 3–4 nights in each sanctuary in the dry seasons (winter and summer). Ten transects in Purna and five in Ratanmahal (varying in length from 1 to 3.5 km) were walked. We undertook 64 such walks, covering a total sampling distance of 83 km. The status of birds was determined based both on their encounter rates (individuals/km) on transects and on general observations throughout the study period. After calculating the encounter rates for each species on each transect, mean encounter rates for each species were derived by averaging these. Thus, sample sizes for mean encounter rates were ten and five for Purna and Ratanmahal respectively. We supplemented our data with information gathered by PT between 1989 and 2004 through intensive birdwatching in the eastern forest belt. Information from the field was supplemented by secondary data collected through interviews with local residents and a survey of the literature.

To assess changes in the status of forest birds over time at Purna, we used two past data sets: Ali (1954–1955) and Worah (1991). There have been no previous surveys at Ratanmahal, so a detailed assessment of avifaunal changes here was not possible. Instead, we depended on secondary information collected from local residents and on previous observations made by PT during 1989–1991. To maximise our chances of detecting rare species, we searched intensively in all habitats and searched specifically for such species. We categorised the distribution (widespread or patchy) and nature of habitat occupancy (forest-interior, edge, open area, etc.) for species using Ali (1969), Worah (1991) and Grimmett *et al.* (1998). Feeding guilds were assigned based on the literature (Ali 1969, Grimmett *et al.* 1998, Raol 1998) as well as our observations in the field. Bird species susceptible to forest alteration and loss were identified primarily based on rarity (mean encounter rates <0.5 individual/km) and habitat specificity (forest-interior species and species preferring moist deciduous forest). This information was compared with published literature documenting susceptible taxa in the Oriental region (e.g. Johns 1986, Worah 1991, Mitra and Sheldon 1993, Raman 1995, Datta 2000, Castelletta *et al.* 2000, Raman 2001).

RESULTS

A total of 191 species were recorded at the two sanctuaries: 139 at Purna and 147 at Ratanmahal.

New records for Gujarat

Two species, Large-tailed Nightjar *Caprimulgus macrourus* and Brown Wood Owl *Strix leptogrammica*, were recorded for the first time from the state. Neither species was recorded by earlier surveys or listed in checklists for Gujarat (Ali 1954–1955, Khacher 1996, ZSI 2000, Khacher and Raol undated).

BROWN WOOD OWL *Strix leptogrammica*

This species was seen at Purna in moist deciduous forest consisting of teak, *Adina cordifolia, Terminalia crenulata* and extensive brakes of *Bambusa arundinacea* (Trivedi 2003). Three daytime sightings were obtained at Dhulda, Bardipada range, on 22 March 2002 (one sighting) and 30 April 2002 (two sightings). Two sightings involved a pair (presumably the same pair), while the third was of a solitary individual. The pair was found perched in a bamboo clump and, when disturbed, flew a short distance within the middle storey and settled at a low height. The absence of concentric barring on the facial disks and the dark coloration clearly distinguished this species from the congeneric Mottled Wood Owl *S. ocellata*. Ali and Ripley (1983) described the distribution of the species as 'dense moist deciduous to semi-evergreen and evergreen biotopes at suitable locations throughout the country', while Grimmett *et al.* (1998) described it as inhabiting the Himalayas, north-east India, Eastern and Western Ghats. Its northernmost record in the Western Ghats is from the

Sanjay Gandhi National Park (Mumbai), Maharashtra (Prasad 2003). Thus our record is a northerly extension of the known range of this species by over 150 km.

LARGE-TAILED NIGHTJAR *Caprimulgus macrourus*
During surveys for nocturnal birds at Ratanmahal, a distinct 'chaunk...chaunk...' call was heard on the plateau at the Ratanmahal temple near the Gujarat-Madhya Pradesh border at 19h00–19h30 on 3 and 17 March 2000. Based on the frequency of notes as well as on their long-drawn nature as compared with the 'chunk...chunk...' call of the Grey Nightjar *C. indicus*, these calls were identified as belonging to the Large-tailed Nightjar. No visual observations were made. Ali (1969) noted that *C. macrorus* is difficult to distinguish by sight in field, but its call is diagnostic. The closest prior records are by D'Abreau (1935), who described this species as breeding in densely shaded ravines of the former Central Provinces (presently Madhya Pradesh and Chhattisgarh states), and by Grimmett *et al.* (1998) from eastern Madhya Pradesh. Our record at Ratanmahal extends the known range of the species considerably to the west.

New records for Purna and Ratanmahal

BLACK EAGLE *Ictinaetus malayensis*
This species was sighted twice (on 20 August 2001 and 22 December 2001) at Purna (the first records for this site) and was also seen at Jambughoda Wildlife Sanctuary (hereafter Jambughoda) in January 2002, 2003, 2004 and 2005. The species was identified by its characteristic upward-angled primaries in flight, dark coloration, yellow cere and feet and, most notably, its behaviour of gliding low over the forest canopy. In Gujarat, this species has been reported from Jambughoda forest (Ali 1954–1955) and Gir forest (Dharmakumarsinhji 1985). In neighbouring states, Mashru (2004) recorded it from Mt Abu in Rajasthan and D'Abreau (1935) reported it from Madhya Pradesh.

ASHY WOODSWALLOW *Artamus fuscus*
We found c.10 individuals of this species at Ratanmahal on 10 September 2000. They were perched on telegraph wires and an adjacent tree while making aerial sallies to hawk insects. This species was not recorded by Ali (1954–1955) from Gujarat, but Khacher (1996) reported a sighting from the Rajpipla area (Narmada district, Satpura mountain range) and Worah (1991) recorded it in the Dangs district. Our record extends the known range of the species by c.75 km north.

GREATER RACKET-TAILED DRONGO *Dicrurus paradiseus*
This species was sighted 24 times (involving 29 individuals) in January, March, April, May, July and December at Ratanmahal and on 40 occasions (involving 58 individuals) in January, February, March, April, June and December at Purna. The mean encounter rate of the species was 0.97 birds/km (SD=0.83) at Ratanmahal and 0.91 birds/km (SD=0.69) at Purna. It was found to be a sentinel species (and possibly an 'active-nuclear' species) in mixed-species flocks at both Ratanmahal and Purna, and it probably plays a key role in such flocks. Ali (1954–1955) reported this species to be common in bamboo and mixed deciduous forests south of the Narmada river, while Monga and Naoroji (1983) and Desai *et al.* (1993) recorded it from Rajpipla forests (now Shoolpaneshwar Wildlife Sanctuary), south of the Narmada. Ratanmahal appears to be the northernmost limit of this species in India and possibly the westernmost boundary of its global range.

BLUE-CAPPED ROCK THRUSH *Monticola cinclorhynchus*
We recorded three sightings (of single individuals) of this species: one in Purna (22 March 2002) and two in Ratanmahal (on the plateau at the Ratanmahal temple near the Gujarat-Madhya Pradesh border on 19 and 30 January 2000). These were the first records at Ratanmahal. At Purna the species was not sighted on transects, while at Ratanmahal, it was sighted on one transect once, with a mean encounter rate of 0.03 birds/km (SD=0.08). All three birds were in dense bamboo brakes in moist deciduous forest. The species is reported to over-winter mainly in the Western Ghats (Grimmett *et al.* 1998) and in Gujarat it has been reported from Hingolgadh (Khacher 1996), Rajpipla forests (Monga and Naoroji 1983) and Dangs district (singly or in pairs in very small numbers during February and March: Ali 1954–1955).

ORANGE-HEADED THRUSH *Zoothera citrina*
At Ratanmahal, two sightings of this species were made: two individuals on a transect on 23 July 2000 (Trivedi 2001) and one on 22 July 2000, while at Purna it was sighted on nine occasions (involving 11 individuals) on two transects during June of 2002. The mean encounter rate was 0.07 birds/km (SD=0.15) at Ratanmahal and 0.19 birds/km (SD=0.40) at Purna. The race was identified as *Z. c. cyanotus* based on the presence of two vertical black stripes across the white ear coverts and throat. In Gujarat, the species has been reported previously only from south of the Narmada river (Monga and Naoroji 1983, Ali 1954–1955). Our records from Ratanmahal extend its known range to c.75 km north of the Narmada river. The species appears to be a summer visitor and possibly breeds at both sites.

CRIMSON SUNBIRD *Aethopyga siparaja*
This species was sighted at Purna and Ratanmahal, and was fairly common in teak and mixed moist forest with *Bambusa arundinacea*. Five sightings (involving seven individuals) were made at Ratanmahal and 29 sightings (involving 42 individuals) were made at Purna. The mean encounter rate was 0.23 birds/km (SD=0.34) at Ratanmahal and 0.74 birds/km (SD=0.94) at Purna. The race observed at both sanctuaries was *A. s. vigorsii* of the Western Ghats. In Gujarat, Ali (1954–1955) recorded the species south of river Narmada at Rajpipla forest. It has also been reported from Shoolpaneshwar Sanctuary in Narmada district (Monga and Naoroji 1983, Desai *et al.* 1993). Our records at Ratanmahal extend its known range by about 75 km and the site is the northernmost for the species in Gujarat.

Noteworthy species
Here we give details of 11 species, most of which are forest-interior species (based on Worah 1991) and show a documented vulnerability to forest fragmentation and alteration.

GREY JUNGLEFOWL *Gallus sonneratii*
This galliform was heard in Purna at only two localities, but was seen as well as heard on four occasions (involving

eight birds) in Ratanmahal. It appears to have been persecuted beyond recovery in many areas of its former distribution (e.g. Jessore Sloth Bear Sanctuary: Trivedi 2005). Pheasants have been found to be sensitive to changes in forest composition (Johns 1986, Castelletta *et al.* 2000, Datta 2000) as well as hunting. Hunting may be a particular problem for this species as ground-dwelling birds are vulnerable to passive methods of trapping, and this species depends on concealment rather than flight for escape.

RUFOUS WOODPECKER *Celeus brachyurus*
This woodpecker was encountered only at Purna, where it was uncommon and appeared to be partial to bamboo brakes in moist deciduous forest. It was reported previously from Dangs district and Vansda National Park (Ali 1954–1955, Worah 1991, Bhatt 2004), but not elsewhere from Gujarat; hence Purna appears to be the north-westerly limit of its distribution. The species is peculiar in its habit of nesting in the nests of *Crematogaster* ants (Ali 1969).

WHITE-BELLIED WOODPECKER *Dryocopus javensis*
We recorded the species three times in Purna at two localities. Purna is the northernmost site for the species in India and the westernmost limit of its global range. This population of White-bellied Woodpecker is isolated, with the nearest neighbouring population at a distance of c.350 km in Melghat Tiger Reserve, Maharashtra (Prasad 2003). The largest woodpecker of peninsular India, this is a bird of primary moist deciduous forest and secondary forest and is also seen in tropical evergreen and semi-evergreen forests (Ali and Ripley 1983, Grimmett *et al.* 1998). In Gujarat, it was reported earlier from Dangs district and adjoining areas of Navsari district (Ali 1954–1955, Worah 1991, Singh *et al.* 2000, Santharam 2003). In the Western Ghats of Maharashtra, the species is extremely rare and has a fragmented distribution (Prasad 2003). Furthermore, its preferred habitat, primary moist deciduous forest, is rare in Gujarat, having been replaced by either secondary forests or plantations (Worah 1991, Santharam 2003). This has resulted in a reduced availability of suitable nesting trees (Santharam 2003). Ali (1954–1955) reported that this species was hunted by tribal people in Dangs district. These factors suggest that the species may be susceptible to local extinction. A similar conclusion was reached for the species in Singapore, where only one pair was found surviving after the loss of a large area of rainforest (Castelletta *et al.* 2000).

HEART-SPOTTED WOODPECKER *Hemicircus canente*
This species was recorded on transects on four occasions (involving seven individuals) in Purna (mean encounter rate: 0.11 birds/km, SD=0.23), where it was confined to moist deciduous forest with bamboo. It has been reported from the same localities in Gujarat as White-bellied Woodpecker, with additional records further north from Rajpipla forests (Monga and Naoroji 1983). Santharam (1995) described it as a specialist based on its foraging mode. Prasad (2003) considered it rare in western Maharashtra.

LESSER YELLOWNAPE *Picus chlorophus*
This was a rare species, being sighted on only four occasions at three localities in Purna. It was reported earlier by Ali (1954–1955) and Worah (1991) from Dangs district and from Vansda National Park (Bhatt 2004) and inhabits moist deciduous forests with bamboo (Trivedi 2003). There are no records of the species from other parts of Gujarat. In western Maharashtra, the species is rare with a restricted range (Prasad 2003).

WHITE-CHEEKED BARBET *Megalaima viridis*
The occurrence of this species was confirmed on only one occasion in Purna based on its call. This represents the northernmost extent of the distribution of this Western Ghats endemic. The congeneric Brown-headed Barbet *M. zeylanica* was common at Ratanmahal and Purna.

MALABAR TROGON *Harpactes fasciatus*
This species was sighted only in Purna at three localities. While Ali (1954–1955) reported it to be 'fairly common' in Dangs district, we considered it to be uncommon. Ali (1954–1955) mentioned one of the locations of the species as Ajwa (in present day Vadodara district), situated more than 150 km north-west of the Dangs district. This appears to be a typographical error with 'Ajwa' being printed instead of 'Ahwa' (the capital of Dangs district). We suspect this because, although a record at Ajwa would be unusual and noteworthy, Ali (1954–1955) does not refer to this locality or emphasise the importance of this record in his annotations to the sites where this species was collected. Malabar Trogon has also been reported from Vansda National Park (Singh *et al.* 2000). It is found in moist deciduous forest with bamboo and secondary growth (Ali 1954–1955). The species has been found sensitive to forest fragmentation and alteration in the southern Western Ghats in India (Raman 2001) as have congeners elsewhere in the Orient (e.g. Johns 1986, Castelletta *et al.* 2000).

CRESTED TREESWIFT *Hemiprocne coronata*
This species was sighted only in Purna (only off transects) and Ratanmahal (eight sightings including 30 individuals on transects). Its mean encounter rate at Ratanmahal was 0.86 individuals/km (SD=1.83). Ali (1954–1955) encountered it only in Rajpipla forests (see also Monga and Naoroji 1983) and Dangs district. It has also been reported from the Gir forest (Khacher 1996). We found it in forest with *Lannea coromandelica, Boswellia serrata* and *Anogeissus latifolia* on boulder-studded dry hills. Crested Treeswift may be sensitive to forest loss and degradation, as Castelletta *et al.* (2000) recorded the local extinction of the congeneric Whiskered Treeswift *H. comata* in Singapore.

BAR-WINGED FLYCATCHER-SHRIKE *Hemipus picatus*
A rare resident, this species was seen only once on transects (23 June 2002) in Bhenskatri range in Purna. Both Ali (1954–1955) and Worah (1991) reported the species earlier from Dangs district, but Singh *et al.* (2000) did not record it from the nearby Vansda National Park. It is easily overlooked owing to its rarity, inconspicuous colouration and small size. Prasad (2003) reported it as an uncommon, localised resident in western Maharashtra, while placing it among the species affected by loss of forests. Johns (1986) and Castelletta *et al.* (2000) also regarded the genus *Hemipus* to be sensitive to forest degradation.

MALABAR WHISTLING THRUSH *Myophonus horsfieldii*
This species was sighted only once, on 24 December 2001 on a stream bank in moist deciduous forest at Purna.

Although it is known for its melodious song, we never heard it during the study period. Ali (1954–1955) recorded it as resident in Dangs district, but not common. It is a terrestrial omnivore, known to forage along streams for a variety of invertebrates, including aquatic insects (Ali 1969). Its rarity could conceivably have resulted from changes in hydrology caused by the building of check-dams, perhaps affecting prey availability.

WHITE-RUMPED SHAMA *Copsychus malabaricus*
We saw this species only at Purna where it was confined to moist deciduous forest and bamboo patches, and was usually seen rummaging among leaf litter in search of insects. It was previously reported in Dangs district by Ali (1954–1955) and Worah (1991) and from Vansda National Park by Singh *et al.* (2000), but not elsewhere in Gujarat. It has a patchy distribution in India (Grimmett *et al.* 1998), and belongs to the terrestrial insectivore guild, which is susceptible to forest fragmentation (Raman 2001).

Species susceptible to habitat loss and degradation
We used encounter rates and information from the literature and from personal observations on the habitat specificity of species to identify those that we considered likely to be susceptible to forest loss and degradation at the two sanctuaries. At Purna, we found 64 species that had a mean encounter rate of =0.5 individuals/km, while at Ratanmahal there were 47 such species (with 28 of these occurring at both sites). Of the total of 83 rarely encountered species, we excluded 53 widespread species (including raptors) and 17 migrants. The remaining 13 species comprised Grey Junglefowl, Rufous Woodpecker, Heart-spotted Woodpecker, Lesser Yellownape, White-cheeked Barbet, Indian grey Hornbill, Malabar Trogon, Black Eagle, Bar-winged Flycatcher-shrike, White-throated Fantail *Rhipidura albicollis*, White-rumped Shama, Velvet-fronted Nuthatch *Sitta frontalis* and Black-lored Tit *Parus xanthogenys*. Although Indian Peafowl *Pavo cristatus* is widespread in India, it was considered to

Table 2. Possible local extinctions of birds in Purna and Ratanmahal Wildlife Sanctuaries.

Species	Extinct at	Past status	Source
JUNGLE BUSH QUAIL *Perdicula asiatica*	Purna	Common	Ali (1954–1955)
RED SPURFOWL *Galloperdix spadicea*	Purna	Common	Ali (1954–1955)
INDIAN GREY HORNBILL *Ocyceros birostris*	Ratanmahal	Unknown	Local reports
STORK-BILLED KINGFISHER *Halcyon capensis*	Purna, Ratanmahal	Not uncommon	Ali (1954–1955)
WHITE-THROATED FANTAIL *Rhipidura albicollis*	Purna	Not stated	Ali (1954–1955)
LARGE WOODSHRIKE *Tephrodornis gularis*	Purna	Rare? 1 specimen procured	Ali (1954–1955)
VELVET-FRONTED NUTHATCH *Sitta frontalis*	Ratanmahal	Rare, 1 sighting	PT (personal observations 1989–1991)
BLACK-LORED TIT *Parus xanthogenys*	Purna	Not uncommon	Ali (1954–1955)

Table 3. Species susceptible to forest loss and degradation in Purna and Ratanmahal Wildlife Sanctuaries.

Species[a]	Distribution in India	Guild[b]	Habitat occupancy	Occurrence
LARGE WOODSHRIKE *Tephrodornis gularis*	Patchy	FGI	Forest interior	Purna
RED SPURFOWL *Galloperdix spadicea*★	Widespread	GFO	Forest interior	Purna
JUNGLE BUSH QUAIL *Perdicula asiatica*★	Patchy	GFO	Forest edge	Purna
STORK-BILLED KINGFISHER *Halcyon capensis*	Widespread	AQC	Forest edge	Purna, Ratanmahal
BLACK-LORED TIT *Parus xanthogenys*★	Patchy	FGI	Forest interior	Purna
WHITE-THROATED FANTAIL *Rhipidura albicollis*	Patchy	FSI	Forest edge	Purna
VELVET-FRONTED NUTHATCH *Sitta frontalis*	Patchy	BF	Forest interior	Ratanmahal
INDIAN GREY HORNBILL *Ocyceros birostris*★	Widespread	AFO	Forest interior	Ratanmahal
MALABAR TROGON *Harpactes fasciatus*★	Patchy	FSI	Forest interior	Purna
MALABAR WHISTLING THRUSH *Myophonus horsfieldii*★	Patchy	GFO	Forest interior	Purna
WHITE-BELLIED WOODPECKER *Dryocopus javensis*	Patchy	BF	Forest interior	Purna
HEART-SPOTTED WOODPECKER *Hemicircus canente*	Patchy	BF	Forest interior	Purna
LESSER YELLOWNAPE *Picus chlorophus*	Patchy	BF	Forest interior	Purna
WHITE-RUMPED SHAMA *Copsychus malabaricus*	Patchy	GFI	Forest interior	Purna
RUFOUS WOODPECKER *Celeus brachyurus*	Patchy	BF	Forest interior	Purna
WHITE-CHEEKED BARBET *Megalaima viridis*★	Patchy	AFR	Forest interior	Purna
BROWN WOOD OWL *Strix leptogrammica*	Patchy	C	Forest interior	Purna
BAR-WINGED FLYCATCHER-SHRIKE *Hemipus picatus*	Patchy	FSI	Forest interior	Purna
LARGE-TAILED NIGHTJAR *Caprimulgus macrourus*	Patchy	HI	Forest interior	Ratanmahal
BLACK EAGLE *Ictinaetus malayensis*	Patchy	C	Forest interior	Purna
INDIAN PEAFOWL *Pavo cristatus*★	Widespread	GFO	Forest interior	Ratanmahal, Purna
GREY JUNGLEFOWL *Gallus sonneratii*★	Widespread	GFO	Forest interior	Purna

[a]★ = endemic to India

[b]AFO = Arboreal frugivore-omnivore; AFR = Arboreal frugivore; BF = Bark-forager; C = Carnivore; AQC = Aquatic carnivore; FGI = Foliage-gleaning insectivore; FSI = Foliage-sallying insectivore; GFI = Ground-foraging insectivore; GFO = Ground-foraging omnivore; HI = Hawking insectivore

be susceptible owing to its rarity at the two sites and vulnerability to hunting. Two additional species that were only encountered off transects, White-bellied Woodpecker and Malabar Whistling Thrush, were also considered susceptible. Further, we suspect the local extinction of eight species based on an absence of sightings during our study: six from Purna and two from Ratanmahal (Table 2). Velvet-fronted Nuthatch and White-throated Fantail occurred in both the categories as the former was locally extinct at Ratanmahal and rare at Purna, while the latter was suspected as extinct from Purna and rare at Ratanmahal. In all, we identified 22 species as likely to be 'susceptible' to forest degradation and loss at the two study sites (Table 3).

DISCUSSION

Inferences about local extinctions require that sufficient effort be expended in searching for species. The species discovery curves obtained for Purna and Ratanmahal (Fig. 2) reached asymptotes roughly at the eleventh visit. At Purna, the four species added on the last two visits included three nocturnal species (two owls and one nightjar) recorded after intensive night monitoring. These two graphs suggest that our sampling effort was adequate, although it is almost impossible to record all species owing to the dynamic nature of forest avifaunas (Johns 1986).

We identified 22 species that we considered to be likely to be susceptible to habitat change. The status of most of these has changed from 'common' or 'not uncommon' to rare or locally extinct (Table 4). For one species, Stork-billed Kingfisher *Halcyon capensis*, there has been no recent record from any part of Gujarat. The six species that appeared to be extinct at Purna were seen by Ali (1954–1955) but not by Worah (1991), supporting our conclusion. Others, like Large Woodshrike *Tephrodornis gularis*, Black-lored Tit *Parus xanthogenys*, Stork-billed Kingfisher *Halcyon capensis*, White-throated Fantail *Rhipidura albicollis* and Indian Grey Hornbill *Ocyceros birostris*, are known to be vocal and conspicuous, so these are also likely to be genuinely extinct now at these sites.

Nineteen of the 22 susceptible species are characteristically forest-interior species. Such species show reduced fecundity near forest edges and their populations decline as fragment sizes reduce unless immigration from larger forest patches occurs (Temple and Cary 1988). Terborgh *et al.* (1990) recognised two types of rarity among birds in the Amazon rainforests of Peru: species that were locally rare (i.e. in the surveyed locality or habitat) and species that were constitutively rare. They considered the latter as truly rare and vulnerable to human intervention; these included large birds with low population densities (<1 pair/km^2) such as raptors, parrots, woodpeckers and a few other species that were among the largest members of their respective guilds. In our study, the White-bellied

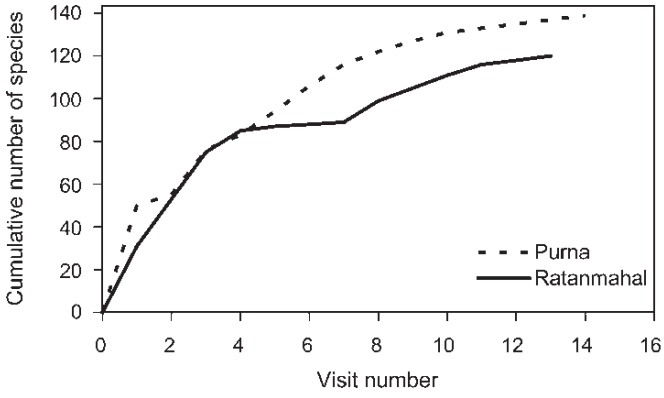

Figure 2. Bird species discovery curves for Purna and Ratanmahal Wildlife Sanctuaries, Gujarat, India.

Table 4. Abundance of species susceptible to forest loss and degradation remaining extant in Purna Wildlife Sanctuary.

Species	Past status		Current status		
	Ali (1954–1955)	Worah (1991)[a]	No. sightings on transects	Relative abundance[b]	Encounter rate[c]
GREY JUNGLEFOWL *Gallus sonneratii*	Not uncommon	0.036	2	0.001	0.05±0.16
INDIAN PEAFOWL *Pavo cristatus*	Common in Gujarat	—	1	0.0015	0.06±0.19
RUFOUS WOODPECKER *Celeus brachyurus*	Rare?	—	2	0.0015	0.03±0.08
WHITE-BELLIED WOODPECKER *Dryocopus javensis*	3 specimens collected in 1 week	0.012	*	*	*
HEART-SPOTTED WOODPECKER *Hemicircus canente*	Not uncommon	0.024	4	0.0035	0.11±0.23
LESSER YELLOWNAPE *Picus chlorophus*	Not uncommon	—	1	0.0005	0.03±0.08
WHITE-CHEEKED BARBET *Megalaima viridis*	Not uncommon	0.012	1	0.0005	0.02±0.05
INDIAN GREY HORNBILL *Ocyceros birostris*	Not uncommon	0.012	7	0.0065	0.20±0.29
MALABAR TROGON *Harpactes fasciatus*	Fairly common	0.145	1	0.0005	0.01±0.04
BROWN WOOD OWL *Strix leptogrammica*	—	—	*	*	*
BAR-WINGED FLYCATCHER-SHRIKE *Hemipus picatus*	Not common	0.012	1	0.0005	0.02±0.06
MALABAR WHISTLING THRUSH *Myophonus horsfieldii*	Not common	0.072	*	*	*
WHITE-RUMPED SHAMA *Copsychus malabaricus*	Few individuals	0.024	7	0.0035	0.12±0.17
VELVET-FRONTED NUTHATCH *Sitta frontalis*	Fairly common	—	1	0.0005	0.01±0.04

[a]Relative abundance based on point counts (number of birds in highest count divided by total number of points)
[b]Number of individuals of each species divided by number of individuals of all species recorded on transects (n=10 transects)
[c]Mean±SD individuals/km (n=10 transects)
*species not detected on transects

Woodpecker as well as some other woodpeckers (see Tables 3 and 4) and the Stork-billed Kingfisher showed the latter kind of rarity, whereas the other susceptible species were locally rare. The replacement of primary moist deciduous forest either by secondary forest or by plantations at Purna has lead to fragmentation of the habitat (Worah 1991, Santharam 2003) and is a likely reason for the reduced abundance of such species in this sanctuary (Worah 1991).

Other ecological traits were associated with some of the species we identified as susceptible. These were ground-foraging and bark-foraging guilds, large body size, endemism and edge-of-range distribution. As suggested by Henle *et al.* (2004), these traits probably operate synergistically.

Ground-foraging (six species) and bark-foraging guilds (five species) represented 50% of the susceptible species. These two guilds constituted only 19% (36 species) of the 191 species recorded in either sanctuary. Ground- and bark-foraging guilds were thus significantly more likely to be susceptible ($\div^2=15.77$, df=1, $P<0.001$). Ground-foraging birds have been found susceptible to forest fragmentation in the southern Western Ghats (Raman 2001), and bark-foraging birds are known to be susceptible to changes in micro-climate and foraging substrate resulting from logging (Johns 1986), forest loss and fragmentation (Castelletta *et al.* 2000, Raman 2001).

Stork-billed Kingfisher is likely to be susceptible on account of its large body size. Ali (1954–1955) regarded it as 'not uncommon on forest streams' in the eastern forest belt of the state. However, Khacher (1996) called for a special investigation to ascertain its status in relation to the limnological changes which have taken place in forest streams. The species presumably feeds on relatively large fish as is suggested by its much larger bill (84–93 mm long) and body size compared with the congeneric White-throated Kingfisher (bill length: 60–67 mm) (Ali 1954–1955). We suspect that degradation of the lotic ecosystems by siltation (Khacher 1996), over-fishing and construction of check-dams has adversely affected the availability of the size and/or species of fish favoured by Stork-billed Kingfisher. In addition, competition with the White-throated Kingfisher *Halcyon smyrnensis*, a widespread, open-area species with a varied diet (Khacher 1996) that has colonised Purna in recent years, could also have affected its abundance.

Gaston (1985), Daniels *et al.* (1990) and Raman (2001) showed that endemic bird species in the Indian peninsula and Western Ghats were more vulnerable to habitat loss than non-endemic species. In the Atlantic forest fragments of Brazil, Ribon *et al.* (2003) found that endemic species were more likely to go locally extinct than non-endemics. A total of 23 species (12 % of those recorded in either sanctuary) were endemic to the Indian subcontinent. Of the 22 susceptible species, nine (41%; Table 3) were subcontinent endemics, which is significantly higher than expected ($\div^2=19.56$, df=1, $P<0.001$).

Populations found at the peripheries of a species' distributional range tend to occur at lower densities (Hengeveld and Haeck 1982) and hence be more vulnerable to extinction (Lawton 1995) than those in the core parts of its distribution. Of the 22 susceptible species we identified, 14 have their westernmost distributional limits in Gujarat's eastern forest belt (see Grimmett *et al.* 1998). The species for which Purna marks the northern, western or northwestern distributional limit are Large Woodshrike, White-bellied Woodpecker, Rufous Woodpecker, Lesser Yellownape, Brown Wood Owl, Malabar Trogon and White-cheeked Barbet. Ratanmahal is probably the northernmost distributional limit for Velvet-fronted Nuthatch and westernmost boundary for Large-tailed Nightjar. It is notable that Large Woodshrike was also reported locally extinct in Singapore (Castelletta *et al.* 2000) which is near its southernmost range limit.

Poaching may also influence forest avifaunas (Castelletta *et al.* 2000, Henle *et al.* 2004). For example, phasianids are popular game birds and have been hunted to extinction from several areas in Gujarat (Trivedi 2005, personal observations). The effect of hunting on Indian Peafowl is particularly clear. In most parts of Gujarat, where there is a taboo against hunting this species, it is common, occurring in very high abundance at Gir forest (Trivedi 1993) and in several human-inhabited areas. However, in the region populated by tribal groups where Ratanmahal and Purna are located, there is no hunting taboo and the species is extremely rare (Trivedi 2001, 2003).

Forest fragmentation is another possible cause of avifaunal impoverishment, and may act synergistically with anthropogenic activities such as hunting and logging (Laurance *et al.* 2002). We encountered eight widespread species at Purna that are known to favour edges or open areas (Ali 1954–1955, Grimmett *et al.* 1998), but were not recorded by earlier studies: Barred Buttonquail *Turnix suscitator*, Common Hoopoe *Upupa epops*, Black-headed Cuckooshrike *Coracina melanoptera*, Common Myna *Acridotheres tristis*, White-browed Fantail *Rhipidura aureola*, Purple-rumped Sunbird *Nectarinia zeylonica*, Spotted Owlet *Athene brama* and White-throated Kingfisher *Halcyon smyrnensis*. Colonisation by these species has possibly been facilitated by the road-building and habitat degradation that accompanied forestry operations (also see Johns 1986). Whether these species have played a role in the impoverishment of forest avifauna could not be ascertained, although instances of edge-tolerant or edge-favouring competitor species causing a decline of forest-interior or rare species have been reported elsewhere (see Harris 1988, Laurance *et al.* 2002, Henle *et al.* 2004).

CONCLUSIONS

Gujarat's forest avifauna is in a fragile situation. While intensive surveys are adding species to the state's checklist, there are indications of avifaunal impoverishment and local extinctions. Ratanmahal and Purna are among the last remaining patches of moist deciduous forest in Gujarat and hence mark the global distributional limits for several forest birds. As a result of past forestry operations, the habitat at Purna is more fragmented than that at Ratanmahal, and this has a bearing on future avifaunal impoverishment and conservation. The situation is made worse by the increased isolation of bird populations in forest patches. Intensive surveys should be carried out in all forested regions of the state, including existing and potential forest corridors. Studies on the ecology of susceptible forest birds and the impacts of anthropogenic activities also need to be undertaken.

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REFERENCES

Ali, S. (1950) The Gujarat Satpuras in Indian ornithogeography: the highway of Malayan forms to the Western Ghats. *Prakriti* 9: 9–23.

Ali, S. (1954–1955) The birds of Gujarat I and II. *J. Bombay Nat. Hist. Soc.* 52: 374–458, 735–802.

Ali, S. (1969) *Birds of Kerala. Second edition of the Birds of Travancore and Cochin*. Delhi: Oxford University Press.

Ali, S. and Ripley, S. D. (1983) *A pictorial guide to the birds of the Indian subcontinent*. Delhi: Oxford University Press.

Anonymous (2001) Management Plan of Purna Wildlife Sanctruary (2002–2011): Vols. I– II. Ahmedabad: Forest Department, Gujarat State.

Bedi, S. J. (1968) Floristic study of Ratan Mahal and surrounding hills. Ph.D. thesis, M. S. University, Baroda, India.

Bhatt, M. (2004) [Bird-watching in Vansda National Park.] *Vihang* 21: 9–10. (In Gujarati.)

Castelletta, M., Sodhi, N. S. and Subaraj, R. (2000) Heavy extinctions of forest avifauna in Singapore: lessons for biodiversity conservation in Southeast Asia. *Conserv. Biol.* 14: 1870–1880.

D'Abreau, E. A. (1935) A list of the birds of the Central Provinces. *J. Bombay Nat. Hist. Soc*. 38: 95–116.

Daniels, R. J. R., Hegde, M. and Gadgil, M. (1990) Birds of the man-made ecosystems: the plantations. *Proc. Indian Acad. Sci. (Anim. Sci.)* 99(1): 79–89.

Datta, A. (2000) Pheasant abundance in selectively logged and unlogged forests of western Arunachal Pradesh, northeast India. *J. Bombay Nat. Hist. Soc.* 97: 177–183.

Desai, I. V., Suresh, B. and Pilo, B. (1993) Birds of Shoolpaneshwar Wildlife Sanctuary. *Pavo* 31: 55–72.

Dharmakumarsinhji, K. S. (1985) The Black Eagle *Ictinaetus malayensis* TEMM. and LAUG at Sawai Madhopur (Rajasthan). *J. Bombay Nat. Hist. Soc*. 82: 655.

Gaston, A. J. (1985) Is habitat destruction in India and Pakistan beginning to affect the status of endemic passerine birds? *J. Bombay Nat. Hist. Soc*. 81: 636–641.

Grimmett, R., Inskipp, C. and Inskipp, T. (1998) *Birds of the Indian Subcontinent*. New Delhi: Oxford University Press.

Harris, L. D. (1988) Edge effects and conservation of biodiversity. *Conserv. Biol.* 2: 330–332.

Hengeveld, R. and Haeck, J. (1982) The distribution of abundance. I. Measurements. *J. Biogeog.* 9: 303–316.

Henle, K., Davies, K. F., Kleyer, M., Margules, C. and Settele, J. (2004) Predictors of species sensitivity to fragmentation. *Biodiv. Conserv.* 13: 207–251.

Johns, A. D. (1986) Effects of selective logging on the ecological organization of a peninsular Malaysian rainforest avifauna. *Forktail* 1: 65–79.

Khacher, L. (1996) The birds of Gujarat - a Salim Ali centenarary year overview. *J. Bombay Nat. Hist. Soc*. 93(3): 331–373.

Khacher, L. and Raol, L. M. (undated) [Checklist of birds of Gujarat.] Compilation based on separate accounts serially published in *Chatak*, the newsletter of WWF-India. Baroda: Gujarat State Office. (In Gujarati.)

Laurance, W. F., Lovejoy, T. E., Vasconcelos, H. L., Bruna, E. M., Didham, R. K., Stouffer, P. C., Gascon, C., Bierregaard, R. O., Laurance, S. G. and Sampaio, E. (2002) Ecosystem decay of Amazonian forest fragments: a 22-year investigation. *Conserv. Biol.* 16: 605–618.

Lawton, J. H. (1995) Population dynamic principles. Pp. 147–163 in J. H. Lawton and R. M. May, eds. *Extinction rates*. Oxford, U.K.: Oxford University Press.

Lindenmayer, D. B., Cunningham, R. B., Donnelly, C. F., Nix, H. and Lindenmayer, B. D. (2002) Effects of forest fragmentation on bird assemblages in a novel landscape context. *Ecol. Monogr.* 72: 1–18.

Mashru, A. (2004) [Black Eagle in Mount Abu, Rajasthan.] *Vihang* 22: 5–6. (In Gujarati.)

Mitra, S. S. and Sheldon, F. H. (1993) Use of an exotic tree plantation by Bornean lowland forest birds. *Auk* 110: 529–540.

Monga, S. G. and Naoroji, R. K. (1983) Birds of the Rajpipla Forest - South Gujarat. *J. Bombay Nat. Hist. Soc.* 80: 575–612.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. and Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Newton, I. (1995) The contribution of some recent research on birds to ecological understanding. *J. Anim. Ecol.* 64: 675–696.

Prasad, A. (2003) Annotated checklist of the birds of western Maharashtra. *Buceros* 8: 1–174.

Raman, T. R. S. (1995) Shifting cultivation and conservation of tropical forest bird communities in Mizoram, northeast India. M.Sc. dissertation, Saurashtra University, Dehradun, India.

Raman, T. R. S. (2001) Community ecology and conservation of tropical rainforest birds in the southern Western Ghats, India. Ph.D. thesis, Indian Institute of Science, Bangalore, India.

Raol, L. M. (1998) *Van upvanna pankhi* [*Birds of forest and garden*]. Ahmedabad, India: Centre for Environment Education. (In Gujarati.)

Ribon, R., Simon, J. E. and De Mattos, G. T. (2003) Bird extinctions in Atlantic forest fragments of the Vicosa region, southeastern Brazil. *Conserv. Biol.* 17: 1827–1839.

Santharam, V. (1995) Ecology of sympatric woodpecker species of Western Ghats, India. Ph.D. thesis, Pondicherry University, India.

Santharam, V. (2003) Distribution, ecology and conservation of the White-bellied Woodpecker *Dryocopus javensis* in the Western Ghats, India. *Forktail* 19: 31–38.

Simberloff, D. (1985) Habitat fragmentation and population extinction of birds. *Ibis* 137: S105–S111.

Singh, H. S. (2001) *Natural heritage of Gujarat (forests and wildlife)*. Gandhinagar, India: GEER Foundation.

Singh, H. S., Patel, B. H., Trivedi, P., Raval, B. R., Pawar, J. S., Vyas, R. and Patel, B. H. (2002) *Biodiversity study in Ratanmahals Wildlife Sanctuary (a comprehensive ecological and socio-economic study)*. Gandhinagar, India: GEER Foundation.

Singh, H. S., Raval, B. R., Patel, B. H., Tatu, K., Patel, D., Vyas, R. and Patel, B. H. (2000) *Biodiversity study on Vansda National Park. A comprehensive ecological and socio-economic study*. Gandhinagar, India: GEER Foundation.

Stattersfield, A. J., Crosby, M. J., Long, A. J. and Wege, D. C. (1998) *Endemic Bird Areas of the World: priorities for biodiversity conservation*. Cambridge, U.K.: BirdLife International.

Temple, S. A. and Cary, J. R. (1988) Modeling dynamics of habitat-interior bird populations in fragmented landscapes. *Conserv. Biol.* 2: 340–347.

Terborgh, J. W., Robinson, S. K., Parker, T. A., Munn, C. A. and Pierpont, N. (1990) Structure and organization of an Amazonian forest bird community. *Ecol. Monogr.* 60: 213–238.

Trivedi, P. (1993) Habitat selection by Indian Peafowl (*Pavo cristatus* Linn.) in Gir forest, Gujarat, India. M.Sc. dissertation, Saurashtra University, Dehradun, India.

Trivedi, P. (2001) Biodiversity study: Ratanmahal Wildlife Sanctuary. Bird study interim report II. Unpublished report. Gandhinagar, India: GEER Foundation

Trivedi, P. (2003) Bird study of Purna Wildlife Sanctuary, Dangs under biodiversity study of Purna Wildlife Sanctuary. Unpublished final report. Gandhinagar, India: GEER Foundation.

Trivedi, P. (2005) Avifauna study of Jessore Wildlife Sanctuary. Unpublished final report Gandhinagar, India: GEER Foundation.

Worah, S. (1991) The ecology and management of a fragmented forest in south Gujarat India: the Dangs. Ph.D. thesis, University of Poona, Pune, India.

ZSI (2000) *State fauna series 8: fauna of Gujarat, part - I: Aves*. Calcutta, India: Zoological Survey of India.

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