BIRD COMMUNITIES OF THE THORN AND DRY DECIDUOUS FORESTS IN MUDUMALAI WILDLIFE SANCTUARY, SOUTH INDIA

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in

ZOOLOGY

By

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DECLARATION

I do hereby declare that the thesis entitled " **Bird communities of the thorn and dry deciduous forests in Mudumalai Wildlife Sanctuary, South India**" submitted to the Bharathiar University, Coimbatore, for the award of the Degree of Doctor of Philosophy in Zoology, is a record of original and independent research work done by me during 1994-1998 under the supervision and guidance of **Dr. Lalitha Vijayan**, Principal Scientist, Salim Ali Centre for Ornithology and Natural History, Coimbatore, and it has not previously formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or other similar title to any candidate of any University.

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CERTIFICATE

This is to certify that the thesis, entitled " **Bird communities of the thorn and dry deciduous forests in Mudumalai Wildlife Sanctuary, South India**" is a record of original research work done by **V. Gokula** in the Division of Avian Ecology, Salim Ali Centre for Ornithology and Natural History, as a full time Research Scholar during the period of study 1994-1998 under my guidance and supervision for the award of the Degree of Doctor of Philosophy in Zoology. I further certify that this research work has not previously formed the basis for the award of any other Degree or Diploma or Associateship or Fellowship or other similar title to any candidate of this or any other University.

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and Natural History.

To my beloved parents

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V.GOKULA

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CHAPTER I

GENERAL INTRODUCTION AND STUDY AREA

1. GENERAL INTRODUCTION

Birds are important components of forest ecosystem, playing a major role as pollinators, consumers and dispersers of plant seeds, and predators of insects. In nature different species form intricate assemblages as a result of the local ecological make up. Whittaker (1975) states that communities are assemblages of populations of species which occur together in space and time. Studies on bird community ecology starting from MacArthur and MacArthur (1961) have attracted wide attention. The main focus of community ecology is the manner in which groupings of species are formed and distributed in nature and the ways in which these can be influenced or caused by interactions between or among the species and the physical and biological factors of their environment. The cause-effect relation of such assemblages led to an increased interest in studies on bird communities (Cody, 1974; Cody and Diamond, 1975). An understanding of the determinants of bird community structure is extremely important for the practical development of guidelines for the habitat management.

Majority of bird community studies were focused on understanding the structure of a community based on population (eg., MacArthur and MacArthur, 1961; Lack, 1971; James, 1971; Willson, 1974; Cody, 1974; Wiens, 1989). These studies attempted to explain the diversity especially with respect to floristics, forest structure or with foliage diversity. However, the majority of these studies did not relate environmental parameters to the functional aspects of each

bird species. The result was lack of information which explained the presence of a particular species in a type of forest; a relationship which was traditionally explained in terms of the availability of foraging substrates and vegetative layers. In recent years, the trend among community ecologists is to elucidate the function of a community via focussing on habitat selection.

A number of environmental factors are known to influence population of birds directly. Availability of food, detectability and capture of prey, location of nesting sites, availability of nesting materials, presence of predators and competitors are the major factors influencing foraging and breeding of birds and subsequently their population.

The partitioning of available resources for nesting and foraging by a group of species has also become a central theme of several avian community studies in recent years. Studies on resource partitioning among species in birds have increased since the work of Lack (1971) and MacArthur (1971) in finches. These studies broadly considered three dimensions of resource partitioning, namely habitat, food and time. Habitat, particularly microhabitats, was the most common means of partitioning followed by food.

In the habitat, the microhabitat used for foraging is of utmost importance. One of the key aspects in community structure is the food habits of a species which is critical in understanding the patterns and processes of community organization (Wiens, 1989). As birds often exhibit differences in how they exploit resources, some species has been considered as generalists that will search for food on a variety of substrates and heights, while others show varying degrees of specialization. Those specialized species are more sensitive to changes in their

habitat. Hence, specialization may lead to population decline when scarcity of a particular resource happens in their habitat (Terborgh, 1989; Katti and Price, 1996; Sherry and Holmes, 1996).

The food habits of birds have been found affected by various factors such as habitat structure (Fitzpatrick, 1980; Robinson and Holmes, 1982; Holmes and Schultz, 1988), plant species (Holmes and Robinson, 1981), substrate (Fitzpatrick, 1980), structural complexity of vegetation (Robinson and Holmes, 1982; 1984) and degree of human modification (VanderWerf, 1994).

Nest-site is one of the crucial factors in the organization of a community (Martin, 1992; Kozma and Mathews, 1997). Martin (1993a, 1993b) and Steele (1993) suggested that an increase in availability of nest-sites may explain the changes in the structure of a community. Hence, the reduction in number of a species may be ascribed to a decrease in the availability of nest-sites (Naranjo and Raitt, 1993). This observation has been widely reported for hole-nesting birds (VanBalen *et al.*, 1982; Cody, 1985; Rohrbaugh and Yahner, 1997). The availability of snags in general, in an area has been proved to be crucial for determining the hole-nester's population (e.g., Von Haartman, 1957; Hamerstrom *et al.,* 1973). Several other factors involved in nest-site selection such as abiotic and biotic qualities of nest-sites (Giroux, 1981; Hines and Mitchell, 1983; Hill, 1984; Jackson *et al.,* 1988; Crabtree *et al.*, 1989; Peterson, 1990), inter- and intra-specific interaction (Wiklund, 1982; Minot and Perrins, 1986), prevailing winds (Ferguson and Siegfried, 1989), tree density (Selas, 1997) and distribution of available nest sites (Li and Martin, 1991) also influence the population of concerned species.

In brief, a knowledge of the ways in which birds exploit the resources and the inter and intra-specific overlap in their utilization (food and habitat) within a habitat would help to identify the ecological requirements for their survival. Moreover, one can predict how the impact of human interference may alter the existing bird community structure in future.

In India, studies on community dealing, in a whole, with aspects such as foraging-guild, nest-site selection, and population are very meagre. These aspects were studied separately for a community, individual or a group of species. As far as community studies in India are concerned, population of birds based on census data alone were discussed without relating to other aspects. Among the three aspects, studies on foraging behavior and nesting were largely limited to single species or particular groups of birds (Vijayan, 1975, 1980; Khan, 1977, 1978; Zacharias, 1979; Yahya, 1980; Vijayan, 1984; Zacharias and Mathew, 1988; Vijayan, 1989; Thiyagesan, 1991). In other community studies such as Beehler *et al.* (1987), Daniels (1989), Johnsingh *et al.* (1987), Sundramoorthy (1991), and Johnsingh and Joshua (1994) foraging of birds was discussed based on the information given by Ali and Ripley (1987).

In India, the state of the studies on the nest-site selection of forest birds are similar to that of the community studies (Lamba, 1966; Vijayan, 1980; Panicker, 1980; Yahya, 1980; Rajasekaran, 1982; Vijayan, 1984; Thiyagesan , 1991; Kannan, 1994; Mudappa and Kannan, 1997). No attempt has been made in relating the information such as foraging and nest-site selection with the population in an area.

Based on the above considerations, a study was taken up with the objective of **identifying the patterns and processes of bird communities in the thorn and dry deciduous forests.**

Field studies were carried out in the thorn and dry deciduous forests of Mudumalai Wildlife Sanctuary in Tamil Nadu from 1994 to 1997 which included: 1. a survey of birds throughout the sanctuary to identify their status in different habitats, 2. analysis of habitat structure (densities of trees, shrubs, herbs, and the foliage in different layers of the canopy) and the human use of plants in thorn and dry deciduous forests, 3. estimation of bird population in the thorn and dry deciduous forests, 4. studies on the foraging ecology of birds in these forests and 5. studies on the nest and nest-site characteristics of breeding birds in the above habitats.

These aspects were studied in detail with the supporting data on the habitat structure (vegetation physiognomy) and the general avifauna of Mudumalai Wildlife Sanctuary. The results are presented and discussed in different chapters. The general avifauna of the Mudumalai Wildlife Sanctuary is discussed in the second chapter. Vegetation physiognomy and the impact of human interference on plant community, and population of bird communities in the thorn and dry deciduous forests are analyzed in the third and fourth chapters respectively. Foraging pattern and nest and nest-site characteristics of birds in the thorn and dry deciduous forests are presented and assessed in the fifth and sixth chapters. Conservation perspectives of the bird communities and habitats in the Mudumalai Wildlife Sanctuary are presented in the final chapter with the management implications and suggestions.

2. STUDY AREA

2.1. Location

The Mudumalai Wildlife Sanctuary (WLS) is located between 11°30' to 11°39'N and 76°27' and 76°43' E in the Nilgiri district, Tamil Nadu (Fig 1). The sanctuary covers an area of 321 sq km and lies at the tri-junction of three states, Tamil Nadu, Karnataka and Kerala. Mudumalai Wildlife Sanctuary is a part of a complex of four contiguous sanctuaries in the Nilgiri Biosphere Reserve, the others being Bandipur Tiger Reserve, Nagerhole National Park (both in Karnataka) and Wyanaad Wildlife Sanctuary (Kerala).

The eastern and southern parts of the sanctuary are bordered by Revenue lands (private agriculture and estate lands, private forests and forested land under the control of the Revenue Department) and Reserve Forests. The Western part is characterized by the frequent occurrence of *vayals* (swamps) at the foothills. Undulating terrain with poor drainage has been responsible for the formation of these *vayals*.

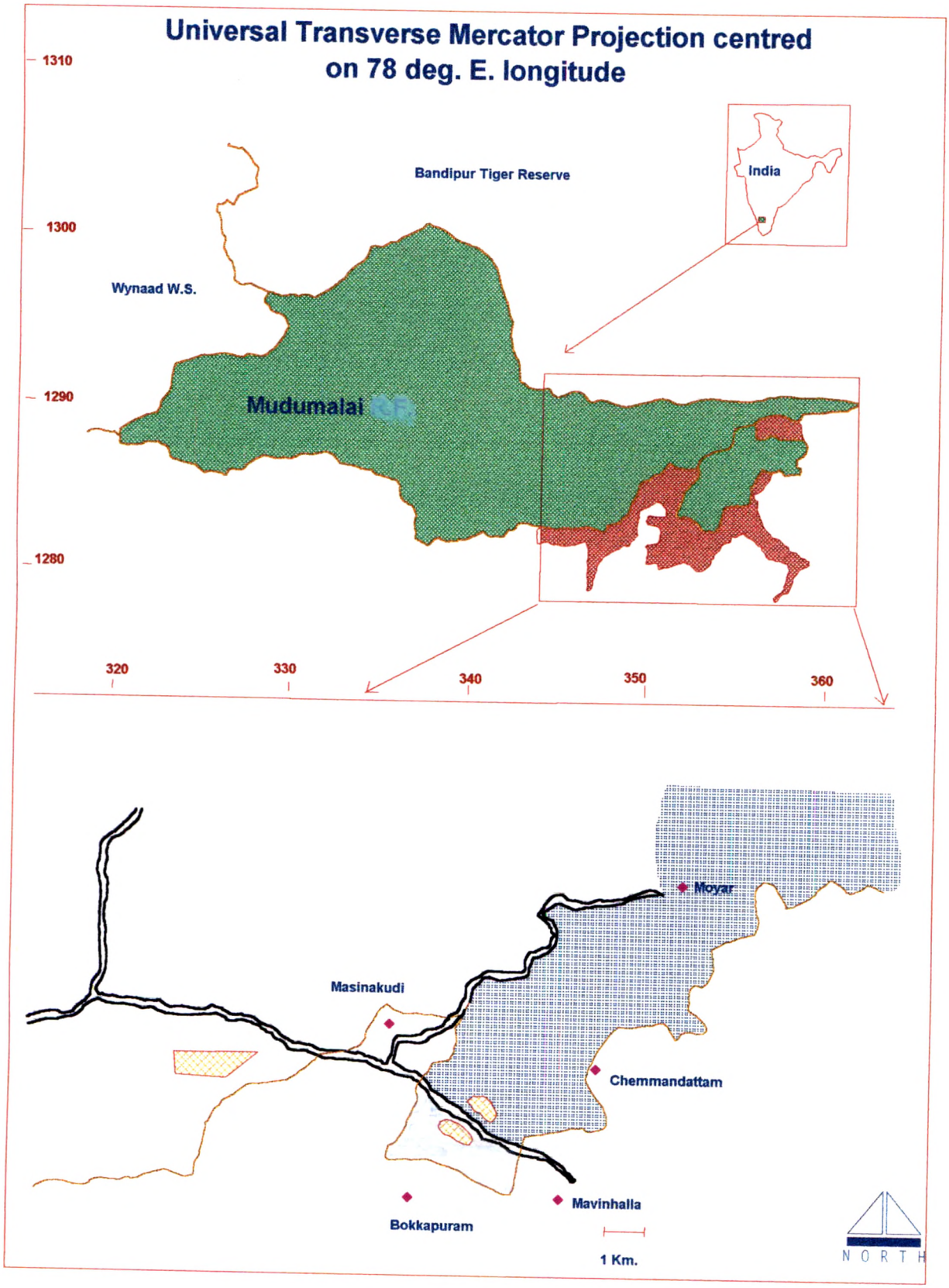
2.2. Altitude

The Mudumalai Wildlife Sanctuary is situated at an average elevation of 1000m (850 to 1258m) with a maximum of 1258m at Morganbetta.

2.3. Climate

The climate is moderate, and temperatures vary from 14°-17°C during December-January to 29°-33°C during March-May. The annual rainfall varies from 600 mm to 2000 mm which is received in two periods; the first with high rainfall (June-

Figure. 1. Map of Mudumalai Wildlife Sanctuary showing the study areas.


Universal Transverse Mercator Projection centred on 78 deg. E. longitude
1310
1300
1290
1280
320
330
340
350
360
Bandipur Tiger Reserve
India
Wynaad W.S.
Mudumalai
Moyar
Masinakudi
Chemmandattam
Mavinhalla
Bokkapuram
1 Km.
N O R T H
Wildlife Sanctuary
Thorn Forest
Revenue Lands
Study Plots
Dry Deciduous Forest
Sanctuary Boundary
Road
Village

August) from the Southwest Monsoon and the second with low rainfall (September-November) from the Northeast Monsoon. The eastern areas get the least rainfall and the western part of the sanctuary the highest. December and January usually are cool months. The dry spell begins at the end of January and continues till the end of May.

2.4. Geology

Soil is red loamy, with the soil in swampy areas being clay in Nature. Underlying rocks are Gneissic in origin and belong to Archaen age of great antiquity (Shetty, 1986). They consist of a very heterogeneous mixture of different types of granites intrusive into the schistose rocks after the latter were folded, crumpled and metamorphosed. The next important group of rocks is the Charnockite Series (Krishnan, 1982).

2.5. Drainage

The sanctuary is drained mainly by the perennial River Moyar and partly by various semi perennials namely Bennehole, Bidarhalla, Kakkanhalla, Doddagatihalla, Imberhalla and Avarhalla. Apart from the rivers, Singara flume channel, various small ponds, swamps and check dams also provide water throughout the year or seasonally.

2.6. Vegetation

In Correspondence to the rainfall, the vegetation varies from thorn forest in the east to Semi-evergreen forest in the west. The sanctuary consists of three major

vegetation types namely moist deciduous, dry deciduous and thorn Forests.

2.6.1. Tropical dry thorn forest

This vegetation type occurs along the foot of the Nilgiri Hills in the eastern side of the sanctuary. Annual rainfall is in the range of 600 to 900 mm. Dominant plants are *Acacia spp.* (including *A.chundra, A. leucophloea,* and *A.ferruginea*) *Anogeissus latifolia, Ziziphus spp., Sapindus emarginatus, Phyllanthus emblica, Erythroxylum monogynum, Cassia fistula, Capparis spp.* Succulents such as *Opuntia dillenii, Euphorbia antiquorum*, and *Caralluma adscendens* are also common. Since many villages are present in and around this vegetation type, it is the most affected due to anthropogenic pressure such as collection of fuelwood and non-timber forest products and cattle grazing.

2.6.2. Tropical dry deciduous forest

The dry deciduous forest type dominates the sanctuary. The annual rainfall ranges from 900-1500 mm in this type. It consists of a combination of *Tectona grandis* and *Anogeissus latifolia* species. *Terminalia spp.* are fairly abundant. The understorey includes *Kydia calycina, Cassia fistula* and *Ziziphus xylopyrus.* Dominant shrubs include *Helicteres isora* and *Pavetta indica.* The eastern portion of the deciduous forest is subjected to anthropogenic pressure due to proximity to villages.

2.6.3. Tropical moist deciduous forest

In Mudumalai, this vegetation type occurs in the western and southern areas

receiving above 1500 mm of rainfall per annum. It is dominated by *Lagerstroemia microcarpa, Tectona grandis, Terminalia tomentosa, T.bellirica, Olea dioica, Anogeissus latifolia*, and *Kydia calycina. Bambusa arundinacea* is common in moist soils, especially along the margins of the *vyals* or swamps that extent through this region. This forest type has been largely degraded into drier type because of the extensive logging for timber in the past.

2.6.4. Semi-evergreen forest

Apart from the major types, this sanctuary has some patch of semi-evergreen forest in the western portion. This patches are dominated by moist deciduous species such as *Olea dioica* and *Parsea macrantha* along some deciduous species.

2.7. Fauna

The Mudumalai Wildlife Sanctuary harbours herbivores such as Asian Elephant (*Elephas maximus*), Gaur *(Bos gaurus)*, Sambar (*Cervus unicolor*), Chital (*Axis axis*), Muntjac (*Muntiacus muntjack)*, Four-horned Antelope (*Tetracerus quadricornis*), and Mouse Deer (*Tragulus meminna*), carnivores such as Tiger (*Panthera tigiris*), Leopard (*Panthera pardus*), Wild Dog (*Cuon alpinus*), omnivores such as Sloth bear (*Melursus ursinus*) and Wildboar (*Sus scrofa*), and primates such as Common Langur (*Presbytis entellus*) and Bonnet Macaque (*Macaca radiata*). In addition, it also supports a considerable number of herpetofauna. The list of avifauna of this sanctuary is given in the appendix (I).

2.8. Biotic & Abiotic Pressure

2.8.1. Tribal community

Kurumbas, Nayakers, Paniyas and Chettys are the major tribal communities inhabiting the sanctuary. They live in about 29 hamlets with a total population of about 1200. Of these, the Chettys are comparatively wealthy in terms of education, food, and agriculture than others. The Kurumbas work as fire-watchers, guides, and elephant mahouts in the Forest Department. The Nayakers and Paniyas are tribal hunters in profession. Paniyas also work under Chettys as labourers.

Apart from the tribal settlement, many villages are also present in and around this sanctuary. More than one third of the human population settled inside the sanctuary depends on any one or more of the forest resources such as firewood, honey, fruits, soil and timber for various purposes. Although this exploitation has been banned by the forest department, it continues and has a considerable impact on the habitat.

2.8.2. Cattle population

The cattle population in and around the sanctuary is a major pressure on the habitat. More than half of the cattle population are kept for dung, and are left inside the forest for grazing. Apart from domestic consumption the dung is also collected regularly for commercial purposes. An average of 10 to 15 individuals fall victim to predators every year. The cattle population in this Sanctuary is probably one of the biggest biotic threats to the ecosystem.

2.8.3. Fire.

Fire is another important factor which gives a different dimension to the habitat every year. As the shrub, grass and litter cover are more, the intensity of fire is high in the dry and moist deciduous forests during the dry spell. But it is not the case in the thorn forest where the vegetation cover is low and patchy. The proliferation of weeds here would make this habitat subject to fire in future years. Since fire occurs mostly during the breeding season of birds, it affects the birds' breeding success.

2.9. Research activities

Since 1980, the fauna and flora of the Mudumalai Wildlife Sanctuary has been studied by researchers from various organizations such as Bombay Natural History Society, Indian Institute of Science, Zoological Survey of India, Botanical Survey of India, Salim Ali School of Ecology, A.V.C.College, and Salim Ali Centre for Ornithology and Natural History.

Flora of this sanctuary has been studied by Sukumar *et al.*, (1992), Murali and Sukumar (1994), and Stephen (1994). Among the mammals, elephant has been studied intensively (e.g., Baskaran *et al.*, 1995; Baskaran and Desai, 1996; Desai and Baskaran, 1996) followed by sloth bear (Baskaran *et al.*, 1997) and Dhole (Venkataraman *et al.*, 1995). Except some status report (Bhupathy and Kannan, 1997; Gokula, 1997), no studies are available on herpetofauna of this area.

As far as birds are concerned, studies are scanty. Very recently, avifauna of this sanctuary is documented by Gokula and Vijayan (1996).

2.10. Study plots

As the thorn and dry deciduous forests are subject to severe anthropogenic pressure, these two habitats were selected for the present study (Fig. 1). But, to get an idea of the overall assemblage of birds, the entire sanctuary was surveyed initially. Intensive studies (vegetation, population, foraging pattern, and nest-site selection) were done in 10 ha of thorn and dry deciduous forests.

CHAPTER II

AVIFAUNA OF MUDUMALAI WILDLIFE SANCTUARY

1. INTRODUCTION

Baseline information on the avifauna of an area is a prerequisite to assess the status of birds and the habitat quality with special attention to indicator species including the rare and endemic species of the region. Information on the history of fauna and flora for most of the places in India has not been well documented and as a result predicting the changes in the population of fauna by the human-caused problems become difficult. Deforestation has become a matter of serious concern throughout the world. The effect of deforestation on fauna of an area can be documented only when proper information such as 1. details of habitats, 2. list of species utilizing the habitat, and 3. their population, community and ecology are available.

In recent years, the Mudumalai Wildlife Sanctuary has been subjected to severe anthropogenic pressures, mainly from the construction of dams and development of tourism in terms of constructing resorts around the sanctuary has considerably increased the human population. As a result, crucial habitats of animals are exploited by people for various purposes. Desai and Baskaran (1996) stated that the elephant home ranges are affected by developmental activities in this area. Baskaran *et al.*,(1997) reported that the immediate threat to the Sloth Bear in thorn forest is loss of ground cover through severe grazing by cattle. They further stressed the importance of protection of microhabitats and non-timber forest products in Mudumalai Wildlife Sanctuary for Sloth Bear.

Desai (1991) reported the importance of corridors present in the thorn forest of Mudumalai Wildlife Sanctuary for movement of elephants. All these recommendations are applicable not only for the concerned species but also for the other animals present in the area. But, as far as the avifauna is concerned, special attention is needed to identify the problems as it consists of a variety of species which differ in their requirements. Although Mudumalai Wildlife Sanctuary has been having research programs since early 1980s, no information is available on avifauna. Even proper checklist of birds present in this area was not available before Gokula and Vijayan (1996). Gupta (1997) very recently documented the status and distribution of raptors in this area.

In order to fill up this lacuna, the present study is designed to:

understand the status and distribution of avifauna in various habitats present in the area.

Though the study is purely based on species list, it was proposed to be achieved with the help of other information collected on nesting and foraging of birds in different habitats.

2. METHODS

In order to know the overall assemblage of birds, the entire Sanctuary was surveyed on foot. Bird species were recorded separately for the three major habitats available in the Sanctuary, namely the thorn, dry deciduous and moist deciduous forests. Habitats were surveyed almost in all the months of the year. Based on the presence and absence data, birds were classified as (1) specialist - birds sighted in only one habitat; and (2) generalists - birds sighted in more than

one habitat. For these analyses, only forest or land birds were considered. No such classification was made for the Wetland birds. Similarly, all the birds (including the Wetland birds) were further classified as (1) migratory - species that migrate from outside India, mainly the Palaeartic region during autumn and winter and (2) resident - sighted throughout the year or all the seasons. Based on these, number of generalists, specialists, residents, and migrants for each habitat were noted and compared between habitat types.

3. RESULTS

3.1. Overall status

In total, 265 bird species belonging to 17 orders were recorded in three major habitats of Mudumalai Wildlife Sanctuary (Appendix I). Among the habitats, number of birds sighted were more in the thorn forest and low in the moist deciduous forest which included 210 resident birds and 55 migrant birds (Table 1). Of the 265 birds, 237 were forest or terrestrial birds and 28 were water or aquatic birds. Half of the number of species were passerines and the remaining was contributed by 16 orders. Based on the food, birds were classified into five types, namely granivore, aquatic feeder (vegetation and animals), insectivore, carnivore, and nectarivore and frugivore. Half of the birds species in this sanctuary were insectivores (139) while granivores and aquatic-feeders were 25 and 24 species respectively.

3.2 Habitat-wise status

The Mudumalai Wildlife Sanctuary was divided into three major habitats based

on vegetation. Number of bird species recorded and area of each habitat is given in the table (2). More than half of the area of this sanctuary is of dry deciduous type and only a very small portion is thorn. Although the availability of thorn forest is very low, number of bird species recorded during the study period in this type was higher than the rest two habitats.

Table 1. Number of birds and their status recorded in Mudumalai Wildlife Sanctuary

Order	Species status			Feeding guild				
	Res	Mig	Tot	A	C	NF	G	I
Podicipitiformes	1	-	1	1	-	-	-	-
Pelecaniformes	4	-	4	4	-	-	-	-
Ciconiiformes	7	2	9	8	-	-	-	1
Anseriformes	-	4	4	4	-	-	-	-
Falconiformes	17	8	25	1	24	-	-	-
Galliformes	6	-	6	-	-	-	6	-
Gruiformes	3	-	3	-	-	-	-	3
Charadriiformes	5	5	10	-	-	1	-	9
Columbiformes	10	-	10	-	-	3	7	-
Psittaciformes	5	-	5	-	-	5	-	-
Cuculiformes	8	2	10	-	-	-	-	10
Strigiformes	8	-	8	-	8	-	-	-
Caprimulgiformes	3	-	3	-	-	-	-	3
Apodiformes	5	-	5	-	-	-	-	5
Coraciiformes	14	1	15	6	-	4	-	5
Piciformes	14	-	14	-	-	4	-	10
Passeriformes	100	33	133	-	4	24	12	93
Total	**210**	**55**	**265**	**24**	**36**	**41**	**25**	**139**

Tot= Total, Res=Resident, Mis=Migrant, A=aquatic-feeders, I=Insect-feeder, G=Granivore, NF=nectar/fruit-feeder, C=Carnivore

Table 2. Number of birds recorded in three habitats of Mudumalai Wildlife Sanctuary.

Habitats	Area		# of bird species
	sq.km	%	
Thorn forest	47.50	15.0	149
Dry deciduous forest	183.50	57.00	145
Moist deciduous forest	90.00	28.00	127
Total	**321.00**	**100.00**	**265**

Considering only forest or terrestrial birds, among the three habitats, specialists (recorded only in one habitat type) were more in moist deciduous (50) followed by thorn (42) forest (Fig. 1). Only 8 species were recorded only in the dry deciduous habitat. Sixty bird species occurred both in the thorn and dry deciduous habitat while only 30 birds shared the dry and moist deciduous habitat. Only 47 birds were recorded in all the habitats in the sanctuary.

In general, of the 237 forest or terrestrial birds, 42 % (100) of them were restricted to any one of the three habitats while 59% were observed using two or three habitats. Specialists of thorn and moist deciduous habitats were dominated largely by insectivores while carnivores were more among the specialists of dry deciduous forest (Table 3). In general, regardless of habitats, the specialists and generalists were largely in the insectivore and nectar/fruit feeder groups; the latter group which are more specialized were more in the moist deciduous forest. The other specialized group of granivores were more in the thorn and dry deciduous habitats.

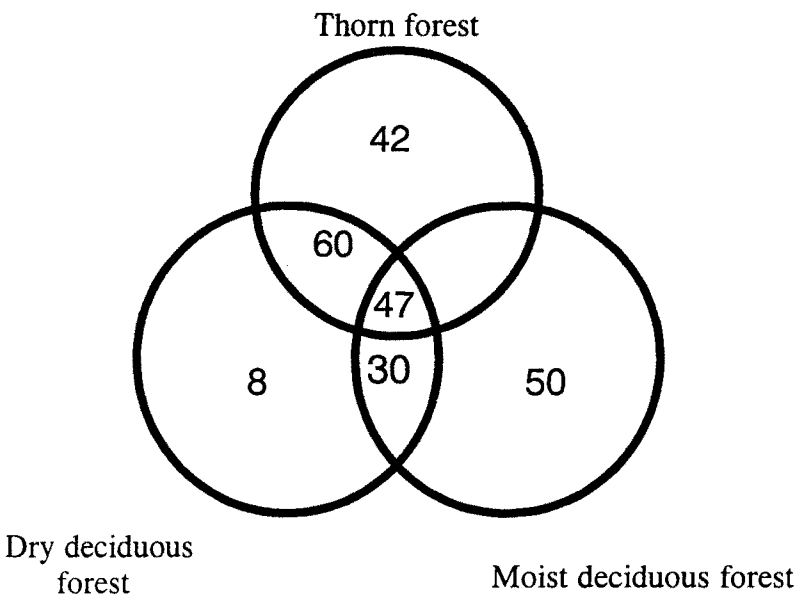


Figure 1. Number of bird species recorded in various habitats of Mudumalai Wildlife Sanctuary

Only 28 aquatic birds belonging to 7 orders were recorded in Mudumalai Wildlife Sanctuary. Of the nine species of ciconiiformes, Openbill Stork (*Anastomus oscitans*) and Blacknecked Stork (*Ephippiorhynchus asiaticus*) were sighted only occasionally in the thorn forest. All the four species of Anseriformes were found either in the *Ombetta* swamp or *Gamehut* Swamp which are the two major water sources in the area apart from the River Moyar.

Table 3. Feeding-guild composition of birds in different habitat types (excluding waterbirds).

Habitat	# of species (specific to habitats/ common)	Feeding guild				
		A	C	NF	G	I
Thorn	42	1	1	2	2	36
Dry deciduous	08	-	4	1	2	1
Moist deciduous	50	2	7	13	4	24
Thorn & dry deciduous	60	3	8	8	10	31
Dry & moist deciduous	30	2	8	4	-	16
Thorn, dry & moist deciduous	47	-	8	12	6	21
Total	**237**	**8**	**36**	**40**	**24**	**129**

A= Aquatic feeder, C=Carnivore, NF=Nectar/fruit feeder, I=Insectivore, G= Granivore

3.3 Status of endemic birds of Western Ghats and globally threatened birds

Nine of the 15 species endemic to the Western Ghats (Ali and Ripley 1987, Daniels 1997) were observed in the moist deciduous forest. Only one of these was found in scrub forest while 8 of them were found in moist deciduous habitats (Table 4).

Thirty one near-threatened species occur in Western Ghats (Collar *et al.*1994) of which 20 were observed in the sanctuary. Two of these were aquatic while 17 were terrestrial. Here also moist deciduous habitat is more important, since 11 of the 17 species were observed with seven species specific to this habitat. Although there were 7 and 9 of these species occurring in dry deciduous and thorn forest respectively, only four and one were specific to thorn and dry deciduous forests respectively.

Table 4. Status of birds endemic to Western Ghats and globally near-threatened birds in Mudumalai Wildlife Sanctuary

Species	Status		Habitats					
	EN	GT	T	D	M	TD	DM	TDM
Malabar Grey Hornbill	*	*	-	-	-	-	*	-
Bluewinged Parakeet	*	-	-	-	*	-	-	-
Nilgiri Wood Pigeon	*	*	-	-	*	-	-	-
Broadtailed Grass Warbler	*	*	*	-	-	-	-	-
Wynaad Laughing Thrush	*	*	-	-	*	-	-	-
Small Sunbird	*	-	-	-	*	-	-	-
Black and Orange Flycatcher	*	*	-	-	*	-	-	-
Whitebellied Blue Flycatcher	*	*	-	-	*	-	-	-
Whitebellied Treepie	*	*	-	-	*	-	-	-
Grey Junglefowl	-	*	-	-	-	-	-	*
Malabar Pied Hornbill	-	*	-	-	*	-	-	-
Forest Eagle Owl	-	*	-	-	*	-	-	-
Greyheaded Fishing Eagle	-	*	-	-	-	-	*	-
Indian Whitebacked Vulture	-	*	-	-	-	*	-	-
Indian Longbilled Vulture	-	*	-	*	-	-	-	-
King Vulture	-	*	-	-	-	-	-	*
Pale Harrier	-	*	-	-	-	*	-	-
Oriental Darter	-	*	A	A	A	A	A	A
Yellowthroated Bulbul	-	*	*	-	-	-	-	-
Openbilled Stork	-	*	A	A	A	A	A	A
Whitebellied Minivet	-	*	*	-	-	-	-	-
Tytler's Leaf Warbler	-	*	*	-	-	-	-	-
Total	**9**	**20**	**4**	**1**	**9**	**3**	**2**	**2**

E= Endemic to Western Ghats,G=Globally near-threatened birds, T=Thorn forest, D=dry deciduous, M=Moist deciduous, TD= thorn & dry deciduous, DM=dry & moist deciduous, TDM= Thorn, Dry, & moist deciduous, A= Aquatic.

4. DISCUSSION

To understand the conservation of the avifauna of the Mudumalai Wildlife Sanctuary, it is necessary to examine the changes in the vegetation and human pressure over years. As far as Mudumalai is concerned, literature available on the land use pattern and the avifauna is scanty. During the pre-colonial period, the Mudumalai was sparsely populated with tribal communities (*Kurumbas* and *Irulas*), living on a subsistence mode of resource use with an intricate exchange relationship between them. In 1800, the cold and damp environment of Nilgiris attracted Europeans to settle in this district. The changes in the vegetation can be assumed to have been occurred only after 1853 when plantation work such as cultivation of food crops carried out by the natives and the growth by Europeans of special products such as coffee, tea, and rubber started (Francis, 1908). The expansion in cultivation and plantation needed large labour inputs resulted in increase in the human population in this district. In Mudumalai, a drastic increase in the human population has occurred when the execution of hydro-electric project was started (Prabhakar and Gadgil, 1994). Many of them who came in as labour in the projects settled in and the demand for the resources started increasing. A massive destruction of forest started with the time of migrants (people) arrival. The greater demand for firewood and building material resulting in reckless felling of teak and other wood was recorded during 1860-82. Conservation work started only after 1885. During that period, the population of Masinankudi village was about 1,291 (Francis, 1908) which is now

about 3,924 (Silori and Mishra, 1995). In addition, development of tourism resulted in the increase of various resorts, and buildings nearby the sanctuary.

Similarly, in the case of avifauna, Francis (1908) reported that Europeans has considerably reduced the population of raptors, game birds and waterbirds. No quantitative information is available on changes in the fauna over the years due to human disturbances.

4.1. Habitats of conservation concern

Among the three vegetation types, the thorn forest and moist deciduous habitats are adjacent to human settlements and are subject to heavy anthropogenic pressure. The dry deciduous habitat as it extends away from the human settlements is considerably less disturbed than the other two habitats. Apart from some tribal colonies, there are a number of villages situated in and around the sanctuary. During the past few decades, establishment of power projects and expansion of tourist facilities attracted more number of people resulting in the manyfold increase in the population. However, the developmental projects have not much changed the economy of the tribal, native, and newly settled people who depend mainly on forest (Silori and Mishra, 1995).

Among the three habitats, the result shows the importance of thorn forest and moist deciduous habitat for conservation of avifauna. Low species richness in dry deciduous habitat can be attributed to the homogenous nature of the habitat. Lower number of species in the moist deciduous forest is mainly because of less visibility. The teak and eucalyptus were introduced into the Nilgiris in 1858 (Abbasi and Vinithan, 1997) and a considerable portion of the dry deciduous part

of this sanctuary has been planted with teak. As a result, major part of the dry deciduous habitat is dominated largely by teak. The early forest working plans of South Indian Western Ghats were mainly aimed at the extraction of commercial timbers such as teak. The rising demand for teak and its depletion in nature made the foresters to initiate massive vegetational changes in favour of teak monoculture (Dixit, 1985; Gadgil and Chandran, 1989). The teak plantation is structurally less complex in providing nest substrate and foraging opportunities to birds than other plants. Beehler *et al.*, (1987) reported that teak offers virtually no useful environment for birds until it matures, especially for species that are larger or sensitive to habitat changes. Although teak trees in the study area are matured, it support only a few bird species. Moreover, homogenous nature of a habitat can give foraging opportunity to only a limited number of species in a particular season, whereas the thorn and moist deciduous forests are more complex and heterogenous ecosystems which give ample foraging and breeding environment throughout the year and hence, support more number of species. Moreover, these two habitats have variety of microhabitats in the form of nullahs, riverain patches, and bamboo clumps. Although the dry deciduous seems to be less important in terms of conservation of avifauna, it can not be neglected as it provides various foraging and nesting opportunities to raptors.

Although thorn forest dominated by shrubs and short trees occupy a small portion (about 47.5 sq.km) of Mudumalai Wildlife Sanctuary, it extends eastward which is only Reserve Forest and hence human pressure is unavoidable. Hence, more areas may be included in the Mudumalai Wildlife Sanctuary in order to provide better protection to this habitat.

4.2. Birds of conservation concern

4.2.1. Raptors

Francis (1908) presented a list of birds present in the Nilgiris district. A total of 209 birds belonging to 16 orders was reported for the Nilgiris district which included the forest areas such as Mudumalai Wildlife Sanctuary, Mukuruthi NP and Upper Bahavani. Although, the present list far exceeded the old list, some species are found to be missing. Ali and Ripley (1987) also recorded these bird species in the Nilgiris. Hence, species recorded on or before 1908 but not in my study period was only taken into consideration. Eleven species belonging to 5 orders were found missing and of which 37% are raptors (Table 5).

Table 5. List of species not recorded in the present study but recorded by Francis (1908)

Family	Species	# of species	%
Charadriidae	Woodcock Wood-Snipe Pintail Snipe	3	27
Columbidae	Imperial Pigeon	1	9
Falconidae	Lesser Kestrel Redlegged Falcon Indian Hobby Shaheen Falcon	4	37
Cuculidae	Emerald Cuckoo	1	9
Trogonidae	Malabar Trogon	1	9
Podargidae	Ceylon Frogmouth	1	9
Total		**11**	**100**

Francis (1908) reported that rewards were awarded for the slaying of several of the more destructive members of the falcon family and a fair number were killed annually during the British period. Hence, the drastic reduction in the species of falcons can be attributed to earlier hunting practices or the increase in the human population and habitat loss.

4.2.2. Waterfowl

As far as the waterfowl of Mudumalai Wildlife Sanctuary is concerned, no species can be said to be abundant in this area. All of them were sighted fewer in numbers (<15). Although wintering waterfowl are attracted to sites with favourable weather and ample food supplies, they do exhibit some year-to-year fidelity to sites used. In Mudumalai, the available sites suitable for waterfowl could support only very few species. No illegal attempt to capture or collect or destroy the chicks, eggs, and nests were observed during the study period. The sites such as Ompetta and Gamehut are the important sites for waterfowl; the quality of these sites may be improved and proper record of the wintering and breeding population maintained every year.

4.2.3. Gamebirds

Similarly, very few gamebird species were recorded in the sanctuary. Among the gamebirds, Grey Patridge, Grey Junglefowl and Peafowl were sighted very frequently in this sanctuary. The major threat to gamebirds are illegal trapping almost in all the habitat types and it was very frequent in the moist deciduous for commercial as well as personal use by the people residing in and around the

sanctuary. Similarly, collection of feathers and eggs of the Peafowl by the tribal people were common during the study.

4.2.4. Other avifauna

As far as other groups of birds (eg., passerines) are concerned, no threats were observed except that the chicks of parakeets were seen caught, but not frequently, by tribal children.

In general, as far as the avifauna of this area is concerned, apart from other indirect impacts due to human or nature (eg., habitat loss, wood cutting, fire, drought etc.,) only gamebirds are facing severe threats from poaching as people trap them quite frequently. Hence, proper attention has to check poaching and to monitor the population of gamebirds in future.

4.3. Threats

4.3.1. Habitat alteration

This is the single most important threat facing the endemic species of Western Ghats as most of them are habitat specialists. Species such as Broadtailed Grass Warbler, Whitebellied Treepie, and Nilgiri Wood Pigeon were sighted very less frequently throughout the study period. Only Bluewinged Parakeets were in fairly good numbers. Due to the small size of the thorn and moist deciduous habitats than the dry deciduous type, reduction in areas of suitable habitat could well jeopardize the ability of some endemic species to maintain a viable population. The thorn forest specialists are most at risk as the habitat is subject to severe anthropogenic pressure.

4.3.2. Grazing

Another important threat to wildlife in this area is cattle grazing. Ninety percent of cattle, goat, and sheep are unproductive and raised for dung only (Silori and Mishra, 1995). As a result percentage of bare ground increases and soil surface conditions are changed by grazing which affects water retention / runoff properties; perennial grasses decrease in importance; impact is generally highest close to water sources; and there is less stability between years in floristic composition (Burrows *et.al.*, 1986; Mott *et.al.*, 1979; Pressland *et.al.*, 1988). Livestock may trample nests of ground-breeding birds. Moreover, they alter the abundance and seasonal availability of resources through change in plant species composition, phenology and density.

4.3.3. Fire

Fire also considerably threatens the avifauna every year. Among the habitats, dry deciduous forest is prone to frequent fire almost every year during the dry season. Accumulation of dry leaves (largely of teak) on the ground during dry season, and the availability of weeds in the ground layer makes fire uncontrollable during dry season but the discontinuity of the ground layer in the thorn forest and moisture in the moist deciduous habitats often reduce the effect of fire in these two habitats. As the occurrence of fire and breeding season of birds peak during dry season, majority of hole and cup-nesting birds are affected in the dry deciduous part of the sanctuary.

4.3.4. Conservation measures

Changes in land-use patterns that alter habitat may have a delayed negative effect on animal species occupying that habitat, and thus such effects may not be recognized for years (Ligon and Stacey, 1996). As there is limited prehistoric information available both on the avifauna and landscape changes of Mudumalai Wildlife Sanctuary, a proper long-term monitoring of population of avifauna of this area would give the impact of changes in the habitat on the avifauna.

5.SUMMARY

Avifauna of Mudumalai Wildlife Sanctuary was studied between 1994-1997 to understand their status and distribution among habitat or forest types. The results are as follow:

1. In total, 265 bird species belonging to 17 orders were recorded. Among the major habitat types (thorn, dry and moist deciduous), the number of birds sighted were more in the thorn forest and low in the moist deciduous forest. Nine of the 15 species endemic to the Western Ghats were observed.

2. Birds were classified as generalists and specialists based on the sightings in the habitat types. Among the habitats, specialists were more in the thorn forest and low in the dry deciduous forests.

3. Among the birds, insectivorous birds dominated in all the habitats followed by the nectarivores/frugivores.

4. As far as birds are concerned, both the thorn and moist deciduous forests need more attention with respect to conservation as they harbour greater number of specialists and endemics.

CHAPTER III

VEGETATION PHYSIOGNOMY AND HUMAN IMPACT ON PLANT COMMUNITIES

1. INTRODUCTION

The availability of plant resources for animals has been of immense concern in recent years as forested habitats are severely exploited by man for various purposes. The importance of vegetation to animals was highlighted by MacArthur and MacArthur (1961) and since then, studies on vegetation have been increasing in the field of ecology. Vegetation analysis in general, serves to characterize a plant community, describe its floristic composition, and moreover, offers valuable criteria for the rational and efficient selection of priority sites for conservation. In the studies on animal ecology, vegetation has been mostly studied to correlate its availability with utilization by animals. But in most of the studies, utilization of the same resources (plants) by the local people is poorly documented or left incomplete.

Apart from the major developmental activities such as industries, river valley projects, and plantations, dependence of people living in and around the protected areas on forest resources has a serious impact on the ecosystem. Human interference on forest not only alters the vegetation structure but also reduces the resources available for animals. Knowledge of the extent of such pressures would enable the manager to make proper management plans for the concerned area.

In recent years, studies on people's interference on forest has considerably increased (e.g., Infield 1988; Newmark and Leonard, 1991; Balakrishnan and Ndhlovu, 1992; Newmark *et al.*, 1993). However, in India, very few studies are available (Beehler *et al.*, 1987; Daniels, 1989; Joshua and Johnsingh, 1994; Silori and Mishra, 1995; Ramakrishnan and Sivaganesan, 1997). Of which, studies by Joshua and Johnsingh (1994), Silori and Mishra (1995), Ramakrishnan and sivaganesan (1997) have only concentrated on the people's dependence on forests. Although Silori and Mishra (1995) studied in Mudumalai Wildlife Sanctuary, their concentration was focused on the elephant-food plants available on existing corridors. In order to quantify the plant resources available for the birds and as well as to identify the human-impact on it, similar attempt was made in the thorn and dry deciduous forest with following aims:

1. to identify the availability of plant resources and 2. to identify and quantify to a certain extent people's dependence on the plant resources in the thorn and dry deciduous forests.

2. METHODS

2.1. Plant density and diversity

Vegetation was sampled to estimate the density and diversity of plant species in 50*20 m plot established at every 100 m interval along a transect in thorn (c. 1.5km) and dry deciduous (c.2.km) forests. In total, 30 and 40 plots were laid in thorn and dry deciduous forests respectively. All the trees and shrubs present within the plots were identified to species level. The height, girth at breast height (GBH), and canopy cover were estimated for all the tree species (>20 cm GBH)

within the plot. Number of individuals of each shrub species was counted. Snags (>20 cm GBH) available within the plot were identified to species level and their numbers were noted. A snag is a standing dead or partially dead tree (Evans and Conner, 1979). But, only trees completely dead were considered as snags in the present study.

Based on the vegetation data and visual observation, vegetation profile for both the habitats were made.

2.2 Phenological study

The major plant species identified from the vegetation data of the study area were marked for phenological studies. A minimum of 10 individuals of each major tree species were monitored once in every 15 days during 1995-1996. The reproductive phase (buds, flowers, and fruits) of the plant species was estimated separately in percentage. The data were averaged and given as phenological status of each species during the study period.

2.3. Foliage Height Diversity

Vertical distribution of foliage was sampled along 1 km transect in the thorn and dry deciduous forests following the method of MacArthur and Horn (1969). At every 50 m interval, a circular plot (15 m radius) was established. The centre of the circle was considered as the centre point from where an addition of 12 points at every 5 m interval on four cardinal directions were established. A total of 260 points (13 points per plot) were made for the vegetation profile study in thorn and dry deciduous habitats. An aluminum rod marked in 1 m divisions (up to 15 m)

was placed vertically at every point. The percentage of foliage thickness in each vertical stratum was recorded. From these measurements, the foliage height diversity (FHD) in each stratum was determined for both habitats.

2.4. Impact studies

To quantify the impact of man on plant resources available for birds, informal interviews were conducted during the dry season with individuals collecting firewood within the study area, to assess qualitatively their perceptions of preferred firewood species. There was no set questionnaire, nor was a sampling strategy adopted. Where permission was granted, the size class and species were determined for stems within the bundle of wood that had been collected. As wood collection is prohibited inside the sanctuary, getting the opinion about the preferred species from the people and inspecting the firewood bundle were difficult and hence, a total of only 103 people were questioned. Moreover, as their opinion on the preferred species did not deviate much, no extra effort was taken to increase the sample size. Transect (3km in length and 10m width) starting from the village (Masinangudi) was laid each in thorn and dry deciduous habitat, and intensity of wood collection was quantified. The presence of lopping or woodcutting signs on every plant species was enumerated to know the people's preference of species.

2.5. Statistical analysis

Diversity was calculated using Shannon-Weaver index (1949) $H' = \sum p_i \log p_i$ (Where H'= diversity and pi= the proportion of observation in subset i).

3. RESULTS

3.1. Thorn forest

3.1.1. Species richness, density, and diversity of plants

In the 3 ha area sampled, 28 species of trees, 34 shrubs, and 2 snags were recorded in the thorn forest (Table 1). Shrub diversity was greater than that of trees.

Although 304 individuals of 28 tree species were recorded, only a very few tree species viz., *Acacia chundra, Erythroxylum monogynum,* and *Eucalyptus globulus* were abundant (Table 2). The relative density of these three species alone was 64.80. All other species were present in low density. Only two species of snags namely *Anogeissus latifolia* and *Acacia chundra* were recorded.

Table 1. Species richness and diversity (H') of various plantforms in thorn forest.

Plant forms	Species richness	Diversity (H')
Trees	28	2.308
Shrubs	34	2.579
Snags	2	0.683

3.1.2. Foliage height diversity.

In thorn forest, foliage was available up to a maximum of 7-8m height class (Fig 1). Foliage density was greater in the 0-3 m height class and decreased as the height increased after 5 m. The higher strata are dominated largely by tree species such as *Eucalyptus globulus, Anogeissus latifolia, Ficus benghalensis* and *Elaeodendron glaucum* (Fig 2).

Table 2 . Density of tree species recorded in thorn forest.

Species name	# of individuals /3 ha	Density/ha	Relative density
Acacia catechu	4	1.3	1.28
Acacia ferruginea	8	2.7	2.66
Acacia leucophloea	3	1.0	0.99
Acacia chundra	35	11.7	11.54
Anogeissus latifolia	17	5.7	5.62
Bauhinia racemosa	1	0.3	0.30
Butea monosperma	2	0.7	0.69
Chloroxylon swietenia	5	1.7	1.68
Dalbergia paniculta	7	2.3	2.27
Diospyros montana	8	2.7	2.66
Elaeodendron glaucum	7	2.3	2.27
Erythroxylum monogynum	51	17.0	16.77
Eucalyptus globulus	111	37.0	36.49
Euphorbia antiquorum	2	0.7	0.69
Ficus benghalensis	2	0.7	0.69
Givotia rottleriformis	5	1.7	1.68
Jatropha curcas	1	0.3	0.30
Limonia alata	2	0.7	0.69
Naringi crenulata	2	0.7	0.69
Phyllanthus emblica	2	0.7	0.69
Plectronia didyma	3	1.0	0.99
Premna tomentosa	3	1.0	0.99
Pterocarpus marsupium	1	0.3	0.30
Randia dumetorum	7	2.3	2.27
Strychnos potatorum	1	0.3	0.30
Vitex altissima	1	0.3	0.30
Ziziphus mauritiana	3	1.0	0.99
Ziziphus xylopyrus	10	3.3	3.25
Total	304	101.4	100.00

3.1.3.Reproductive phenology of trees.

No clear trend was found in the fruiting phenology of trees (Fig 3). Individuals of species such as *Ficus benghalensis* were with fruits almost all through the year. However, a peak was observed in February where a maximum of 17 tree species were in fruit. But some trend was observed in flowering which reached a peak during April to August corresponding to the rainfall.

Figure 1. Foliage height diversity (FHD) recorded in the thorn forest

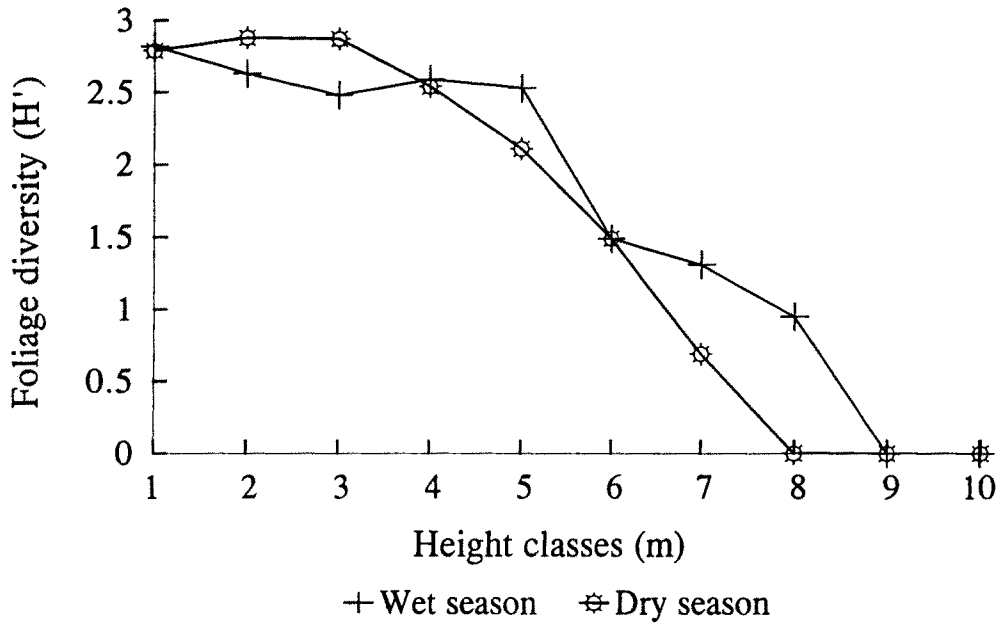
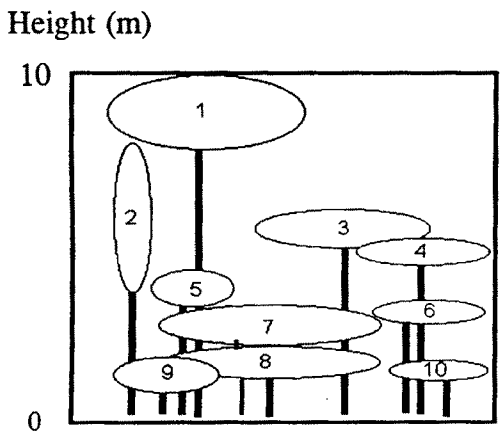
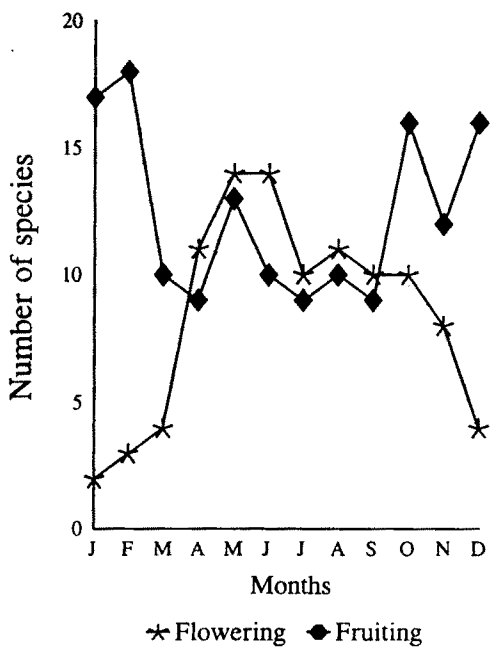


Figure 2. Vegetation profile of the thorn forest



1. Ficus benghalensis
2. Eucalyptus globulus
3. Dalbergia paniculata
4. Anogeissus latifolia
5. Diospyros montana
6. Randia dumetorum
7. Erythroxylum monogynum
8. Gymnosporia montana
9. Ziziphus mauritiana
10. Ziziphus xylopyrus

Figure 3. Phenology of tree species in the thorn forest



3.2. Dry deciduous forest

3.2.1. Species richness, density, and diversity of plants

44 tree species, 48 shrub species, and 3 snag species were recorded in a sampled area of 4ha in the dry deciduous forest (Table 3). Shrub diversity was greater than that of trees.

Table 3. Species richness and diversity (H') of various plantforms in dry deciduous forest.

Plant forms	Species richness	Diversity (H')
Trees	44	1.982
Shrubs	48	2.313
Snags	3	1.084

In total, 1274 individuals of 44 species of trees were recorded (Table 4). Species of *Anogeissus latifolia*, *Phyllanthus emblica,* and *Tectona grandis* dominated the entire study area as relative density of these three species was 79.70. *Acacia chundra, Dalbergia latifolia, Elaeodendron glaucum, Pterocarpus marsupium*, and *Terminalia spp* were the second dominant group of trees present in the study area. *Anogeissus latifolia*, *Tectona grandis*, and *Acacia chundra* were the three species of snags found in the study area.

3.2.2. Foliage height diversity.

In dry deciduous forest, foliage was available up to a maximum of 10-11m height class (Fig. 4). Foliage density was greater in 3-6m height class and decreased as the height increased after 9 m.

Vegetation profile of the study area showed three distinct regions such as short trees and shrubs, medium trees, and larger trees (Fig. 5).

Table 4. Density of tree species recorded in dry deciduous forest

Species name	# of individuals	Density/ ha	Relative density
Acacia chundra	33	8.25	2.59
Anogeissus latifolia	484	121.00	37.99
Bauhinia racemosa	7	1.75	0.55
Bombax ceiba	4	1.00	0.31
Bridelia retusa	2	0.50	0.16
Butea monosperma	2	0.50	0.16
Cassia fistula	4	1.00	0.31
Cordia domestica	1	0.25	0.08
Cordia myxa	1	0.25	0.08
Dalbergia latifolia	18	4.50	1.41
Dalbergia paniculata	1	0.25	0.08
Diospyros melanoxylon	7	1.75	0.55
Diospyros montana	4	1.00	0.31
Dolichandrone falcata	6	1.50	0.47
Elaeodendron glaucum	13	3.25	1.02
Eriolaena quinquelocularis	10	2.50	0.78
Flacourtia indica	6	1.50	0.47
Givotia rottleriformis	6	1.50	0.47
Grewia tiliifolia	4	1.00	0.31
Gymnosporia montana	3	0.75	0.24
Lagerstroemia parviflora	9	2.25	0.71
Melia arborea	1	0.25	0.08
Mitragyna parvifolia	2	0.50	0.16
Persea macrantha	1	0.25	0.08
Phyllanthus emblica	257	64.25	20.17
Premna tomentosa	1	0.25	0.08
Pterocarpus marsupium	14	3.50	1.10
Radermachera xylocarpa	2	0.50	0.16
Randia dumetorum	8	2.00	0.63
Schleichera oleosa	5	1.25	0.39
Stereospermum colais	1	0.25	0.08
Tectona grandis	268	67.00	21.04
Terminalia arjuna	1	0.25	0.08
Terminalia bellirica	1	0.25	0.08
Terminalia chebula	12	3.00	0.94
Terminalia tomentosa	29	7.25	2.28
Unidentified	7	1.75	0.56
Ziziphus xylopyrus	39	9.75	3.06
Total	**1274**	**318.5**	**100.00**

3.2.3. Reproductive phenology of trees.

Some trend was found in the fruiting phenology of trees as most of the tree species were in fruit during the IInd wet season (Figure 6); a maximum of 18 tree species were fruiting in October. Flowering reached a peak between February and May.

3.3 Impact of human interference on plants

Interviews with 103 people who regularly cut wood inside the protected area suggested that plant species are largely used as firewood, as wood is their primary energy source for cooking in local communities. The removal of large trees for non-firewood purposes by people was also observed in the study area.

A total of seven plant species were said to be preferred by the local people (Table 5). Among the seven species, though only leaves of *Erythroxylum monogynum* were said to be collected for the cattle, wood-cutting of this species was seen very often in the field. Usage of this species for fencing was observed.

Table 5 . List of plant species preferred for various purposes by the local people (based on interview)

Plant species	Usage
Anogeissus latifolia	Firewood
Acacia chundra	Firewood
Acacia catechu	Firewood
Acacia leucophloea	Firewood
Erythroxylum monogynum	For cattle (leaves)
Snags	Firewood
Eucalyptus globulus	Sale/construction of house

Figure 4. Foliage height diversity (FHD) recorded in dry deciduous forest

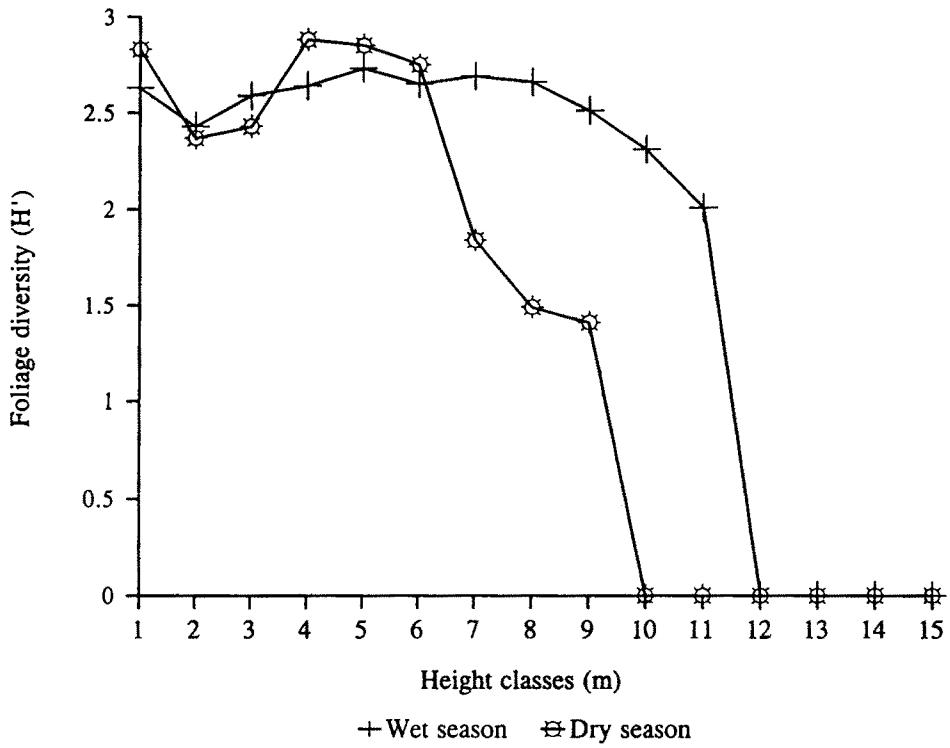
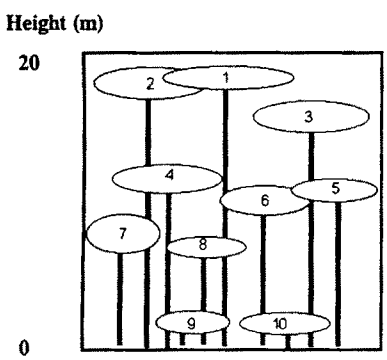
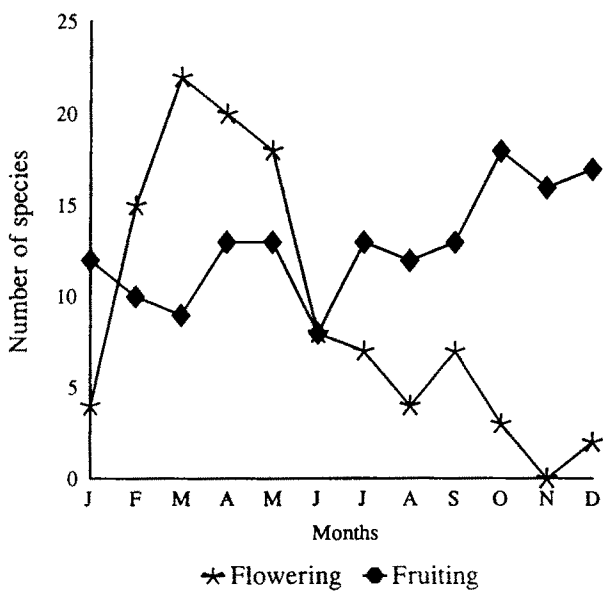


Figure 5. Vegetation profile of the dry deciduous forest



1. Bombax ceiba
2. Terminalia spp.
3. Dalbergia latifolia
4. Tectona grandis
5. Pterocarpus marsupium
6. Elaeodendron glaucum
7. Anogeissus latifolia
8. Bauhinia racemosa
9. Ziziphus xylopyrus
10. Phyllanthus emblica

Figure 6. Phenology of tree species in the dry deciduous forest



The selection of particular species was evidenced through the inspection of firewood bundles. 11 species were found in the wood-bundles (Table 6). Bundles of *Anogeissus latifolia, Acacia chundra, Erythroxylum monogynum*, and *Eucalyptus globulus* dominated (66%).

Table 6. Percentage of plant species found in wood bundles.

Plant species	%
Anogeissus latifolia	23
Acacia chundra	17
Erythroxylum monogynum	16
Eucalyptus globulus	10
Snags (*Anogeissus* sp)	8
Snags (unidentified)	8
Dalbergia latifolia	5
Diospyros montana	4
Acacia leucophloea	4
Pterocarpus marsupium	4
Phyllanthus emblica	1

The number of plant species exploited by the people varied between habitats (Table 7). It was more in the thorn forest than in the dry deciduous forest. In total, based on informal interview, inspection of wood bundles, and vegetation survey, 17 plant species were identified as extensively used by the local people for various purposes.

Table 7. Number and percentage of plant species with woodcutting signs observed in thorn and dry deciduous habitat.

Plant species	Thorn forest		Dry deciduous forest	
	No.	%	No.	%
Anogeissus latifolia	2	5.0	6	22
Anogeissus latifolia (snag)	1	2.5	2	8
Acacia catechu	10	25.0	4	15
Cassia fistula	1	2.5	-	-
Ziziphus xylopyrus	3	7.5	-	-
Chloroxylon swietenia	1	2.5	-	-
Randia dumetorum	1	2.5	3	11
Acacia chundra	3	7.5	-	-
Premna tomentosa	1	2.5	-	-
Tectona grandis	-	-	9	33
Tectona grandis (snag)	-	-	3	11
Stereospermum colais,	1	2.5	-	-
Eucalyptus globulus	10	25.0	-	-
Erythroxylum monogynum	6	15.0	-	-
Total	**40**		**27**	

4. DISCUSSION

4.1. Species richness, density, and diversity of plant species

Although the tree diversity was greater in the thorn forest, the density of trees in dry deciduous forest was considerably higher (Table 1-4). Both the availability of snags and its diversity were greater in dry deciduous than in thorn forest. The thorn forest was dominated by short and small trees whereas the dry deciduous forests had comparatively taller and broader trees. The greater abundance of *Eucalyptus* spp. in thorn forest can be attributed to the ca. 1.5 ha planted with *Eucalyptus* spp. in 1843 (Francis 1908). However, no mature *Eucalyptus* trees are available due to cutting at earlier stages and illegal felling. The difference in

the species diversity between habitats can be attributed to habitat heterogeneity and rainfall as suggested by Tilman and Pacala (1993) and Wright *et al.*, (1997) respectively. Habitat heterogeneity can result from disturbances, e.g. treefalls, or from underlying physical properties, e.g. moisture gradients, soil nutrient variation, topographic and soil nature.

4.2. Foliage height diversity.

The foliage height diversity was greater in the lower strata in the thorn forest while it was in the higher strata in dry deciduous forest. It can be attributed to the nature of trees (stunted or larger) available in the study area. As dominant tree species of thorn forest such as *Acacia chundra* and *Erythroxylum monogynum* are short and stumpy, foliage was greater mostly in the lower strata. Although another dominant species *Eucalyptus* spp is taller, the foliage of this species is not dense. In contrast, tree species of dry deciduous forest are dominated by the broader and taller trees, and therefore foliage is greater in the higher strata in the dry deciduous habitat. Foliage diversity was greater in the wet season than the dry season. Murali and Sukumar (1993) suggested that leaf flushing peaks are often associated with the dry season and high temperatures in Mudumalai Wildlife Sanctuary. Immediately after leafflushing monsoon starts and hence, the availability of foliage was greater in the wet season than the dry season in both the habitats.

4.3. Reproductive phenology of trees.

Reproductive phenology of trees differed considerably between habitats. Flowering starts earlier in the dry deciduous than in the thorn forest and this corroborates the findings of Murali and Sukumar (1994) who suggest that the differences in the phenological events may be due to competition and moisture stress. In both the habitats, there was some fruiting activity in some plant species throughout the year. In thorn forest, year-round fruiting pattern of *Ficus* sp makes them key resources, because frugivore community relies on fruiting figs for sustenance during lean fruiting periods. Borges (1993) found that fig fruit production peaked when other species experienced a trough in fruiting, and could therefore be considered a candidate for keystone species.

4. 4. Impact of human interference on plants.

Interviews with people suggested that plant species are largely preferred for firewood. Labour was one of the main occupations for 43% of the total families and 89% families had no regular income (Silori and Mishra 1995), wood becoming primary energy and income source for the local communities of this area. Silori and Mishra (1995) estimated that villagers removed 1,800 tones of fuelwood in their study period. But this level might have considerably increased with the increasing population. Apart from this, plant species were also cut for feeding the cattle but negligible as Silori and Mishra (1995) estimated that 98% of the cattle were left free inside the forest and 2% were stall-fed. Positive selection of particular species was confirmed through the inspection of fuelwood bundles. A total of 11 species was found in the woodbundles. The variation in the

number of plant species exploited by people between habitats can be attributed to the availability of the plant species. As the dry deciduous habitat is very close to forest check post and the thorn forest is situated in the middle of the several villages greater number of plants species were exploited from the thorn forest. In total, based on informal interview, inspection of wood bundles, and vegetation survey, 17 plant species were identified as used extensively by the local people for various purposes. Ramakrishnan and Sivaganesan (1997) recorded a minimum of seven to a maximum of 25 plant species being used by the people for various purposes in the eastern portion of the Nilgiri hills. The changes in the number can be attributed to the availability of preferred plant species in habitats. Similarity in the utilization of some plant species in both the areas (e.g., *Cassia fistula, Chloroxylon swietenia, Erythroxylum monogynum,* and *Randia dumetorum*) showed the importance of those species. Moreover, the people of these two areas are culturally more or less similar. The existing level of human pressure on plants affects the bird species largely by nest-plant reduction (see chapter V), and bird community through alteration of the foliage strata (see chapter IV).

5. SUMMARY

Vegetation in the thorn and dry deciduous forests was enumerated to discuss the following issues; 1. the density and diversity of plant species, 2. the foliage height diversity and 3. the reproductive phenology of tree species.

1. In thorn forest, three species, viz., *Acacia chundra, Erythroxylum monogynum,*

and *Eucalyptus globulus* were only abundant. In dry deciduous forest, *Anogeissus latifolia*, *Phyllanthus emblica,* and *Tectona grandis* were the dominant tree species. Although the tree diversity was greater in the thorn forest, almost there was a fourfold increase in tree density available in the dry deciduous as compared to the thorn forest. Both the availability of snags and its diversity were greater in dry deciduous than in thorn forest.

2. The Foliage density was greater in the lower strata in the thorn forest while it was in the higher strata in dry deciduous forest. Number of strata were more in the dry deciduous forest than in the thorn forest.

3. Flowering starts earlier in the dry deciduous forest than in the thorn forest. In both the habitats, at least one or two species would be either in flowering or fruiting in a month.

It can be speculated that the habitat heterogeneity and rainfall are the factors responsible for the changes in the vegetation physiognomy between habitats.

4. In addition, interviews with local people and field enumeration on wood-cutting were made to identify the impact of human populations on plant resources in the study areas. Seventeen plant species were used extensively by the local people. Number of plant species exploited by the people was more in the thorn forest than in the dry deciduous forest. Plant species are exploited largely for fuelwood purposes.

CHAPTER IV

BIRD COMMUNITIES

1. INTRODUCTION

In recent years many animal species throughout the world are threatened with extinction or are becoming increasingly endangered due to human-caused and other factors. As a result of natural and human-caused changes in the habitat, forecasting the effects of habitat degradation or impending global climate change on the dynamics of animal populations, community and biodiversity is of worldwide concern. Such studies are important because naturally occurring levels of biodiversity are critical to preserve, not only because of the potential economic or medical benefits yet to be uncovered, but also because maintaining biodiversity is synonymous with maintaining an intact ecosystem within which we too live (Soule and Wilcox, 1980; Wilson, 1985).

In most of the studies, the community has largely been expressed in terms of species richness, abundance, density and diversity. All these components have been used as an indicator of habitat quality, because an increase in the value of the components is generally thought to reflect larger amounts of the necessary resources to sustain larger population within a given area. Moreover, it is believed that if the factors determining the distribution of the animals are known, predictions can be made concerning the responses of animals to specific perturbations, and hence, such animals can be used to monitor environment quality.

In avian studies, an age-old pursuit of biologist has been to relate the above said components (eg., species abundance, diversity, richness etc.) with various vegetative features to identify the key factors responsible for the assemblage of birds in a given area. It was initiated by MacArthur and MacArthur (1961) who suggested that bird species diversity (BSD) is determined by foliage height diversity (FHD) and not by the number of tree species. Many studies support this finding (MacArthur *et al.*, 1962; MacArthur *et al.*, 1966; Recher, 1969; Cody, 1970; Erdelen, 1984; Verner and Larson, 1989) but however, a few studies in tropical forests could not find a positive relationship between BSD and FHD (Pearson, 1982; Wiens, 1983; Johnsingh and Joshua, 1994). Later, various aspects of vegetation structure other than FHD such as foliage volume (Karr and Roth, 1971), total crown volume (verner and Larson 1989), and percent vegetation cover (Karr, 1968; Karr and Roth, 1971) were found as influencing factors. In some cases, the species richness is said to be influenced by factors such as plant taxa (Holmes and Robinson, 1981), tree species richness (James and Wamer, 1982), and physiognomy and horizontal heterogeneity of vegetation (Roth, 1976). In general, food availability, vegetation complexity, and inter- and intra-specific competition have largely been accepted as major factors responsible for the assemblage of community though, it varies from habitat to habitat as biotic and abiotic factors vary.

Quantitative information on bird species abundance in different habitats is necessary for solving many fascinating ecological problems. Ali (1979) reports that the studies on the ecology as well as ethology of birds in different habitats would give valuable input for forest management. Several studies abroad

(Anderson, 1970; Beedy, 1981; Manuwal, 1983) and within India (Beehler *et al.*, 1987; Johnsingh *et al.*, 1987; Daniels, 1989; Katti, 1989; Rai, 1991; Jonsingh and Joshua, 1994) have identified the factors responsible for variations in avifauna between habitats

As the population studies has traditionally been used to monitor large-scale, long-term changes in avian population, and to assess both habitat quality and the responses of birds to both management practices and natural and human-caused environmental changes (Wiens, 1989), a study was designed:

1. to determine the structure of the bird community and its seasonal variations in the thorn and dry deciduous habitats
2. to find the relationship between FHD and BSD and
3. to compare the structure of bird community between the thorn and dry deciduous forests in Mudumalai Wildlife Sanctuary.

2. METHODS

2.1. Abundance and diversity of bird species

The diversity of bird species present in both the principal study habitats (thorn and dry deciduous) was estimated by using strip transect method (Conner and Dickson, 1980). All the birds seen or heard were counted within 25 m on either side of the 1 km transect. Swallows and swifts were excluded as they depend purely on air for their prey. Raptors were also excluded. The average time taken to complete the transect was 50 min. Census was done only in moderate weather condition within first four hours after sunrise during the dry (January to April) and wet (May to August) seasons in 1995 and 1996. Two transects were walked 6

times in each season. The average number of sightings were taken into account for calculating bird diversity.

2.2. statistical analysis

Diversity was calculated using Shannon-Weaver index $H' = \sum p_i \log p_i$ (Where H'= diversity and pi= the proportion of observation in subset i). Composition of feeding guilds were compared between habitats as well as seasons using G-tests (Sokal and Rohlf, 1981). Spearman's rank correlation was used to test whether there is any correlation between FHD and BSD.

3. RESULTS

3.1. Abundance and diversity of birds.

3.1.1. Thorn forest

3.1.1.1. Species richness, abundance and diversity (H')

A minimum of 219 (during wet season 1995) to a maximum of 319 (during dry 1996) individuals were recorded in thorn forest. Richness (number of species), abundance (number of individuals) and diversity of the avifauna in the thorn forest peaked in the dry season and was the least in the wet season during the study period (Fig. 1). Species richness showed a maximum value (56) in the dry season 1995 and a minimum value (37) in the wet season of 1996. Both the highest (3.74) and lowest (3.32) values of diversity of avifauna was during the dry and the wet seasons respectively of 1996.

3.1.1.2. Feeding guild composition.

The avifauna of thorn forest was dominated largely by the insectivore guild (50-60%) throughout the study period (Fig. 2). Frugivores were the second largest group. Composition of feeding guild showed some seasonal fluctuations in their abundance. But it significantly differed ($G=16.175$ $df=4$ $p<0.05$) between dry and wet season only in 1996, and not in 1995. Among the guilds (insectivores, frugivores, nectarivores, insect/frugivores, granivores and others), seasonal pattern was obvious in insectivorous, frugivorous, and granivorous birds. Insectivorous birds were abundant during the dry season and low during the wet season. In contrast, the frugivores were abundant during the wet season and low during the dry season. Granivores were abundant in the dry season. No distinct pattern was observed in the other guilds.

3.1.1.3. Abundance of hole-nesters and others.

Birds were classified into two types based on their nest types: hole-nesters and others. All nests (platform, cup, dome, and ground) except hole were grouped as others. All species of hole-nesters were resident and bred in the sanctuary but others included both migrant and resident species. Both categories of nesters were abundant during the dry season throughout the study period (Fig. 3). A maximum of 76 individuals of hole-nesters and 243 individuals of others were recorded in dry season 1996.

Figure 1. Species richness, abundance, and diversity of birds in thorn forest during 1995-1996

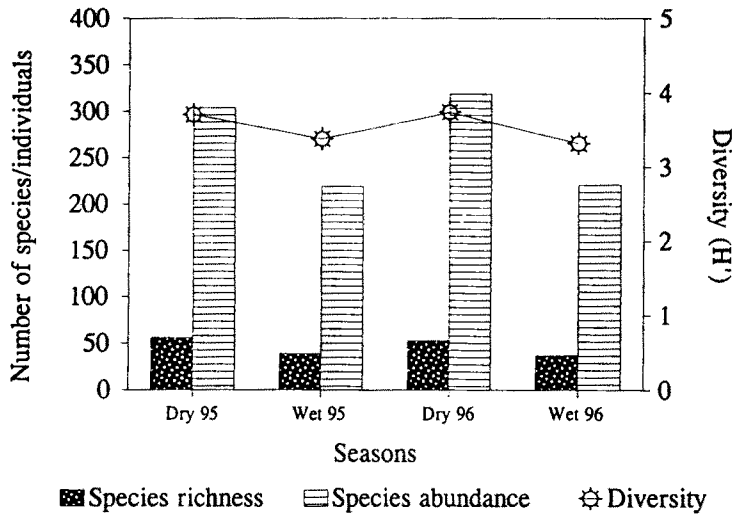
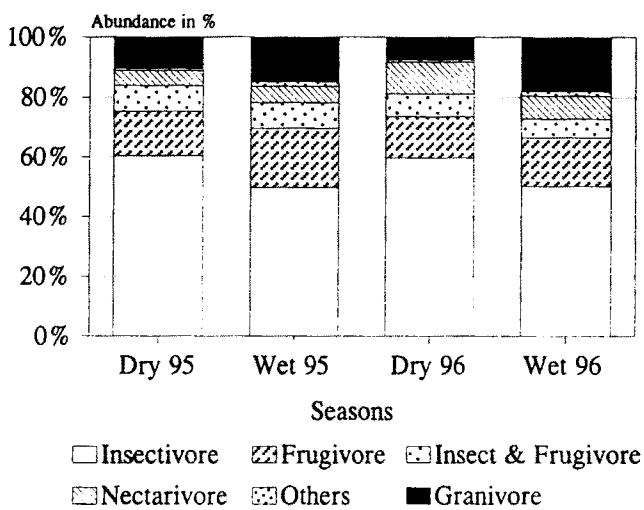


Figure 2. Guildwise abundance of birds in the thorn forest during 1995-1996



3.1.1.4. Relationship between foliage height diversity (FHD) and bird species diversity (BSD).

In order to find whether the BSD is influenced by FHD or not, foliage availability in different heights was collected and FHD was calculated only during the dry and wet seasons in 1996. No significant correlation was found between FHD and BSD (Fig. 4 & 5).

3.1.2. Dry deciduous forest.

3.1.2.1. Species richness, abundance and diversity (H')

A minimum of 210 (wet season 1995) to a maximum of 363 (dry 1996) individuals were recorded during the study period. Abundance (number of individuals) and diversity of the avifauna in the dry deciduous forest peaked in the dry season and these parameters reached the lowest values in the wet season during the study period (Figs. 6). Although species richness (44) was equal in wet and dry seasons during 1995, it peaked in the dry season in the subsequent year. Species richness reached a maximum value of 46 in dry 1996 and a minimum of 43 in wet season 1996. Both maximum (3.69) and minimum (3.43) value of diversity of avifauna were recorded in dry and wet season 1996 respectively.

3.1.2.2. Feeding guild composition.

The avifauna of the dry deciduous forest was dominated largely by the insectivore guild throughout the study period and was followed by the frugivores (Fig. 7). Seasonal pattern existed in insectivores and frugivores. Insectivores were abundant during the wet and low during the dry season. In contrast, the

Figure 3. Abundance of hole-nesters and others in the thorn forest during 1995-96.

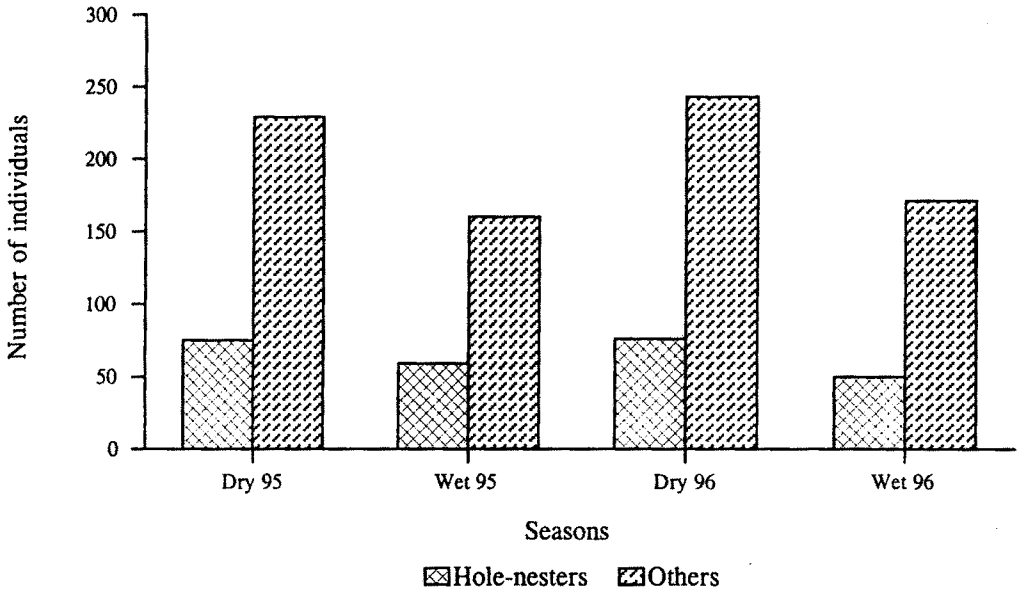


Figure 4. Relationship between bird species diversity and foliage height diversity during dry season 1996 in the thorn forest

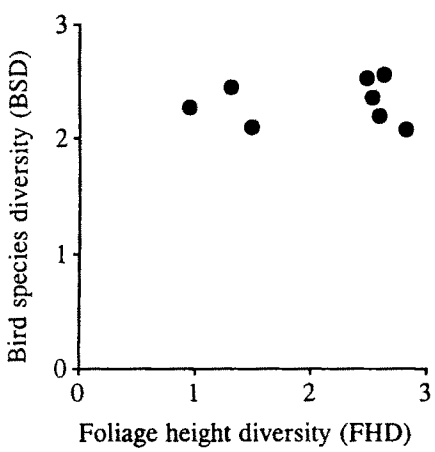
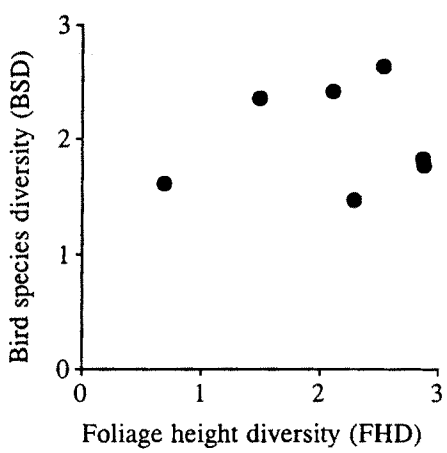


Figure 5. Relationship between bird species diversity and foliage height diversity during wet season 1996 in the thorn forest



frugivores were abundant during the dry, and at lower number in the wet season. No such distinct pattern was evident in the rest of the guilds. Feeding-guild composition differed significantly ($G=11.209$ $df=4$ $p<0.05$) between dry and wet seasons only in 1996 but not in 1995.

3.1.2.3. Abundance of hole-nesters and others.

The abundance of both the types of nesters was greater during the dry season (Fig. 8). A maximum of 125 individuals of hole-nesters were recorded in dry 1996 while a maximum of 244 individuals of others were recorded in dry 1995. Both of them showed similar seasonal pattern in their abundance.

3.1.2.3. Relationship between foliage height diversity (FHD) and bird species diversity (BSD).

A significant correlation ($r_s= -0.77$, $p=0.003$) existed between FHD and BSD in the dry but not in wet season of the year 1996 (Figs. 9 & 10).

3.2. Comparison of bird community between habitats

3.2.1. Species richness, abundance and diversity

The pattern in the species richness in the two habitats differed with greater fluctuations between seasons in the dry deciduous forest, especially in 1995 (Fig. 11). Abundance of birds was consistently more in the dry deciduous forest throughout the study period except the wet season of 1995. In dry season, species diversity was more in thorn forest than in dry deciduous forest (Figure 12) whereas during wet season it was more in dry deciduous forest.

Figure 6. Species richness, abundance, and diversity of birds in dry deciduous forest during 1995-96.

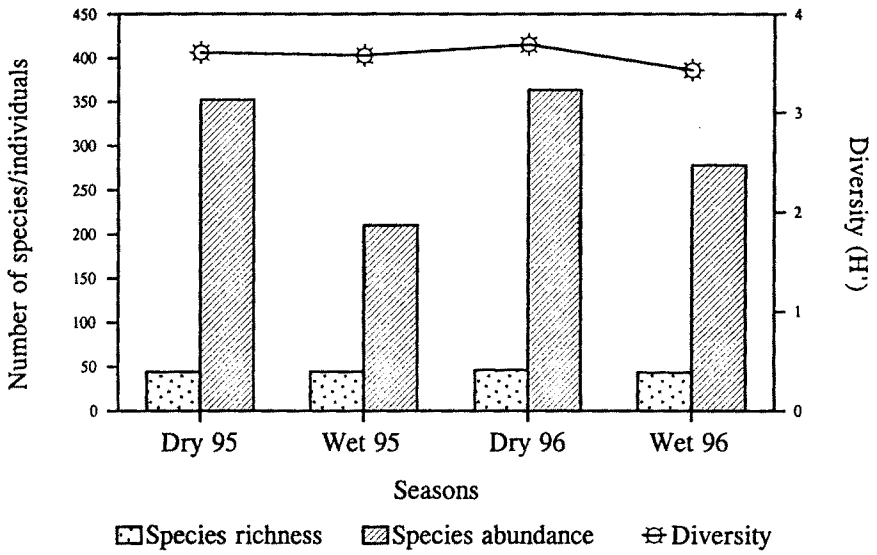


Figure 7. Guildwise abundance of birds in in dry deciduous forest during 1995-96

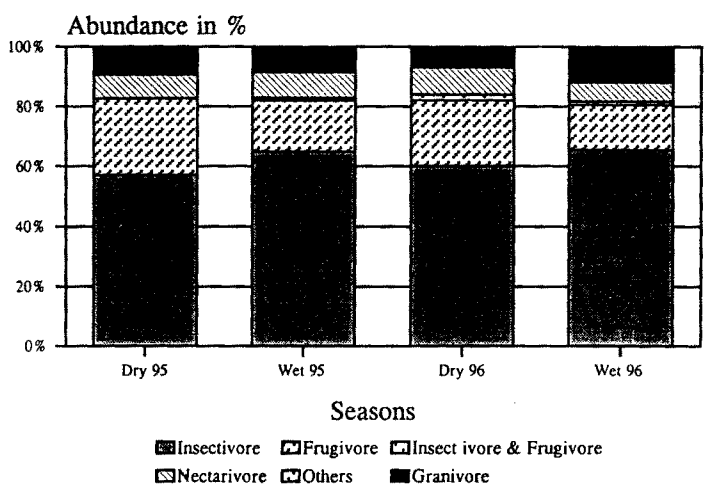


Figure 8. Abundance of hole-nesters and others in dry deciduous forest during 1995-96.

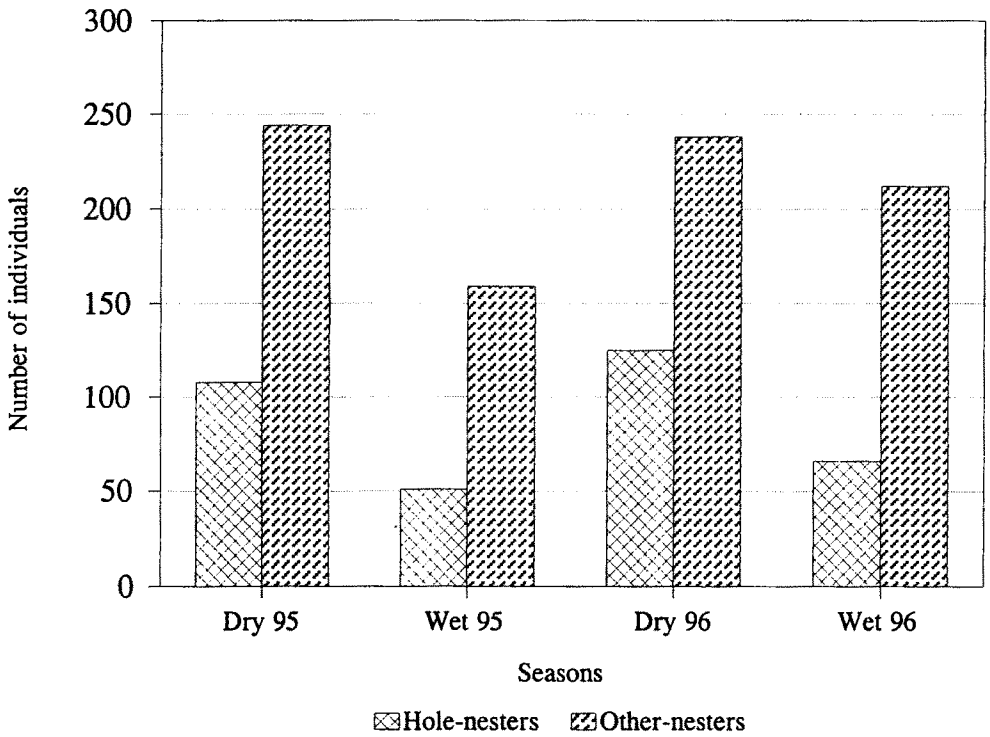


Figure 9. Relationship between bird species diversity and foliage height diversity in the dry deciduous forest during dry season 1996

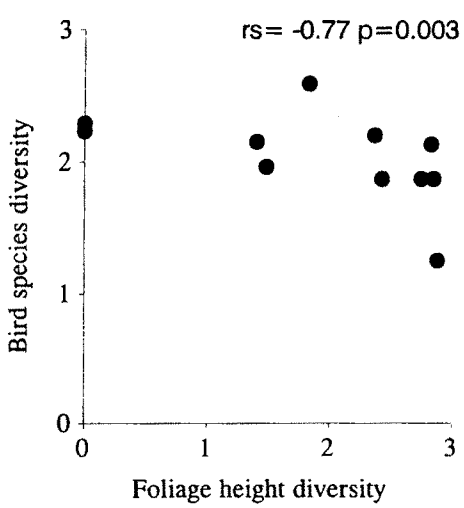


Figure 10. Relationship between bird species diversity and foliage height diversity in the dry deciduous forest during wet season 1996

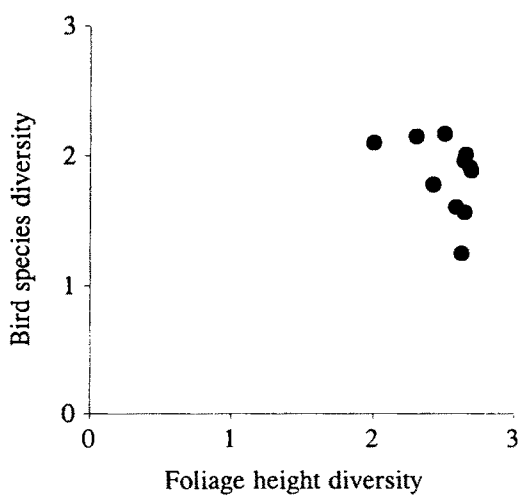
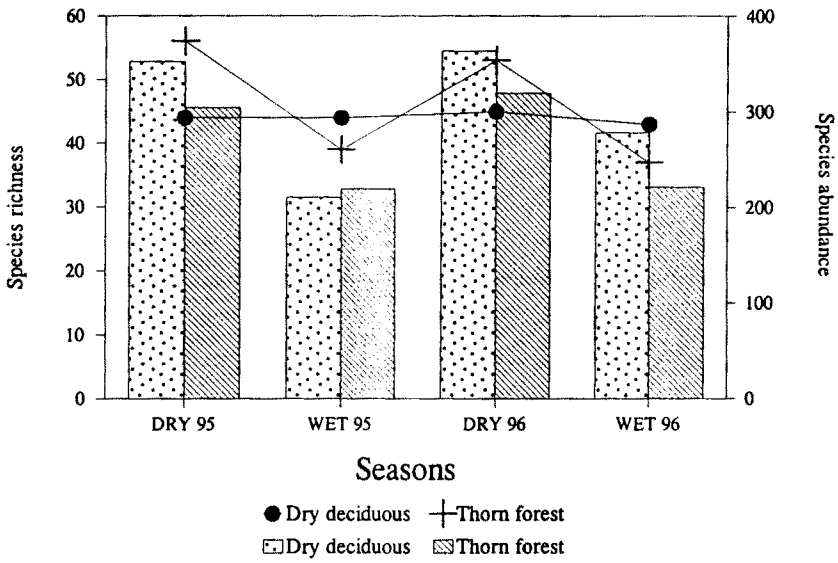
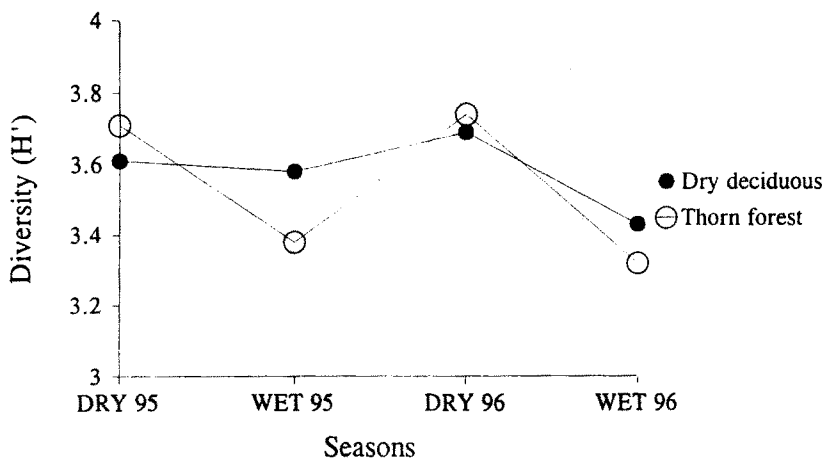


Figure 11. Bird species richness and abundance in various seasons during 1995-1996 in the thorn and dry deciduous forests



Line = species richness, Bar = Abundance of birds

Figure 12. Diversity of birds recorded in various seasons during 1995-1996 in the thorn and dry deciduous forest



3.2.2. Feeding guild composition

The composition of feeding-guild of avifauna of thorn and dry deciduous habitats is given in Table (1). The feeding guild composition significantly differed between thorn and dry deciduous forests in all the seasons (G=36.175 DF=5 P≤ O.OO5 for dry season 1995, G=18.717 DF=5 P≤ O.OO5 for wet season 1995, G=16.29 DF=5 P ≤ O.O1 for dry season 1996, G=17.085 DF=5 P ≤ O.OO5 for wet season 1996). The abundance of insectivore and frugivore of two habitats distinctly showed different trends. Insectivores were abundant during the dry season in the thorn forest and in the wet season in dry deciduous. Similarly frugivores were abundant during the wet season in thorn forest and in the dry season in the dry deciduous forest. Granivores were more in the thorn than in the dry deciduous forest in all the seasons.

3.2.3 Population of hole-nesters and others

The hole-nesters were more abundant in the dry deciduous habitat except in the wet season of 1995 (Fig 13). Similarly species richness was consistently higher in the dry deciduous habitat than in the thorn forest. The abundance of others did not show any clear seasonal pattern between habitats (Fig 14).

Figure 13. Abundance of hole-nesters in the thorn and dry deciduous forests during 1995-96.

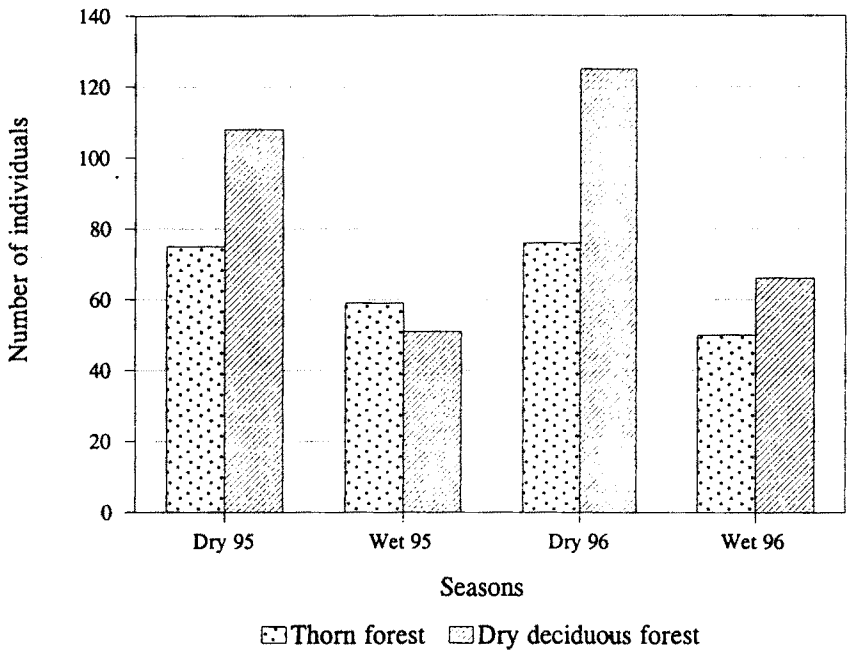


Figure 14. Abundance of other-nesters in the thorn and dry deciduous forests during 1995-96.

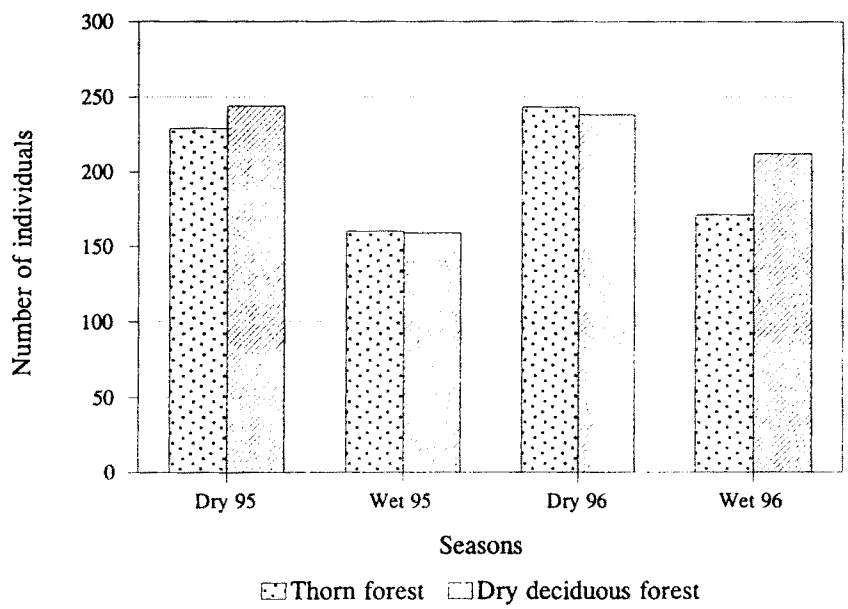


Table 1. Comparison of Feeding-guild composition of birds between habitats.

Feeding guilds	Dry season 1995		Wet season 1995		Dry season 1996		Wet season 1996	
	T	D	T	D	T	D	T	D
Frugivores	45	90	44	36	44	80	36	42
Insectivores	184	201	110	137	190	218	111	182
Insectivores/ Frugivores	26	0	19	2	24	7	14	3
Nectarivores	15	28	12	18	34	33	17	18
Omnivores	2	0	3	1	2	1	3	1
Granivores	32	33	33	17	24	24	40	32
Total	**304**	**352**	**221**	**211**	**319**	**364**	**221**	**278**

T= Thorn forest, D=Dry deciduous forest.

4.DISCUSSION

4.1. Abundance and diversity of birds in the thorn and dry deciduous forests.

Temporal and spatial variation in abundance are characteristic of most tropical avian communities (e.g., Karr, 1976a; Greenberg, 1981; Wong, 1986; Loiselle, 1988; Blake and Loiselle, 1991). The present result showed that population of avifauna considerably changes between seasons in both the habitats. Species richness, abundance and diversity of avifauna were more during the dry season (January to April) than during the wet season (May to August) throughout the study period in both the thorn and dry deciduous forests. Presence of migrants

is one of the major factors responsible for the higher diversity in the dry season. Abundance of more insectivores in the dry season is also because of the migrants many of which are insectivores. Although the arrival of migrants starts from September they stay till early April. Also the residents start breeding and the population is mostly equally distributed or stabilized resulting in higher diversity.

In general, the insectivores and frugivores were dominant in both the habitats, and showed distinct seasonal fluctuations in their abundance. Bird species that face seasonal irregularity in the availability of food resources have two alternatives: they may change to feeding on other resources or they may emigrate to another area where the original food is available (Karr, 1976b; Foster, 1977). As the population alone was considered, it was not clear whether any of the above said behavioural responses influence the feeding-guild composition in the community of this area.

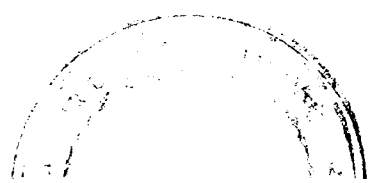
Although Murali and Sukumar (1994) found that the insects emerge in relation to rainfall and their abundance increases as the rainy season progresses in thorn and dry deciduous forest of Mudumalai Wildlife Sanctuary, in the present study, insectivores were abundant during the wet season only in the dry deciduous forest but not in the thorn forest. Of the two seasons selected, migrants were present only during the dry season. Among the migrants, the abundance of warblers were more in the thorn forest as they largely obtain their insect-food from shrubs and moreover, the availability of which was higher in the thorn forest. The greater availability of foraging substrate and less inter-specific competition on foraging substrate may influence the population of warblers which contributed to an increase in the overall insectivore population during dry season.

In dry deciduous forest, fruiting reached a peak during the late wet season, and extended into the early dry season. Fruiting however reached a peak during the early dry season in thorn forest. The abundance of frugivores of dry deciduous forest synchronized with the availability of fruits in that habitat. Frugivores were also abundant during wet season in thorn forest thereby showing no synchronization as a few *Ficus* species provided fruits during the wet season. No distinct pattern (seasonal fluctuations) was found in nectarivorous birds.

MacArthur and MacArthur (1961) suggested that bird species diversity is determined by foliage height diversity. As no relationship (-ve or +ve) between foliage height diversity and bird species diversity was consistent over seasons or years, it can be assumed that the bird species diversity is not influenced by foliage height diversity in Mudumalai Wildlife Sanctuary as found in other studies (Pearson, 1982; Wiens, 1983; Jonsingh and Joshua, 1994). Hence, bird species diversity may be influenced by patchiness as suggested by Wiens and Rottenberry (1981). The availability of microhabitats in the form of nullahs, small waterbodies (check-dams), dry stream beds, rocky areas, and open grass patches may influence the BSD of Mudumalai Wildlife Sanctuary. However, foliage diversity showed significant correlation with foraging aspects (see chapter VII) and thus it can not be ignored.

4.2. Comparison of bird community between habitats

The species richness and diversity showed distinct pattern between seasons and habitats. These parameters were more in the thorn forest during the dry season and in the dry deciduous forest in wet season . The dry season coincides with



the breeding season of most of the birds and presence of migrants in this sanctuary. The greater diversity of shrubs and trees in the thorn forest provide various nesting opportunities to the open-nesters which may explain the larger number of birds found nesting (see also chapter VI) and thus, thorn forest can be said to be more suitable for migrants and nesting birds. The dry deciduous forest seems to be good for resident birds during the non-breeding season as it provides various foraging opportunities as the availability of strata was more in the dry deciduous (see also chapter III & V).

Most studies have established the significant relationship between snag density and abundance of hole-nesters (e.g., Carey *et al.,* 1991; Schreiber and DeCalesta, 1992). As the availability of snags was greater in the dry deciduous than in the thorn forest, hole-nesters were more abundant in the dry deciduous forest. In contrast, the greater availability of open patches in thorn forest increased the number of granivores.

The species composition (guild structure) of avifauna of two habitats differed significantly throughout the study period. The distinct guild structure suggests that the resource utilization pattern of birds in two habitats is different as the availability of resources change between the habitats (see chapter III).

5. SUMMARY

Bird community structure of thorn and dry deciduous forests was studied in dry (January to April) and wet seasons (May to August) using strip transect method during 1995 and 1996. The following issues are discussed: 1. structure of the bird community and its seasonal variations, 2. relationship between foliage

height diversity and bird species diversity, and 3. comparison of the structure of bird community between habitats.

1. Species richness, abundance and diversity of avifauna were greater during the dry season in both the habitats. The presence of migrants and breeding season of many of the resident birds resulted in the higher diversity in the dry season. Insectivores and frugivores were the predominant groups in both the habitats. These groups showed distinct seasonal fluctuations in their abundance in both the habitats as the availability of their food resources fluctuate seasonally.

2. No relationship between foliage height diversity and bird species diversity was consistent. However, functional aspect of birds (foraging) showed significant positive correlation with FHD in both the habitats.

3. Comparison of bird community between habitats revealed that species richness and diversity were more in the thorn forest during dry season and in the dry deciduous forest during wet season.

CHAPTER V

FORAGING PATTERNS OF BIRDS

1. INTRODUCTION

Breaking down assemblages of species into feeding guilds (Root, 1967) or functional groups (Cummins, 1973) is one of the main techniques animal ecologists have developed to come to grips with community structure and dynamics. Guilds are groups of more than one species that seem to exploit the same kind of resources in similar ways. These guilds have been used extensively in analyses of many taxonomic groups and in many types of biomes, but ornithologists have been among the most active in interpreting assemblages of species in these terms (e.g., Emlen, 1977; Wiens and Rotenberry, 1979; Recher *et al.*, 1985; MacNally, 1994; Wheeler and Calver, 1996).

Such studies on feeding guilds have been greatly concerned with the problems of co-existence patterns of species through resource partitioning. At a finer level, studies on feeding guilds mainly considered the method of exploiting the resources, as birds often exhibit differences in how they exploit resources, especially in the insectivores such as hawking, gleaning, flycatching species. Some species, for instance, are generalists that will search for food at all heights and on a variety of substrates, while others show varying degrees of specialization. Species therefore differ in their response to changes in their habitat that may result from human activities. Logging, the establishment of plantations, an increased incidence of wildfire are examples of events initiated

by people which can change the vegetative structure and plant species composition of forests and thereby affect the survival of forest birds. Thus knowledge of key resources and how they are shared among members of the guild would give valuable inputs for the conservation management of species and habitats.

In feeding-guild studies, feeding patterns of birds have been found affected by various factors. Habitat structure affects the abundance, distribution, and perceptibility of prey, and also which search-and-attack methods birds employ to capture prey (Fitzpatrick, 1980; Robinson and Holmes, 1982; Holmes and Schultz, 1988). Aspects of habitat structure known to affect foraging of insectivorous forest birds include: plant species (Holmes and Robinson, 1981); substrate (Fitzpatric, 1980); and structural complexity of vegetation (Robinson and Holmes, 1984). VanderWerf (1994) found differences in the foraging behaviour between habitats which differed in degree of human modification.

As resources differ from habitat to habitat, insights into the effect of habitat structure on foraging patterns may be gained only by comparing the behaviour of a single or group of species in two habitats that differ in structure (Robinson and Holmes, 1982). But a few attempts have been made on comparison of foraging behaviour of birds between habitats (Szaro and Balda, 1979; Maurer and Whitemore, 1981; VanderWerf, 1994).

In India, such studies have been made on foraging of single species or a particular group or family (Vijayan, 1975; Khan, 1978; Yahya, 1980; Vijayan, 1984; Zacharias and Mathew, 1988; Vijayan, 1989; Thiyagesan, 1991; Santharam, 1995). In rest of the community studies (Beehler *et al.*, 1987;

Johnsingh *et al.*, 1987; Daniels, 1989; Sundramoorthy, 1991; Johnsingh and Joshua, 1994) the foraging of birds was discussed based on the information given by Ali and Ripley (1987). Community based studies in India have, to date, not considered how changes in the habitat types affect the foraging behaviour of birds occupying different habitats .

Understanding the effects of habitat structure on foraging is particularly useful in the conservation of species with restricted habitat or specialized habitat requirements and in making management decisions that will alter habitat structure. Moreover, a knowledge of the ways in which birds exploit resources within a forest will not only increase understanding of how they use their environment but also the essential requirements for their survival. This information, in turn, is required for the development of sound, scientifically based plans of management for national parks and sanctuaries.

This study examines the feeding behaviour of birds in the tropical thorn and dry deciduous forests in the Mudumalai WLS. The goals of the study were: (1) to identify the foraging pattern and microhabitat utilization of birds in the thorn and dry deciduous forests and (2) compare the foraging behaviour of birds in the two habitats.

2. METHODS

2.1 Foraging guild

Foraging records were collected at the study site during January to April (dry spell) in 1995 and 1996 as most of the birds start breeding during this period, demands for energy are greatest and birds spend most of their time in foraging.

Most records were collected within the first four hours after sunrise. For rarer species additional observations were made throughout the day. Only one foraging record (initial record) was taken from any individual encountered as done by Morrison (1984) and MacNally (1994).

For each foraging attempt microhabitat details such as the height above ground level, substrate, and species of plant the prey was on, and foraging method were recorded.

2.1.1. Foraging height

Foraging attempts were assigned to 12 height categories: 0 m (ground), and at every 1 metre interval up to 10, and >10m based on the general physiognomy of the vegetation.

2.1.2. Foraging substrate

A substrate is the material from which food is taken by birds. Substrate from which food items were taken were classified as (1) ground - including debris, litter and grass; (2) trunk/main branches - the main axes of trees; (3) foliage - leaves including leaf-blades and petioles; (4) twigs - small branches to which leaves were attached (5) flower/and fruits, and (6) air. Among these, the nectar/seed/fruit category represent the food taken by birds. As other five categories are meant purely for insectivorous birds, to separate the non-insect feeders (nectar/seed/fruit) from the insect feeders, the nectar/seed/fruit category was included as one substrate. The plant in which foraging attempts were made

was identified to species or genus or at least the life form of the plant (tree, shrub, etc.).

2.1.3. Foraging methods

Foraging methods of insectivorous birds were broadly categorized as follow: (1) glean : a stationary food item is picked from its substrate by a standing or hopping bird; (2) probe : as glean, only the bird's beak penetrates or lifts the substrate to locate concealed food; (3) pounce : a bird flies from a perch and grabs the food item as it lands on the substrate which is similar to flycatcher-gleaning explained by Croxall (1977); and (4) sally or flycatching : a bird fly into air to catch flying prey. To cluster or segregate the species on a micro level, the sally and glean were classified further into finer levels based on the vegetation. The method "sally" was further classified into four types and "gleaning" into five categories based on the location of the prey (Table 1). In order to separate the non-insect feeders from the insect feeders, methods were classified based on the food items (nectar/seed/ and fruit used) rather than method adopted. Moreover, the fruit/nectar classification was used to record all frugivores and nectarivores behaviour since the use of plants by omnivorous birds was only of relevance in comparison to their insectivorous behaviour (Wheeler and Calver, 1996). In total, 18 categories were used to collect information on foraging (Table 1) which encompasses the behaviours described by Crome (1978) and expanded by Holmes *et al.*, (1979) and MacNally (1994). Based on the 18 methods, major nine foraging guilds were determined (Table 2).

Table 1. Definition of foraging activities used to assess guild structure of avifauna

No	Activity (description)
1	Abovecanopy-sally (Sally to airborne insects in or above the main canopy)
2	Belowcanopy-sally (Sally from perched position to airborne insects below the main canopy)
3	Bush-sally (Sally to airborne insects from the bushes)
4	Ground-sally (sally to airborne insects from the ground)
5	Leaf-glean (Gleaning of perched prey from leaves of trees)
6	Twig-glean (Gleaning of perched prey from twigs of trees)
7	Wood-search (Gleaning of perched prey on trunks or main branches)
8	Wood-probing (Probing the bark)
9	Bark-tear (Searching for prey by tearing the bark)
10	Bush-gleaning (Gleaning of perched prey from bush)
11	Litter-search (Scratch and search through litter for insects)
12	Fallen-log-gleaning (Searching fallen logs)
13	Ground-pounce (Attack on grounded prey from perched position)
14	Ground-search (Searching ground for insects)
15	Arboreal-granivory (Consumption of seeds in trees)
16	Ground-granivory (Consumption of seeds in ground)
17	Fruit-exploiting (Consumption of fruits)
18	Flower-exploiting (Consumption of pollen and nectar or blossoms)

For the purposes of getting sufficient sample size, the information was pooled irrespective of years. Though it had bias towards year, it was nullified by considering the same season in different years. At least 30 foraging observations on each species (33 species in thorn, 30 in dry deciduous and overall 35 species) were allocated to the most appropriate clusters explained as foraging guilds in each habitat. As thirty independent observations are recommended to

represent the behaviour of a bird accurately (Morrison 1984), all species were used for analysis. Although 30 observations may seem small, numbers for majority of the species far exceeded this figure. The number of foraging records for different individuals observed depended on the density of each species.

Table 2. Major feeding guild and Predominant foraging activities of members of each guild based on species with >50 % observations.

Guild	Major activities
Sallier	Sally above and belowcanopy, Bush-sally, Ground-sally
Pouncer	Ground-pounce
Foliage-gleaner	Gleaning leaf and bush
Wood-gleaner	Gleaning twig, wood and log
Wood-prober	Probing and tearing wood
Ground-carnivore	Ground- and litter-search
Frugivore	Fruit-exploiting
Nectarivore	Flower-exploiting
Granivore	Arboreal- and ground-granivore

2.2 Statistical analyses

2.2.1 Specialist-Index *J'*

The foraging specialization of each bird category for each foraging dimension and forage height was analyzed using the Shannon-Weaver index (1949) $H' = \sum pi \ln pi$ (Where H'= diversity and pi= the proportion of observation in subset i). These values were then converted to a standardized range using the formula $J' = H'/H$ max (Where J'=specialization and H max= the H' value obtained when the observations are distributed equally across all subsets of the foraging

dimension) followed by Crome (1978) and Recher *et al.*, (1985). *J'* values range between one to zero, with foraging specialization increasing as *J'* falls.

2.2.2 Niche overlap

The degree of species overlap in niche utilization for the different categories recorded (i.e. foraging method, substrate and foraging height) has been quantitatively expressed using Horn's (1966) equation:

$$R_0 = \frac{\sum(x_i+y_i)\log(x_i+y_i) - \sum x_i \log x_i - \sum y_i \log y_i}{(X+Y)\log(X+Y) - X\log X - Y\log Y}$$

where X and Y are the total number of observations for species, for the particular category, and x_i and y_i are the number of occurrences made in the i'th subdivision within each category for X and Y, respectively.

2.2.3 Diversity

Diversity was calculated using Shannon-Weaver index $H' = \sum p_i \log p_i$ (Where H'= diversity and pi= the proportion of observation in subset i).

2.2.4 Cluster analysis

To compare foraging behaviour, substrate use, and height use between species, cluster analyses were performed on a data matrix (species * characteristics), following Holmes *et al.*, (1979). The variables were log

transformed ($log_{10}(x+1)$)to reduce the skewness. Since too many zero values were in the data set, all the values were added with one and log transformed. The analysis used the unweighted pair group clustering method with arithmetic averages (UPGMA) and Euclidian distance coefficients (Legendre and Legendre, 1983; and Rohlf, 1987).

2.2.5. Other tests

Based on the number of observations, a Chi square test (Sokal and Rohlf, 1981) was used to find whether the differences in foraging between habitats were significant. Number 5 was added to each datum in tests of significance to eliminate cell frequencies less than five. Foraging methods or heights used infrequently by species were combined into a single category, because they often resulted in cells which had expected value that were too less for the Chi Square test. Horn's (1966) index was used for the niche overlap.

Results are reported as significant if they are associated with probability value of <0.05. The SPSS software (Nouris 1990) was used for the data analyses.

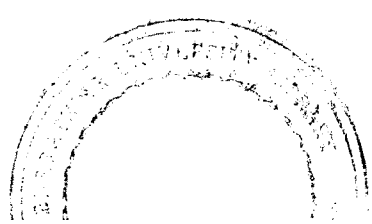
3. RESULTS

In the thorn and dry deciduous forests in Mudumalai Forest, observations were made on the foraging behaviour of only very common breeding and migrant species. A total of 2562 observations were made on 33 bird species in thorn forest and 30 species in dry deciduous forest with a total of 35 bird species (Table 3).

Table 3 . Number of foraging records made in thorn and dry deciduous habitats of Mudumalai Wildlife Sanctuary.

# of spp.	Species name	Number of observations		
		Thorn forest	Dry deciduous forest	Total
1	Grey Junglefowl	30	30	60
2	Spotted Dove	38	30	68
3	Lorikeet	32	39	71
4	Small Green Bee-eater	35	31	66
5	Hoopoe	34	37	71
6	Large Green Barbet	32	33	65
7	Yellownaped Woodpecker	33	35	68
8	Lesser Goldenbacked Woodpecker	34	35	69
9	Yellowfronted Pied Woodpecker	31	39	70
10	Heart-spotted Woodpecker	*	32	32
11	Indian Baybacked Shrike	37	30	67
12	Blackheaded Oriole	32	*	32
13	Whitebellied Drongo	32	36	68
14	Racket-Tailed Drongo	*	32	32
15	Brahminy Myna	44	44	88
16	Scarlet Minivet	36	40	76
17	Small Minivet	48	43	91
18	Whitebellied minivet	30	*	30
19	Common Iora	34	33	67
20	Redvented Bulbul	69	44	113
21	Yelloweyed Babbler	66	*	66
22	Whiteheaded Babbler	103	66	169
23	Whitebrowed Fantail Flycatcher	34	39	73
24	Paradise Flycatcher	33	32	65
25	Franklin's Wren-Warbler	64	62	126
26	Indian Tailor Bird	33	31	64
27	Blyth's Reed Warbler	36	30	66
28	Dull Green Leaf Warbler	46	45	91
29	Indian Robin	31	30	61
30	Grey Tit	43	*	43
31	Chestnutbellied Nuthatch	60	73	133
32	Nilgiri Flowerpecker	38	38	76
33	White-eye	58	43	101
34	Yellowthroated Sparrow	43	44	87
35	Common Rosefinch	37	*	37
	Total	**1386**	**1176**	**2562**

* = no records. Scientific names are given in the appendix I



3.1 Foraging patterns of bird species in the thorn forest

3.1.1. Foraging height

Nine height categories such as Ground, 0-1 m, 1-2 m, 2-3 m, 3-4 m, 4-5 m, 5-6 m, 6-7 m, and 7-8 m were utilized by 33 bird species observed in the thorn forest (Table 4). Although most species foraged over a broad range of heights, they were grouped according to the layer of vegetation in which the majority of their foraging was recorded.

Foliage was apportioned between 3 layers of strata: ground (0m), shrub/short trees (0-2m) and tree (>2m). For the avian community as a whole, a higher percentage of foraging manoeuvres were recorded in the tree layers (>2m). Ten species foraged mainly on or near the ground. Species like Indian Robin, Hoopoe, Grey Junglefowl, and Spotted Dove absolutely used the ground layer while others showed plasticity in their height preference. Among the bird species, diversity of usage of height classes was more in the Whitebrowed Fantail Flycatcher (1.60).

The 0-2m height (shrub/short tree layer) was utilized by seven species. Of the seven species, only warblers such as Franklin's Wren-Warbler and Blyth's Reed Warbler constantly used this layer while White-eye, Chestnutbellied Nuthatch and Redvented Bulbul showed variety in their height usage. Moreover, the warbler used only the shrubs for their prey. Diversity of usage of different height classes was found more in White-eye (1.74)

The tree layer (>2m) was used by 16 bird species. Within the tree layer, higher percentage of foraging manoeuvres were recorded only in 2-3m and 5-6m categories which can be considered as lower canopy and middle canopy

respectively. Only Lesser Goldenbacked Woodpecker showed higher diversity of height preference (1.63).

3.1.2 Foraging substrate

Six substrates namely air, ground, twigs, trunk/main branches, foliage, and nectar/seed/fruits were recognized in the thorn forest (Table 5).

Air: Five species, namely Paradise Flycatcher, Common Bee-eater, Whitebellied Drongo, Whitebrowed Fantail Flycatcher, and Scarlet Minivet fed predominantly from air (Table 5). No absolute usage (100%) of air as substrate was found in any one of the bird species.

Ground: Among the six substrates, ground was predominantly used by more number of birds (8) of which Grey Junglefowl, Indian Robin, Hoopoe, and Spotted Dove used only this substrate. while the Yellowthroated Sparrow and Tailor Bird used this substrate less frequently than the others. Both insectivores and granivores used this substrate.

Twigs: Only four species namely Dull Green Leaf Warbler, Yelloweyed Babbler, Whitebellied Minivet and Common Iora largely exploited their prey from twigs (Table 5). No absolute usage of this substrate by any one of the birds was found in this category. Foliage was used after twigs by all the species of this guild. The Common Iora used equally both twigs and foliage.

Trunk/Main branches: Chestnutbellied Nuthatch and Woodpeckers largely obtained their prey from the trunk/main branches (Table 5). In addition to this substrate, only Yellownaped Woodpecker utilized ground for their prey.

Foliage: Warblers namely Blyth's Reed Warbler and Franklin's Wren-Warbler exploited foliage absolutely (100%) while the other species

Table 4. Height distribution of birds in thorn forest (% of prey attacks)

Guild/Species name	Foraging heights(m)									
	G	1	2	3	4	5	6	7	8	H'
GROUND										
Indian Robin	100	-	-	-	-	-	-	-	-	0.00
Hoopoe	100	-	-	-	-	-	-	-	-	0.00
Grey Junglefowl	100	-	-	-	-	-	-	-	-	0.00
Spotted Dove	100	-	-	-	-	-	-	-	-	0.00
Whiteheaded Babbler	94	6	-	-	-	-	-	-	-	0.22
Yellowthroated Sparrow	74	-	5	12	9	-	-	-	-	0.84
Tailor Bird	58	6	33	3	-	-	-	-	-	0.96
Baybacked Shrike	56	4	33	7	-	-	-	-	-	1.01
Brahminy Myna	43	-	11	32	-	14	-	-	-	1.25
Whitebrowed Fantail Flycatcher	46	9	15	6	12	-	12	-	-	1.60
Shrub/short trees										
Franklin's Wren-Warbler	-	100	-	-	-	-	-	-	-	0.00
Blyth's Reed Warbler	3	97	-	-	-	-	-	-	-	0.13
Paradise Flycatcher	4	22	74	-	-	-	-	-	-	0.69
Yelloweyed Babbler	-	44	56	-	-	-	-	-	-	0.69
White-eye	-	7	29	26	5	10	5	-	18	1.74
Chestnutbellied Nuthatch	20	17	50	-	-	13	-	-	-	1.23
Redvented Bulbul	4	-	42	28	-	3	22	1	-	1.23
Tree										
Grey Tit	5	-	12	65	9	9	-	-	-	1.12
Whitebellied Drongo	9	-	27	59	5	-	-	-	-	1.02
Yellownaped Woodpecker	33	3	15	42	7	-	-	-	-	1.29
Lesser Goldenbacked Woodpecker	12	9	-	38	21	12	8	-	-	1.63
Small Minivet	-	-	6	35	19	25	15	-	-	1.49
Common Iora	-	-	18	35	32	9	6	-	-	1.42
Whitebellied Minivet	-	-	-	-	60	40	-	-	-	0.67
Nilgiri Flowerpecker	-	-	-	14	50	29	7	-	-	1.17
Yellowfronted Pied Woodpecker	-	-	23	35	42	-	-	-	-	1.07
Scarlet Minivet	-	-	-	11	36	17	25	11	-	1.50
Blackheaded Oriole	-	-	-	-	23	32	32	13	-	1.34
Rosefinch	-	-	-	-	-	-	100	-	-	0.00
Large Green Barbet	-	-	-	-	-	14	77	9	-	0.69
Small Green Bee-eater	20	-	14	14	-	14	38	-	-	1.52
Lorikeet	-	-	-	6	6	6	48	34	-	1.24
Dull Green Leaf Warbler	-	-	-	-	-	26	48	26	-	1.05
Total	**27**	**9.8**	**14.0**	**14.1**	**10.1**	**8.2**	**13.4**	**2.8**	**0.5**	

predominantly used foliage to obtain their prey (Table 5). The warblers used only foliage of shrubs while others used foliage of the trees.

Nectar/Seed/Fruit. Seven species formed this guild and of which Lorikeet, Nilgiri Flowerpecker and Rosefinch absolutely (100%) used this substrate (Table 5). Other four bird species also used this substrate predominantly.

3.1.3. Foraging methods

Based on the 18 foraging techniques employed by the birds, 9 major methods were possibly distinguished for the birds in the thorn forest. At least one bird species was found using predominantly any one of the nine major methods. The major prey attack manoeuvres used by birds in thorn forest were sallying, pouncing, foliage-gleaning, wood-gleaning, wood-probing, ground animal-exploiting (carnivore), nectar-exploiting, fruit-exploiting and grain- or seed-exploiting (Table 6).

Sallying: Five bird species were recognized as salliers (Table 6). No absolute use of this method was found in any one of the birds. Except Scarlet Minivet, pounce was used as next major manoeuvre by the members of this guild.

Pouncing: Only Baybacked Shrike and Indian Robin were recognized as pouncers in the thorn forest (Table 6). Ground-carnivory was the second dominant method used by the pouncers in the thorn forest.

Foliage-gleaning: Five bird species formed this guild. The warblers (Franklin's Wren-Warbler and Blyth's Reed Warbler) used fully this method

Table 5. Per cent use of substrate by birds in the thorn forest

Species	Air	Ground	Twigs	Trunk/ Main branches	Foliage	Nectar/ Seed/ Fruits
Air						
Paradise Flycatcher	96	4	-	-	-	-
Small Green Bee-eater	91	9	-	-	-	-
Whitebellied Drongo	91	9	-	-	-	-
Whitebrowed Fantail Flycatcher	88	9	-	-	3	-
Scarlet Minivet	61	-	-	-	39	-
Ground						
Grey Junglefowl	-	100	-	-	-	-
Indian Robin	-	100	-	-	-	-
Hoopoe	-	100	-	-	-	-
Spotted Dove	-	100	-	-	-	-
Whiteheaded Babbler	3	94	3	-	-	-
Baybacked Shrike	7	93	-	-	-	-
Yellowthroated Sparrow	-	74	-	-	-	26
Tailor Bird	-	60	13	-	27	-
Twigs						
Dull Green Leaf Warbler	-	-	83	-	17	-
Yelloweyed Babbler	-	-	74	-	26	-
Whitebellied Minivet	-	-	65	-	35	-
Common Iora	-	-	50	-	50	-
Trunk/Main branches						
Yellowfronted Pied Woodpecker	-	-	-	100	-	-
Lesser Goldenbacked	-	-	-	100	-	-
Woodpecker	-	-	-	100	-	-
Chestnutbellied Nuthatch	-	34	-	66	-	-
Yellownaped Woodpecker						
Foliage						
Blyth's Reed Warbler	-	3	-	-	97	-
Franklin's Wren-Warbler	-	-	-	-	100	-
Blackheaded Oriole	18	-	-	-	82	-
Grey Tit	-	2	14	26	58	-
Small Minivet	19	-	19	-	62	-
Nectar/seed/fruits						
Lorikeet	-	-	-	-	-	100
Nilgiri Flowerpecker	-	-	-	-	-	100
Rosefinch	-	-	-	-	-	100
Redvented Bulbul	-	4	-	-	-	96
White-eye	-	-	29	-	7	64
Large Green Barbet	-	-	-	-	41	59
Brahminy Myna	-	43	-	-	-	57

(100%) while the Grey Tit, Blackheaded Oriole, and Small Minivet used mainly this method along with sallying or wood-gleaning (Table 6).

Wood-gleaning. The number of bird species forming the wood-gleaning guild was more than the other groups. Woodpeckers, Dull Green Leaf Warbler, and Nuthatch were recognized as wood-gleaners. Only Chestnutbellied Nuthatch (100%) absolutely used this manoeuvre while woodpeckers used this method predominantly.

Wood-probing. Only the Lesser Goldenbacked Woodpecker frequently used this method along with wood-gleaning.

Ground carnivore. Hoopoe, Whiteheaded Babbler and Tailor Bird formed this guild, of which the Hoopoe absolutely used this method.

All the above mentioned methods are applied to get their invertebrate prey. In the case of nectar/seed/fruits as food the method applied is glean but it will overlap with insect gleaners. Hence, they are treated separately as nectar-exploiting, fruit-exploiting and seed-exploiting.

Nectar-exploiting: The Nilgiri Flowerpecker, Lorikeet and White-eye were the species coming under this group; the former two used only this method (100%) while the White-eye employed wood- and foliage-gleaning methods also.

Fruit-exploiting: Only 3 species formed this group of which only the Redvented Bulbul used mostly this method. Large Green Barbet and Brahminy Myna used this method less frequently. In addition to fruit-exploiting, the Barbet used foliage-glean (41%) while the Myna used seed-exploiting (43%).

Seed-exploiting: All the members in this group (Yellowthroated Sparrow, Spotted Dove, Rosefinch, Grey Jungle Fowl) used only this method. Among

these, the Spotted Dove and Jungle Fowl took their food only from the ground and the other two mostly from the tree.

The Common Iora, although basically a gleaner was found difficult to fit in any one of the nine groups as they used foliage-gleaning and wood-gleaning manoeuvres equally (50%).

3.1.4. Niche overlap

One way of measuring the extent to which feeding activities of the various species overlap, is to calculate the overlap values and this was done with respect to (a) foraging height (12 categories), (b) foraging manoeuvres (18 categories), and foraging substrate (6 categories). Overlap between species was calculated in each habitat and mean overlap of each species with others is presented in appendix (II).

The results suggest that all the bird categories in this study overlapped with others in at least one foraging dimension (Table 7). Among the three dimensions (foraging height, foraging method, and foraging substrate), highest mean overlap for the whole avian community was found in the height category (0.50) while lowest was in foraging method (0.32).

Foraging height: of the 33 species studied, Yellownaped woodpecker (0.62), Whitebrowed Fantail Flycatcher (0.66), Lesser Goldenbacked Woodpecker (0.62), Brahminy Myna (0.61) and Common Bee-eater (0.63) had highest niche overlap while Franklin's Wren Warbler (0.28) and Blyth's Reed Warbler (0.31) had the lowest niche overlap.

Table 6. Percent prey attack manoeuvres by birds in thorn forest

Species	Sallier	Pouncer	Foliage-gleaner	Wood-gleaner	Wood-prober	Ground-carnivore	N	F	G
Sallier									
Paradise Flycatcher	96	4	-	-	-	-	-	-	-
Whitebellied Drongo	91	9	-	-	-	-	-	-	-
Small Green Bee-eater	91	9	-	-	-	-	-	-	-
Whitebrowed Fantail Flycatcher	88	9	3	-	-	-	-	-	-
Scarlet Minivet	61	-	39	-	-	-	-	-	-
Pouncer									
Baybacked Shrike	7	82	-	-	-	11	-	-	-
Indian Robin	-	52	-	-	-	48	-	-	-
Foliage-gleaner									
Franklin's Wren-Warbler	-	-	100	-	-	-	-	-	-
Blyth's Reed Warbler	-	-	97	-	-	3	-	-	-
Blackheaded Oriole	18	-	82	-	-	-	-	-	-
Small Minivet	19	-	62	19	-	-	-	-	-
Grey Tit	-	-	58	40	-	2	-	-	-
Wood-gleaner									
Chestnutbellied Nuthatch	-	-	-	100	-	-	-	-	-
Dull Green Leaf Warbler	-	-	17	83	-	-	-	-	-
Yelloweyed Babbler	-	-	26	74	-	-	-	-	-
Yellowfronted Pied Woodpecker	-	-	-	68	32	-	-	-	-
Whitebellied Minivet	-	-	35	65	-	-	-	-	-
Yellownaped Woodpecker	-	-	-	36	30	34	-	-	-
Wood-prober									
L.Goldenbacked Woodpecker	-	-	-	8	92	-	-	-	-
Ground-carnivore									
Hoopoe	-	-	-	-	-	100	-	-	-
Whiteheaded Babbler	3	-	-	3	-	94	-	-	-
Tailor Bird	-	24	27	13	-	36	-	-	-
Nectarivore (N)									
Nilgiri Flowerpecker	-	-	-	-	-	-	100	-	-
Lorikeet	-	-	-	-	-	-	100	-	-
White-eye	-	-	7	29	-	-	64	-	-
Frugivore (F)									
Redvented Bulbul	-	-	-	-	-	4	3	93	-
Large Green Barbet	-	-	41	-	-	-	-	59	-
Brahminy Myna	-	-	-	-	-	-	-	57	43
Granivore (G)									
Yellowthroated Sparrow	-	-	-	-	-	-	-	-	100
Spotted Dove	-	-	-	-	-	-	-	-	100
Rosefinch	-	-	-	-	-	-	-	-	100
Grey Junglefowl	-	-	-	-	-	-	-	-	100
*** Common Iora**	-	-	50	50	-	-	-	-	-

N= Nectarivore, F= Frugivore, G=Granivore

Foraging method: The highest mean overlap was found in the following birds viz., Whitebellied Minivet (0.40), Small Minivet (0.43), Grey Tit (0.44) and Common Iora (O.41) while the lowest was in Rosefinch (0.23) and Paradise Flycatcher (0.24).

Foraging substrate: Tailor bird showed the highest niche overlap (0.49) while Yellowfronted Pied Woodpecker (0.21) and Chestnutbellied Nuthatch (0.21) were with lowest niche value.

Overall: On taking all the three dimensions together, the Small Minivet (0.5) and Tailor bird (0.5) showed the highest overlap while Franklin's Wren-Warbler (0.29), Rosefinch (0.28), and Blyth's Reed Warbler (0.27) showed low mean overlap.

3.1.5. Specialist index

Of the three dimensions, specialization was more in the substrates (12) followed by method (7) and height (6) categories (Table 8). Bird species such as Spotted Dove, Rosefinch, Hoopoe, Grey Jungle Fowl, and Franklin's Wren-Warbler can be considered as specialists as their J' value were 0 in all the three dimensions. Species such as Indian Robin, Nilgiri Flowerpecker can be considered as height and method specialist respectively.

3.1.6. Determination of foraging guilds

The relationships among the 33 bird species based on the substrates and foraging method, are summarized in the cluster diagram in the figure (1). The species were separated into a number of distinct groups whose members exploit

Table 7 . Mean niche overlap for each bird species in thorn forest (High values are in Bold type).

Species name	Niche overlap			
	Foraging Height	Foraging Method	Foraging substrate	Overall
Yellowthroated Sparrow	0.58	0.30	**0.43**	0.44
Yellownaped Woodpecker	**0.62**	0.34	0.35	0.44
Yelloweyed Babbler	0.41	0.39	0.34	0.38
Whiteheaded Babbler	0.47	0.26	0.40	0.38
White-eye	0.57	0.37	0.39	0.44
Whitebellied Minivet	0.39	0.40	0.35	0.38
Whitebrowed Fantail Flycatcher	**0.66**	0.35	0.34	0.45
Whitebellied Drongo	0.55	0.32	0.32	0.40
Tailor Bird	0.57	**0.41**	**0.49**	**0.49**
Spotted Dove	0.45	0.28	0.36	0.36
Small Minivet	0.57	**0.43**	**0.43**	**0.47**
Scarlet Minivet	0.53	0.39	0.38	0.43
Redvented Bulbul	0.58	0.28	0.32	0.39
Rosefinch	0.33	0.23	0.28	0.28
Paradise Flycatcher	0.45	0.24	0.29	0.32
Nilgiri Flowerpecker	0.49	0.27	0.28	0.35
Yellowfronted Pied Woodpecker	0.51	0.30	0.21	0.34
Large Green Barbet	0.41	0.36	0.40	0.39
Lorikeet	0.46	0.27	0.28	0.34
Lesser Goldenbacked Woodpecker	**0.62**	0.27	0.21	0.37
Indian Robin	0.45	0.31	0.36	0.37
Hoopoe	0.45	0.26	0.36	0.36
Grey Junglefowl	0.45	0.28	0.36	0.36
Grey Tit	0.55	**0.44**	**0.43**	**0.47**
Franklin's Wren-Warbler	0.28	0.25	0.33	0.29
Dull Green Leaf Warbler	0.41	0.38	0.32	0.37
Chestnutbellied Nuthatch	0.56	0.28	0.21	0.35
Common Iora	0.57	**0.41**	0.37	0.45
Small Green Bee-eater	**0.63**	0.30	0.32	0.42
Brahminy Myna	**0.61**	0.31	0.42	0.45
Blackheaded Oriole	0.47	0.38	0.38	0.41
Baybacked Shrike	0.58	0.31	0.39	0.43
Blyth's Reed Warbler	0.31	0.26	0.33	0.30
MEAN	**0.50**	**0.32**	**0.35**	**0.39**

Table 8 . Extent of specialization by birds in foraging method and foraging height as shown by J'values in thorn forest. J'values range from 0-1, and specialization increases as J' falls. (Specialists are in bold type).

Species name	Foraging Height		Foraging Method		Foraging substrate	
	H'	J'	H'	J'	H'	J'
Yellowthroated Sparrow	0.84	0.34	0.57	0.20	0.57	0.32
Yellownaped Woodpecker	1.29	0.52	1.10	0.38	0.63	0.35
Yelloweyed Babbler	0.69	0.28	0.57	0.20	0.57	0.32
whiteheaded Babbler	0.22	0.09	0.26	0.09	0.27	0.15
White-eye	1.74	0.70	0.83	0.29	0.83	0.46
Whitebellied Minivet	0.67	0.27	0.65	0.22	0.65	0.36
Whitebrowed Fantail Flycatcher	1.60	0.64	1.14	0.39	0.43	0.24
Whitebellied Drongo	1.02	0.41	0.69	0.24	0.30	0.17
Tailor Bird	0.96	0.38	1.32	0.46	0.91	0.51
Spotted Dove	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Small Minivet	1.49	0.60	0.92	0.32	0.93	0.52
Scarlet Minivet	1.50	0.60	1.05	0.36	0.67	0.37
Redvented Bulbul	1.35	0.54	0.31	0.11	0.17	0.09
Rosefinch	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Paradise Flycatcher	0.69	0.28	0.18	0.06	0.17	0.09
Nilgiri Flowerpecker	1.17	0.47	**0.00**	**0.00**	**0.00**	**0.00**
Yellowfronted Pied Woodpecker	1.07	0.43	0.63	0.22	**0.00**	**0.00**
Large Green Barbet	0.69	0.28	0.68	0.23	0.68	0.38
Lorikeet	1.24	0.50	**0.00**	**0.00**	**0.00**	**0.00**
Lesser Goldenbacked Woodpecker	1.63	0.65	0.29	0.10	**0.00**	**0.00**
Indian Robin	**0.00**	**0.00**	0.69	0.24	**0.00**	**0.00**
Hoopoe	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Grey Junglefowl	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Grey Tit	1.12	0.45	1.27	0.44	1.01	0.56
Franklin's Wren-Warbler	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Dull Green Leaf Warbler	1.05	0.42	0.46	0.16	0.46	0.25
Chestnutbellied Nuthatch	1.23	0.49	0.50	0.17	**0.00**	**0.00**
Common Iora	1.42	0.57	0.69	0.24	0.69	0.39
Small Green Bee-eater	1.52	0.61	0.91	0.31	0.30	0.17
Brahminy Myna	1.25	0.50	0.68	0.23	0.68	0.38
Blackheaded Oriole	1.34	0.54	0.47	0.16	0.47	0.26
Baybacked Shrike	1.01	0.40	0.59	0.20	0.25	0.14
Blyth's Reed Warbler	0.13	0.05	0.13	0.04	**0.00**	**0.00**
Number of specialists	**6**		**7**		**12**	

H' = Diversity index, J' = Specialist index

food resources in similar substrates, methods, and heights, and can thereby be considered guilds.

Starting from the top of figure (1), two distinct guilds were arbitrarily recognized from the cluster diagram as follows : Guild I contains birds that foraged extensively on or near ground. This was further divided into 3 guilds based on the foraging method: ground-granivore, ground- carnivore, and pouncers. Guild II consists of birds that predominantly obtained their prey from the air and plant species (tree/shrub). Within this guild, there were three major group of birds such as nectar/fruit/seed-exploiters, salliers, and gleaners. The group gleaners were further divided into 3 groups based on their use of substrate: wood-gleaners, bush-gleaners, and foliage-gleaners.

Based on the observational data, birds foraged in similar ways or height or substrate for food were grouped in a schematic way (Figure 2). The schematic portrayal of the groupings relies on foraging behaviour, foraging height, and foraging substrates differences to associate species. Among the 33 species, 23 were insectivores followed by nectar/fruit-eaters (6 species) and granivores (4 species). More number of species (3 of 4) in the granivore group largely obtained their food (seeds) from the ground while more number of species (18 of 23) in the insectivorous group largely obtained their insect prey from above ground level. Within the insectivores (aboveground group), the number of species obtained their prey from wood was more than those from the other substrates (foliage and air). Only two species of warblers used only foliage of shrubs for finding their prey.

Figure 1. Cluster dendrogram showing interspecific relationships of 33 bird species in the thorn forest, based on multivariate analyses of foraging method, foraging substrate and foraging height use.

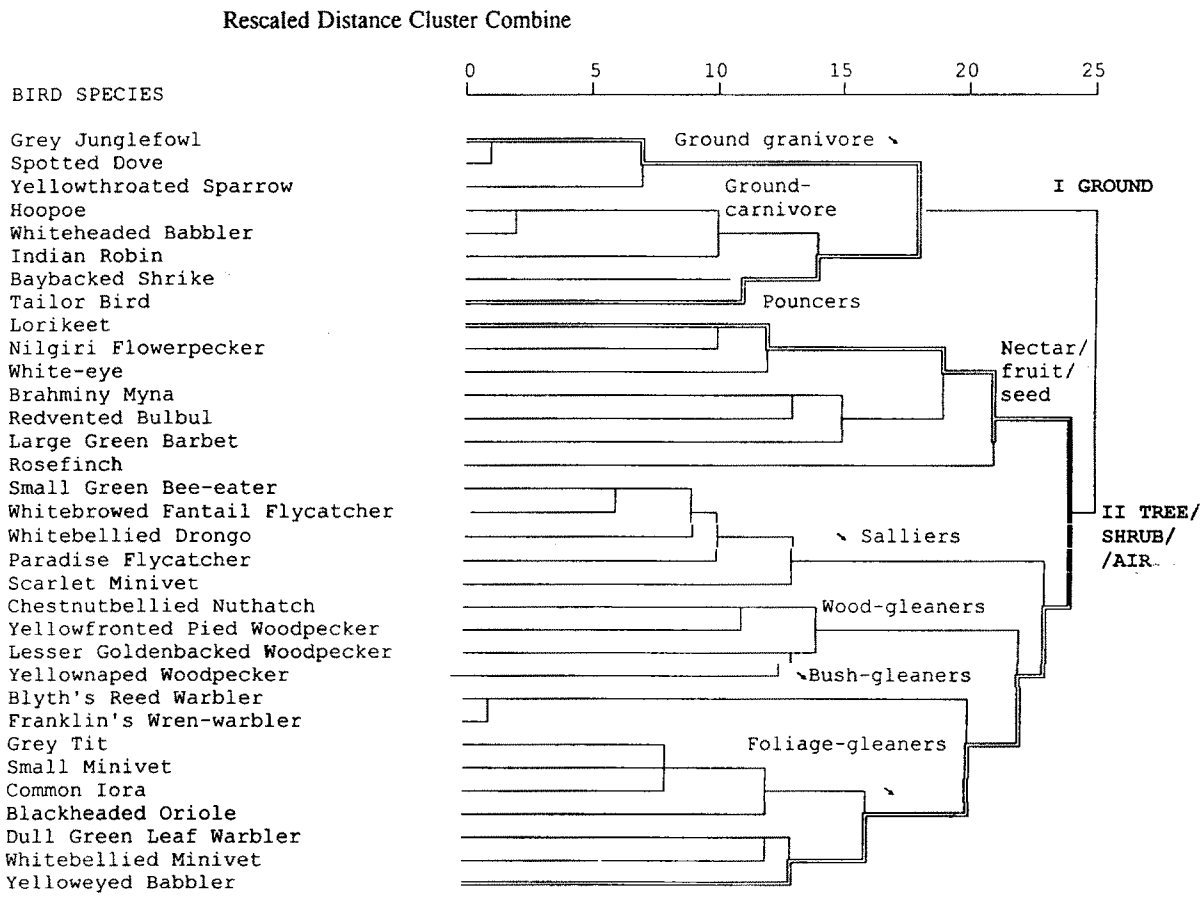
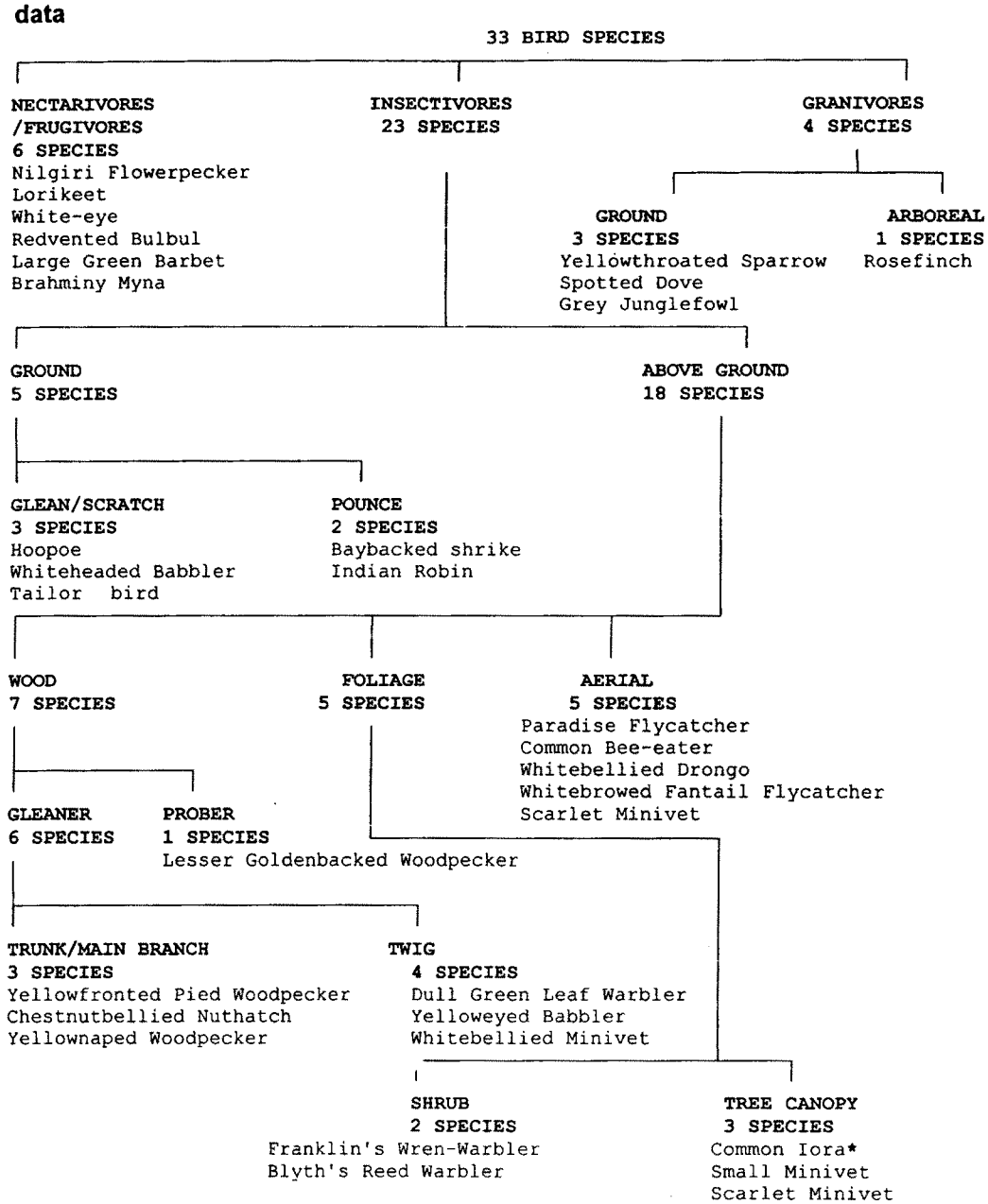


Figure 2. A hierarchial cluster of 33 bird species found in the thorn forest based on observational data



*= Common Iora can be included either in the twig or tree canopy category

3.2. Foraging patterns of bird species in the dry deciduous forest

3.2.1. Foraging height

All the 12 height categories such as ground, 0-1m, 1-2m, 2-3m, 3-4m, 4-5m, 5-6m, 6-7m, 7-8m, 8-9m, 9-10m, and >10m were utilized by 30 bird species in the dry deciduous forest (Table 9). Foliage was apportioned between 3 layers of strata: ground (0m), shrubs (0-2m) and trees (>2m). For the avian community as a whole, a higher percentage of foraging manoeuvres were recorded in different height categories on trees. After ground, layers such as 0-1m, 4-5m and 5-6m were utilized heavily by the birds.

Eight species foraged mainly on or near the ground. Among them, the Indian Robin, Hoopoe, Grey Jungle Fowl, and Spotted Dove absolutely used the ground layer while Yellowthroated Sparrow showed variety in their height preference

The 0-2m height (shrub layer) category was utilized by five species. Of the five species, warblers such as Franklin's Wren- Warbler and Blyth's Reed Warbler, and Paradise Flycatcher constantly used this layer while Tailor Bird, Nuthatch, and Redvented Bulbul showed diverse variety in the usage of height classes. Most of the foraging observations were on *Lantana camara* which dominated this layer.

The tree layer (>2m) was used by 17 bird species. Within the tree layer, percentage of foraging manoeuvres was more in the 4-6m category. A few species such as the Iora, Large Green Barbet, Racket-tailed Drongo, Dull Green Leaf warbler and the Lesser Goldenbacked Woodpecker preferred feeding from the upper strata (6-9m)

Table 9. Height distribution of birds in dry deciduous forest (% of prey attacks)

Bird species/guilds	Foraging heights (m)												
	G	1	2	3	4	5	6	7	8	9	10	>10	H'
Ground													0.0
Indian Robin	100	-	-	-	-	-	-	-	-	-	-	-	0.0
Hoopoe	100	-	-	-	-	-	-	-	-	-	-	-	0.0
Grey Junglefowl	100	-	-	-	-	-	-	-	-	-	-	-	0.0
Spotted Dove	100	-	-	-	-	-	-	-	-	-	-	-	0.0
Baybacked Shrike	97	-	3	-	-	-	-	-	-	-	-	-	0.14
Whiteheaded Babbler	97	-	-	-	3	-	-	-	-	-	-	-	0.13
Yellowthroated Sparrow	55	-	-	11	15	9	5	5	-	-	-	-	1.36
Brahminy Myna	44	20	36	-	-	-	-	-	-	-	-	-	1.05
Shrub/short trees													
Blyth's Reed Warbler	-	100	-	-	-	-	-	-	-	-	-	-	0.00
Franklin's Wren-Warbler	-	100	-	-	-	-	-	-	-	-	-	-	0.00
Redvented Bulbul	2	85	2	11	-	-	-	-	-	-	-	-	0.56
Paradise Flycatcher	-	-	100	-	-	-	-	-	-	-	-	-	0.00
Tailor Bird	24	-	32	10	14	10	-	10	-	-	-	-	1.66
Trees													
White-eye	-	7	12	12	47	15	7	-	-	-	-	-	1.52
Yellownaped Woodpecker	26	-	-	14	34	20	6	-	-	-	-	-	1.48
Whitebellied Drongo	-	-	-	-	38	54	8	-	-	-	-	-	0.90
Scarlet Minivet	-	-	-	-	-	50	25	25	-	-	-	-	1.04
Whitebrowed Fantail Flycatcher Small	10	14	3	10	7	38	14	-	4	-	-	-	1.80
Minivet	-	-	-	-	7	42	51	-	-	-	-	-	0.89
Small Green Bee-eater	-	-	-	-	-	-	74	7	-	13	6	-	1.23
Lorikeet	-	-	-	-	-	28	36	10	-	26	-	-	1.67
Chestnutbellied Nuthatch	-	-	-	-	4	22	37	37	-	-	-	-	1.20
Lesser Goldenbacked Woodpecker	-	-	-	12	4	-	20	64	-	-	-	-	0.99
Dull Green Leaf Warbler	-	-	-	-	-	-	38	40	22	-	-	-	1.17
Nilgiri Flowerpecker	-	-	-	-	-	-	-	-	68	14	11	7	0.46
Racket-tailed Drongo	-	-	-	-	-	-	9	28	38	25	-	-	1.29
Large Green Barbet	-	-	-	-	-	-	13	9	13	65	-	-	1.19
Common Iora	-	-	-	-	-	-	-	-	33	64	3	-	0.64
Yellowfronted Pied Woodpecker	-	-	-	7	14	7	21	14	10	-	7	20	2.00
Heart-spotted Woodpecker	-	-	-	-	-	-	-	13	19	30	-	38	1.31
Total	**24**	**13**	**6**	**3**	**6**	**10**	**13**	**9**	**6**	**7**	**1**	**2**	

3.2.2. Foraging substrate

Six substrates such as air, ground, twigs, trunk and main branches, foliage, and nectar/seed/fruit were recognized in the dry deciduous forest of which, ground was used by more number of bird species (8) and only one species used twigs (Table 10).

Air: Five species formed this guild and four of them obtained their prey absolutely from air. The Whitebrowed Fantail Flycatcher used ground also as substrate in addition to air.

Ground: The ground-foraging guild was with more species (8) than any other guild in the dry deciduous forest. Similar to air, majority of them (5) absolutely exploited the ground for the prey. Foliage, nectar/seed/fruit, trunk/main branches, and air were used very rarely (3.5%) as substrate by the other members of this guild.

Twigs: Dull Green Leaf Warbler alone formed this guild but, did not use this substrate absolutely.

Trunk/Main branches: All the four woodpeckers and nuthatch used this substrate. Absolute usage of this substrate was found in all except the Heart-spotted Woodpecker and Yellownaped Woodpecker.

Foliage: Five bird species formed this guild and of which Blyth's Reed Warbler and Franklin's Wren-Warbler consistently used this substrate. Twigs were the second dominant substrate used by the rest of the bird species of this guild.

Nectar/Seed/Fruit. Six bird species exploited this substrate predominantly. Lorikeet and Nilgiri Flowerpecker used only this category while

other species used other substrates also but less frequently along with these substrates.

3.2.3. Foraging methods

Only eight major techniques were possibly distinguished from the 18 classified foraging manoeuvres for 30 bird species in the dry deciduous forest. The major prey attack manoeuvres were sallying, pouncing, foliage-gleaning, wood-gleaning, ground animal-exploiting, nectar-exploiting, fruit-exploiting and seed-exploiting (Table 11).

Sallying: Five species such as Paradise Flycatcher, Whitebellied Drongo, Common Bee-eater, Racket-tailed Drongo and Whitebrowed Fantail Flycatcher used this method to obtain their prey. Except Whitebrowed Fantail Flycatcher, all other birds of this guild used only sally as prey attacking manoeuvre.

Pouncing: Three species such as Baybacked Shrike, Indian Robin, and Tailor Bird were recognized as pouncer; no absolute usage was found in any one of the birds.

Foliage-gleaning: Of the five foliage-gleaners, the warblers (Franklin's Wren-Warbler and Blyth's Reed Warbler) used only this method while others predominantly used this method. In addition to foliage-gleaning, both minivets used the sallying and wood-gleaning as other dominant method.

Wood-gleaning. Six species including woodpeckers, warbler, and nuthatch were recognized as wood-gleaners. The Chestnutbellied Nuthatch, Yellowfronted Pied Woodpecker, and Heart-spotted Woodpecker used only this manoeuvre while others used this method frequently.

Table 10. Per cent use of substrate by birds in dry deciduous forest

Species/guilds	Air	Ground	Twigs	Trunk/ Main branches	Foliage	Nectar/ Seed/ Fruits
Air						
Whitebellied Drongo	100	-	-	-	-	-
Racket-tailed Drongo	100	-	-	-	-	-
Small Green Bee-eater	100	-	-	-	-	-
Paradise Flycatcher	100	-	-	-	-	-
Whitebrowed Fantail Flycatcher	90	10	-	-	-	-
Ground						
Grey Junglefowl	-	100	-	-	-	-
Indian Robin	-	100	-	-	-	-
Hoopoe	-	100	-	-	-	-
Spotted Dove	-	100	-	-	-	-
Whiteheaded Babbler	-	100	-	-	-	-
Baybacked Shrike	3	94	-	3	-	-
Tailor Bird	-	90	-	-	10	-
Yellowthroated Sparrow	-	55	-	-	-	45
Twigs						
Dull Green Leaf Warbler	-	-	82	18	-	-
Trunk/Main branches						
Yellowfronted Pied Woodpecker	-	-	-	100	-	-
Lesser Goldenbacked Woodpecker	-	-	-	100	-	-
Chestnutbellied Nuthatch	-	-	-	100	-	-
Heart-spotted Woodpecker	-	-	6	94	-	-
Yellownaped Woodpecker	-	26	-	74	-	-
Foliage						
Blyth's Reed Warbler	-	-	-	-	100	-
Franklin's Wren-Warbler	-	-	-	-	100	-
Common Iora	-	-	30	-	70	-
Scarlet Minivet	22	-	20	-	58	-
Small Minivet	21	-	30	-	49	-
Nectar/seed/fruits						
Nilgiri Flowerpecker	-	-	-	-	-	100
Lorikeet	-	-	-	-	-	100
Redvented Bulbul	-	2	-	-	-	98
Large Green Barbet	-	-	-	-	4	96
Brahminy Myna	-	43	-	-	-	57
White-eye	-	-	30	-	23	47

Ground animal-exploiting. Hoopoe, Whiteheaded Babbler and Grey Junglefowl formed this guild and of which the Hoopoe and Babbler used only this method (100%) to get their prey from ground.

Nectar-exploiting: In total, five species exploited the nectar. The Nilgiri Flowerpecker, Lorikeet and Large Green Barbet used only this method frequently while others used this method predominantly.

Fruit-exploiting: Only Redvented Bulbul frequently used this method along with flower-exploiting and ground-granivory.

Seed-exploiting: Seeds were exploited by only two bird species such as Yellowthroated Sparrow and Spotted Dove. Both of them took seeds only from the ground.

3.2.4. Foraging overlap

Mean niche overlap of each species in each dimensions as well as together is given in table (12). The overlap between species is given in Appendix (II). Among the dimensions (foraging height, foraging method, foraging substrate), the highest mean overlap among species was found in vertical strata or height (0.41) and the lowest in method (0.31).

Height: Of the 30 species studied, Whitebrowed Fantail Flycatcher and Yellowthroated Sparrow had the highest niche overlap (0.54) while lowest (0.24) was found in Paradise Flycatcher.

Method: The mean overlap in feeding method was the highest in White-eye (0.39) while the lowest was found in Paradise Flycatcher (0.23).

Table 11. Per cent prey attack manoeuvres by birds in dry deciduous forest

Species/guilds	Sallier	Pouncer	Foliage-gleaner	Wood-gleaner	Wood-prober	Ground-carnivore	N	F	G
Sallier									
Paradise Flycatcher	100	-	-	-	-	-	-	-	-
Whitebellied Drongo	100	-	-	-	-	-	-	-	-
Small Green Bee-eater	100	-	-	-	-	-	-	-	-
Racket-tailed Drongo	100	-	-	-	-	-	-	-	-
Whitebrowed Fantail Flycatcher	90	10	-	-	-	-	-	-	-
Pouncer									
Indian Robin	-	97	-	-	-	3	-	-	-
Baybacked Shrike	3	94	-	3	-	-	-	-	-
Tailor Bird	-	52	10	-	-	38	-	-	-
Foliage gleaner									
Franklin's Wren-Warbler	-	-	100	-	-	-	-	-	-
Blyth's Reed Warbler	-	-	100	-	-	-	-	-	-
Common Iora	-	-	70	30	-	-	-	-	-
Scarlet Minivet	22	-	58	20	-	-	-	-	-
Small Minivet	21	-	49	30	-	-	-	-	-
Wood gleaner									
Chestnutbellied Nuthatch	-	-	-	100	-	-	-	-	-
Yellowfronted Pied Woodpecker	-	-	-	100	-	-	-	-	-
Heart-spotted Woodpecker	-	-	-	100	-	-	-	-	-
Dull Green Leaf Warbler	-	-	18	82	-	-	-	-	-
L.Goldenbacked Woodpecker	-	-	-	60	40	-	-	-	-
Yellownaped Woodpecker	-	-	-	54	20	26	-	-	-
Ground carnivore									
Hoopoe	-	-	-	-	-	100	-	-	-
Whiteheaded Babbler	-	-	-	-	-	100	-	-	-
Grey Junglefowl	-	-	-	-	-	86	-	-	14
Nectarivore (N)									
Nilgiri Flowerpecker	-	-	-	-	-	-	100	-	-
Lorikeet	-	-	-	-	-	-	100	-	-
Large Green Barbet	-	-	4	-	-	-	96	-	-
Brahminy Myna	-	-	-	-	-	43	57	-	-
White-eye	-	-	23	30	-	-	47	-	-
Frugivore (F)									
Redvented Bulbul	-	-	-	-	-	3	11	86	-
Granivore (G)									
Yellowthroated Sparrow	-	-	-	-	-	-	-	-	100
Spotted Dove	-	-	-	-	-	10		-	90

N= Nectarivore, F= Frugivore, G= Granivore

Substrate: The highest mean overlap was found in Yellowthroated Sparrow (0.43) while the lowest was found in warblers, namely Blyth's Reed Warbler (0.24) and Franklin's Wren- Warbler (0.24).

Overall: All the dimensions together when combined, Paradise Flycatcher, Blyth's Reed Warbler and Franklin's Wren-Warbler showed the lowest mean overlap (0.25) while Tailor Bird (0.42) showed the highest overlap with 29 species.

3.2.5. Specialist index

Among the three dimensions, number of specialists (J'= 0) was more in the substrate (16) followed by method (8) and feeding strata or height (7) dimensions (Table 13).

Hoopoe, Blyth's Reed Warbler, Franklin's Wren-Warbler, and Paradise Flycatcher are specialists as their J' value is '0' in all the dimensions.

3.2.6. Determination of foraging guilds

The relationships among the 30 bird species based on the use of substrates, method, and vertical strata (height) as a multidimensional analysis are summarized in the cluster diagram in the figure (3). The species were separated into a number of distinct groups whose members exploit food resources from similar substrates and/or heights using similar methods, and can thereby be considered as guilds. Starting from the top of figure (1), and basing the substrate and method use by birds, the guilds were characterized as follows: **Guild I** comprised birds that glean their prey on the foliage of shrubs. The Blyth's

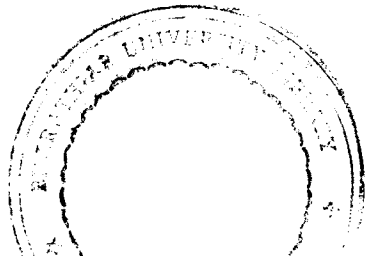
Table 12 . Mean niche overlap for each bird species in dry deciduous forest (high values are in Bold type)

Species name	Niche dimensions			
	Foraging Height	Foraging Method	Foraging substrate	Overall
Yellowthroated Sparrow	**0.54**	0.27	**0.43**	**0.41**
Heart-spotted Woodpecker	0.37	0.33	0.27	0.33
Tailor Bird	**0.51**	0.34	0.40	**0.42**
Indian Robin	0.41	0.28	0.36	0.35
Blyth's Reed Warbler	0.27	0.24	0.24	0.25
Baybacked Shrike	0.42	0.29	**0.41**	0.37
Racket-tailed Drongo	0.43	0.31	0.27	0.34
Brahminy Myna	0.44	0.35	**0.42**	0.40
Small Green Bee-eater	0.41	0.27	0.27	0.32
Large Green Barbet	0.41	0.33	0.30	0.35
Chestnutbellied Nuthatch	0.47	0.31	0.25	0.34
Hoopoe	0.41	0.24	0.36	0.34
Common Iora	0.33	0.33	0.29	0.32
Dull Green Leaf Warbler	0.43	0.31	0.25	0.33
Franklin's Wren-Warbler	0.27	0.24	0.24	0.25
Grey Junglefowl	0.41	0.29	0.36	0.35
Lesser Goldenbacked Woodpecker	0.41	0.32	0.25	0.33
Spotted Dove	0.41	0.29	0.36	0.35
Yellownaped Woodpecker	**0.51**	0.35	0.37	**0.41**
Whiteheaded Babbler	0.42	0.28	0.36	0.36
White-eye	0.45	**0.39**	0.36	0.40
Whitebrowed Fantail Flycatcher	**0.54**	0.33	0.34	0.40
Whitebellied Drongo	0.40	0.31	0.27	0.33
Small Minivet	0.43	0.37	0.35	0.38
Scarlet Minivet	0.44	0.37	0.35	0.39
Redvented Bulbul	0.33	0.27	0.30	0.30
Paradise Flycatcher	0.24	0.23	0.27	0.25
Nilgiri Flowerpecker	0.33	0.32	0.27	0.31
Yellowfronted Pied Woodpecker	**0.50**	0.31	0.25	0.35
Lorikeet	0.48	0.32	0.27	0.35
Mean	**0.41**	**0.31**	**0.32**	**0.35**

Table 13 . Extent of specialization by birds in foraging method and foraging height as shown by J'values in dry deciduous forest. J'values range from 0-1, and specialization increases as J' falls. (Specialists are in bold type)

Species name	Foraging Height		Foraging Method		Foraging substrate	
	H'	J'	H'	J'	H'	J'
Yellowthroated sparrow	1.36	0.55	0.69	0.24	0.69	0.38
Heart-spotted Woodpecker	1.31	0.53	0.23	0.08	0.23	0.13
Tailor Bird	1.66	0.67	0.93	0.32	0.31	0.18
Indian Robin	**0.00**	**0.00**	0.14	0.05	**0.00**	**0.00**
Blyth's Reed Warbler	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Baybacked Shrike	0.14	0.06	0.29	0.10	0.30	0.17
Racket-tailed Drongo	1.29	0.52	0.44	0.15	0.00	0.00
Brahminy Myna	1.05	0.42	0.68	0.24	0.68	0.38
Small Green Bee-eater	1.25	0.50	0.24	0.08	**0.00**	**0.00**
Large Green Barbet	1.19	0.48	0.18	0.06	0.17	0.09
Chestnutbellied Nuthatch	1.20	0.48	**0.00**	**0.00**	**0.00**	**0.00**
Hoopoe	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Common Iora	0.64	0.26	0.61	0.21	0.61	0.34
Dull Green Leaf Warbler	1.17	0.47	0.47	0.16	0.47	0.26
Franklin's Wren-Warbler	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Grey Junglefowl	**0.00**	**0.00**	0.40	0.14	**0.00**	**0.00**
Lesser Goldenbacked Woodpecker	0.99	0.40	0.67	0.23	**0.00**	**0.00**
Spotted Dove	**0.00**	**0.00**	0.33	0.11	**0.00**	**0.00**
Yellownaped Woodpecker	1.48	0.60	1.00	0.35	0.57	0.32
Whiteheaded Babbler	0.13	0.05	0.27	0.09	**0.00**	**0.00**
White-eye	1.52	0.61	1.05	0.36	1.05	0.59
Whitebrowed Fantail Flycatcher	1.80	0.72	0.95	0.33	0.33	0.18
Whitebellied Drongo	0.90	0.36	0.49	0.17	**0.00**	**0.00**
Small Minivet	0.89	0.36	1.04	0.36	1.04	0.58
Scarlet Minivet	1.04	0.42	1.10	0.38	0.98	0.55
Redvented Bulbul	0.56	0.23	0.46	0.16	0.10	0.05
Paradise Flycatcher	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Nilgiri Flowerpecker	0.46	0.18	**0.00**	**0.00**	**0.00**	**0.00**
Yellowfronted Pied Woodpecker	2.00	0.81	**0.00**	**0.00**	**0.00**	**0.00**
Lorikeet	1.67	0.67	**0.00**	**0.00**	**0.00**	**0.00**
Number of specialists	**7**		**8**		**16**	

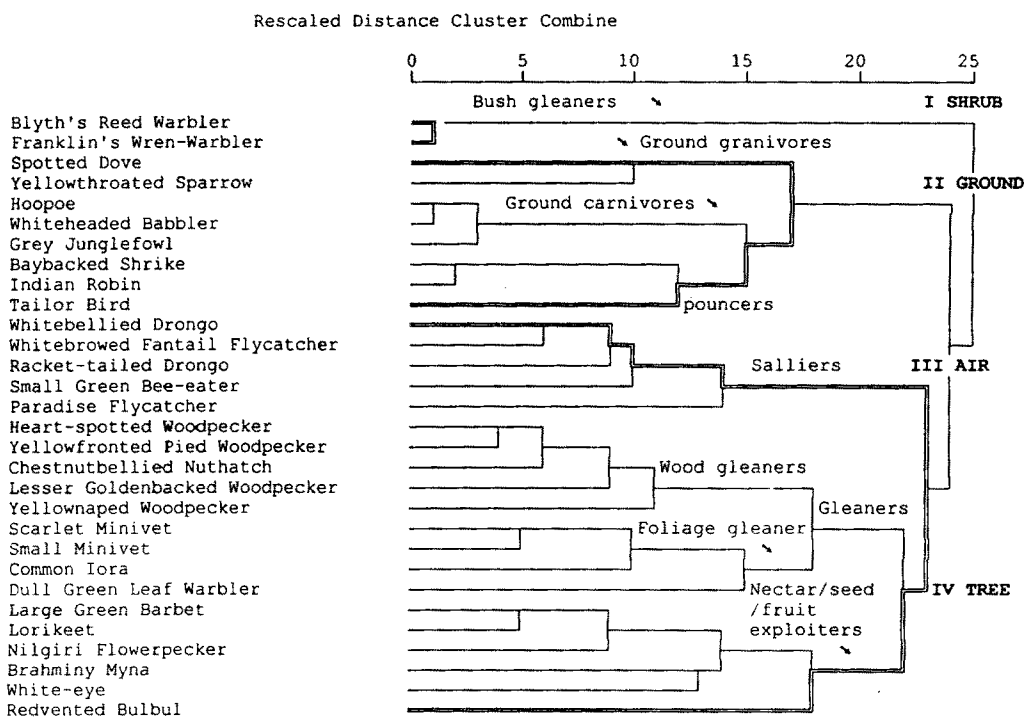
H' Diversity index, J' Specialist index



Reed Warbler and Franklin's Wren-Warbler. The **guild II** consisted of eight species that largely obtained their food such as insects or seeds from the ground. Within the guild, the spotted Dove and Yellowthroated Sparrow mainly fed on seed or grains from the ground. The Hoopoe, Whiteheaded Babbler, and Grey Jungle Fowl predominantly fed on invertebrates from the ground by gleaning the ground or litter while the Indian Robin, Baybacked Shrike, and Tailor bird obtained their insect prey by pouncing. Among these three, ground carnivore and pouncer had closer relationship with each other and these two joined with the ground granivore. **Guild III & IV** comprised 20 bird species that extensively obtained their prey either from the tree or at tree height (air). Within the guild, there were three major groups differed by the use of foraging method: salliers, gleaners and nectar/seed/fruit-exploiters. The group sallier comprised 5 species which predominantly obtained their prey from air. The gleaners can be further divided into two subgroups based on the use of substrates: wood-gleaners and foliage-gleaners. The nectar/seed/fruit-exploiters consist of 6 species which predominantly fed from flowers or on fruits. Among the three major groups in the guild III, gleaners and nectar/seed/fruits-exploiters showed highest similarity and these two together showed similarity with the salliers. Of the three recognized guilds, the second and third guilds showed closest similarity with each other.

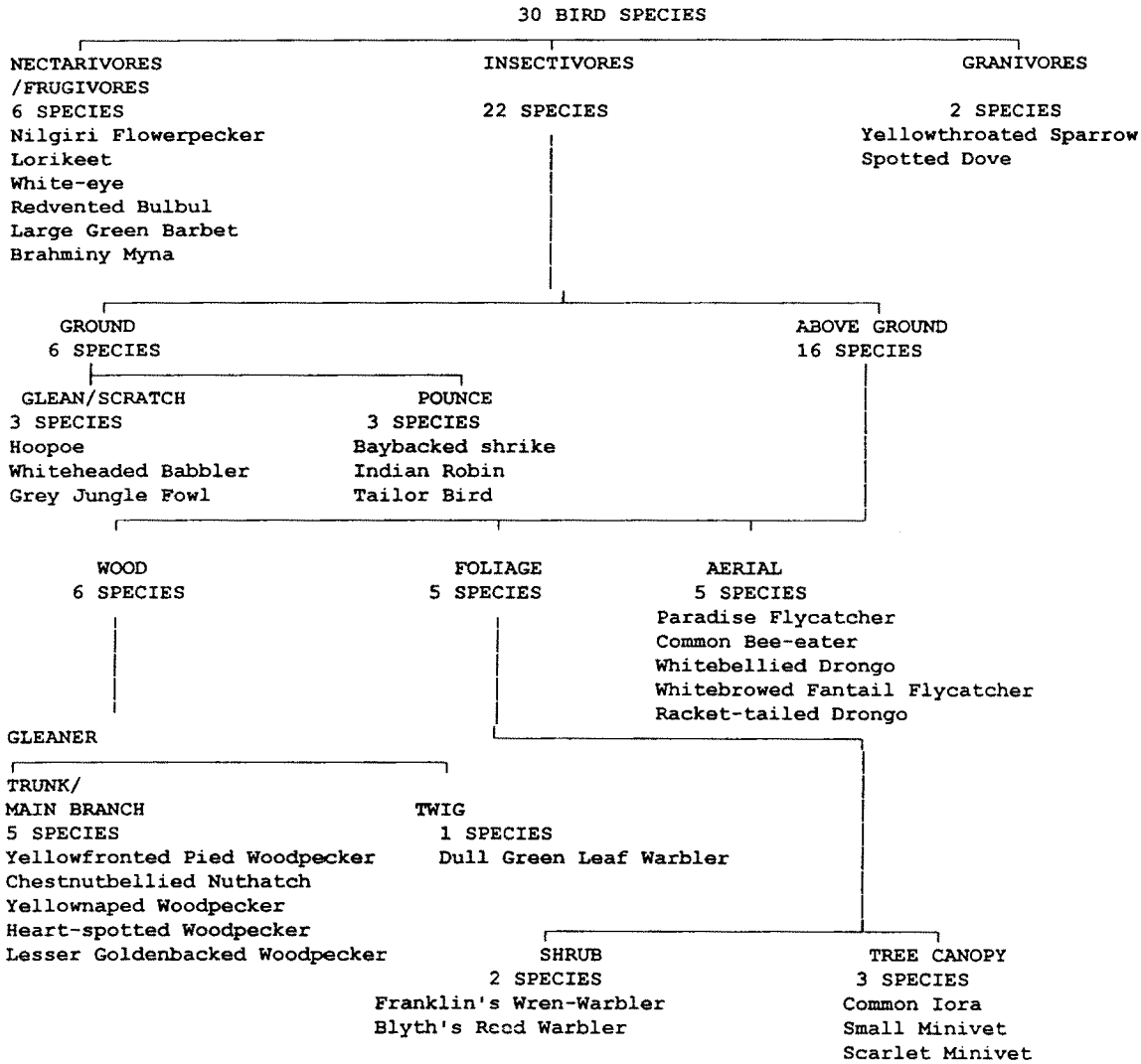
Based on the observational data, birds foraged in similar ways or exploited the same resources for food were grouped in a schematic way (Figure 4). The schematic portrayal of the groupings relies on foraging behaviour, foraging height, and foraging substrate differences to associate species. Of the 30

Figure 3. Cluster dendrogram showing interspecific relationships of 30 bird species in dry deciduous forest, based on multivariate analyses of foraging method, foraging substrate and foraging height use.



* Guild III (air) and IV (Tree) are mentioned as single guild (III) in text

Figure 4. A hierarchial cluster of 30 bird species found in dry deciduous forest based on observational data



species, major group was insectivores which comprised 22 bird species followed by Nectar/fruit-exploiters (6) and granivores (2).

3.3. Comparison of foraging patterns of birds in the thorn and dry deciduous forests.

3.3.1. Foraging height: Though number of bird species utilizing the >3m height classes were more in both the habitats, number of height classes used by the birds were more in the dry deciduous forest (see table 4 and 9).

3.3.2. Foraging substrate: In both the habitats, six substrates were recognized but the number of bird species using the substrates differed (see table 5 and 10). In the case of dry deciduous forest only one species utilized twigs while there were four of it in the thorn forest.

3.3.3. Method: Guilds and number of bird species forming each guild differed between habitats (see table 6 and 11). Moreover wood-probing was used predominantly by the Lesser Goldenbacked Woodpecker only in the thorn forest.

3.3.4. Niche overlap and *J'* index: Although the overall mean overlap in the foraging dimensions showed difference in values, the highest and lowest values were found in height and method in the two habitats respectively (see table 7 and 12). Similarly specialists were found more in the substrate and less in the height use (see table 8 and 13). Number of guilds arbitrarily recognized for the thorn

was only two while it was three in the dry deciduous forest (see fig. 1 and 3). Shrub was separated from the ground and tree in the dry deciduous forest while it joined with tree and formed a joined guild (tree/shrub) in thorn forest.

3.4. Foraging behaviour of bird species

In this section, details of foraging dimensions (method and height) of each species is discussed and compared between habitats. As method is substrate dependant, substrate is not dealt separately. Niche overlap between species in all the three dimensions (foraging height, substrate, and method) together is considered separately for each habitat (Appendix II).

3.4.1. Galliformes: Only Grey Jungle Fowl was studied in this order. Regardless of habitats, the Grey Junglefowl was absolute ground-granivore in the thorn forest while it used litter-search (86%) than ground-search method in the dry deciduous forest (Table 14). The method used differed significantly between habitats (χ^2=24.32 P<0.01). But in both the habitats, all the foraging was done on the ground. In all the dimensions together, highest overlap was found with Spotted Dove (1.00) in thorn forest and Whiteheaded Babbler (0.97) in dry deciduous forest (Appendix II).

3.4.2. Columbiformes: Spotted Dove was studied in this order. Regardless of habitats, ground-granivory and ground animal-search (carnivory) were the two methods employed by Spotted Dove to obtain their prey (Table 14). Of the two methods, ground-granivory was used predominantly (95%). All the

foraging attempts were made only on the ground. No significant difference was observed in the height and method used between habitats. In both the habitats, Spotted dove had highest overlap (1.00 and 0.82) with Grey Junglefowl (Appendix II).

Table 14 . Percent use of height and foraging method by Grey Jungle Fowl and Spotted Dove in thorn and Dry deciduous forests.

Grey Jungle Fowl		
Habitat	Height (m) 0 (Ground)	Method LS GG GH
Thorn Dry deciduous	100 100	0 100 0 86 14 0
Spotted Dove		
Habitat	Height (m) 0 (Ground)	Method LS GG GH
Thorn Dry deciduous	100 100	O 100 0 O 90 10

LS=Litter animal-search, GG=Ground grain-search, GH= Ground animal-search,

3.4.3. Psittaciformes: Only Lorikeet was studied in this order. Flower-exploitation was the only method used by the Lorikeet in both the habitats (Table 15). The height at which the foraging attempts were made differed significantly between the two habitats (χ^2=6.62 P<0.05). In both the habitats, foraging was largely at higher strata of vegetation (>5m). In both the habitats, in all the dimensions together, Lorikeet had highest overlap with Nilgiri Flowerpecker (Appendix II).

Table 15. Percent use of height and foraging method by Lorikeet in thorn and Dry deciduous forests

Habitats	Height (m)						Method
	3	4	5	6	7	9	FL
Thorn	6	6	6	48	34	0	100
Dry	0	0	28	36	10	26	100

FL=Flower-exploiting

3.4.4. Coraciiformes: Two species, namely the Small Green Bee-eater and Hoopoe belonging to two different families were studied (Table 16).

The Small Green Bee-eater used salty as the major method while pounce was used very less. Regardless of habitats, among the sally, abovecanopy-sally was used predominantly followed by the subcanopy-sally and ground-sally. The methods used did not differ significantly but, the height used differed significantly (χ^2=13.41 P<0.01) between habitats. Only G-6m height classes were used in the thorn forest while only ≥6m classes were used in dry deciduous forest. In general, 5-6m height class was predominantly used. All the prey items were taken largely from air. The small Green Bee-eater, when all the dimensions combined, had high overlap with the Racket-tailed drongo (0.73) and Whitebrowed Fantail Flycatcher (0.81) in dry deciduous forest and thorn forest respectively (Appendix II).

Hoopoe used only ground-search (100%) to get their invertebrate prey from the ground (100%) in both the habitats (Table 16). No significant difference was found between habitats either in the use of method or height. Hoopoe

overlapped much with Indian Robin (0.92) in the thorn forest while it was with Spotted Dove (0.80) in the dry deciduous forest when three dimensions were taken together (Appendix II).

Table 16. Percent use of height and foraging method by Common Bee-eater and Hoopoe in thorn and Dry deciduous forests

Bee-eater		
Habitat	0 2 3 5 6 7 9 10	Method CS SS GS GP
Thorn Dry	20 14 14 14 38 0 0 0 0 0 0 0 74 7 13 6	71 9 11 9 94 6 0 0
Hoopoe		
Habitat	Height (m) 0 (ground)	Method GH
Thorn Dry	100 100	100 100

CS= Abovecanopy-sally, SS= Belowcanopy-sally, GS= Ground-sally, GP=Ground-pounce

3.4.5. Piciformes: Five species namely Large Green Barbet, Heart-spotted Woodpecker, Lesser Goldenbacked Woodpecker, Yellowfronted Pied Woodpecker, and Yellownaped Woodpecker belonging to two families were studied.

Large green Barbet used foliage-gleaning, and fruit and flower-exploiting as methods to obtain the food such as insect, fruit, and nectar in both the habitats (Table 17). The method adopted varied significantly between habitats (χ^2=25.6 P<0.01). Fruit exploiting was used more in the thorn forest while flower-

exploiting was more in dry deciduous forest. In both the habitats, foraging attempts were made only at ≥5m height classes. The height preference between habitats varied significantly (χ^2=16.9 P<0.01). In all the three dimensions together, Large Green Barbet overlapped much with Redvented Bulbul (0.73) in the thorn forest and with Lorikeet (0.91) in dry deciduous forest (Appendix II).

Table 17 . Percent use of height and foraging method by Large Green Barbet in thorn and Dry deciduous forests

Habitats	Height (m)					Method		
	5	6	7	8	9	FG	FR	FL
Thorn	14	77	9	0	0	41	59	0
Dry	0	13	9	13	65	4	0	96

FG= Foliage-gleaning, FR= Fruit-exploiting, FL= Flower-exploiting

Four woodpeckers were studied and of which except the Heart- spotted Woodpecker (not recorded in the thorn forest) foraging dimensions of all other species were compared between habitats (Table 18).

The Heart-spotted Woodpecker used chiefly wood-gleaning (94%) followed by twig-gleaning (6%). Foraging attempts were more >10m height class. It overlapped much with Yellowfronted Pied Woodpecker (0.88) (Appendix II).

The Lesser Goldenbacked Woodpecker chiefly used wood-probing and wood-gleaning in both the habitats. But it differed in the use of method between habitats (χ^2=9.67 P<0.01). Wood-gleaning was used more in the dry deciduous forest (60%) while wood-probing (92%) was used more in the thorn forest. It used consistently trunk/main branches to obtain the prey. The height at which the prey

was taken varied significantly between habitats (χ^2=19.61 P<0.01) using ground and lower canopy more in the thorn forest and middle and upper canopy in the dry deciduous forest. It overlapped much with Yellowfronted Pied Woodpecker (0.84) in the thorn forest and with Chestnutbellied Nuthatch (0.89) in the dry deciduous forest (Appendix II).

The Yellowfronted Pied Woodpecker also used wood-gleaning and wood-probing and among which wood-gleaning only was used in the dry deciduous forest whereas wood-probing (32%) was also employed in the thorn forest. It differed significantly in the use of method between habitats (χ^2=6.02 p<0.05). Trunk/main branches was used as substrate in both the habitats. The height at which all the foraging attempts were made differed significantly between habitats (χ^2=16.3 P<0.05) as it was 1-4m in the thorn forest while it was the middle and upper strata (2-7m) in dry deciduous forest. It overlapped much with Lesser Goldenbacked Woodpecker (0.84) in the thorn forest and with Chestnutbellied Nuthatch (0.92) in the dry deciduous forest (Appendix II).

The Yellownaped Woodpecker used wood-gleaning, wood-probing, and ground-search in both the habitats. Wood-gleaning was used predominantly followed by ground-searching in the dry deciduous forest while all three methods were almost equally employed in the thorn forest. No significant difference was found in the use of method between habitats. The trunk/main branches were largely used as substrate. The use of height classes varied significantly (χ^2=15 P<0.01) between habitats; in the thorn forest it was ground to 4m whereas in dry deciduous lower height classes (1-2m) were not used. It overlapped much with

Yellowfronted Pied Woodpecker both in the thorn forest (0.84) and dry deciduous forest (0.78) (Appendix II).

Table 18. Percent use of height and foraging method by Woodpeckers in thorn and Dry deciduous forests

Heart-spotted Woodpecker		
Habitat	Height (m) 7 8 9 >10	Method TG WG
Dry	13 19 30 38	6 94
Lesser Goldenbacked Woodpecker		
Habitat	Height (m) G 1 3 4 5 6 7	Method WG WP
Thorn Dry	12 9 38 21 12 8 0 0 0 12 4 0 20 64	8 92 60 40
Yellowfronted Pied Woodpecker		
Habitat	Height (m) 2 3 4 5 6 7 8 10 >10	Method WG WP
Thorn Dry	23 35 42 0 0 0 0 0 0 0 7 14 7 21 14 10 7 20	68 32 100 0
Yellownaped Woodpecker		
Habitat	Method (m) G 1 2 3 4 5 6	Method WG WP GH
Thorn Dry	33 3 15 42 7 0 0 26 0 0 14 34 20 6	36 30 34 54 20 26

TW= Twig-gleaning, WG= Wood-gleaning (Trunk/main branches), WP= Wood-probing, GH= Ground animal-search

In general, all the woodpeckers used predominantly wood-gleaning method. Interestingly, the Lesser Goldenbacked Woodpecker used predominantly wood-probing in the thorn forest. In other species also this method was used in the thorn forest more than in the dry deciduous. Among the

woodpeckers, only Yellownaped Woodpecker used ground as substrate. Almost in all the occasions, it was found feeding on termites from the termite mound.

3.4.6. Passeriformes: Twenty five species belonging to 14 families in this order were studied.

Lanidae: Baybacked Shrike.

This shrike used four types of methods such as pounce, sally, ground-search, and wood-glean (Table 19). Pounce was used more predominantly than other methods in both the habitats. Ground was used frequently as substrate followed by air. No significant difference was observed in the method used. In both the habitats, although all the foraging attempts were restricted to 0-3m height class it showed significant difference between the two habitats (χ^2=8.78, P<0.01). Overall, high overlap was found with Indian Robin in both the forests (0.89 in thorn forest and 0.98 in dry deciduous).

Oriolidae: Blackheaded Oriole.

Sally and Foliage-glean were the two methods used by this oriole and of which glean (82%) was used very frequently (Table 19). Prey was mostly taken from the foliage between 3 and 7m. It overlapped highly with Scarlet Minivet (0.89) (appendix II).

Dicruridae:

The Whitebellied and Racket-tailed Drongos were studied and of which the latter was not recorded in the thorn forest (Table 20).

The Whitebellied Drongo used pounce and sally to obtain prey (table 20). The latter was used more frequently in both the habitats while no pounce was observed in dry deciduous. In thorn forest, it used frequently G-4m height classes

while only 4-6m height classes in dry deciduous forest. The height used differed (χ^2=22.2 P<0.05) between habitats. It overlapped much with Whitebrowed Fantail Flycatcher in both the forests, 0.82 in the thorn forest and 0.86 in dry deciduous (Appendix II).

Table 19 . Percent use of height and foraging method by Baybacked Shrike and Blackheaded Oriole in thorn and Dry deciduous forests

Baybacked Shrike		
Habitat	Height (m) G 1 2 3	Method GS GP WG GH
Thorn	56 4 33 7	7 82 0 11
Dry	97 0 3 0	3 94 3 0
Blackheaded Oriole		
Habitat	Height (m) 4 5 6 7	Method SS FG
Thorn	23 32 32 13	18 82

GS= Ground-sally, GP= Ground-pounce, WG= Wood-gleaning (trunk/main branches), GH= Ground animal-search, SS= Belowcanopy-sally, FG= Foliage-gleaning

Sally was the only method used by the Racket-tailed Drongo and within that, belowcanopy-sally (64%) was used more than the abovecanopy-sally (16%). All the foraging attempts were made at higher height classes. It overlapped much with the Whitebellied Drongo only in the method, but not in the vertical strata or height (Appendix II).

Sturnidae: Brahminy Myna

Brahminy Myna used ground grain-search, flower-exploiting and fruit-exploiting for their food (table 20). Although the ground feeding was secondarily

used in both the habitats, regardless of habitats, it was the predominant method. The flower and fruit-exploiting differed between habitats (χ^2=35.7 P<0.01), so also the height classes used (χ^2=18.5 P<0.01). In both the forests, it overlapped much with Yellowthroated Sparrow (Appendix II)

Table 20 . Percent use of height and foraging method by Whitebellied Drongo, Racket-tailed Drongo, and Brahminy Myna in thorn and Dry deciduous forests

Whitebellied Drongo		
Habitat	Height (m) G 1 2 3 4 5 6	Method CS SS GP
Thorn	9 0 27 59 5 0 0	0 91 9
Dry	0 0 0 0 38 54 8	19 81 0
Racket-tailed Drongo		
Habitat	Height (m) 6 7 8 9	Method CS SS
Dry	9 28 38 25	16 84
Brahminy Myna		
Habitat	Height (m) G 1 2 3 5	Method FL FR GG
Thorn	43 0 11 32 14	0 57 43
Dry	44 20 36 0 0	57 0 43

CS= Abovecanopy-sally, SS= Belowcanopy-sally, GP= Ground-pounce, FL= Flower-exploiting, FR= Fruit-exploiting, GG= Ground-granivory

Campephagidae:

In this family, three species of minivets, namely Scarlet Minivet, Small

Minivet, and Whitebellied Minivet were studied of which the last one was recorded only in the thorn forest.

Scarlet Minivet chiefly used sally and glean to get their prey (Table 21). Regardless of habitats, foliage-gleaning (48.5%) was used more than the other methods. Scarlet Minivet showed significant difference (χ^2=11.4 $p<0.01$) in the use of feeding methods. All the insect food were taken from the foliage, air, and twigs. Significant difference was also observed in the use of height classes (χ^2=15.3 $p<0.01$) between habitats not using <4m in the dry deciduous forest. It overlapped much with Blackheaded Oriole (0.89) in the thorn forest and with Small Minivet (0.92) in the dry deciduous forest (Appendix II).

Small Minivet also used only sally and glean (Table 21) in both the habitats with more of foliage-gleaning without significant difference between habitats. But, they showed significant difference in the height used (χ^2=19.5 $P<0.05$) between habitats, not using the lower strata <3m in the dry deciduous almost like that of the Scarlet Minivet. It overlapped much with Common Iora (0.90) in the thorn forest and with Scarlet Minivet (0.92) in the dry deciduous forest (appendix II).

Whitebellied Minivet restricted to thorn forest chiefly used gleaning (table 21). Twig-gleaning (65%) was used more frequently than the foliage-gleaning (35%). Only higher height classes (≥4m) were used. It overlapped much with Common Iora (0.89) in the thorn forest (appendix II).

Table 21. Percent use of height and foraging method by Minivets in thorn and Dry deciduous forests

Habitat	Height (m) 2 3 4 5 6 7	Method CS SS FG TG
Scarlet Minivet		
Thorn	0 11 36 17 25 11	19 42 39 0
Dry	0 0 0 50 25 25	17 5 58 20
Small Minivet		
Thorn	6 35 19 25 15 0	0 19 62 19
Dry	0 0 7 42 51 0	0 21 49 30
Whitebellied Minivet		
Thorn	0 0 60 40 0 0	0 0 35 65

CS= Abovecanopy-sally, SS= Belowcanopy-sally, FG= Foliage-gleaning, TG= Twig-gleaning

Gleaning was the predominant method used by all the Minivets with more types in the Scarlet Minivet and highly specialized or restricted in the Whitebellied Minivet. Most of the prey were taken from the foliage. Use of height classes also showed more narrow range in the Whitebellied Minivet.

Pycnonotidae: Redvented Bulbul

Redvented Bulbul used fruit-exploiting, flower-exploiting and ground-search to obtain their food such as fruit, flower, and insects respectively (Table 22). The fruit-exploiting was used chiefly than other methods in both the habitats. The method adopted did not vary significantly between habitats. The height classes used varied significantly (χ^2=62.2 P<0.01) between habitats, more of

lower strata (G-1m) in dry deciduous while it was 2-6m in the thorn forest. It overlapped much with Brahminy Myna both in the thorn forest as well as dry deciduous (Appendix II).

Irenidae: Common Iora

They largely glean the leaves and twigs for their prey (Table 22), the former was used more frequently in dry deciduous but equally in the thorn forest. However, this did not vary significantly. But, the height used varied significantly (χ^2=35.6 P<0.01) between habitats. It overlapped much with Small Minivet in both the habitats (appendix II).

Table 22. Percent use of height and foraging method by Redvented Bulbul and Common Iora in thorn and Dry deciduous forests

Redvented Bulbul														
Habitat	Height (m)											Method		
	G		1		2		3	5		6	7	GH	FL	FR
Thorn	4		0		42		28	3		22	1	4	3	93
Dry	2		85		2		11	0		0	0	3	11	86
Common Iora														
Habitat	Height (m)											FG		TG
	2		3		4		5	6		8	9	10		
Thorn	18		35		32		9	6		0	0	0	50	50
Dry	0		0		0		0	0		33	64	3	70	30

GH= Ground animal-search, FL= Flower-exploiting, FR= Fruit-exploiting, FG= Foliage-gleaning, TG= Twig-gleaning

Muscicapidae:

In this family, species such as Yelloweyed Babbler, Whiteheaded Babbler, Whitebrowed Fantail Flycatcher, Franklin's Wren-Warbler, Indian Tailor Bird, Blyth's Reed Warbler, Dull Green Leaf Warbler, Paradise Flycatcher, and Indian Robin were studied.

Of the two flycatchers, Whitebrowed Fantail Flycatcher used sally, pounce and glean (Table 23) to get their insect food. Among sally the predominant method used by the Flycatcher was belowcanopy-sally. The usage of ground-sally and bush-sally varied between habitats. In general, the method used differed significantly between habitats (χ^2=9.67 $p<0.05$) so also the vertical strata or height classes (χ^2=11.1 $p<0.05$). It overlapped much with the Whitebellied Drongo in both the habitats (Appendix II).

The Paradise Flycatcher used mostly sally (98%) in both the habitats (Table 23). Ground-pounce (4%) was used very rarely in the thorn forest since they obtained their prey from air. No difference was found in the method adopted to exploit the prey between habitats. It showed difference in the height used, only 1-2m in the dry deciduous and G-2m in the thorn forest; this difference being significant (χ^2 =20.09 $p<0.05$). They largely made their attempt in the gap between the clumps of the Lantana or shrubs. It overlapped much with Whitebrowed Fantail Flycatcher in both the habitats (appendix II).

The Whiteheaded Babbler used four major methods: ground-search, twig-gleaning, litter-search and ground-sally (Table 24). Among the four methods, litter-search was used chiefly in both the habitats. The other three methods were

less frequently used. Its behaviour was very similar in the use of feeding method and height in the two habitats. It overlapped much with Tailor Bird (0.80) in the thorn forest and with Grey Junglefowl (0.97) in dry deciduous (Appendix II).

Table 23. Percent use of height and foraging method by Flycatchers in thorn and Dry deciduous forests

Whitebrowed Fantail Flycatcher														
Habitat	Height (m)								Method					
	G	1	2	3	4	5	6	8	CS	SS	BS	GS	GP	FG
Thorn	46	9	15	6	12	0	12	0	3	47	0	38	9	3
Dry	10	14	3	10	7	38	14	4	3	66	21	0	10	0
Paradise Flycatcher														
Habitat	Height (m)								BS	GP				
	G	1	2											
Thorn	4	22	74						96	4				
Dry	0	0	100						100	0				

CS= Abovecanopy-sally, SS= Belowcanopy-sally, BS= Bush-sally, GS= Ground-sally, GP= Ground-pounce, FG= Foliage-gleaning

The Yelloweyed Babbler largely gleaned the substrates(twigs and foliage) to obtain the prey (Table 24). Twig-gleaning (74%) was used more than foliage-gleaning (26%). They largely obtained their prey from twigs and foliage. Almost all the foraging attempts were on the shrubs and short trees present in the 0-2m height category. It overlapped much with Common Iora (0.79) in the thorn forest (Appendix II).

Both babblers differed in the use of feeding method as well as height to exploit the prey. The whiteheaded babbler preferred litter-search while the Yelloweyed Babbler used twig-gleaning.

The Indian Robin used ground-pounce and ground-search (Table 24). Pounce was used more frequently than ground-search in both the habitats. All the foraging attempts were made chiefly on the ground. No significant difference was found in the use of any one of the foraging dimensions between the habitats. It overlapped much with Baybacked Shrike in both the habitats (Appendix II).

The Blyth's Reed Warbler used bush-gleaning and ground-search , the former being predominant in both the habitats (Table 25). Ground-search was occasionally used only in the thorn forest. All the feeding attempts were made largely at 0-1m height class. No difference was found either in the use of vertical strata or method. It overlapped much with Franklin's Wren-Warbler in both the habitats (Appendix II).

The Franklin's Wren-Warbler largely obtained insects present on the foliage of the shrubs at 0-1m height class by gleaning the foliage in both the habitats (Table 25). No significant difference was observed between habitats in any one of the two dimensions. It overlapped much with Blyth's Reed Warbler in both the habitats (Appendix II).

The Dull Green Leaf Warbler used foliage-gleaning and twig-gleaning of which the twig-gleaning was used more in both the habitats (Table 25). Prey were largely taken from the tree. The use of height varied significantly between habitats (χ^2=12.94 P<0.01).

Table 24 . Percent use of height and foraging method by Babblers and Indian Robin in thorn and Dry deciduous forests

Whiteheaded Babbler		
Habitats	Height (m) G 1 4	Method GS TG LS GH
Thorn	94 6 0	3 3 94 0
Dry	97 0 3	0 0 92 8
Yelloweyed Babbler		
Habitats	Height (m) 1 2	Method FG TG
Dry	44 56	26 74
Indian Robin		
Habitats	Height (m) G	Method GP GH
Thorn	100	52 48
Dry	100	97 3

GS=Ground-sally, TG= Twig-gleaning, LS= Litter animal-search, FG=Foliage-gleaning, GP=Ground-pounce, GH= Ground animal-search

It overlapped much with Whitebellied Minivet (0.80) in the thorn forest and with Small Minivet (0.65) in dry deciduous (Appendix II).

Gleaning was the predominant method for all the three warblers studied, the first two showed considerable similarity in the use of method and height and gleaning from shrubs. But, Dull Green Leaf Warbler differed from the other two in the use of method, height and plant form (shrub or tree).

Tailor Bird used method such as ground-pounce, foliage-glean, twig-glean, and litter-search to obtain their prey (Table 25). Among the four methods, regardless of habitats, litter-search and ground-pounce were more or less equally used in both the habitats. No significant difference was found in the use of method adopted by the Tailor Bird between habitats. But, the use of height differed significantly (χ^2=8.4 $p<0.05$) between the habitats. It overlapped much with Whiteheaded Babbler (0.80) in the thorn forest and with Baybacked Shrike (0.79) in the dry deciduous (Appendix II).

Parinae: Grey Tit.

Grey Tit used a diverse variety of foraging methods such as foliage-gleaning, twig-gleaning, wood-gleaning, bark-tearing, fallen log-gleaning and ground-search (Table 26). Among the methods, foliage-gleaning (58%) was most frequently used. Although Grey Tit was observed in both the habitats, observation on foraging records could be made only in the thorn forest. Of the 35 birds studied in both the habitats, only Grey Tit used bark tearing to get their prey. Similarly, Grey Tit and chestnutbellied Nuthatch only used the fallen log-gleaning. It overlapped highly with Common Iora (0.86) and Small Minivet (0.85) in the thorn forest (Appendix II).

Table 25. Percent use of height and foraging method by Warblers and Tailor bird in thorn and Dry deciduous forests

Blyth's Reed Warbler														
Habitat	Height (m)									Method			
	G	1	2	3	4	5	6	7	8	BG	GH	FG	TG
Thorn	3	97	-	-	-	-	-	-	-	97	3	0	0
Dry	0	100	-	-	-	-	-	-	-	100	0	0	0
Franklin's Wren-Warbler													
Thorn	0	100	0	0	0	0	0	0	0	100	0	0	0
Dry	0	100	0	0	0	0	0	0	0	100	0	0	0
Dull Green Leaf Warbler													
Thorn	0	0	0	0	0	26	48	26	0	0	0	17	83
Dry	0	0	0	0	0	0	38	40	22	0	0	18	82
Tailor Bird													
Habitat	Height (m)							Method					
	G	1	2	3	4	5	7	GP	FG	TG	LS		
Thorn	58	6	33	3	0	0	0	24	27	13	36		
Dry	24	0	32	10	14	10	10	52	10	0	38		

BG= Bush-gleaning, GH= Ground-search, FG= Foliage-gleaning, TG= Twig-gleaning, GP= Ground-pounce, LS= Litter animal-search

Sittidae: Chestnutbellied Nuthatch

Nuthatch used wood-gleaning and fallen log-gleaning as their foraging method (Table 26). Wood-gleaning was used very frequently in both the habitats. Prey were largely taken from the trunk/main branches. The method employed did not vary much but, the height at which the prey was taken varied significantly (χ^2=75.5 P<0.01) between habitats, lower strata in the thorn and higher strata

(>4m) in dry deciduous. It overlapped much with Yellowfronted Pied Woodpecker in both the habitats (Appendix II).

Diaceidae: Nilgiri Flowerpecker

Regardless of habitats, the Nilgiri Flowerpecker consistently preferred nectar (Table 26). Their height preference differed significantly between habitats (χ^2=27.81 P<0.01). It overlapped much with Lorikeet in both the forests (appendix II).

Zosteropidae: White-eye

White-eye used foliage-gleaning, twig-gleaning and flower- exploiting in both the habitats (Table 26). Flower-exploiting was used constantly more in both the habitats. Almost all the height classes except >6m were used in both the habitats. Of the two dimensions, only the use of height differed significantly between habitats (χ^2=20.7 P<0.05). It overlapped much with the Nilgiri Folwerpecker (0.78) in the thorn forest and with Small Minivet (0.69) in dry deciduous forest (appendix II).

Ploceidae: Yellowthroated Sparrow

Arboreal seed-search and ground grain-search were the predominant methods (Table 27) used by the Yellowthroated Sparrow. Among the two methods, ground granivory was predominant in both the habitats. They largely searched the ground for their food. No significant difference was found either in the height or method used by this sparrow between the habitats. It overlapped

much with Spotted Dove (0.90) and Grey Junglefowl (0.90) in the thorn forest but with Spotted Dove (0.78) in dry deciduous forest (Appendix II).

Fringillidae: Rosefinch

Rosefinch largely fed on seeds from the top canopy of the trees (Table 27). All the foraging attempts were made at higher height classes. Although Rosefinch was observed in the dry deciduous forest, observation of foraging records of this species was not possible in dry deciduous forest. Rosefinch overlapped much with Lorikeet (0.65) in the three dimensions together in the thorn forest (Appendix II).

Table 26. Percent use of height and foraging method by Grey Tit, Chestnutbellied Nuthatch, Nilgiri Flowerpecker, and White eye in thorn and Dry deciduous forests

Grey Tit		
Habitat	Height (m) G 2 3 4 5	Method FG TG WG BT FAL GH
Thorn	5 12 65 9 9	58 14 12 12 2 2
Chestnutbellied Nuthatch		
Habitat	Height (m) G 1 2 4 5 6 7	Method WG FAL
Thorn	20 17 50 0 13 0 0	80 20
Dry	0 0 0 4 22 37 37	100 0

Nilgiri Flowerpecker									
Habitat	Height (m)								Method
	3	4	5	6	8	9	10	>10	FL
Thorn	14	50	29	7	0	0	0	0	100
Dry	0	0	0	0	68	14	11	7	100

White-eye									
Habitat	Height (m)							Method		
	1	2	3	4	5	6	8	FG	TG	FL
Thorn	7	29	26	5	10	5	18	7	29	64
Dry	7	12	12	47	15	7	0	23	30	47

FG= Foliage-gleaning, TG= Twig-gleaning, WG= wood-gleaning, BT= Bark-tearing, FAL= Fallen log-gleaning, GH= Ground animal-search, FL= Flower=exploiting

Table 27 . Percent use of height and foraging method by Yellowthroated Sparrow and Common Rosefinch in thorn and Dry deciduous forests

Yellowthroated Sparrow									
Habitat	Height (m)							Method	
	G	2	3	4	5	6	7	AG	GG
Thorn	74	5	12	9	0	0	0	26	74
Dry	55	0	11	15	9	5	5	45	55
Common Rosefinch									
Thorn	0	0	0	0	0	100	0	100	0

AG= Arboreal grain-search, GG= Ground grain-search

4. DISCUSSION

4.1.Foraging pattern of birds in the thorn and dry deciduous forests

Besides understanding the species composition of the assemblages, it is essential to find out how they utilize the resources available by partitioning these effectively in order to reduce competition and co-exist peacefully (Cody 1974). For the present study, assuming that the food is an important limiting resource (eg., Lack, 1954, 1966; Cody, 1974), it can be proposed that communities should be structured on the basis of how food is partitioned, and that syntopic species should differ in physical or behavioural characteristics resulting in differential food utilization.

In many ecological studies, communities have been divided into guilds (Root, 1967) or other groupings which contain >1 species that seem to exploit the same kinds of resources in similar ways. As grouping members are the most likely potential competitors, it is appropriate to study competitive interactions and resource partitioning within a guild framework (Wilson, 1974; Pearson, 1977; Feinsinger, 1976). The guild analyses in the community studies frequently involve circular reasoning. From many foraging axes a few are subjectively chosen for quantification. The relevancy of axes depends upon the observer's knowledge of the organisms studied (Landers and MacMahon, 1980). In the present study, to understand the foraging pattern of birds in the thorn and dry deciduous forests, axes such as foraging substrate, foraging manoeuvres, and vertical foraging strata or height were studied.

Among the birds of the thorn and dry deciduous forests there were four major groupings based on the food eaten: insectivores, nectarivores, granivores,

and frugivore (see schematic diagram 2 and 4). The most important factor dividing the bird community into foraging guilds relate to the physical structure of the habitat. First, height and height-related characteristics separate the ground foragers from all other species. Then, the locations of foraging and method of foraging separate the species into minor guilds. There are, therefore, two distinct foraging environments (forest floor and plant surface) at thorn forest and four (forest floor, air, shrub, and trees) in dry deciduous forest. The plant (shrubs and trees) surface provide microhabitats such as foliage and wood. Each of these regions (environments and microhabitats) is exploited by bird species which have the specialized morphology and behaviour necessary for feeding there. Distinction of ground and above-ground (air, shrubs, and trees) emphasizes the importance of foraging opportunities on these three environments. The availability of various plant forms (shrubs, short trees, trees) in these habitats not only increases the vertical habitat dimension and, as a consequence, the foliage layering and complexity, but also provides supporting substrates (e.g., twigs, trunk/main branches, and foliage). The proportion of foliage at different heights is also a function of the branching structure of the plant forms. As branches of most of the short tree species in the thorn forest are pendant or branching downwards, it overlaps with the shrub foliage. Thus, no distinction between shrubs and short trees could be made in thorn forest.

In general, four substrates such as air, ground, wood (twigs and trunk/main branches), foliage, and Nectar/seed/fruit were recognized in the thorn and dry deciduous forests. It can be further reduced into air, ground and plant of which, larger number of bird species fall under the plant-guild because plant

offers a greater variety of microhabitats (trunk, branches, twigs, foliage) to find suitable food in this habitat. In the dry deciduous forest, wood (twigs, trunk/main branches) was utilized by more number of birds, because wood offers a greater variety of places to find suitable food in this habitat. Moreover, most of the trees here drop their leaves during the dry spell (see chapter III, and Murali and Sukumar 1993) thus increasing the opportunities of searching the wood and visibility of the prey.

In total, to obtain the food, nine and eight methods were chiefly used by birds in the thorn and dry deciduous forests respectively. Wood-probing was identified as a major method for Lesser Goldenbacked Woodpecker only in the thorn but not in the dry deciduous forest. Searching patterns are largely a function of the morphological and perceptual traits of each species, which allow the birds to move through the foliage, locate, detect, and capture prey in specific ways. Hence, feeding methods are more specialized in each species notwithstanding the habitat structure.

Resource partitioning reduces the effect of competition by decreasing the amount of overlap between the competing species (Wiens, 1989). So, the incidence of overlap amongst potential competitors may be used to assess the extent of resource partitioning on the niche dimensions measured. All the birds in these habitats overlapped with others (mean overlap), but only to a smaller extent, below 50 %. Although some species had higher overlap in certain dimensions they had very little overlap in the other dimensions or exploited different sizes of food with overlapping microhabitat and method. in at least one foraging dimension. Thus it can be said that partitioning of foraging dimensions

among birds occurred in both the habitats as reported earlier for bird communities of various places (eg., Recher *et al.*, 1985; Wheeler and Calver, 1996).

Niche breadths and overlaps are shaped by several factors such as vegetation structure and productivity, competitors and social dominance, seasonality, size and morphology of species, and abundance of food (MacArthur, 1968; Cody, 1974, 1981; Ulfstrand, 1977; Herrera, 1978; Hogstad, 1987; Morse, 1978; Alatalo, 1981, 1982; Carrascal, 1984; Rolando and Robotti, 1985; Szekely, 1985). In this study in all three dimensions (foraging height, foraging method and foraging substrate), for the avian community as a whole, highest mean niche overlap was found in the use of foraging height followed by foraging substrate and the least in the foraging method. Of the three, foraging methods and substrates may be constrained by morphology and thus it showed low niche overlap value. The high value in the height dimension can be attributed to the distribution of different food items (insects, fruits, seeds, and flowers) particularly at certain height category. For example, both seeds and insects were available in the ground layer and similarly, insects were available close to a height where flowers, fruits, and seeds are available. Low and high niche overlap value shown by certain birds can be attributed to the availability of food resources and inter-specific competition. It should also be stressed, however, that species coexistence may be influenced by factors other than foraging height, since foraging is done by using different methods by which they can exploit different types of food without much competition as seen in the Scarlet and Whitebellied Minivets (see table 21). Such overlap may vary when the congeneric species

feed together in a flock or separately as seen in the drongos (Vijayan, 1984). Also these species of different size classes exploit prey of different sizes which reduce competition.

Among the three dimensions, there were more number of specialists in the substrate category. Among the substrates, specialists were more in the ground and wood categories. Organisms may specialize because only a few resources are available in a particular environment, or because characteristics of the organisms constrain diets. Among the dimensions (foraging height, foraging method and foraging substrate), prey largely depends on the substrate and thus, substrate determines what sort of prey it can support. The birds are evolved with special morphological adaptations to exploit the particular substrates for particular prey and hence, specialists were more in the substrate. In the thorn forest, Species such as Spotted Dove, Rosefinch, Hoopoe and Franklin's Wren-Warbler were specialists in all the dimensions and hence these can be called as specialists in the habitat. The Rosefinch and Spotted Dove purely depend on seeds or grains available on the plants and ground respectively. Hoopoe and Franklin's Wren-Warbler obtained their insect prey from the ground and shrub respectively and thus partitioning the resources. In the dry deciduous forest, species such as Blyth's Reed Warbler, Hoopoe, Paradise Flycatcher, and Franklin's Wren-Warbler were specialists in all the dimensions and hence these can be called as specialists in the habitat. The presence of distinct shrub layer without overlapping with other layers (short trees and trees) in dry deciduous forest may be the reason for the above said species except the Hoopoe to be specialized in these dimensions.

When interpreting the niche value for all the three dimensions used by various bird species it is necessary to bear in mind that the value obtained are likely to have been influenced by the fineness or coarseness of the variables used. For example high overlap value for height category would probably have been reduced, if the zone had been divided into more layers for scoring purposes. Likewise in the method category, the high overlap for the ground-foraging method would probably have been reduced, if the ground-foraging had been divided into more sub-categories for the scoring purposes. Also there are other dimensions such as microhabitats or size of the prey which are not considered here. As mentioned earlier, the specialist index *J'* also purely depends on the fineness or coarseness of the variables. Further, it should also be noted that categorizing species as specialist or generalist can be ambiguous and it depends on the frame of reference and the methods used to quantify specialization.

4.2. Comparison of foraging patterns of birds between habitats

Of the 35 bird species studied, foraging records of 28 species were available for both the habitats. Although species namely Grey Tit, Blackheaded Oriole, and Common Rosefinch were found in both the habitats, foraging records could be made from one of the habitats only.

In both the habitats, there were four major groupings based on the food eaten: insectivores, nectarivores, granivores or seed-eaters, and frugivore (see schematic diagram 2 and 4). Almost similar substrates and methods were recognized in both the habitats regardless of number of bird species utilized. The

comparison is made based on the number of substrates or height or method recognized rather than the number of bird species or individuals involved within the guild between habitats. Similarity in the number of predominant substrates and methods recognized between habitats can be attributed to similarity of bird species present in both the habitats. Moreover, majority of tree and shrub species were common to both the habitats (see chapter III) which provide similar foraging opportunity to bird species. The emergence of wood-probing as a guild only in thorn forest can be attributed to interspecific competition. As the Lesser Goldenbacked Woodpecker showed extensive overlap in the use of height and substrate with other woodpeckers, use of different method may be a strategy to avoid competition with other woodpeckers.

In the present study, closely related species used the same basic searching methods indicating the importance of phylogenic and evolutionary process in determining the patterns (Robinson and Holmes, 1982). However, adaptive radiations in certain groups provide facilities for them to diverse resource utilization using different methods. In most of the cases, guild was formed by a group of birds which are similar in their morphological adaptation. For example, all the woodpeckers were chiefly wood-gleaning and mostly on the trunk/main branches. But, species with different morphologies also utilize the same general searching mode and take the similar types of prey, suggesting that morphology does not necessarily predetermine the foraging behaviour or diet, as has been inferred by insectivorous birds (Ricklefs and Travis, 1980). Therefore, it may be concurred with Hutto (1981) that morphological analyses will never provide a complete characterization of the food exploitation patterns and

ecological relations of co-occurring bird species. Among the birds of these two habitats, wood-gleaners and salliers were comparatively more than the others. During the dry spell most of the trees of these two habitats shed leaves (see chapter III and Murali and Sukumar 1993) as a result area of wood exposed to the birds would be more. Also less availability of foliage would enhance the bird's ability to catch the flying-prey easily in the open area.

The foraging height showed considerable difference between habitats. As foliage height diversity (FHD) differed between habitats (see chapter III), foraging pattern of thorn and dry deciduous forest is largely separated by the foraging height even within the species. As branches of most of the short tree species in the thorn forest are pendant or branching downwards, it overlaps with the shrub foliage. Thus, no distinction between shrubs and short trees was made in thorn forest. In contrast, as the availability of short trees were less in dry deciduous habitat, the shrubs can be distinctly separated from the trees and hence a typical shrub guild emerged in dry deciduous habitat.

The difference in the mean niche overlap between forest types (both within species as well as avian community as a whole) can be attributed to the level of competition among the species for resources. The birds are evolved with special morphological adaptations to exploit the particular substrates for particular prey and hence, in both the habitats, specialists were more in the substrate. Warblers such as Franklin's Wren-Warbler and Blyth's Reed Warbler and Hoopoe were specialists in all the dimensions and in both the forest types and thus can be called as specialists. Others such as Rosefinch, Paradise Flycatcher and Spotted Dove showed consistency in particular habitats.

Based on the foraging behaviour of birds between habitats but without considering the number of bird species involved, it can be assumed that these two habitats are separated largely by the vegetation layer (height dimensions) and are determined by the vegetation structure and complexity, and availability of food resources.

It was difficult to quantify the foraging of other birds which frequented the thorn and dry deciduous habitats in small numbers. It would have been more meaningful if they were also included in the community analysis.

4.3. Foraging behaviours of bird species between habitats.

Valuable insights on the effect of habitat structure on foraging patterns may be gained by comparing the behaviour of a single species in two habitats that differ in structure (Robinson and Holmes, 1982). In the present study, foraging behaviour of 28 bird species were compared between habitats. 20 of 28 species showed changes in their foraging heights between habitats. Only eight species did not show changes in their height preference between habitats and among the eight all except two warblers were ground foragers because birds are more likely to change their foraging height as it may not be so constrained by morphology as in substrate or method. Moreover, the availability of foraging substrate (foliage, wood, twigs etc) at different heights significantly differed between these two habitats and hence, change in the height preference.

Of the 28 bird species common to both the habitats, only two species (Common Iora and Scarlet Minivet) differed in their use of substrates between habitats. Among these two, no clear pattern was found in the case of

Common Iora in thorn forest and thus it may be due to limited sample size. Changes in the Scarlet Minivets can be attributed to competition. Less use of foliage-and Twig-gleaning may be to reduce competition with other minivets whose predominant foraging methods were foliage- and twig-gleaning. Although there was overlap between Scarlet and Small Minivets, competition would be less because of difference in size of prey corresponding to that of the species.

Only 7 of 28 species showed changes in the proportions of prey attack manoeuvre used between habitats. In other studies comparing foraging between habitats, Szaro and Balda (1986) found that foraging methods (manoeuvres) of species comprising the bird community in ponderosa pine (*Pinus ponderosa*) forest did not change with forest structure and that only 5 of 15 species changed proportions of manoeuvre. Maurer and Whitmore (1981) found that of the five species, only the American Redstart (*Setophaga nuticialla*) changed foraging manoeuvres between forests with different structure and that other birds instead changed tree species, substrates or height. Martin and Karr (1990) opined that species were plastic only within certain limits determined by their evolutionary histories. Because attack manoeuvres used by a species may be constrained by morphology, birds may be more likely to change other aspects of foraging, such as height or plant species (Hutto, 1981a, 1981b; Fitzpatrick, 1985; Sherry, 1985; Martin and Karr, 1990; Moermond, 1990). Yet behaviours were not totally fixed or stereotyped for species such as Scarlet Minivet, Yellowfronted Pied Woodpecker, and Lesser Goldenbacked Woodpecker which showed significant changes in the prey attack manoevres between habitats. Species such as Large Green Barbet, Grey Junglefowl, and Brahminy Myna showed changes in their

prey between habitats. As some of the categories such as nectar/seed/fruit-exploitation, ground granivory etc., were derived based on the type of food used, changes in the prey attack manoeuvre is unavoidable when the type of food differs. Species generalized in feeding tend to vary in feeding technique, substrate choice, and height, as the type of food varies. The availability of diverse food items may vary between habitats and hence, birds that feed on variety of foods (eg., insects, nectar, fruit) may change their manoeuvre according to the habitat. There are several possible explanations for the differences in foraging between habitats. Arthropod abundance and diversity undoubtedly affect foraging behaviour of insectivorous birds (Holmes and Schultz, 1988; Cale, 1994). If it is true, changes in the foraging manoeuvres would have been possible for all the insectivorous birds. But, only 4 of 23 insectivorous birds showed changes in their foraging manoeuvres between habitats. The risk of predation may affect how long birds forage or which foraging sites they choose (Lima, 1985). No predation of any one of the adult birds was recorded during the study period in both the habitats. But, predation of fledglings of almost all the breeding birds in both the habitats was observed. Interspecific competition also can alter foraging behaviour (Morse, 1967; Alatalo, 1981; Carothers, 1986). Number of species of woodpeckers present was more in dry deciduous than in the thorn forest. Similarly, number of species of minivets present was more in thorn forest than in dry deciduous forest. Thus, changes in the foraging manoeuvres may be a strategy to avoid competition. But the role of food cannot be neglected. Hence, it is likely that the combination of factors such

as availability of food, habitat structure and interspecific competition are responsible for the changes.

Apart from this, variables such as sex (e.g., Sodhi and Paszkowski 1995; Engstrom and Sanders, 1997), age-related (VanderWerf, 1994), and social context (Gosler, 1987), breeding status (Moysey, 1997) are described as factors responsible for the changes within species. By averaging behavioural data without regard for variables such as age, status, or social context, information may be lost, and emerging patterns may not be representative of any individuals in the study population (McKean, 1990). Although, all my observations were to a certain extent independent of all these factors, these factors should not be overlooked and are to be considered in future.

As foraging ecology of most of the birds have been poorly documented in India, comparison was made only on foraging method rather than the proportion of usage for most of the species. In some cases, groups (families or orders) are discussed. In general, most of the bird species foraged in similar manner as observed by Ali and Ripley (1987) though they described only the major foraging method such as glean, hawk, and pounce.

Species for which information is available on foraging are compared with the present study in detail.

Hoopoe: Substrate (ground) and method (ground animal-exploiting) used by Hoopoe is similar to Thiyagesan (1991). Further, Hoopoe showed no difference in the use of substrate and method even between forest types (table 16) and are considered specialized in the use of method and substrate.

Woodpeckers: The predominant use of wood as substrate by the woodpeckers in the present study was similar to the findings of Thiyagesan (1991) and Santharam (1995) but differed in the use of method. Wood-gleaning was used mainly by all the woodpeckers except Lesser Goldenbacked Woodpecker in the thorn forest but drilling (Thiyagesan 1991) and Pecking (Santharam 1995) were reported as major methods elsewhere. Excavating is an energy-consuming (expensive) mode of foraging and it is profitable for bird to forage using more superficial mode when insects are found on the surface of trees and thus gleaning was used more. Extensive wood-probing by Lesser Goldenbacked Woodpecker in the thorn forest can be to avoid competition with other woodpeckers. Also less availability of trees in the thorn forest might have led this species to use different methods. In the dry deciduous forest greater availability of trees and tree surface (trunk) would probably be sufficient enough to reduce competition.

Drongos: Racket-tailed Drongo and Whitebellied Drongo predominantly used sallying in the present study. The proportion of foraging method used by the Whitebellied Drongo is similar to that found by Vijayan (1984). But foraging manoeuvre of the Racket-tailed Drongo of the present study differed from that reported by Vijayan (1984) who found flycatcher-gleaning as predominant. Such a difference can be attributed to the changes in the habitat as food availability and demand may change when habitat changes.

Whiteheaded Babbler: Although Zacharias and Mathew (1988) identified nine methods of foraging to quantify foraging behaviour of the Babblers , the higher usage of ground-foraging was similar to that in the present study. But only

four methods were recognized in the present study and of which three were used less frequently. Moreover, the less frequently used methods differed between habitats. Thus the plasticity in the method use may be a strategy to overcome the changes in the food availability and demand.

Dull Green Leaf Warbler: Gleaning was the dominant method adopted by Dull Green Leaf Warbler. Price and Jamdar (1991) reported that the Yellowbrowed Leaf Warbler frequently used standpicks and rarely flypicks. The standpicks they mentioned is the same as glean.

Resource partitioning i.e., difference among co-existing species in their use of resources is commonly observed and often thought to reflect the primary role of competition in determining coexistence of species(Martin and Roper 1988). This is evident in the present study in the case of woodpeckers (Table 18), drongos (Table 20), minivets (Table 21), flycatchers (Table 23), babblers (Table 24), and warblers (Table 25) as members of each group showed difference in at least one of their resource dimensions with other members of the same group.

5. SUMMARY

Foraging patterns of birds in the thorn and dry deciduous forests were studied during the dry season (January to April) in 1995 and 1996 in Mudumalai Wildlife Sanctuary. The goals of the study were: (1) to identify the foraging pattern and microhabitat utilization of birds in the thorn and dry deciduous forests and (2) compare the foraging behaviour of birds in the two habitats.

1. Foraging pattern and microhabitat utilization of birds in the thorn and dry deciduous forests

a. Thorn forest

In total, 1386 foraging observations were made for 33 bird species in the thorn forest. A total of 6 substrates, 9 methods, and 3 layers were found used predominantly by the 33 bird species. Among the foraging dimensions (foraging height, method and substrate), highest niche overlap was found in the height followed by the substrate and method. Specialists were found more in the substrate category followed my method and height. The cluster analysis (based on foraging dimensions) separated the birds of thorn forest mainly by the height into two guilds (ground, and shrub/trees). Further, they were separated based on the foraging method and substrate.

b. Dry deciduous forest

In total, 1176 foraging observations were made for 30 bird species in the thorn forest. A total of 6 substrates, 8 methods, and 3 vegetation layers were used predominantly by the 30 bird species. Among the foraging dimensions (foraging height, method and substrate), highest niche overlap was found in the height followed by the substrate and method. Specialists were found more in the substrate category followed my method and height. The cluster analysis (based on foraging dimensions) separated the birds of thorn forest mainly by the height into three guilds (ground, shrub/short trees, and trees). Further, birds were separated based on the foraging method and substrate.

2. Comparison of foraging pattern between forests

The foraging patterns of birds of these two forests differed largely by vegetation layer rather than other dimensions i.e., method and substrate. Of the 28 bird species studied in both the forest types, 20 species differed significantly in their height use while only seven species differed in their foraging method and only two species in the use of substrates between forests. As the use of foraging method and substrate may be constrained by morphology, not much difference was found in most of the birds.

CHAPTER. VI

NESTING AND NEST-SITE CHARACTERISTICS.

1. INTRODUCTION

A nest is defined as a structure that aids the development of the eggs and the survival of young in birds (Collias, 1964). Nest-site is a place within the immediate vicinity of the nest. As nest-site determines the environment to which the adults, eggs, and altricial chicks will be exposed during critical periods, selection of a proper nest-site is vital in the reproduction of birds (Skutch, 1976; O'Connor, 1984). Nest-site selection involves discrimination among alternative sites that provide different sets of circumstances affecting survival and reproduction. Hence, an important decision which has to be made by birds is where to place the nest (Cody, 1985; Johnson *et al.*, 1992).

Traditionally bird species diversity was correlated with vertical vegetation diversity (MacArthur and MacArthur, 1961; James, 1971; Willson, 1974), a relationship explained by the increasing availability of foraging substrate with increasing numbers of vegetation layers. More recently, Martin (1993a, 1993b) and Steele (1993) suggested that an increase in the number of nest-sites may explain the observed relationships between bird species diversity and vegetation diversity. Conversely, the extirpation of some species especially from a forest

disturbed in various ways may be due to a decrease in the availability of nest-sites.

In earlier studies, attention was mostly given to morphology of nests and importance of nest-trees. The importance of nest-site (characteristics within the immediate vicinity of the nest), and nest-patch (characteristics of the habitat patch surrounding the nest) in the studies on nest-site selection of birds has only recently been recognized (Martin and Roper, 1988). Kern *et al.*, (1993) found that the nest-site is more important than the nest for protecting eggs and chicks and especially for maintaining a microclimate suitable for embryonic and nestling developments.

Several abiotic and biotic factors can influence nest-site selection. The characteristics of nest-sites influence nesting success by concealing the nest from predators (Giroux, 1981; Hines and Mitchell, 1983; Hill, 1984; Jackson *et al.*, 1988; Crabtree *et al.,* 1989; Petersen, 1990) or by reducing the exposure of the eggs to harsh environments (Cooch, 1965; Schamel, 1977). Interaction with other individuals, both interspecific and intra-specific, can affect the selection of the nest-site and the subsequent success of the nest (Wiklund, 1982; Minot and Perrins, 1986). Other factors such as tree density (Selas, 1997), and the distribution of available nest cavities and sites (Li and Martin, 1991) have also been reported as influencing the selection of a nest-site. In general, birds select habitat by responding to cues (proximate factors) that stimulate settling at a location. Natural selection operates on the appropriateness of those selections

through ecological processes (ultimate factors) that influence survival and reproductive success of individuals (Hilden, 1965).

Knowledge of what constitutes an available nest-site, or more specifically a successful nest-site, is necessary for the management of concerned species (Martin, 1993a). For example, Martin and Roper (1988) found that successful Hermit Thrush (*Catharus guttatus*) nests were characterized by a greater diversity of white fir (*Abies concolar*) saplings in a five metre radius surrounding the nest. There is a need to identify such specific habitat features that affect the nest for each species.

In recent years, studies on nest-site selection or nest-site characteristics of birds has increased considerably (e.g., Negro and Hiraldo, 1993; Norment, 1993; Johnson, 1994; Bogliani *et al.*, 1994; Vlachos and Papageorgiou, 1994; Cerasoli and Penteriani, 1996; Kilgo *et al.*, 1996; Selas 1997). In general, among birds, raptors and cavity-nesters are better studied than other species. As a result of such studies, actions have been taken to preserve the population of concerned species by installing nest-boxes or assuring the nesting requirements.

In India, the nesting requirements of birds are comparatively less examined except for studies conducted on Bulbul (Vijayan, 1975), Black- and - Orange Flycatcher (Khan, 1977), Babblers (Zacharias, 1979), Barbets (Yahya, 1980), Laughing Thrushes (Islam, 1985), and Drongos (Vijayan, 1984). All these studies mostly documented the characters of nests and nest-trees of the concerned bird species rather than nest-site characteristics. Moreover, in all studies the nest-site characteristics were not compared with random-site

characters. As a result only preference could be documented but not selection. Thiyagasen (1991), Kannan (1994), and Mudappa and Kannan (1997) have attempted to compare the random-sites with nest-sites of cavity-nesters, Great Indian Hornbill, and Malabar Grey Hornbill respectively.

In Mudumalai Wildlife Sanctuary, the thorn and dry deciduous forests are subject to severe anthropogenic pressure therefore, nest-site selection or characteristics of single or group of species is crucial for the management of bird species. Considering this, the present study was designed to address the following issues:

1. breeding seasonality of birds 2. nest-tree selection of certain breeding birds and 3. the nest-site selection of certain breeding birds in thorn and dry deciduous forest of Mudumalai Wildlife Sanctuary.

2. METHODS

In both habitats, a 10 ha plot was laid for nest-site selection studies. Searches were made on foot for nest structures by examining trees, shrubs, and substrates suitable for nesting (ground, rock, holes etc.,). An active nest was corroborated if adults were seen performing breeding activities (nest-building or renovation, incubation, feeding the young etc.,) in or adjacent to the nest. Date of presence of eggs in the nests of all the bird species were recorded to know the breeding seasonality of birds in both the habitats. Due to nearness of the two habitats and limitations of sample size, the result of breeding seasonality was considered for both the habitats together.

2.1. Nest-site characteristics.

The methods of determining nest-site selection are similar to that already established in a number of nest-site selection studies (Titus and Mosher, 1981; Warkentin and James, 1988; Bechard *et al.*, 1990; Hullsieg and Becker, 1990). Variables were selected based on factors that were considered or assumed to have potential effect on nest-site selection and on the results of previous studies. Variables were measured to characterize the vegetation structure at nests following termination of the nesting attempt by the birds. Variables were set at three levels: the nest, nest-tree and nest-patch. Features of nest, nest-plant or substrate and nest-patch were quantified based on several variables (Table 1).

Table 1. List of variables collected for the nest-site selection study

No.	Variables
	Nest variables
1	Nest-height (m)
2	Nest-length (cm)
3	Nest-width (cm)
4	Nest-depth (cm)
5	Nest-concealment
	Nest-tree variables
6	Nest-tree species
7	Nest-tree height (m)
8	Nest-tree gbh (cm)
	Nest-patch variables
9	Canopy-cover (%)
10	Ground-cover (%)
11	Shrub-cover (%)
12	Distance to water (1=close, 2=far and 3=very far)
13	Distance to settlement (Km)
14	Microhabitat (Nullah, Other)
15	Distance to road (km)

2.1.1. Nest variables

The nest variables were collected to get the information on the shape and size (morphology) of the nest. Among the variables "nest concealment" was estimated by viewing the nest at above or below or nest level from a distance of 2 m, 5 m, 7 m and 10 m in each of four cardinal directions (Martin and Roper, 1988). Concealment of the nest was estimated using a rating (0-4=very high, 4-8=high, 8-12=low and 12-16=very low).

2.1.2. Nest-tree variables

The nest-tree or substrate variables were to identify the key characteristics of the nest-plants which are responsible for supporting the nest of a particular bird species.

2.1.3. Nest-patch variables

The nest-patch variables were measured within a 0.07ha circular plot centered at the nest-tree. As the study includes small to larger sized birds, a 15 m radius circular plot (0.07ha) was selected as suggested for raptor studies (Titus and Mosher 1981). A "nest-patch" was defined as the area surrounding a nest-tree, including vegetation and topographic features used by a nesting pair during the entire nesting season exclusive of foraging areas (Reynolds *et al.*, 1982). It was to identify the microhabitat required for nesting of bird species. An attempt was made to select variables that might indicate whether site selection was affected by human activity or agricultural landuse. Such variables included distance to

road or powerline, and to settlement. Those distances were measured directly in the field when short and long distances were measured from topographical map. Height measurements were made using a clinometer when needed. Percentage of vegetation cover (shrub and ground) was visually estimated. The percent canopy-cover immediately over the nest was measured using a hand mirror marked with a grid. The shaded area was estimated as canopy cover (Martin and Roper, 1988). Other variables were aimed at identifying the physical structure of the nest-site.

2.2 Random plot

All parameters except nest measurements were compared with similar measurements at randomly selected sites to identify the factors responsible for selecting a nest-site. Random sites were selected on the basis of a place having potential as nest-site and should also be close enough to the used sites. The 10 ha plot for nest-searches in each habitat was divided into 40 grids (50*50m). All the grids in both the habitats were plotted and numbered on a enlarged topographic map of the study area. In each habitat, 10 grids were selected from the 40 using lot method and were identified in the study area. Once the approximate grid or site was located, the nearest tree or shrub was made the centre of random plot. Except the nest variables, all other variables (nest-tree and nest-patch) were enumerated from the plot. As the Crested Hawk-Eagle nests were found only in the dry deciduous forest and not within the plot,

separate random plots were laid in the dry deciduous forest using the same method.

Analyses were done for the whole data together due to sample size limitations. Based on the sample size and available information on the species, only 5 species were selected for detailed nest-site selection studies, namely the Crested Hawk-Eagle, Paradise Flycatcher, Whitebrowed Fantail Flycatcher, Spotted Munia and Baybacked Shrike (Fig. 1). For rest of the breeding species, plant species preference for nesting was only assessed.

2.3. Statistical analyses

2.3.1. Diversity

Diversity was calculated using Shannon-Weaver index (1949): $H' = -\sum p_i \log p_i$ (Where H'= diversity and pi= the proportion of observation in subset i).

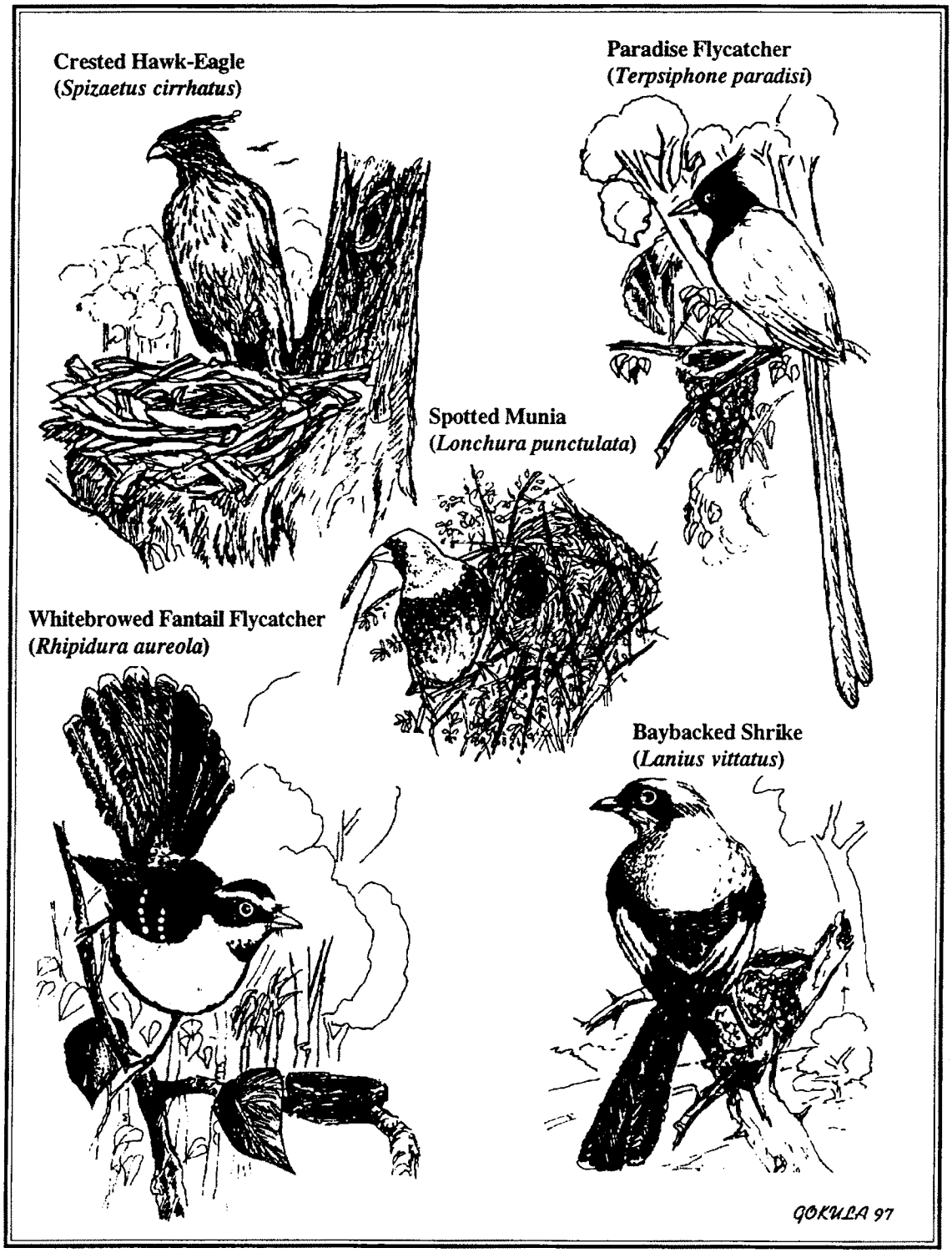
2.3.2. Principal Component and Discriminant Function Analyses.

Principal Component Analysis was performed on the nest-site characters to determine the most important factors in delimiting the habitat niche of the species. Discriminant function analysis was performed to identify factors separating the nest-sites from the random sites.

2.3.3. Other tests

Uni-variate analyses of variances (ANOVA), Mann-Whitney *U*, Chi-square, Correlation, and other simple statistics (Mean and SD) were used wherever

Figure 1. Bird species selected for the nest-site selection studies



appropriate (Sokal and Rohlf, 1981). Uni-variate analyses of variances (ANOVA) was used on continuous variables while Mann-Whitney *U* was performed on ranked variables to compare nest-sites and random sites (Titus and Mosher, 1981). Results are reported significant if associated with a value of $P<0.05$. The SPSS.software package (Noruis,1990) was used for data analyses.

3. RESULTS

3.1. Nest-types

A total of 302 nests of 30 species of birds were observed during 1995 and 1996; 200 nests of 22 species in thorn forest and 102 nests of 20 species in dry deciduous forest (Table 2).

Cup-nests were larger in number than other type of nests (Table 3). Hole-nests were abundant (35%) in the dry deciduous forest than in the thorn forest (2%), while the dome-nests were high (30%) in the thorn forest than in dry deciduous forest (8%).

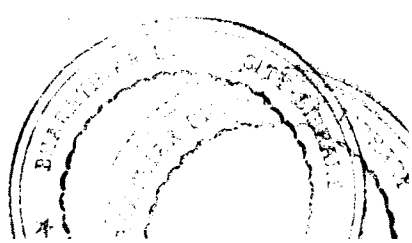


Table 2. Number of nests of birds in thorn and dry deciduous forests.

Bird species	Thorn forest	Dry deciduous forest	Total
Crested Hawk-Eagle	-	12	12
Redwattled Lapwing	1	-	1
Spotted Dove	1	-	1
Blossomheaded Parakeet	-	16	16
Large Green Barbet	1	-	1
Lesser Goldenbacked Woodpecker	-	5	5
Yellowfronted Pied Woodpecker	-	1	1
Yellownaped Woodpecker	-	1	1
Baybacked Shrike	20	4	24
Blackheaded Oriole	1	1	2
Whitebellied Drongo	-	1	1
Common Myna	-	2	2
Blackheaded Cuckoo-Shrike	3	-	3
Scarlet Minivet	2	3	5
Whitebellied Minivet	3	-	3
Wood Shrike	-	1	1
Redwhiskered Bulbul	2	-	2
Redvented Bulbul	16	9	25
Whiteheaded Babbler	27	13	40
Whitebrowed Fantail Flycatcher	14	10	24
Paradise Flycatcher	11	-	11
Grey Tit	1	-	1
Tailor Bird	1	-	1
Indian Robin	19	9	28
Magpie Robin	1	-	1
Chestnutbellied Nuthatch	1	2	3
Purple Sunbird	8	2	10
White-eye	7	2	9
Spotted Munia	57	6	63
Whitethroated Munia	3	2	5
Total	200	102	302

Table 3. Abundance of various nest-types in the thorn and dry deciduous forests

Nest-types	Thorn forest	Dry deciduous	Total
Cup	98(49%)	31(30%)	129(43%)
Hole	4(2%)	36(35%)	40(13%)
Dome	60(30%)	8(8%)	68(22%)
Platform	28(14%)	13(13%)	41(14%)
Pendulum	8(4%)	2(2%)	10(3.3%)
Ground	1(0.5%)	-	1(0.3%)
Others	1(0.5%)	-	1(0.3%)
Raptor Nests (Platform)	-	12(12%)	12(4%)
Total	200	102	302

Others=Tailor bird nest

3.2. Breeding seasonality

The major breeding season of birds was from February to June with a peak in May (Fig. 2). However, considerable difference was notable in this period among hole-nesters, cup-nesters and dome-nesters. No correlation was found in the case of cup-nesters and overall with temperature and rainfall. Since, the major portion of the total nests located during the study was cup-nests, the pattern shown by these nests skews the overall pattern of nest seasonality. The hole-nesters showed a significant positive correlation with temperature (r_s = 0.61 $p<0.05$) and negative correlation with rainfall (r_s= -0.56 $p<0.05$). Only two species

(Whitethroated Munia and Spotted Munia) constructed dome-nests. The period was July to November a period with frequent rains. The number of nests were positively correlated with rainfall (r_s= 0.53 $p<0.05$) and grass height (r_s= 0.58 $p<0.05$). With temperature it was negatively related (r_s= -0.58 $p<0.05$).

3.3. Plants harbouring nests

In order to understand which plant species support more nests and also species of birds, the data from both the habitats were pooled.

In total, 26 plant species were used by various bird species for nesting (Table 4). As birds show preference for snags, it was considered as a plant substrate regardless of species. Of the 26 plants, the diversity of nests was greater on *Anogeissus latifolia* (2.0) followed by Snags (1.6). Species such as *Lantana camara, Erythroxylum monogynum, Ziziphus mauritiana, Randia dumetorum* and *Acacia chundra* were the next group which supported more or less the same diversity of nests. Nests (platform) were found even on succulent species such as *Euphorbia antiquorum* and *Opuntia dillenii.*

Eventhough the maximum number of nests were on *Toddalia asiatica*, only seven species nested on this species. Moreover, no nest was found on this species when it was not associated with an other plant species such as *Gymnosporia sp, Erythroxylum sp* or *Strychnos potatorum*. Mostly dome-nests were found on this species.

A total of 19 nests of 2 species was found on the ground.

Figure 2. Breeding seasonality of birds in the study areas during 1995-1996.

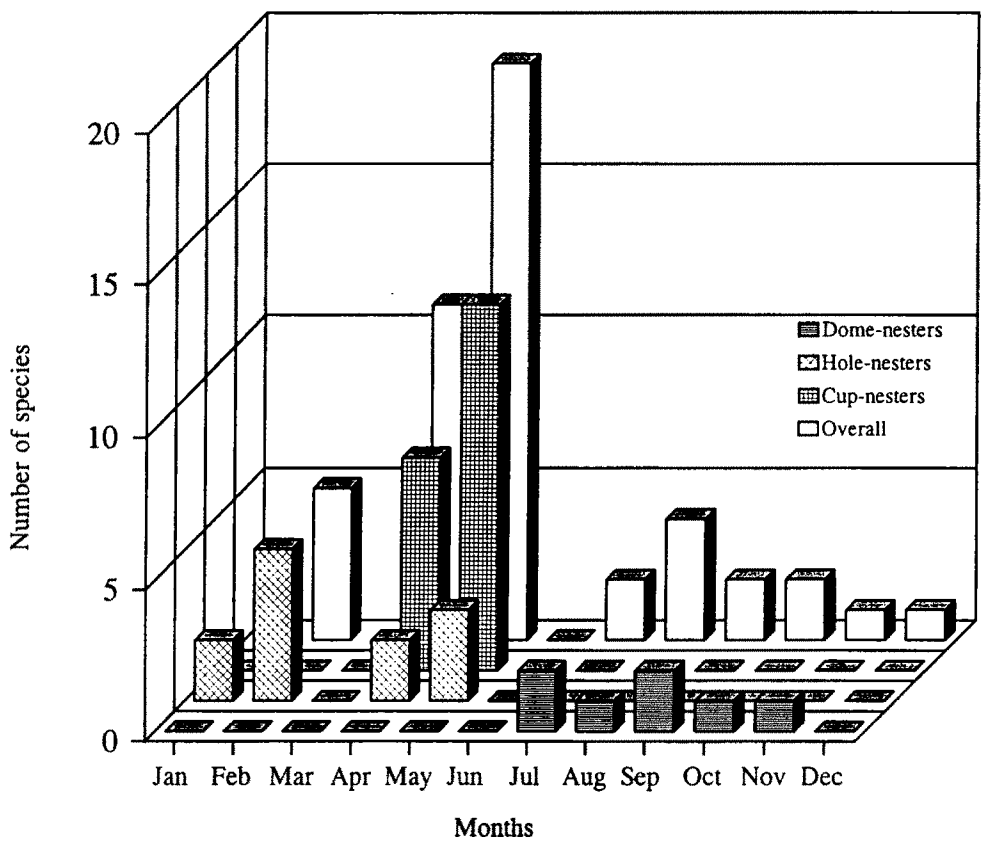


Table 4 . Number of bird species and nests on various plants

Plant species	# of bird species nesting	# of nests	Diversity (H')
Acacia chundra	5	25	1.3
Acacia catechu	1	4	0.0
Anogeissus latifolia	13	45	2.0
Bombax ceiba	1	2	0.0
Cordia sp	1	1	0.0
Dalbergia latifolia	1	3	0.0
Elaeodendron glaucum	3	6	0.8
Erythroxylum monogynum	5	17	1.3
Eucalyptus globulus	1	3	0.0
Euphorbia antiquorum	1	1	0.0
Ficus bengalensis	1	1	0.0
Gymnosporia montana	3	22	0.7
Lagerstroemia lanceolata	1	2	0.0
Lantana camara	4	30	1.2
Mangifera indica	1	1	0.0
Opuntia dillenii	1	2	0.0
Phyllanthus emblica	3	4	1.0
Pterocarpus marsupium	1	1	0.0
Randia dumetorum	5	13	1.4
Snag	8	23	1.6
Strychnos potatorum	1	2	0.0
Tectona grandis	2	7	0.5
Terminalia bellirica	1	4	0.0
Toddalia asiatica	7	50	1.2
Unidentified bush	2	2	0.6
Ziziphus mauritiana	4	12	1.3
Ground	2	19	0.2

3.4 Nest-plant selection of individual species

Bird species with >10 nests were selected for the analysis. Of the 30 species, only nine were selected.

3.4.1. Whiteheaded Babbler (*Turdoides affinis*) .

In total, 40 nests were found on 11 different species of plants (Fig. 3a). Number of nests were higher on *Lantana camara* (28%) and fewer on *Euphorbia antiquorum* (3%).

3.4.2. Indian Baybacked Shrike (*Lanius vittatus*).

In total, 24 nests of Baybacked Shrike were seen on 8 plant species (Fig. 3b). Majority of the nests were on *Erythroxylum monogynum* (21%) and *Toddalia asiatica* (21%). Only 13% of nests were on *Gymnosporia montana, Randia dumetorum, Eucalyptus sp,* and *Acacia chundra*.

3.4.3. Paradise Flycatcher (*Terpsiphone paradisi*).

Only 11 nests were found during the study period, 64% of these nests were on *Erythroxylum monogynum* while 36% were on *Toddalia asiatica* (Fig. 3c).

3.4.4. Blossomheaded Parakeet (*Psittacula cyanocephala*).

All the nests (16) of Blossomheaded Parakeet were found in the dry deciduous habitat. The nests were found equally on snags and live trees (Fig. 3d). But

regardless of the condition of tree (dead or alive), it showed a preference for *Tectona grandis* (65%).

3.4.5. Indian Robin (*Saxicoloides fulicata*).

Of 28 nests of Indian Robin, 19 were in the thorn forest and nine in dry deciduous forest. The nests in thorn forest were located mostly on ground (Fig. 3e). But in the dry deciduous habitat, nests were placed mostly on plants. In total, 64% of the nests were on the ground and the rest on plants (36%). The preferred plants were *Anogeissus latifolia* (21%) and *Phyllanthus emblica* (14%) and. The nests were largely found on dead rather than on live trees.

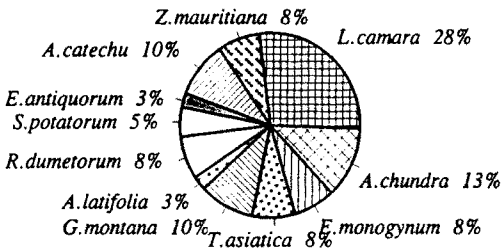
3.4.6. Spotted Munia (*Lonchura punctulata*).

Sixty nests of this species were found only on four species of plants (Fig. 3f). The Spotted Munia showed higher preference for *Toddalia asiatica* (50%) followed by *Gymnosporia montana* (25%) and *Acacia chundra* (20%). Only 5% of the nests were on *Ziziphus mauritiana*. Eventhough, 50% of the nests were found on *Toddalia asiatica* a straggler, no nest was built on it when this was not associated with *Gymnosporia montana*.

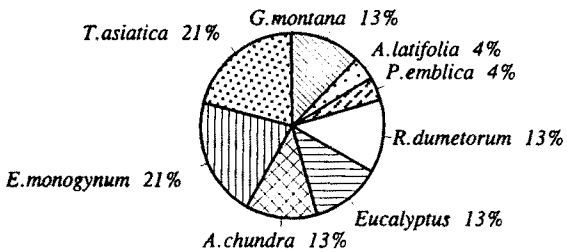
3.4.7. Purple Sunbird (*Nectarinia asiatica*).

The Purple Sunbird used only two plant species for nesting. Of the 10 nests, 70% was on *Lantana camara* and 30% on *Ziziphus mauritiana* (Fig. 3g).

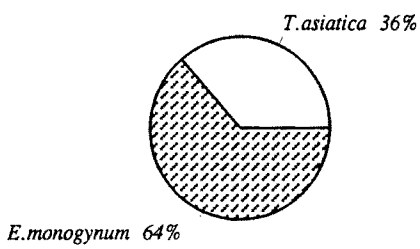
Figure 3. Percentage of nests of various bird species found on plant species



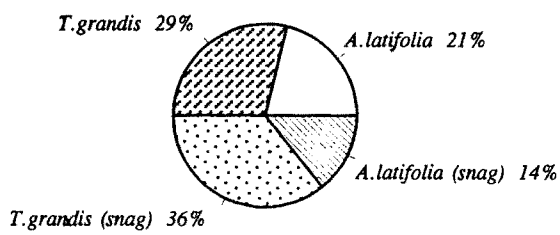
a. Whiteheaded Babbler (n=40)



b. Baybacked shrike (n=24)



c. Paradise Flycatcher (n=11)



d. Blossomheaded Parakeet (n=16)

3.4.8. Whitebrowed Fantail Flycatcher (*Rhipidura aureola*).

The Whitebrowed Fantail Flycatcher used only trees for nesting (Fig. 3h). 83% of nests was on *Anogeissus latifolia* and the rest on *Elaeodendron glaucum* (17%).

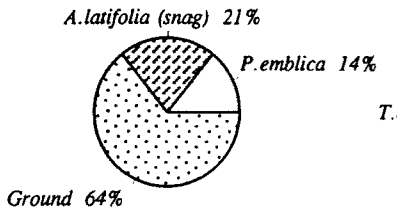
3.4.9. Crested Hawk-Eagle (*Spizaetus cirrhatus*).

Twelve nests of Crested Hawk-Eagle were found on five plant species, of which *Terminalia bellirica* was the most preferred (33%) followed by *Dalbergia latifolia* (25%) (Fig. 3i).

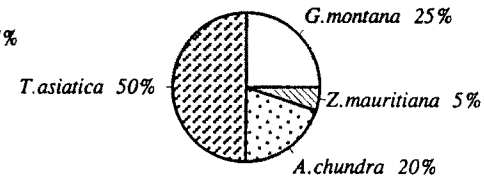
3.5. Nest-site selection and nesting details.

Five bird species were selected for analyses of nest-site selection because these were poorly studied. A subset of 12 vegetational parameters of the nest-site were subjected to Principal Component Analysis (PCA). All the values were standardized using log(x+1) transformation for the analysis as PCA may be affected by the scaling of individual variables (Manly 1986). Step-wise Discriminant Function Analysis was done to identify the factors responsible in discriminating the nest-site from the random-site for each species. The PCA and DCA were done only on five species which had a sample size of more than 20 nests.

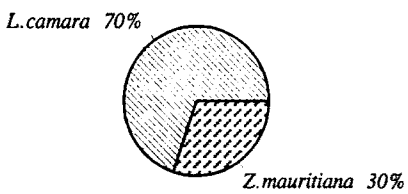
Figure 3. contd.



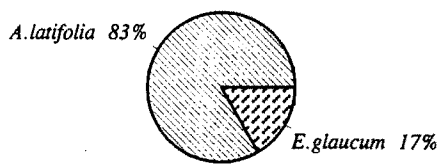
e. Indian Robin (n=28)



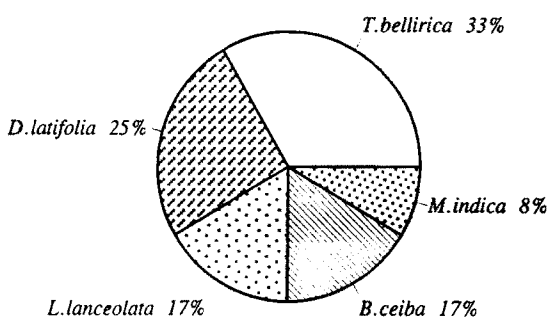
f. Spotted Munia (n=60)



g. Purple Sunbird (n=10)



h. Whitebrowed Fantail Flycatcher (n=24)



i. Crested Hawk-Eagle (n=12)

3.5.1. The Crested Hawk-Eagle.

In total, 12 nests of the Crested Hawk-Eagle were located. Of these only seven nests were with either eaglets or eggs. The rest were empty and assumed to have been used in the previous year. This was confirmed with the help of experienced biologists and tribal people in the area. No new nest was built during the study period, instead old nests were renovated for use. The nests were mostly renovated in December with twigs or branches and leaves. Fresh green leaves were also found inside the nest. Replacement of old leaves with new was also observed. Both the sexes were involved in the activity. The clutch size was only single (n=4). The mean incubation period was 42.5 days (n=2).

Nests were mostly located in the upper one-third portion/part of a tree where two or more lateral branches extended from the trunk to form a platform. The nests were placed at a mean height of 20.3 m from the ground level. The mean length and width of the nests were 115.5 cm and 61.5 cm respectively. The girth class of the nest materials (twigs and branches) varied from 10 cm to 59 cm. The mean nest-tree height and gbh were 22.1 $\pm$ 3.3m and 302.7 $\pm$ 60.5 cm respectively (Table 5).

Analysis of variance and other univariate procedures indicated that the Crested Hawk-Eagle did not select nest-sites randomly in Mudumalai Wildlife Sanctuary. The sites are selected to fulfill specific nesting requirements . Of the environmental variables, except ground cover and shrub cover, all others (nest-tree height $F=18.55$, $P=0.0004$; nest-tree gbh $F=6.0375$, $P=0.0244$; distance to water $U= 12.0$, $P=0.0006$; distance to settlement $U= 12.0$, $P=0.0048$; and

canopy-openness U=0.5, P=0.0001) differed significantly between nest-sites and random-sites. It corroborates that the Crested Hawk-Eagle selects the site with the microhabitat features such as availability of larger and broader trees, open space, proximity to water source, and farther from human settlement.

3.5.2. Baybacked Shrike.

In total, 24 nests of Baybacked Shrike were studied. The nests almost in a bowl shape were built with fine grass, moss and rootlets. The inner side was lined with feathers and cobweb. Both sexes shared the nesting activities. The clutch size varied from 3 to 5 eggs. The eggs were pinkish in colour with brown spots. The mean incubation period was 15 ± 0.78 (n=13).

Table 5. Nest-site characteristics of the Crested Hawk Eagle in comparison with random-site characters.

Variables	Nest-plot (n=12)		Random plot (n=12)		P =
	Mean	SD	Mean	SD	
Nest-height(m)	20.3	±3.0	-	-	-
Nest-length(cm)	115.5	±20.5	-	-	-
Nest-width(cm)	61.5	±18.2	-	-	-
Tree-height(m)	22.1	±3.3	15.62	±3.3	<.01
Gbh(cm)	302.7	±60.5	20.75	±90.2	<.05
Ground-cover(%)	24.6	±14.8	45.62	±35.0	ns
Shrub-cover(%)	40.4	±16.2	43.75	±18.1	ns
Distance to water(rank)	1.0	±0.0	1.75	±0.4	<.01
Distance to settlement(km)	3.7	±1.5	1.40	±0.8	<.01
Canopy-openness(%)	79.6	±4.0	43.12	±17.5	<.01

ns=not statistically significant

The nests were placed at a mean height of 1.56 m above the ground (Table 6). The nest height varied from 0.87 m to 2.21 m. The mean depth and diameter of the nests were 3.65 cm and 8.57 cm respectively. Most of the nests were found on disturbed plant species (with cutting or lopping sign). The mean GBH of the nest-plant was 31.44 ± 13.20 cm. Baybacked Shrike constructed the nests between forked twigs or branches

Of the environmental variables, canopy-cover ($U=75.5$ $p<0.01$), ground-cover ($U=37.5$ $p<0.01$), tree-height ($F=18.9$ $p<0.01$), tree-gbh ($F=15.1$ $p<0.01$), and distance to road ($F=15.1$ $p<0.01$) differed significantly from the random plot (Table 7). The DCA (Stepwise) resulted in identification of three variables (canopy-cover (0.40), ground-cover (0.36), and nest-tree height (0.59)) which discriminated the nest-site from the random-site.

Table 6. Nest-site characteristics of Baybacked Shrike

Variables	Mean	SD(±)
Nest-tree Height (m)	2.66	1.22
Nest-tree Gbh (cm)	31.44	13.20
Nest-height (cm)	156.36	40.43
Ground-cover (%)	26.12	24.40
Shrub-cover (%)	26.00	24.53
Shade over nest (%)	40.36	22.90
Nest-depth (cm)	3.65	0.54
Total nest diameter(cm)	8.57	0.68
Interior diameter(cm)	6.23	0.56
Distance to next tree(m)	3.70	3.40
Distance to road(m)	239.72	355.20
Disturbance on nest tree(%)	18.40	19.53
Nest concealment	6.72	5.06
Distance to trunk (cm)	28.20	48.06

Table 7. Comparison of nest-site variables of the Baybacked Shrike with random-sites.

Parameter	Nest-site(n=24) Mean±SD	Random site(n=20) Mean±SD	*P*
Tree-height(m)	2.6 ± 1.2	7.0 ± 4.82	0.00
Tree-Gbh(cm)	31.44 ± 13.20	51.05 ± 20.40	0.00
Tree-density	4.16 ± 0.7	4.15 ± 2.03	ns
Ground-cover(%)	26.1 ± 24.4	83.50 ± 32.97	0.00
Shrub-cover(%)	26.0 ± 24.5	29.50 ± 28.56	ns
Canopy-cover(%)	36.2 ± 17.4	78.50 ± 22.95	0.00
Distance to Road (m)	239.7± 355.2	567.95 ± 636.10	0.00

ns= not statistically significant

The first three principal components were selected which accounted for 61.2% of the total variance (Table 8). The first component was highly associated with nest-tree height, nest-tree gbh, canopy-cover, and distance to the next tree. The second component was associated with shade over nest and nest concealment. The third component was associated with nest-tree gbh, nest-height and distance to trunk. The factors highly correlated with these three components were those that directly relate to the nest-tree and indicate the characteristics of tree in the nest-site selection.

In general, the nests were placed on a small tree in a microhabitat with less canopy- and ground-cover. Interestingly, nests were found close to the road and on disturbed tree.

Table 8. Factor loadings of various vegetational characteristics with the first three principal components for the nest data of the Baybacked Shrike. (values representing high correlations with their respective principal components are shown in bold)

Variables	PC I	PC II	PC III
Nest-tree height	**-0.93**	0.03	-0.01
Nest-tree Gbh	**-0.61**	-0.02	**0.62**
Nest-height	-0.15	0.12	**0.89**
Ground-cover	0.10	-0.01	0.08
Shrub-cover	0.32	0.08	0.02
Canopy-cover	**0.65**	-0.61	-0.12
Shade over nest	0.12	**-0.88**	0.01
Distance to trunk	0.13	-0.25	**0.78**
Distance to next tree	**0.53**	0.38	0.04
Distance to road	0.12	0.38	0.04
Disturbance on nest-tree	0.05	0.41	-0.01
Nest concealment	0.12	**0.72**	-0.12
Eigen value	3.12	2.42	1.79
% Variance	26.1	20.2	14.9
% Accumulated Variance	26.1	46.3	61.2

3.5.3. Whitebrowed Fantail Flycatcher.

A total of 24 nests of Whitebrowed Fantail Flycatcher was taken for the analysis. Nests were found only on trees, especially *Anogeissus latifolia*. They were built only on the twigs on the outer edge of the lower canopy. The nest was a neatly built cup, often placed on a horizontal fork. Only fine grass and rootlets were used as nesting materials. It took four to five days to construct a nest (n=3). Nest-site fidelity or using the same site in different years for nesting was observed in three cases but it is not known whether the same pair was using it

repeatedly. The clutch size varied from two to three eggs. The mean incubation period and nestling period were 14.5 (n=8) and 16.5 (n=4) days respectively.

The nests were placed at a mean height of 4.71 m from the ground level (Table 9). The nest height varied from 3 m to 5.67 m. The mean depth and diameter of the nests were 3 cm and 5.6 cm respectively. No sign of disturbance was observed on the nesting plant species (cutting or lopping sign). The girth class of the nest-plant varied from 57 cm to 167 cm.

The nest-site differed from the random-site in ground-cover ($U=59.5$ $p<0.01$), canopy-cover ($U=52.5$ $p<0.01$), tree-GBH ($F=32.9$ $p<0.01$) and tree-density ($F=10.3$ $p<0.01$) (Table 10). The DCA (Step-wise) resulted in identification of two variables (canopy-cover 0.55, nest-tree gbh 0.53) which maximized the difference between nest-site and random-site.

Table 9. Nest-site characteristics of the Whitebrowed Fantail Flycatcher

Variables	Mean	SD
Nest-tree height(m)	7.52	0.90
Nest-tree Gbh(cm)	98.85	31.10
Nest-height(cm)	471.80	64.97
Ground-cover (%)	46.00	19.97
Shrub-cover (%)	25.75	14.60
Shade over Nest (%)	83.00	16.23
Nest-depth(cm)	2.98	0.11
Total nest diameter (cm)	5.60	0.13
Interior diameter (cm)	5.00	0.17
Distance to next tree (m)	3.29	1.36
Distance to road(m)	540.50	538.37
% Disturbance on nest tree	0.00	0.00
Nest concealment	2.05	1.15
Distance to trunk	125.0	32.77

Table 10. Comparison of nest-site variables of Whitebrowed Fantail Flycatcher with random-sites.

Parameter	Nest-site (n=24)	Random site (n=20)	*P*
	Mean ± SD	Mean ± SD	
Tree-height (m)	7.52 ± 0.90	7.0 ± 4.82	ns
Tree Gbh (cm)	98.85 ± 31.1	51.05 ± 20.40	0.00
Tree Density	5.40 ± 0.89	4.15 ± 2.03	0.00
Ground Cover (%)	46.00 ± 19.97	83.50 ± 32.97	0.00
Shrub Cover (%)	25.75 ± 14.60	29.50 ± 28.56	ns
Canopy Cover (%)	37.20 ± 16.34	78.50 ± 22.95	0.00
Distance to Road	540.50 ± 538.3	567.95 ± 636.10	ns

ns= not statistically significant

First three components, which accounted for 64.6% of the total variance were considered (Table 11). The first component, which accounted for 29.1% of the total variance was highly correlated with nest-tree Gbh, nest-height and distance to road. The second component associated with variables such as ground-cover, canopy-cover and distance to next tree. The third component was highly correlated with shade over the nest and nest-concealment.

In general, the Whitebrowed Fantail Flycatcher selects a place with more trees.

Table 11. Factor loadings of various vegetational characteristics with the first three principal components for the nest data of the Whitebrowed Fantail Flycatcher. (values representing high correlations with their respective principal components are shown in bold)

Variables	PC I	PC II	PC III
Nest-tree height	0.45	0.48	0.04
Nest-tree gbh	**-0.75**	0.32	0.02
Nest height	**0.68**	-0.18	0.00
Ground-cover	-0.16	**-0.68**	0.46
Shrub-cover	0.16	-0.12	0.14
Canopy-cover	0.22	**-0.85**	0.03
Shade over nest	-0.16	0.10	**0.87**
Distance to trunk	**0.82**	0.09	0.07
Distance from next tree	-0.33	**0.67**	0.19
Distance to road	**-0.54**	0.49	0.11
Nest concealment	-0.35	0.06	**-0.82**
Eigen value	3.19	2.17	1.73
% Variance	29.10	19.80	15.80
% Accumulated Variance	29.10	48.80	64.60

3.5.4. Spotted Munia.

Nest-site variables were measured for 26 nests. The Spotted Munia showed a consistency in selecting thorny plant species as the nesting substrate. The nests were globular or dome shaped with a lateral entrance-hole. It used only grass blades to build the nest. All the nests were built on twigs and mostly in the inner side of the canopy. Both the sexes shared the nesting activities. Only four to six eggs were laid. Incubation period varied from 10 to 15 days (n=17, mean= 11.8, ±1.60). The fledging period varied from 18 to 22 days (mean 20.23 ±=1.30,

n=17). The nests were placed at a mean height of 2.23 m from the ground level (Table 12). The nest height varied from 1.22 m to 3.52 m. The mean depth and diameter of the nests were 12.32 cm and 4.18 cm respectively. A value of 0 up to 80% of disturbance was recorded on the nesting plant species (cut or lop sign). The girth class of the nest tree varied from 20 cm to 56 cm with a mean of 27.45 cm.

Table 12. Nest-site characteristics of Spotted Munia

Variables	Mean	SD
Nest-tree height (m)	3.14	0.78
Nest-tree Gbh (cm)	27.45	11.95
Nest-height (m)	2.23	0.64
Ground-cover (%)	70.91	23.89
Shrub-cover (%)	23.64	20.77
Shade over nest (%)	50.00	25.26
Nest diameter (cm)	4.18	0.33
Nest depth (cm)	12.32	1.39
Distance from nearest tree(m)	2.87	2.11
Distance to road (m)	460.0	637.00
Disturbance on nest-tree	4.32	17.06
Nest concealment	4.77	4.40
Distance to trunk	59.5	53.5

The results indicated that the canopy-cover ($U=78$ $p<0.01$), nest-tree height ($F=13.876$ $p<0.01$), and nest-tree gbh ($F=21.3914$ $p<0.01$) differed significantly between the nesting site and random-site (Table 13). The DCA (Step-wise) showed three variables, nest-tree gbh (0.48) and height (0.40), and canopy cover (0.57) as significant factors deciding nest-site selection.

Table 13 . Comparison of nest-site variables of Spotted Munia with random-sites.

Parameter	Nest-site (n=26)	Random site (n=20)	*P*
	Mean ± SD	Mean ± SD	
Tree Height	3.14 ± 0.78	7.0 ± 4.82	0.00
Tree Gbh	27.45 ± 11.95	51.05 ± 20.40	0.00
Tree Density	4.0 ± 0.87	4.15 ± 2.03	ns
Ground Cover	70.9 ± 23.89	83.50 ± 32.97	ns
Shrub Cover	23.6 ± 20.77	29.50 ± 28.56	ns
Canopy Cover	38.4 ± 19.72	78.50 ± 22.95	0.00
Distance to Road	460.0 ± 637.0	567.95 ± 636.10	ns

ns= not statistically significant

Spotted Munia showed consistency in selecting short and small trees in a microhabitat where the canopy-cover was less. The first three components were selected in PCA as it accounted for 62.0% of the total variance. The first component was associated with canopy-cover and shade over nest positively and disturbance on nest-tree negatively (Table 14). The second component was associated with ground cover and shrub cover. The third component was associated with nest-tree height and gbh, and distance to the next tree.

Table 14. Factor loadings of various vegetational characteristics with the first three principal components for the nest data of the Spotted Munia. (values representing high correlations with their respective principal components are shown in bold)

Variables	PC I	PC II	PC III
Nest-tree height	0.33	0.10	**0.85**
Nest-tree GBH	-0.23	-0.10	**0.72**
Nest-height	0.28	0.04	-0.04
Ground-cover	-0.20	**0.87**	0.32
Shrub-cover	0.18	**0.89**	-0.21
Canopy-cover	**0.88**	-0.04	-0.02
Shade over nest	**0.79**	0.14	-0.16
Distance to trunk	0.19	0.07	-0.01
Distance from next tree	-0.36	0.49	**0.56**
Distance to road	-0.47	-0.47	-0.31
Disturbance on nest-tree	**-0.71**	0.14	-0.20
Nest concealment	-0.63	-0.02	0.01
Eigen value	3.30	2.54	1.58
% Variance	27.50	21.20	13.20
% Accumulated Variance	27.50	48.80	62.00

3.5.5. Paradise Flycatcher.

Nests of Paradise Flycatcher were built with fine roots, fibre and small leaves. These materials were compactly bound together with cobwebs. The nests were cone-shaped and decorated with spider's egg bags. It took 7 days to build the nest (n=3). Only males were seen constructing the nest. The clutch size varied from 3 to 4. The eggs were pinkish white. The mean incubation period was 15 $\pm$ 0.81 (n=3) and the nestling period varied from 13 to 14 days (n=2).

Forked twigs were used as base for constructing the nest. The girth class of the plant species varied from 20 cm to 28 cm which showed its preference for shrubs or saplings. The nests were placed at a mean height of 1.84 m above ground. The diameter of the nest varied from 6.8 cm to 7.2 cm with a depth of 4.2 cm to 4.7 cm. Only a maximum of 10% disturbance was recorded on the plant in which the nest was built (Table 15).

Table 15. Nest-site characteristics of Paradise Flycatcher

Variables	Mean	SD
Nest-tree height (m)	3.3	0.4
Nest-tree Gbh (cm)	24.6	2.7
Nest-height (cm)	184.9	15.7
Ground-cover (%)	72.5	17.9
Shrub-cover (%)	69.0	7.0
Shade over nest (%)	92.0	8.4
Nest depth(cm)	4.44	0.1
Total nest diameter(cm)	6.98	0.1
Interior diameter(cm)	6.44	0.2
Distance from nearest tree(m)	0.67	0.2
Distance to road(m)	189.0	75.8
Disturbance in nest tree (%)	1.0	3.0
Nest concealment	5.3	2.0
Distance to trunk (cm)	150.1	27.5

Of the variables, the nest-sites showed significant differences in the shrub-cover ($U=24.0$ $p<0.01$), tree height ($F=5.8288$ $p<0.05$), tree-Gbh ($F=16.37$ $p<0.01$) and tree density ($F=12.27$ $p<0.01$) from the random-plot (Table 16). In

general, nests were placed on shrub species in a nulla (microhabitat) with more shrub-cover and low tree density.

Table 16. Comparison of nest-site variables of Paradise Flycatcher with random-sites.

Parameter	Nest-site (n=11)	Random site (n=20)	*P*
	Mean ± SD	Mean ± SD	
Tree Height	3.3 ± 0.43	7.0 ± 4.82	0.02
Tree Gbh	24.6 ± 2.80	51.05 ± 20.40	0.00
Tree Density	1.4 ± 0.52	4.15 ± 2.03	0.00
Ground Cover	72.5 ± 17.90	83.50 ± 32.97	ns
Shrub Cover	69.0 ± 7.00	29.50 ± 28.56	0.00
Canopy Cover	62.5 ± 8.25	78.50 ± 22.95	ns
Distance to Road	189.0 ± 75.82	567.90 ± 636.10	ns

4. DISCUSSION

4.1. Nest-types

As majority of the birds in the study areas were cup-nesters, cup-nests were found more frequently in both the habitats. Holenests were found more in the dry deciduous habitat than in the thorn forest. Woodpeckers and other cavity nesting birds are largely dependant on dead or dying trees for nest-sites (Conner *et al.*,1976; Evans and Conner, 1979; Scott, 1979; Raphael and White, 1984). The availability of snags and trees were more in the dry deciduous (see chapter III) and hence, holenests were more in this habitat. Similarly, the availability of thorny

species were more in thorn forest (see chapter III), and hence, dome-nest were abundant in these type of forest.

4.2. Breeding seasonality.

Breeding season in bird species is governed by both ultimate and proximate factors (Immelmann, 1971). Every species breed at the time of the year when it can raise its young most successfully. In the Mudumalai Wildlife Sanctuary, the peak breeding season for most of the birds in the dry deciduous and thorn forests was during dry to early wet season I (Jan-May). Temperature has been reported as an important factor in determining the breeding season and thus breeding starts during or beginning of dry season (Kluijver, 1951; Nice, 1957; Goodacre and Lack, 1959; Naik and Mistry, 1981). It is also recorded that breeding stops during or after the beginning of heavy rains (Moreau, 1950; Thomson, 1950; Naik and Mistry, 1980). This has been confirmed for Bulbuls and Drongos (Vijayan, 1980; Vijayan, 1984). Breeding during the dry season may be a strategy to avoid heavy rain and wind which often destroy the nests while the higher ambient temperature helps the speedy development and successful hatching of eggs.

Apart from the temperature and rainfall (Vijayan *et al.*, 1996), other factors such as availability of food and nesting materials are also important in determining the breeding season (Lack, 1968). Most of the plant species in the dry deciduous and thorn forest flowered during the late dry and early wet seasons (April to June) in Mudumalai Wildlife Sanctuary. Similarly, peak fruiting season in the dry deciduous forest was during the late wet season extending into

the early dry season. In thorn forest it was during January and February (see chapter I, Murali and Sukumar, 1994). The phenological studies revealed that flowers and fruits were considerably more during February to June than in other months (see vegetation chapter). The availability of insects however is greater during the rainy season (Murali and Sukumar, 1993). Hence, food abundance, particularly during the dispersal of juveniles, may be the factor governing the breeding season of birds as reported by Immelmann (1971).

Similarly, nesting materials such as dry leaves and twigs were chiefly available during the dry season. Hence, temperature, and availability of food and nesting materials favour most of the birds breeding during February to June in the study area. Only Munia species were observed nesting during the rainy season. Availability of nesting materials also plays a major role in determining the breeding season (Collias and Collias, 1984). As munias construct their nests mainly with mature grass, its availability plays a key role in determining their breeding season. Mature grass is available only during rainy season (Sivaganesan, 1991) and the availability of food for the young when they fledge is more after rains with the seeds of grass and grains being abundantly available.

In general, food abundance, particularly during the dispersal of juveniles, availability of nesting materials, and temperature may be the factors governing the timing of the breeding season of birds in this area as recognized by Immelmann (1971) in the studies conducted elsewhere.

4.3. Plants harbouring nests

Twenty six plant species were recorded as substrate or platform for 302 nests of 30 bird species. Diversity of nests was greater for nine species of plants. Different plant species have different architecture to which birds respond to build nests on. The arrangements of branches and twigs on certain plant species provide better sites for nests for some species of birds. For raptors, Titus & Mosher (1987) observed that not all trees are suitable for nest location because the size and geometry of branching must produce an acceptable fork within the preferred vertical range of the bird species. Martinsen & Whitham (1994) found that because of the numerous lateral branches and associated crotches, certain hybrid trees may offer better nest-sites to some birds. Nickell (1958) and Ficken (1964) suggested that some species may use tactile and visual stimuli from tree forks to ascertain their suitability as nest locations. Hubert (1993) stated that characteristics of trees such as the angle between the nest branch and trunk, height of the tree, the crown volume, and the average trunk spacing were important in determining the choice of nest-site selection of Common Buzzrd.

In the present study, it is evident that particular species or groups of plants are better suitable for particular types of nests. For example, species such as *Anogeissus latifolia* supported largely hole and cup-nests while *Acacia* spp. and *Gymnosporia montana* largely supported dome-nests. Similarly, larger and broader trees such as *Terminalia bellirica* and *Bombax ceiba* supported larger platform nests (Crested Hawk-Eagle) while, *Tectona grandis* supported mainly hole-nests.

Nest-plant selection has widely been discussed for single or a group of bird species. Besides, the reason for selecting a particular plant has largely been related to the biology of the bird species than to the architecture of plants. Very few studies tried to relate the geometrical configuration of the plant and nesting success. Peterson (1979) and Bednarz and Dinsmore (1982) could not detect any significant influence of the geometry of the plant on the nest success while, Dijak *et al.* (1990) stated that some characteristics of the nest tree (i.e., tree size, understorey) influence the nesting success. Hence, plant supportiveness in terms of harbouring a nest may be attributed to the geometry and physical complexity of the plants present in an area.

Eventhough, no nest success was calculated and related with the plant-geometry, it can be speculated that the architecture may play a major role in deciding the type of nest it can support. For example, the architecture of *Tectona grandis* may not be suitable for dome-nest. Similarly, *Anogeissus latifolia* may not be suitable for nests of Eagles.

Almost all nests were found on common plant species in the study area. Some of the species were very common. To avoid predation, birds build their nests more on common plant species than rare ones as finding rare species in an area would be time consuming for a predator (Martin and Roper, 1988). All the common and abundant species present in the study area were not extensively used for nesting. For example, *Tectona grandis* and *Opuntia dillenii* although common, could support only a few nests. Similarly plant species such as *Randia dumetorum, Acacia cateachu* were in low density, but could support more

number of nests. Kozma and Mathews (1997) studied 24 plant species used as nest-plants by various bird species in Chihuahuan desert and inferred that characteristics such as dense foliage, stiff branches, spinescent stems, and greater height of these plants might be the reason for the selection even when they are in low density. Hence, it can be attributed to the geometry and physical complexity of the plants rather than to their availability.

The snag or live tree of *Anogeissus latifolia* and *Tectona grandis* supported large number of hole-nests. These trees are dominant in the dry deciduous forests where hole-nests were found maximum. Hole-nests were negligible in the thorn forest as snags of these two species were rare/absent. Woodpeckers and other cavity-nesting birds are largely dependent on dead or dying trees for nest-sites (Conner *et al.*, 1976; Evans and Conner, 1979; Scott, 1979; Raphael and White, 1984). Snags are highly preferred by cavity nesters as excavation would be easy on the softer portions of dead trees. The ground moisture, flooding at the base of snags, and rain soaking at the tops may increase microclimate humidity and facilitate softening of the wood by fungal decay. Thus, the availability of holes on these two plant species might be because of the nature of the wood which is suitable for the excavators to make holes in large numbers. In the present study, both the plant species supported excavators as well as non-excavators. Thorny species such as *Acacia sp,* and *Erythroxylum monogynum* were mostly occupied by dome-nests, as their branches are densely interwoven and thorny to provide sufficient structural support to the dome-nest.

In general, architecture of the plant (branch geometry), nature of wood (soft/hard) and the form of plant (Shrub or tree) largely determines the kind of nests it can support.

4.4. Nest-plant selection in the major breeding species

Of the nine species selected, only Whiteheaded Babbler and Baybacked Shrike used a wide variety of plant species for building the nest. It can be said that they were effectively utilizing the study area's floristic variety. The use of wide variety of nest substrates may be a strategy to counteract a predator's search tactics for particular types (Furrer, 1975). As the Blossomheaded Parakeet and Indian Robin are non-excavators, their plant selection can be attributed to the availability of suitable holes already present in the plants and the inter and intra-specific competition of birds in the study area. Among these two species, although the Indian Robin is not a primary hole-nester, constructing nests in holes may be a strategy to reduce predation.

Selection of thorny species (*Acacia spp, Toddalia asiatica* and *Gymnosporia montana*) by Spotted Munia can be attributed to the densely interwoven and thorny nature of the these plants which provide sufficient structural support to their dome-nest. Moreover, the thorny nature of the plant would also protect the nest from predators (Collias and Collias, 1984). Purple Sunbird nests were found abundantly on shrubs (*Ziziphus mauritiana* and *Lantana camara*). Placing the pendant nest on a tree or at a higher location would not be beneficial as the wind velocity will be higher at higher height. The same reason may be applicable to

Paradise Flycatcher. Moreover, both the nest are easily visible if they are built on tree or at higher height which will attract predators. The Whitebrowed Fantail Flycatcher prefers only tree species, especially *Anageissus latifolia*. As the colour of the nest is similar to the bark of the *Anageissus latifolia*, the selection of *Anageissus latifolia* largely for constructing nests may be a strategy to hide it from predators. The Crested Hawk-Eagle preferred *Terminalia bellirica* and *Dalbergia latifolia*. Larger Accipiters are known to use larger trees to support their massive nests (Siders and Kennedy, 1994). Traditional use of nest-sites every year by the same individual is reported in raptors (Collias and Collias, 1984). The Crested Hawk-Eagle may also utilize these strategies in selecting the plants for placing their nests. In the present study, although it is evident that some nests were used in successive years, it is not known whether the same nest was used by the same pair.

4.5. Nest-site selection and nesting details.

4.5.1. Crested Hawk-Eagle.

The clutch size was single in the case of Crested Hawk-Eagle (n=4) as reported by Ali and Ripley (1987). The mean incubation period was 42.5 days (n=2). But this varied from that reported earlier (40 days) by Ali and Ripley (1987), an observation based on only one nest. However, such variations are reported in certain species changing with local conditions.

In the case of Crested Hawk-Eagle, the nest-tree height and gbh (otherwise age) of the tree seem to be the key factor in selecting a tree for nesting. Apart

from that, there seems to be specific preference for tree species (not proportionate to their availability). The explanation for selecting the broader (larger GBH) and taller trees concur with earlier studies reporting that the larger Accipiters apparently use larger trees to support the massive nests (Shiraki, 1994; Siders and Kennedy, 1996). Moreover, nest placement between tree branches and trunks facilitates adults to make frequent trips to nests with food, and youngs to early take off. Reason for the use of green material inside the nest concur with Nores and Nores (1994) that it may be a strategy to diminish infestation by ectoparasites. Traditional use of nest-site every year by the same individual has also been observed in raptors (Collias and Collias, 1984). In the present study, renovation of old nest for use was observed. This strategy is adopted probably to avoid spending energy for constructing massive nests.

The nest-sites were apparently found to be with less canopy, close to water source and farther from human settlement. Brown and Amadon (1968) stated that a nest was in a situation allowing the parents free flight into and out of the nest. Moreover, the lower wing loading (body weight/wing area) and increased tail area are usually associated with increased manoeuvreability (Muller *et al*., 1981) and with species that need wider avenues of approach to the nest. To compensate for decreased manoeuvreability, the Crested Hawk-Eagle nest was positioned higher in the forest canopy for the improvement of accessibility. Moreover, the Eagle is a perch hunter and selection of open habitat would facilitate its accessibility and vigilance over the nest and also the prey. Selas

(1997) reported that for larger species, nest-site selection may be a response both to nest predation risk, microclimate, foraging habitat and food supply.

4.5.2. Baybacked Shrike.

Desai and Malhotra (1986) reported that the clutch size varied from 3 to 4 and the incubation period 14 to 15 days. The average incubation period was 14.6 days. This is similar to the present study and the slight difference can be attributed to larger sample size. Similarly, the nest-height varied considerably from their study which probably because of the difference in habitat structure.

The nests were found largely in small trees or shrubs in a place with low canopy and ground cover, and near to road. Collias and Collias (1984) reported that nests placed closer to areas of human activity may discourage predators from searching near heavily used trails and areas frequented by people. Moreover, the Baybacked Shrike is an aggressive defender capable of chasing predators from open sites. Moreover, the Baybacked shrike mainly pounce for insects on the ground from a perch and hence selects an open area for nesting, in the vicinity of which it can feed. Thus, the feeding strategy may explain why Baybacked Shrike nest in areas with less ground and shrub cover.

4.5.3. Whitebrowed Fantail Flycatcher.

The structure of the nest of WHitebrowed Fantail Flycatcher and repeated use of nests is similar to that reported by Ali and Ripley (1987).

The Whitebrowed Fantail Flycatcher selected a patch with high tree density, less canopy cover and with low to moderate ground cover to construct nest. A nest in a patch with large number of potential nest sites may reduce predator efficiency because they will be forced to search more sites for a successful finding (Martin, 1988; Martin and Roper, 1988). Tendency to choose patches with more trees may reflect the choice of patches with larger potential for nest-sites. More trees at nest patches often higher foliage cover and nest concealment which would help in reducing predation. In many cases, nests were built exactly in the same place or branch in the subsequent years. The obvious advantage of site-fidelity to the bird is familiarity with the area, which may enhance foraging success, predator avoidance, defence and other behaviours which contribute to reproductive performance (Newton and Wyllie, 1992).

4.5.4. Indian Spotted Munia.

Ali and Ripley (1987) reported 16 days as the incubation period for Spotted Munia while Sharma and Bhatt (1996) recorded 11 days. Similarly, Sharma and Bhatt (1996) reported 20 to 22 days as fledging period. These differences can be attributed to the different sample sizes and the environmental factors such as temperature, availability of food and predators as documented in the drongos (Vijayan, 1984).

The Indian Spotted Munia selected patches with high tree density. In most of the cases nests were constructed largely on shrubs which are densely surrounded with other shrub species as well as short trees. They largely

preferred a combination of shrubs and trees to construct their nest. Murphy (1983) and Martin (1992, 1993b) have suggested that predation, as it is the primary cause of nest failure, should be the key factor influencing nest-site selection. Since the spotted Munia construct their nests mostly during rainy period. The selection of combination of tree and shrub species provide better concealment (within nest-plant) from the predators and also protect the chicks from rain.

4.5.5. Paradise Flycatcher.

Ali and Ripley (1987) reported 3-4 eggs as the clutch size and 15-16 days as incubation period for the Paradise Flycatcher. They further stated that both the sexes actively participated in nesting. However, in the present study, only male was found constructing the nest while the female guarded at nest. The incubation period and the clutch size were similar to that reported by Ali and Ripley (1987).

The Paradise Flycatcher preferred to nest on short tree or shrubs in a nullah with higher shrub cover and low tree density. Betham (1910) found most of the Paradise Flycatcher nests within hand reach. But, Rashid *et al* ., (1989) found a nest on *Mangifera indica* about 4m in height, close to human settlement. The present findings are similar to Betham (1910). Murphy (1983) and Martin (1992 and 1993b) have suggested that predation should be the key factor influencing nest-site selection. Selection of nest-sites with dense vegetation theoretically can inhibit predator efficiency by visually screening the nest and the parent's activities, by providing too many potential nest-sites for the predator to search,

and by physically impeding predators (Holway 1991). The Paradise Flycatcher may utilize each of these strategies in the selection of their nest-sites. Furthermore, Paradise Flycatcher catch insects in the air mostly from shrub canopy. Hence, constructing the nest close to the foraging height may be its strategy to save energy and increase vigilance over the nest and prey.

5. SUMMARY

Nesting and nest-site characteristics of breeding birds in the thorn and dry deciduous forests of Mudumalai WLS were studied during 1995 and 1996. The following issues were addressed; 1. the breeding seasonality of birds, 2. the nest-tree selection of selected breeding birds, and 3. the nest-site selection of selected breeding birds.

A total of 302 nests of 30 species of birds was recorded; 200 nests of 22 species in the thorn forest and 102 nests of 20 species in dry deciduous forest.

1. In both habitats, cup-nests were more common. The dry deciduous forest harboured higher number of hole-nests while the thorn forest harboured more number of dome-nests. Regardless of habitats, the major breeding season of birds was from February to June with a peak in May.

2. A total of 26 plant species was used for nesting by various bird species. Diversity of nests was found high in *Anogeissus latifolia* and snags. Among the nine birds selected to study for the nest-plant selection, Whitebrowed Fantail

Flycatcher showed some level of consistency in selection of plant species for nest placement. Whiteheaded Babbler used a wide variety of plants to place their nests.

3. Nest-site selection was studied in only five bird species namely Crested Hawk Eagle, Baybacked Shrike, Whitebrowed Fantail Flycatcher, Spotted Munia, and Paradise Flycatcher. Tree height, tree GBH, tree density, shrub cover and canopy cover were found crucial in various levels in the nest-site selection of these species. All the species except Baybacked Shrike preferred undisturbed areas and plants for nesting.

CHAPTER VII

GENERAL CONCLUSION AND MANAGEMENT RECOMMENDATIONS

Bird communities in the thorn and dry deciduous forests of Mudumalai Wildlife Sanctuary was studied during 1994-1997 with the following objective:

to identify the patterns and processes of bird communities in the thorn and dry deciduous forests.

It was achieved through studies on population, foraging patterns and nest-site selection. These aspects were studied in detail with the supporting data on the habitat structure (vegetation physiognomy) and the general avifauna of Mudumalai Wildlife Sanctuary.

1. Avifauna of Mudumalai Wildlife Sanctuary

Regardless of habitat types, 265 bird species belonging to 17 orders were recorded in Mudumali Wildlife Sanctuary. It included nine of the 15 species endemic to the Western Ghats. In general, insectivorous birds dominated in all the habitats followed by nectarivores/frugivores. Among the major habitat types (thorn, dry deciduous and moist deciduous), the number of birds sighted were more in the thorn forest and low in the moist deciduous forest.

Birds were classified as generalists (if sighted in more than one habitat) and specialists (if sighted in only one habitat). Among the habitats, specialists were more in the thorn forest and low in the dry deciduous forest.

The thorn and moist deciduous forests harboured greater number of specialists, endemics of Western Ghats, waterfowl as well as raptors.

2. Vegetation physiognomy and impact of human interference on plant community .

Vegetation of the thorn and dry deciduous forests was enumerated to identify the density, species richness, and diversity of plant species and to identify the human impact on them. Both the habitat types considerably varied in the plant species composition due to the changes in the environmental factors between habitats. Although tree diversity was more in the thorn forest, there was almost a fourfold increase in the number of trees available in the dry deciduous forest. Both the availability and diversity of snags were also greater in dry deciduous than in the thorn forest, so also the foliage height diversity (FHD). In both the habitats, a few individuals of one or more species were either in flowering or fruiting stage in a given month of the year.

Informal interviews with the people who regularly exercise wood-cutting inside the protected area revealed that plant species were largely preferred for fuelwood purposes as majority of the local communities are dependant upon wood as their primary energy source. A total of seven plant species were preferred by the local people. Number of plant species exploited by the people varied between habitats. It was more in the thorn forest than in the dry deciduous forest. In total, based on informal interview, inspection of wood bundles, and

vegetation survey, 17 plant species were identified as used extensively by the local people for various purposes.

3. Bird community

Abundance of birds in the thorn and dry deciduous forests was estimated in dry and wet seasons between 1995 and 1996. Species richness, abundance and diversity of birds were more during the dry season than in the wet season in both the habitats throughout the study period. The presence of migrants and breeding season of the resident birds resulted in the higher diversity in dry season. In general, the insectivores and frugivores dominated in both the habitats. Both of them showed distinct seasonal fluctuation in their abundance in both the habitats.

No relationship was found between FHD and BSD in both the habitats. However, in order to understand the relationship between FHD and the functional aspects of birds (foraging), foraging observations (see chapter V) collected were used. Since the foraging observations were collected for the dry season, the FHD measured in dry season alone was considered. Here bird diversity correlated positively with foliage height diversity both in the thorn (r_s = 0.9048, P= 0.001) and dry deciduous forest (r_s = 0.6164 P= 0.022). Comparison of population of avifauna between habitats revealed that species richness and diversity were more in the thorn forest during dry and in the dry deciduous forest during wet season.

4. Foraging pattern of birds

Foraging patterns of birds in the thorn and dry deciduous forests were studied during the dry season (January to April) in 1995 and 1996 in Mudumalai Wildlife Sanctuary.

Thorn forest

In total, 1386 foraging observations were made on 33 bird species in the thorn forest. A total of 6 substrates, 9 methods, and 3 layers were found used predominantly by the 33 bird species. Among the foraging dimensions (foraging height, method and substrate), highest niche overlap was found in the vertical strata (height) followed by the substrate and method. Specialists were found more in the substrate category followed my method and height. The cluster analysis (based on foraging dimensions) separated the birds of thorn forest mainly by the foraging height into two guilds (ground, and shrubs/trees). Further, birds were separated based on the foraging method and substrate.

Dry deciduous forest

In total, 1176 foraging observations were made on 30 bird species in the dry deciduous forest. A total of 6 substrates , 8 methods, and 3 vegetation layers were used predominantly by the 30 bird species. Among the foraging dimensions (foraging height, method and substrate), highest niche overlap was found in the height followed by the substrate and method. Specialists were found more in the substrate category followed my method and height. The cluster analysis (based

on foraging dimensions) separated the birds of dry deciduous forest mainly by the height into three guilds (ground, shrub/short trees, and trees). Further, birds were separated based on the foraging method and substrate.

Comparison of foraging pattern between forests

The foraging patterns of birds of these two forests differed largely by vegetation layer rather than other dimensions i.e., method and substrate. Of the 28 bird species studied in both the forest types, 20 species differed significantly in their height use while only seven species differed in their foraging method between forests. As the use of foraging method and substrate may be constrained by morphology, no difference was found in most of the birds.

4.Nesting and nest-site characteristics

Nesting and nest-site characteristics of breeding birds in the thorn and dry deciduous forests of Mudumalai WLS were studied in 1995 and 1996. A total of 302 nests of 30 species of birds was observed; 200 nests of 22 species in the thorn forest and 102 nests of 20 species in dry deciduous forest.

In both habitats, cup-nests were more. The dry deciduous forest harboured more number of hole-nests while the thorn forest harboured more number of dome-nests. Regardless of habitats, birds had the major breeding season from February to June with a peak in May.

A total of 24 plant species were used for nesting by various bird species. Diversity of nests were found more in *Anogeissus latifolia* and snags. Among the

nine birds studied for the nest-plant selection, Whitebrowed Fantail Flycatcher showed some level of consistency while Whiteheaded Babbler used a wide variety of plants.

Nest-site selection was studied on only five bird species, namely Crested Hawk Eagle, Baybacked Shrike, Whitebrowed Fantail Flycatcher, Spotted Munia, and Paradise Flycatcher. Tree height, tree GBH, tree density, shrub cover and canopy cover were found crucial in various levels in the nest-site selection of these species. All the species except Baybacked Shrike preferred undisturbed areas and plants for nesting.

MANAGEMENT RECOMMENDATIONS

1. The thorn and moist deciduous habitats are important as they support more number of specialists. Moreover, these are the two habitats facing severe anthropogenic pressures in Mudumalai Wildlife Sanctuary. Although the dry deciduous habitat is not much disturbed like other habitats, it supports lower number of habitat specialists as it is structurally less complex. However, it is a good nesting habitat for the hole-nesters because of the availability of more trees and snags. These snags have to be preserved from illegal removal. Late II wet season to early I wet season (November to July) is the crucial period for most of the birds as it is the season for migrants and nesting of resident birds. Human pressure has to be minimized at least during this period throughout the sanctuary.

2. Special effort has to be made to preserve the places such as Ompetta and Game Hut for the waterfowl. The quality of these sites may be improved and proper record of the wintering and breeding population of waterfowl maintained every year. Bird census should be exercised at least every year in every habitat type. Fire should be controlled as it affects the breeding birds and vegetation dynamics.

3. The comparison of the foraging guild of birds between habitats showed the importance of some of the resource dimensions. The availability and distribution of food resources at different levels of heights seemed to be very crucial for discriminating the birds between habitats. Hence any sort of selectivity in the plant species in terms of lopping, wood cutting, or removal of trees would lead to the change in the structure of bird community and should therefore be stopped.

4. Species such as *Anogeissus latifolia, Acacia spp, Randia duometorum* are predominantly utilized for nesting by birds. Similarly, all these species are preferred by the local people as firewood. Hence, a proper programme has to be made to preserve these tree species for the survival of the birds. Raising fire-wood plants outside the sanctuary and supplying firewood through the Forest department to the local people would reduce the human impact on these tree species. In the thorn forest, among the microhabitats, nullahs and riparian patches act as nesting habitat for many of the rare species of this area. These

are the places where sand removal is severe which should be stopped and given protection. The Crested Hawk-Eagle, Paradise Flycatcher, and Whitebrowed Fantail Flycatcher showed some level of fidelity to the nest-site and nest-tree. Hence, proper attention has to be given to minimize disturbance to their nesting areas or microhabitats. Large trees are essential in the dry deciduous forest for the Crested Hawk Eagle to nest. Hence, felling of these or disturbance in these areas should be stopped.

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APPENDIX-I

ORDER	FAMILY	COMMON NAME	SCIENTIFIC NAME	TOTAL H	S	F
Podicipitiformes	Podicipedidae	Little Grebe	*Podiceps ruficollis*	S	R	A
Pelecaniformes	Phalacrocoracidae	Large Cormorant	*Phalacrocorax carbo*		R	A
		Indian Shag	*Phalacrocorax fuscicollis*		R	A
		Little Cormorant	*Phalacrocorax niger*		R	A
		Oriental darter	*Anhinga rufa*		R	A
Ciconiiformes	Ardeidae	Grey Heron	*Ardea cinerea*		R	A
		Large Egret	*Ardea alba*		R	A
		Indian Pond Heron	*Ardeola grayii*		R	A
		Cattle Egret	*Bubulcus ibis*		R	I
		Little Egret	*Egretta garzetta*		R	A
		Night Heron	*Nycticorax nycticorax*		R	A
		Black Bittern	*Ixobrychus flavicollis*		R	A
	Ciconiidae	Openbill Stork	*Anastomus oscitans*		M	A
		Blacknecked Stork	*Ephippiorhynchus asiaticus*		M	A
Anseriformes	Anatidae	Pintail	*Anas acuta*		M	A
		Common Teal	*Anas crecca*		M	A
		Cotton Teal	*Nettapus coromandelianus*	M	A	
		Comb Duck	*Sarkidiornis melanotos*		M	A
Falconiformes	Accipitridae	Blackwinged Kite	*Elanus caeruleus*	SDM	R	C
		Honey Buzzard	*Pernis ptilorhynchus*	DM	R	C
		Black Kite	*Milvus migrans*	SD	R	C
		Brahminy Kite	*Haliastur indus*	SD	R	C
		Shikra	*Accipiter badius*	SDM	R	C
		Crested Goshawk	*Accipiter trivirgatus*	M	R	C
		Sparrow-Hawk	*Accipiter virgatus*	M	R	C
		Buzzard	*Buteo buteo*	D	R	C
		Whiteeyed Buzzard	*Butastur teesa*	SD	M	C
		Crested Hawk-Eagle	*Spizaetus cirrhatus*	SD	R	C
		Bonelli's Eagle	*Hieraaetus fasciatus*	D	M	C
		Booted Hawk Eagle	*Hieraaetus pennatus*	D	M	C
		Rufousbellied Hawk Eagle	*Hieraaetus kienerii*	DM	M	C
		Tawny eagle	*Aquila rapax*	DM	R	C
		Black eagle	*Ictinaetus malayensis*	M	M	C
		Greyheaded Fishing Eagle	*Ichthyophaga ichthyaetus*	DM	R	A
		King Vulture	*Sargogyps calvus*	SDM	R	C
		Indian Longbilled Vulture	*Gyps indicus*	D	R	C
		Indian Whitebacked Vulture	*Gyps bengalensis*	SD	R	C
		Egyptian Vulture	*Neophron percnopterus*	SD	R	C
		Pale Harrier	*Circus macrourus*	SD	M	C
		Marsh Harrier	*Circus aeruginosus*	SDM	M	C
		Shorttoed Eagle	*Circaetus gallicus*	DM	R	C
		Crested Serphant Eagle	*Spilornis cheela*	SDM	R	C
	Falconidae	Kestrel	*Falco tinnunculus*	DM	M	C
Galliformes	Phasianidae	Grey Patridge	*Francolinus pondicerianus*	SD	R	G
		Jungle Bush Quil	*Perdicula asiatica*	SD	R	G
		Painted Bush Quil	*Perdicula erythrorhyncha*	D	R	G
		Red Spurfowl	*Galloperdix spadicea*	M	R	G
		Grey Junglefowl	*Gallus sonneratii*	SDM	R	G
		Indian Peafowl	*Pavo cristatus*	SDM	R	G
Gruiformes	Rallidae	Whitebrested Waterhen	*Amaurornis phoenicurus*		R	I
		Moorhen	*Gallinula chloropus*		R	I
		Common Coot	*Fulica atra*		R	I
Charadriiformes	Jacanidae	Bronzewinged Jacana	*Metopidius indicus*		R	I

ORDER	FAMILY	COMMON NAME	SCIENTIFIC NAME	TOTAL H	S	F
	Charadriidae	Red-wattled Lapwing	*Vanellus indicus*	SD	R	I
		Yellow-wattled Lapwing	*Vanellus malabaricus*	SD	R	I
		Common Redshank	*Tringa totanus*		M	I
		Marsh Sandpiper	*Tringa stagnatilis*		M	I
		Green Sandpiper	*Tringa ochropus*		M	I
		Common Sandpiper	*Tringa hypoleucos*		M	I
		Fantail Snipe	*Gallinago gallinago*		M	I
	Burhinidae	Stone Curlew	*Burhinus oedicnemus*	S	R	I
	Laridae	River Tern	*Sterna aurantia*		R	NF
Columbiformes	Pteroclididae	Indian Sandgrouse	*Pterocles exustus*		R	G
	Columbidae	Greyfronted Green Pigeon	*Treron pompadora*	M	R	NF
		Yellowlegged Green Pigeon	*Treron phoenicoptera*	SDM	R	NF
		Blue Rock Pigeon	*Columba livia*	SD	R	G
		Nilgiri Wood Pigeon	*Columba elphinstonii*	M	R	NF
		Indian Ring Dove	*Sterptopelia decaocto*	SD	R	G
		Red Turtle Dove	*Sterptopelia tranquebarica*	SD	R	G
		Spotted dove	*Sterptopelia chinensis*	SDM	R	G
		Little Brown Dove	*Sterptopelia senegalensis*	D	R	G
		Emerald Dove	*Chalcophaps indica*	M	R	G
Psittaciformes	Psittacidae	Alexandrine Parakeet	*Psittacula eupatria*	DM	R	NF
		Roseringed Parakeet	*Psittacula krameri*	SD	R	NF
		Blossomheaded Parakeet	*Psittacula cyanocephala*	SDM	R	NF
		Bluewinged Parakeet	*Psittacula columboides*	M	R	NF
		Indian Lorikket	*Loriculus vernalis*	SDM	R	NF
Cuculiformes	Cuculidae	Pied Crested Cuckoo	*Clamator jacobinus*	DM	M	I
		Large Hawk-Cuckoo	*Cuculus sparverioides*	SD	M	I
		Common Hawk -Cuckoo	*Cuculus varius*	DM	R	I
		Indian Cuckoo	*Cuculus micropterus*	SDM	R	I
		Banded Bay Cuckoo	*Cacomantis sonneratii*	S	R	I
		Indian Plaintive Cuckoo	*Cacomantis passerinus*	S	R	I
		Koel	*Eudynamys scolopacea*	SDM	R	I
		Small Greenbilled Malkoha	*Rhopodytes viridirostris*	S	R	I
		Crow-Pheasant	*Centropus sinensis*	SD	R	I
		Lesser Coucal	*Centropus toulou*	S	R	I
Strigiformes	Strigidae	Barn owl	*Tyto alba*	S	R	C
		Scops Owl	*Otus scops*	DM	R	C
		Collared Scops Owl	*Otus bakkamoena*	M	R	C
		Great Horned Owl	*Bubo bubo*	DM	R	C
		Forest Eagle-Owl	*Bubo nipalensis*	M	R	C
		Brown Wood Owl	*Strix leptogrammica*	M	R	C
		Jungle Owlet	*Glaucidium radiatum*	DM	R	C
		Spotted Owlet	*Athene brama*	SD	R	C
Caprimulgiformes	Caprimulgidae	Indian Jungle Nightjar	*Caprimulgus indicus*	SDM	R	I
		Common Indian Nightjar	*Caprimulgus asiaticus*	SD	R	I
		Franklin's Nightjar	*Caprimulgus affinis*	DM	R	I
Apodiformes	Apodidae	Indian Edible-Nest swiftlet	*Collocalia unicolor*	SD	R	I
		Spinetailed swift	*Chaetura gigantea*	M	R	I
		House Swift	*Apus affinis*	S	R	I
		Palm Swift	*Cypsiurus parvus*	SD	R	I
		Crested Tree Swift	*Hemiprocne longipennis*	S	R	I
Coraciiformes	Alcedinidae	Pied Kingfisher	*Ceryle rudis*	SD	R	A
		Small Blue Kingfisher	*Alcedo atthis*	SD	R	A
		Blue-eared Kingfisher	*Alcedo meninting*	M	R	A
		Threetoed Kingfisher	*Ceyx erithacus*	M	R	A
		Storkbilled Kingfisher	*Pelargopsis capensis*	DM	R	A

ORDER	FAMILY	COMMON NAME	SCIENTIFIC NAME	TOTAL H	S	F
		Whitebreasted Kingfisher	*Halcyon smyrnensis*	SD	R	A
	Meropidae	Chestnutheaded Bee-eater	*Merops leschenaulti*	M	R	I
		Bluetailed Bee-eater	*Merops philippinus*	S	M	I
		Small Green Bee-eater	*Merops orientalis*	SD	R	I
	Coraciidae	Indian Roller	*Coracias benghalensis*	SD	R	I
	Upupidae	Hoopoe	*Upupa epops*	SDM	R	I
	Bucerotidae	Common Grey Hornbill	*Tockus birostris*	DM	R	NF
		Malabar Grey Hornbill	*Tockus griseus*	DM	R	NF
		Malabar Pied Hornbill	*Anthracoceros coronatus*	M	R	NF
		Great Pied hornbill	*Buceros bicornis*	M	R	NF
Piciformes	Capitonidae	Large Greeen Barbet	*Megalaima zeylanica*	SDM	R	NF
		Small Green Barbet	*Megalaima viridis*	DM	R	NF
		Crimsonthroated Barbet	*Megalaima rubricapilla*	SDM	R	NF
		Crimsonbreasted Barbet	*Megalaima haemacephala*	SDM	R	NF
	Picidae	Speckled Piculet	*Picumnus innominatus*	M	R	I
		Rufous Woodpecker	*Micropternus brachyurus*	M	R	I
		Small Yellownaped woodpecker	*Picus chlorolophus*	SD	R	I
		Lesser Goldenbacked Woodpecker	*Dinopium benghalense*	SDM	R	I
		Goldenbacked Threetoed Woodpecker	*Dinopium javanense*	M	R	I
		Great Black Woodpecker	*Dryocopus javensis*	M	R	I
		Yellowfronted Pied Woodpecker	*Picoides mahrattensis*	SD	R	I
		Heartspotted Woodpecker	*Hemicircus canente*	DM	R	I
		Blackbacked Woodpecker	*Chrysocolaptes festivus*	SD	R	I
		Larger Goldenbacked Woodpecker	*Chrysocolaptes lucidus*	DM	R	I
Passeriformes	Pittidae	Indian Pitta	*Pitta brachyura*	SDM	M	I
	Alaudidae	Singing Bush lark	*Mirafra javanica*	S	R	I
		Redwinged Bush lark	*Mirafra erythroptera*	S	R	I
		Ashycrowned Finch-lark	*Eremopterix grisea*	S	R	I
		Rufoustailed Finch-lark	*Ammomanes phoenicurus*	S	R	I
	Hirundinidae	Dusky Crag Martin	*Hirunda concolor*	S	R	I
		Swallow	*Hirunda rustica*	S	M	I
		House Swallow	*Hirunda tahitica*	S	R	I
		Wiretailed Swallow	*Hirunda smithii*	SD	R	I
		Redrumped Swallow	*Hirunda daurica*	SD	R	I
	Laniidae	Grey Shrike	*Lanius excubitor*	SD	R	I
		Baybacked Shrike	*Lanius vittatus*	SD	R	I
		Rufousbacked Shrike	*Lanius schach*	S	M	I
		Brown Shrike	*Lanius cristatus*	SDM	M	I
	Oriolidae	Golden Oriole	*Oriolus oriolus*	SDM	M	NF
		Blacknaped Oriole	*Oriolus chinensis*	M	R	NF
		Blackheaded Oriole	*Oriolus xanthornus*	SDM	R	NF
	Dicruridae	Black Drongo	*Dicrurus adsimilis*	SD	R	I
		Ashy Drongo	*Dicrurus leucophaeus*	M	R	I
		Whitebellied Drongo	*Dicrurus caerulescens*	SDM	R	I
		Bronzed Drongo	*Dicrurus aeneus*	M	R	I
		Racket-tailed Drongo	*Dicrurus paradiseus*	DM	R	I
	Sturnidae	Greyheaded Myna	*Sturnus malabaricus*	D	R	NF
		Brahminy Myna	*Sturnus pagodarum*	SD	R	NF
		Rosy pastor	*Sturnus roseus*	S	M	NF
		Common Myna	*Acridotheres tristis*	SD	R	NF
		Jungle Myna	*Acridotheres fuscus*	SD	R	NF
		Hill Myna	*Gracula religiosa*	M	R	NF
	Corvidae	Indian Treepie	*Dendrocitta vagabunda*	SDM	R	C
		Whitebellied Treepie	*Dendrocitta leucogastra*	M	R	C
		House Crow	*Corvus splendens*	SDM	R	C

ORDER	FAMILY	COMMON NAME	SCIENTIFIC NAME	TOTAL H	S	F
		Jungle Crow	*Corvus macrorhynchos*	SDM	R	C
	Campephagidae	Pied Flycatcher-Shrike	*Hemipus picatus*	DM	R	I
		Large Wood Shrike	*Tephrodornis virgatus*	M	R	I
		Common Wood Shrke	*Tephrodornis pondicerianus*	SD	R	I
		Large Cuckoo-Shrike	*Coracina novaehollandiae*	SDM	R	NF
		Blackheaded Cuckoo-Shrike	*Coracina melanoptera*	SD	R	NF
		Scarlet Minivet	*Pericrocotus flammeus*	SDM	R	I
		Small Minvet	*Pericrocotus cinnamomeus*	SD	R	I
		Whitebellied Minivet	*Pericrocotus erythropygius*	S	R	I
	Irenidae	Common Iora	*Aegithina tiphia*	SDM	R	I
		Goldfronted Chloropsis	*Chloropsis aurifrons*	DM	R	I
		Goldmantled Chloropsis	*Chloropsis cochinchinensis*	DM	R	I
		Fairy Bluebird	*Irena puella*	M	R	NF
	Pycnonotidae	Redwhiskered Bulbul	*Pycnonotus jocosus*	SDM	R	NF
		Redvented Bulul	*Pycnonotus cafer*	SD	R	NF
		Yellowthroated Bulbul	*Pycnonotus xantholaemus*	S	R	NF
		Yellowbrowed bulbul	*Hypsipetes indicus*	M	R	NF
		Black bulbul	*Hypsipetes madagascariensis*	M	R	NF
	Muscicapidae	Spotted Babbler	*Pellorneum ruficeps*	SDM	R	I
		Slatyheaded Scimitar Babbler	*Pomatorhinus schisticeps*	SDM	R	I
		Blackheaded Babbler	*Rhopocichla atriceps*	M	R	I
		Yelloweyed Babbler	*Chrysomma sinense*	S	R	I
		Common Babbler	*Turdoides caudatus*	S	R	I
		Large Grey Babbler	*Turdoides malcolmi*	S	R	I
		Rufous Babbler	*Turdoides subrufus*	DM	R	I
		Jungle Babbler	*Turdoides striatus*	DM	R	I
		Whiteheaded Babbler	*Turdoides affinis*	SD	R	I
		Brown Flycatcher	*Muscicapa latirostris*	SD	R	I
		Black-and-Orange Flycatcher	*Muscicapa nigrorufa*	M	R	I
		Whitebellied blue Flycatcher	*Muscicapa pallipes*	M	R	I
		Bluethroated Flycatcher	*Muscicapa rubeculoides*	M	M	I
		Tickell's Blue Flycatcher	*Muscicapa tickelliae*	M	R	I
		Verdictor Flycatcher	*Muscicapa thalassina*	M	M	I
		Greyheaded Flycatcher	*Culicicapa ceylonensis*	DM	R	I
		Whitebrowed Fantail Flycatcher	*Rhipidura aureola*	SD	R	I
		Whitethroated Fantail Flycatcher	*Rhipidura albicollis*	S	R	I
		Paradise flycatcher	*Terpsiphone paradis*	SDM	R	I
		Blacknaped Flycatcher	*Hypothymis azurea*	SDM	R	I
		Fantail Warbler	*Cisticola exilis*	S	R	I
		Franklin's wren-Warbler	*Prinia hodgsonii*	SD	R	I
		Plain Wren-Warbler	*Prinia subflava*	SD	R	I
		Ashy Wren-Warbler	*Prinia socialis*	S	R	I
		Jungle Wren-Warbler	*Prinia sylvatica*	SD	R	I
		Tailorbird	*Orthotomus sutorius*	S	R	I
		Broadtailed grass Warbler	*Schoenicola platyura*	S	M	I
		Great Reed Warbler	*Acrocephalus stentoreus*	S	M	I
		Blyth's Reed Warbler	*Acrocephalus dumetorum*	SDM	M	I
		Booted Warbler	*Hippolais caligata*	SD	M	I
		Orphean Warbler	*Sylvia hortensis*	S	M	I
		Lesser Whitethroat	*Sylvia curruca*	SDM	M	I
		Chiff-chaff	*Phylloscopus collybita*	S	M	I
		Tytler's Leaf Warbler	*Phylloscopus tytleri*	S	M	I
		Tickell's Leaf Warbler	*Phylloscopus affinis*	S	M	I
		Dull Green warbler	*Phylloscopus trochiloides*	SDM	M	I
		Largebilled Leaf warbler	*Phylloscopus magnirostris*	DM	M	I

ORDER	FAMILY	COMMON NAME	SCIENTIFIC NAME	TOTAL H	S	F
		Bluethroat	*Erithacus svecica*	S	M	I
		Magpie Robin	*Copsychus saularis*	SDM	R	I
		Shama	*Copsychus malabaricus*	M	R	I
		Black Redstart	*Phoenicurus ochruros*	S	M	I
		Stonechat	*Saxicola torquata*	SD	R	I
		Pied Bushchat	*Saxicola caprata*	S	R	I
		Indian Robin	*Saxicoloides fulicata*	SD	R	I
		Blueheaded Rock Thrush	*Monticola cinclorhynchus*	M	M	I
		Bluerock Thrush	*Monticola solitarius*	D	M	I
		Wynaad Laughing Thrush	*Garrulax delesserti*	M	R	I
		Malabar Whistling Thrush	*Myiophonus horsfieldii*	M	R	I
		Orange Headed Ground Thrush	*Zoothera citrina*	SD	M	I
		Blackbird	*Turdus merula*	M	R	NF
	Paridae	Grey Tit	*Parus major*	SDM	R	I
		Yellowcheeked Tit	*Parus xanthogenys*	M	R	I
	Sittidae	Chestnutbellied Nuthatch	*Sitta castanea*	SD	R	I
		Velvetfronted Nuthatch	*Sitta frontalis*	DM	R	I
	Motacillidae	Forest Wagtail	*Motacilla indica*	M	M	I
		Pied Wagtail	*Motacilla alba*	SDM	M	I
		Large Pied Wagtail	*Motacilla maderaspatensis*	SD	R	I
		Yellow Wagtail	*Motacilla citreola*	S	M	I
		Grey wagtail	*Motacilla cinerea*	M	M	I
		Paddyfield Pipit	*Anthus novaeseelandiae*	S	R	I
		Tawny Pipit	*Anthus campestris*	S	M	I
		Brownrock Pipit	*Anthus similis*	DM	R	I
		Tree Pipit	*Anthus trivialis*	DM	M	I
		Indian tree pipit	*Anthus hodgsoni*	M	M	I
	Dicaeidae	Tickell's Flowerpecker	*Dicaeum erythrorhynchos*	SDM	R	NF
		Nilgiri Flowerpecker	*Dicaeum concolor*	SDM	R	NF
	Nectarinidae	Purplerumped Sunbird	*Nectarinia zeylonica*	SD	R	NF
		Small Sunbird	*Nectarinia minima*	M	R	NF
		Purple Sunbird	*Nectarinia asiatica*	SD	R	NF
		Loten's Sunbird	*Nectarinia lotensia*	M	R	NF
		Little Spiderhunter	*Arachnothera longirostris*	M	R	I
	Zosteropidae	White-eye	*Zosterops palpebrosus*	SDM	R	I
	Ploceidae	House Sparrow	*Passer domesticus*	SD	R	G
		Yellowthroated Sparrow	*Petronia xanthocollis*	SD	R	G
		Baya	*Ploceus philippinus*	SD	R	G
		Streaked Weaverbird	*Ploceus manyar*	M	R	G
		Red Munia	*Estrilda amandava*	M	R	G
		Whitethroated Munia	*Lonchura malabarica*	SDM	R	G
		Whitebacked munia	*Lonchura striata*	S	R	G
		Rufousbellied Munia	*Lonchura kelaarti*	SDM	R	G
		Spotted Munia	*Lonchura punctulata*	S	R	G
		Blackheaded Munia	*Lonchura malacca*	SDM	R	G
	Fringillidae	Common Rosefinch	*Carpodacus erythrinus*	SD	M	G
	Emberizidae	Crested Bunting	*Melops lathami*	SD	M	G

1. **H=Habitat**
   Thorn forest, D= Dry deciduous forest, M= Moist deciduous forest, SD= Thorn and dry deciduous forests, DM= Dry and moist deciduous forest, SDM= Thorn, dry and Moist deciduous forest.

2. **Status.**
   R=Resident, M= Migrant.

3. **F= Feeding guild**
   Aquatic feeder, C= carnivore, G= Granivore, I= Insectivore, NF= Nectarivore/frugivore.

- Habitat status is not given to waterbirds as they are wetland dependent

APPENDIX II

Niche overlap calculated for the bird species in the thorn forest (value is for dimensions namely foraging method, height, and substrate together)

BIRD SPECIES (CODE)	BS	BE	BH	BR	BW	CN	DW	FW	JF	TI	HO	IO	RO	LB	LW	LR	NF	PF	RS	RB	SC	SD	SM	TB	WD	WM	WY	WF	WB	YB	YF	YN	YS
Baybacked Shrike (BS)	1.00																																
Small Green Bee-eater (BE)	0.54	1.00																															
Blackheaded Oriole (BH)	0.23	0.48	1.00																														
Brahminy Myna (BR)	0.59	0.45	0.26	1.00																													
Blyth's Reed Warbler (BW)	0.24	0.21	0.46	0.21	1.00																												
Chestnutbellied Nuthatch (CN)	0.41	0.35	0.25	0.36	0.29	1.00																											
Dull Green Leaf Warbler (DW)	0.20	0.37	0.69	0.26	0.28	0.24	1.00																										
Franklin's Wren-Warbler (FW)	0.21	0.20	0.45	0.19	0.99	0.27	0.28	1.00																									
Grey Junglefowl (JF)	0.67	0.36	0.19	0.70	0.18	0.28	0.18	0.16	1.00																								
Grey Tit (TI)	0.36	0.38	0.67	0.44	0.44	0.51	0.56	0.43	0.25	1.00																							
Hoopoe (HO)	0.73	0.36	0.19	0.54	0.20	0.28	0.18	0.16	0.73	0.27	1.00																						
Common Iora (IO)	0.30	0.37	0.69	0.36	0.39	0.30	0.76	0.39	0.19	0.86	0.19	1.00																					
Indian Robin (RO)	0.89	0.40	0.19	0.55	0.21	0.29	0.19	0.16	0.74	0.27	0.92	0.20	1.00																				
Large Green Barbet (LB)	0.20	0.39	0.71	0.56	0.36	0.23	0.57	0.36	0.18	0.51	0.18	0.51	0.19	1.00																			
Lesser Goldenbacked Woodpecker (LW)	0.31	0.38	0.34	0.38	0.25	0.63	0.29	0.24	0.26	0.56	0.26	0.41	0.26	0.28	1.00																		
Lorikeet (LR)	0.21	0.36	0.40	0.46	0.18	0.21	0.42	0.17	0.17	0.28	0.17	0.30	0.18	0.63	0.31	1.00																	
Nilgiri Flowerpecker (NF)	0.22	0.32	0.39	0.51	0.18	0.24	0.30	0.17	0.17	0.36	0.17	0.40	0.18	0.50	0.39	0.86	1.00																
Paradise Flycatcher (PF)	0.46	0.59	0.30	0.30	0.29	0.42	0.20	0.28	0.23	0.29	0.23	0.29	0.26	0.19	0.24	0.19	0.19	1.00															
Common Rosefinch (RS)	0.19	0.35	0.33	0.40	0.16	0.18	0.37	0.16	0.16	0.20	0.16	0.23	0.16	0.64	0.24	0.65	0.51	0.17	1.00														
Redvented Bulbul (RB)	0.39	0.43	0.29	0.79	0.20	0.35	0.30	0.18	0.24	0.41	0.27	0.39	0.27	0.73	0.34	0.63	0.59	0.36	0.58	1.00													
Scarlet Minivet (SC)	0.28	0.70	0.89	0.30	0.37	0.25	0.52	0.37	0.20	0.62	0.20	0.64	0.20	0.59	0.40	0.41	0.43	0.43	0.32	0.33	1.00												
Spotted Dove (SD)	0.67	0.36	0.19	0.70	0.18	0.28	0.18	0.16	1.00	0.25	0.73	0.19	0.74	0.18	0.26	0.17	0.17	0.23	0.16	0.24	0.20	1.00											
Small Minivet (SM)	0.31	0.53	0.88	0.37	0.43	0.29	0.68	0.43	0.20	0.85	0.20	0.90	0.21	0.61	0.43	0.35	0.43	0.35	0.28	0.39	0.85	0.20	1.00										
Tailor Bird (TB)	0.79	0.45	0.46	0.56	0.40	0.42	0.45	0.37	0.63	0.61	0.63	0.60	0.72	0.39	0.31	0.22	0.22	0.43	0.20	0.38	0.41	0.63	0.55	1.00									
Whitebellied Drongo (WD)	0.51	0.71	0.40	0.44	0.19	0.40	0.20	0.18	0.30	0.49	0.30	0.41	0.34	0.20	0.39	0.24	0.29	0.61	0.18	0.42	0.65	0.30	0.56	0.44	1.00								
Whitebellied Minivet (WM)	0.20	0.27	0.66	0.26	0.34	0.25	0.80	0.34	0.18	0.69	0.18	0.89	0.18	0.45	0.34	0.26	0.42	0.19	0.18	0.22	0.59	0.18	0.79	0.49	0.23	1.00							
White-eye (WY)	0.34	0.38	0.40	0.54	0.30	0.37	0.58	0.30	0.20	0.60	0.20	0.69	0.21	0.52	0.38	0.73	0.78	0.36	0.47	0.66	0.42	0.20	0.60	0.49	0.40	0.58	1.00						
Whitebrowed Fantail Flycatcher (WF)	0.62	0.81	0.51	0.44	0.30	0.40	0.30	0.28	0.42	0.41	0.42	0.40	0.47	0.32	0.38	0.30	0.31	0.65	0.27	0.40	0.71	0.42	0.56	0.56	0.82	0.31	0.39	1.00					
Whiteheaded Babbler (WB)	0.69	0.40	0.21	0.55	0.24	0.31	0.23	0.21	0.73	0.29	0.73	0.24	0.74	0.19	0.28	0.19	0.19	0.29	0.17	0.26	0.23	0.73	0.25	0.80	0.33	0.23	0.26	0.48	1.00				
Yelloweyed Babbler (YB)	0.33	0.28	0.43	0.26	0.48	0.41	0.73	0.48	0.18	0.62	0.18	0.79	0.18	0.36	0.24	0.19	0.19	0.44	0.18	0.33	0.38	0.18	0.63	0.61	0.29	0.73	0.65	0.37	0.26	1.00			
Yellowfronted Pied Woodpecker (YF)	0.30	0.31	0.28	0.32	0.18	0.77	0.20	0.18	0.18	0.60	0.18	0.44	0.18	0.20	0.84	0.25	0.36	0.29	0.18	0.36	0.36	0.18	0.40	0.30	0.48	0.33	0.39	0.35	0.19	0.28	1.00		
Yellownaped Woodpecker (YN)	0.61	0.42	0.24	0.54	0.25	0.72	0.21	0.22	0.49	0.61	0.63	0.39	0.60	0.21	0.79	0.25	0.30	0.34	0.19	0.42	0.30	0.49	0.38	0.54	0.53	0.24	0.39	0.47	0.50	0.29	0.82	1.00	
Yellowthroated Sparrow (YS)	0.66	0.41	0.24	0.82	0.21	0.32	0.20	0.18	0.90	0.36	0.67	0.31	0.68	0.31	0.35	0.36	0.40	0.28	0.43	0.46	0.28	0.90	0.30	0.62	0.40	0.25	0.41	0.48	0.67	0.23	0.31	0.56	1.00
BIRD SPECIES	BS	BE	BH	BR	BW	CN	DW	FW	JF	TI	HO	IO	RO	LB	LW	LR	NF	PF	RS	RB	SC	SD	SM	TB	WD	WM	WY	WF	WB	YB	YF	YN	YS

APPENDIX II contd.

Niche overlap calculated for the bird species in the dry deciduous forest (value is for dimensions namely foraging method, height, and substrate together)

BIRD SPECIES (CODE)	BS	BE	BR	BW	CN	DW	FW	JF	HO	HW	IO	RO	LB	LW	LR	NF	PF	RD	RB	SC	SD	SM	TB	WD	WY	WF	WB	YF	YN	YS
Baybacked Shrike (BS)	1.00																													
Small Green Bee-eater (BE)	0.21	1.00																												
Brahminy Myna (BR)	0.56	0.20	1.00																											
Blyth's Reed Warbler (BW)	0.17	0.17	0.28	1.00																										
Chestnutbellied Nuthatch (CN)	0.24	0.35	0.20	0.17	1.00																									
Dull Green Leaf Warbler (DW)	0.21	0.37	0.21	0.18	0.49	1.00																								
Franklin's Wren-Warbler (FW)	0.17	0.17	0.28	1.00	0.17	0.18	1.00																							
Grey Junglefowl (JF)	0.73	0.18	0.60	0.16	0.18	0.18	0.16	1.00																						
Hoopoe (HO)	0.73	0.17	0.54	0.16	0.17	0.18	0.16	0.74	1.00																					
Heart-spotted Woodpecker (HW)	0.24	0.26	0.20	0.18	0.79	0.48	0.18	0.19	0.18	1.00																				
Common Iora (IO)	0.19	0.26	0.20	0.42	0.19	0.60	0.42	0.18	0.18	0.43	1.00																			
Indian Robin (RO)	0.98	0.18	0.54	0.16	0.17	0.18	0.16	0.74	0.76	0.18	0.18	1.00																		
Large Green Barbet (LB)	0.19	0.34	0.61	0.21	0.28	0.34	0.21	0.18	0.18	0.37	0.48	0.18	1.00																	
Lesser Goldenbacked Woodpecker (LW)	0.24	0.32	0.20	0.18	0.89	0.50	0.18	0.18	0.18	0.74	0.20	0.18	0.28	1.00																
Lorikeet (LR)	0.19	0.38	0.61	0.17	0.38	0.34	0.17	0.18	0.17	0.29	0.30	0.18	0.91	0.31	1.00															
Nilgiri Flowerpecker (NF)	0.19	0.23	0.60	0.17	0.18	0.29	0.17	0.18	0.17	0.36	0.39	0.17	0.87	0.19	0.79	1.00														
Paradise Flycatcher (PF)	0.22	0.47	0.34	0.16	0.17	0.18	0.16	0.16	0.16	0.18	0.18	0.16	0.18	0.18	0.17	0.17	1.00													
Racket-tailed Drongo (RD)	0.22	0.73	0.20	0.18	0.31	0.40	0.18	0.18	0.18	0.38	0.39	0.18	0.41	0.33	0.33	0.37	0.48	1.00												
Redvented Bulbul (RB)	0.23	0.19	0.60	0.43	0.19	0.20	0.43	0.22	0.23	0.20	0.20	0.22	0.54	0.22	0.55	0.54	0.19	0.20	1.00											
Scarlet Minivet (SC)	0.22	0.55	0.22	0.41	0.44	0.63	0.41	0.20	0.19	0.30	0.68	0.20	0.33	0.37	0.42	0.21	0.31	0.50	0.21	1.00										
Spotted Dove (SD)	0.73	0.18	0.70	0.16	0.18	0.18	0.16	0.82	0.80	0.19	0.18	0.75	0.18	0.18	0.18	0.18	0.16	0.18	0.22	0.20	1.00									
Small Minivet (SM)	0.22	0.51	0.21	0.39	0.41	0.65	0.39	0.20	0.19	0.27	0.68	0.19	0.31	0.30	0.41	0.21	0.31	0.46	0.21	0.92	0.20	1.00								
Tailor Bird (TB)	0.79	0.23	0.56	0.26	0.29	0.29	0.26	0.74	0.59	0.24	0.32	0.78	0.25	0.30	0.27	0.21	0.34	0.25	0.27	0.41	0.60	0.38	1.00							
Whitebellied Drongo (WD)	0.21	0.66	0.20	0.17	0.33	0.23	0.17	0.18	0.17	0.20	0.20	0.18	0.21	0.24	0.32	0.19	0.47	0.76	0.19	0.57	0.18	0.61	0.31	1.00						
White-eye (WY)	0.23	0.26	0.58	0.37	0.32	0.55	0.37	0.21	0.20	0.28	0.57	0.20	0.63	0.29	0.66	0.58	0.27	0.24	0.53	0.63	0.21	0.69	0.46	0.41	1.00					
Whitebrowed Fantail Flycatcher (WF)	0.42	0.61	0.37	0.28	0.35	0.29	0.28	0.33	0.33	0.23	0.24	0.38	0.26	0.29	0.35	0.24	0.61	0.74	0.33	0.54	0.33	0.61	0.48	0.86	0.41	1.00				
Whiteheaded Babbler (WB)	0.73	0.18	0.54	0.17	0.19	0.19	0.17	0.97	0.78	0.18	0.18	0.75	0.18	0.19	0.18	0.18	0.17	0.18	0.22	0.20	0.76	0.21	0.75	0.20	0.23	0.34	1.00			
Yellowfronted Pied Woodpecker (YF)	0.25	0.33	0.21	0.19	0.92	0.47	0.19	0.19	0.19	0.88	0.25	0.19	0.29	0.85	0.32	0.29	0.19	0.32	0.22	0.36	0.19	0.35	0.31	0.32	0.35	0.35	0.20	1.00		
Yellownaped Woodpecker (YN)	0.50	0.24	0.39	0.19	0.74	0.33	0.19	0.45	0.57	0.64	0.21	0.46	0.23	0.74	0.29	0.20	0.19	0.23	0.27	0.33	0.49	0.36	0.52	0.39	0.43	0.45	0.50	0.78	1.00	
Yellowthroated Sparrow (YS)	0.61	0.24	0.75	0.19	0.29	0.26	0.19	0.66	0.60	0.22	0.21	0.60	0.42	0.29	0.46	0.39	0.19	0.24	0.45	0.31	0.78	0.31	0.61	0.32	0.49	0.43	0.61	0.32	0.54	1.00
BIRD SPECIES	BS	BE	BR	BW	CN	DW	FW	JF	HO	HW	IO	RO	LB	LW	LR	NF	PF	RD	RB	SC	SD	SM	TB	WD	WY	WF	WB	YF	YN	YS