Ecology of Bird Communities in the Anaikatty Hills, Coimbatore

Thesis submitted to the

BHARATHIAR UNIVERSITY, COIMBATORE

for the award of

DEGREE OF DOCTOR OF PHILOSOPHY

in

ZOOLOGY

by

Sr. T. NIRMALA, M.Sc., B.Ed.,

SACON

Division of Avian Ecology

Salim Ali Centre for Ornithology and Natural History

Coimbatore - 641 108

February 2002

DEDICATED TO

VERY REV. Sr. EDWIGE S.A.T., MOTHER GENERAL

DECLARATION

I do hereby declare that the thesis entitled " ***Ecology of Bird Communities in the Anaikatty Hills, Coimbatore***" 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 1999 – 2001 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.

Signature of the Candidate

CERTIFICATE

This is to certify that the thesis, entitled " ***Ecology of Bird Communities in the Anaikatty Hills, Coimbatore***" is a record of original research work done by **Sr. T. Nirmala** in the Department of Division of Avian Ecology, Salim Ali Centre for Ornithology and Natural History, as a full time Research Scholar during the period of study 1999 - 2001 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.

Signature of the guide

DR. LALITHA VIJAYAN
PRINCIPAL SCIENTIST & HEAD
Division of Avian Ecology
Salim Ali Centre for Ornithology
and Natural History
Coimbatore - 641 108.

Countersigned
Director
Head of the Department
Salim Ali Centre For Ornithology,
and Natural History
Moongilpallam
Anaikatty Po,
Coimbatore-641108.

ACKNOWLEDGEMENT

I am very much grateful to my Mother General, Provincials, Superiors of my community, Secretary, Principal, and Department of Zoology, Jayaraj Annapackiam College for Women, Periyakulam, and Mr. C. Jaypaul, Secretary of Jayaraj Chelladurai College, Nallakaruppanpatty without whose support this research would not have been conducted. I can not stand aside without thanking sisters of my community, Singanallur and Puliakulam communities for their prayer, caring and accommodation.

Special thanks are due to Dr. V. S. Vijayan, Director, Salim Ali Centre for Ornithology and Natural History for the opportunity rendered, logistic support and encouragement.

I place on record my deep gratitude to my research supervisor Dr. Lalitha Vijayan for her guidance, encouragement, constant support and hospitality. I am extremely thankful to her for constructive suggestions, criticisms, motivation and care extended throughout the study period.

I am gratefully acknowledging University Grants Commission (UGC) for selecting me under Fellowship Improvement Programme, and Tamil Nadu Forest Department for their support in giving permission to do research in Field Ornithology at Anaikatty Hills.

My grateful thanks are also to the scientists of SACON, Drs. Ajith Kumar, P. Balasubramanian, S. Bhupathy, P. A. Azeez, S. N. Prasad, S. Muralidharan, P. Pramod and N. Sivaganesan who despite their busy schedule, shared their knowledge and provided constructive criticism.

I greatly appreciate the help rendered by Mr. K. K. Ramakrishnan, Computer Assistant, Drs. P. R. Arun, A. Rajasekaran, G. Umapathy, Sivakumar, Mrs. Jayashree Muralidharan, Finance Officer, SACON, and Shankar Raman, Indian Institute of Science, Divya Mudappa, Wildlife Institute of India, Drs. S. Balachandran, Senior Scientist (BNHS), Justus Joshua (GUIDE), T. Surulivelu, Senior Entomologist (CICR), Jayson, Scientist (KFRI) and Dr. K. Muralidar M.D., Medical Superintendent, Bethany Medical Centre.

I am extremely thankful to Dr. R. J. R. Daniels who encouraged me to refer his library and shared constructive criticism and the Librarians at SACON for their support.

I gratefully acknowledge the blessing and prayer of Most Rev. Dr. M. Arockiasamy D. D., ArchBishop of Madurai. My special thanks are due to Rev. Fr. Dr. Ignaci Muthu S. J., Vice-chancellor, Bharathiar University, Coimbatore; despite his busy schedule he encouraged and supported me by correcting the final draft of my thesis.

I sincerely extend my gratitude to my field assistant, Prakash, and members of the family of Mrs. Gracy Mathews.

I am greatly indebted to my parents and sisters, Mr. P. Thivyanathan, Mrs. Agathammal, Mr. Kulandaisamy, Mrs. Cecilie, Mr. Rajarethinam Pichai, Mrs. Daisy, Jenoe, Jency, Pandian and Pradeep for their constant blessing, support and encouragement to complete my thesis work.

CONTENTS

CHAPTER 7. BREEDING OF BIRDS AND IMPACT OF DISTURBANCES ON THEM

TABLES & APPENDICES

SUMMARY

Structural and functional aspects of bird communities are believed to have direct relation with the structure of habitat and thereby act as indicators of environmental changes. Various components such as the type of resource, quantity of resource and spatial and temporal distribution of resources play a major role in determining the community structure. In general, the central theme in the functional aspects of the avian community studies has been, how the available resources for biological activities such as foraging, roosting and nesting are partitioned among the existing group of species. Studies on bird community in different habitats are very few in India, and the pattern and processes of a group of species or an individual species were studied separately. The study of birds in relation to habitats will give valuable data for forest management. Area outside protected area network is also equally important for birds and biodiversity conservation. This study was designed to determine the ecology of the bird communities in the mixed dry deciduous forest and scrub forest (SACON) in Anaikatty Reserve Forest, foothills of Nilgiri Biosphere Reserve, Coimbatore, South India.

The present study was initiated with the following major objectives:

- To determine the structure of bird communities in different habitats (mixed dry deciduous forest and scrub forest) in Anaikatty Reserve Forest;
- To assess the seasonality of birds in these two habitats

- To analyze the impact of disturbance in these two habitats, especially on bird communities, and
- To investigate the general ecology of select bird species.

Study Area

Although 81% of land birds out of 1295 species of birds in the Indian subcontinent are recorded, ecology and biology of only a few species have been studied in detail. The present study was designed to determine the ecology of the bird communities in the mixed dry deciduous forest (MDDF) and in the highly degraded and regenerating area scrub forest. Scrub forest (SF) is in the campus of Salim Ali Centre for Ornithology and Natural History (SACON) and the mixed dry deciduous forest is in Anaikatty Reserve Forest, foothills of the Nilgiri Biosphere Reserve, at an elevation of about 610-750m above mean sea level. **These** an undulating terrain comprising the foothills and hills, situated between 76^0 39' and 76^0 47'E and from 11^0 5' to 11^0 31'N. The total area of Anaikatty Reserve Forest is 4447.74 ha (2292.08 ha of south division and 2155.66 ha of north division) and the area of SACON is 55 acres.

The climate varies considerably in different seasons in these forests. Seasons observed during the study period (1999-2001) were classified into four, namely southwest monsoon, northeast monsoon, winter and summer. The average rainfall during the last 10 years was 668 mm. Rainfall was moderately higher during northeast monsoon, than southwest monsoon and lowest during winter. Maximum temperature varied between 28 °C and 36 °C during the study period. The monthly mean of the relative humidity showed fluctuation between

31-75 (at 8.30 hours) and 72-89 (at 17.30 hours). The monthly mean windspeed recorded was between 3 and 14 km/h.

Vegetation Physiognomy

Altogether 118 plant species belonging to 44 families were recorded from Anaikatty Hills. Phenology of plants was studied on 36 species in mixed dry deciduous forest and 27 species in scrub forest. Shrub species richness and diversity were higher than those of tree species in the mixed dry deciduous forest. The density values of 23 tree species were <1 and only four tree species had >1. Species (50) having medicinal value are preferred for collection by the tribals.

The scrub forest consisted of the regenerating trees such as *Albizia amara, Diospyros ferrea, Elaeodendron glaucum* and *Cassia fistula* and shrubs. Cattle frequently visited this area while goats and elephants occasionally. Tree species richness was very low in scrub forest than that of shrubs. Of the 32 shrub species only a few had >1 as their density value. The most common shrub species were *Lantana camara* and *Chromolaena odorata.*

The number of species of plants in flower and fruit as well as the abundance of flower and fruit was similar in both the years, but varies between the two habitats. Plant species in fruit were higher in mixed dry deciduous forest than scrub forest in all the seasons. Abundance of flower was high during summer in both the habitats. In the scrub forest phenological trend was the same for both the years and it showed two peak periods. The maximum fruit abundance was in June-July and flower was recorded in April-May with a minor peak in October during both the years. Foliage height diversity was high and foliage was available up to 11-12 m in the mixed dry deciduous forest while it was only upto 5m in the scrub forest.

Bird community structure

A total of 129 species were recorded in the study area by census, which was 69% of the total species (187) observed in the Anaikatty Hills. Of the 129 species, 113 species belonged to 38 families in mixed dry deciduous forest and 84 species belonged to 34 families in the scrub forest. 35% of bird species were restricted to the mixed dry deciduous forest and 12% to the scrub forest. The species common to both the habitats were 53%. The number of species decreased but the abundance increased during the second year. The migratory status of bird species in the Anaikatty hills was enumerated as residents, resident/local migrants and winter visitors. The proportions of residents were more in both the habitats. Granivore abundance was higher than the nectarivore abundance in the scrub forest and the former was comparatively higher in the scrub forest than in the mixed dry deciduous forest.

Species belonging to the families of Pycnonotidae, Muscicapidae, Irenidae and Centropodidae were sighted more frequently in these areas. They are Crow-pheasant, Gold-mantled Chloropsis, Gold-fronted Chloropsis, Common Iora, Flycatchers, Warblers, Bulbuls and Babblers. In the mixed dry deciduous forest bird abundance reached the peak in September and the lowest was seen in

June. In scrub forest, highest abundance was noted in January and lowest in July. There was no significant variation between the years.

Unlike abundance, richness was high in mixed dry deciduous forest throughout the year and bird species richness peaked in October and a minor peak was seen in March. There was a definite trend in fluctuation of species richness in mixed dry deciduous forest. Scrub forest peaked in species richness during January. Maximum number of species was observed in October and minimum in June in the mixed dry deciduous forest. In the scrub forest the maximum was in January and the minimum in July. In general, the most common species and dominant species in both the habitats were determined.

To relate bird community structure with habitat, vertical distribution of the foliage was sampled. A hypothesis, namely "Higher foliage profile layers harbour more species", was tested. Foliage thickness was recorded at different strata seasonally and foliage height diversity was calculated for each stratum. Indices of bird species diversity and foliage height diversity were correlated to test the birds' **relationship** on foliage height diversity, and there was a significant positive correlation between these two in all the seasons except summer.

Seasonality of Birds and Insects

Bird abundance was high during northeast monsoon and winter and low during southwest monsoon in mixed dry deciduous forest and scrub forest respectively. The total number of species shared by the mixed dry deciduous forest during southwest monsoon was 63% and the scrub forest was 37%. The avifauna of the mixed dry deciduous forest was largely dominated by insectivore guild throughout the study period, followed by omnivore and frugivore. In the scrub forest, the avifauna was dominated by frugivores followed by insectivores. Frugivore abundance was high during northeast monsoon when an exotic weed *Lantana camera* was in fruit and low during southwest monsoon. As frugivores were high, insectivores and omnivores were low during northeast monsoon.

Sixteen groups of insects were encountered in the six various sampling techniques employed in the field. Large sized invertebrates were very few,only 4% in the mixed dry deciduous forest and 2% in the scrub forest. Small sized insects were profoundly abundant in both the habitats. The general abundance of invertebrates from the pooled data in the mixed dry deciduous forest showed, arachnid to be responsible for 21% of invertebrate abundance. The major contribution among the insect groups was Lepidoptera followed by Orthoptera, Diptera and Hymenoptera. In the scrub forest, Hymenoptera was responsible for 26% of invertebrate abundance followed by Arachnid, Hemiptera, Diptera, Lepidoptera and Orthoptera. This hierarchy of abundance was statistically significant. Among the insect groups, Lepidoptera, Orthoptera and Diptera in the mixed dry deciduous forest and Hymenoptera, Hemiptera and Diptera in the scrub forest formed the first three higher abundant groups.

Rainfall showed positive correlation with abundance of birds in mixed dry deciduous forest. Insectivore abundance of the mixed dry deciduous forest showed positive correlation with total insect abundance whereas the insectivore abundance in the scrub forest showed significant positive correlation with lepidoptera. Total abundance of birds in the mixed dry deciduous forest correlated highly with fruiting plants and abundance of fruits. In the scrub forest also, significant relation was obtained with abundance of birds and plants in fruit, while young and mature leaves had no significance with bird abundance. Shrikes, Warblers, Flycatchers, Drongos, Common Iora, Yellow-eyed Babbler, Oriental Magpie Robin, White-browed Wagtail, Chestnut-Headed Bee-Eater, Plain Prinia, Black-rumped Woodpecker, Rufous Woodpecker, Asian Paradise Flycatcher, Bee-eaters, Swifts and Swallows significantly increased with insect abundance.

Foraging behavior

Foraging data were collected early in the morning during the study period. In total, 42 species were observed, 36 species from the mixed dry deciduous forest and 22 from the scrub forest and they were analyzed. Various foraging dimensions such as method, substrate, height and position in the canopy in both the habitats were analyzed. Foraging attempts were assigned to 12 height categories, seven substrate categories, 9 positions in the canopy and 20 foraging methods. Niche breadth of the species, overlap between and among the species of a community were discussed. Two major guilds, namely gleaners and salliers were identified in both the habitats. The gleaners again formed four and five guilds in the mixed dry deciduous and scrub forests respectively. Foraging dimension of 16 species were compared between the habitats since these occurred in both the habitats. Thirteen species shared change in the use of substrate while only five species changed the method used.

Five bird species in the mixed dry deciduous forest and 11 species in the scrub forest were considered as specialists as their J' values were zero. In four dimensions (foraging height, foraging method, position in the canopy and foraging substrate), highest mean niche overlap was found in the use of foraging height in the mixed dry deciduous forest and canopy in the scrub forest and the least in the foraging method in both the habitats. There were four major groupings among the bird species based on the food eaten in both the habitats: insectivores, nectarivores, frugivores and omnivores. The plants (shrubs and trees) provided microhabitats such as foliage, twig, flower, fruit, secondary branches and trunk and the proportion of foliage use at different heights was higher in the mixed dry deciduous forest.

Breeding of birds

The study area of 20 ha. was combed for nests in both the habitats. Both opportunistic and observational records were made to enumerate the nests in different seasons. Variables of nests and nest-site characteristics were set at nest, nest tree and nest patch levels. Altogether, 410 nests of 32 species were observed during 1999-2001. There were 118 and 292 nests of 19 and 22 species breeding in the mixed dry deciduous and scrub forests respectively. The maximum number of nests found in both the habitats was of the Red-vented Bulbul.

Ten breeding species were restricted to MDDF, namely Black-hooded Oriole, Common Iora, Crow Pheasant, Jungle Crow, Jungle Babbler, Long-tailed Nightjar, Green-billed Malkoha, Chestnut-headed Babbler, Scimitar Babbler and Spotted Dove while 13 species bred only in SF and 9 species in both the habitats.

Breeding seasonality of birds in both the habitats was examined. Six different types of nests were recorded with statant-cupped nests being more in number. Eight plant species were predominantly used for nesting. Breeding biology including nesting, nest-site selection, clutch size, incubation period and nestling period was studied for nine species, namely Laughing Dove, Yellow-eyed Babbler, Tawny-bellied Babbler, Yellow-billed Babbler, Jungle Babbler, Red-whiskered Bulbul, Red-vented Bulbul, Purple-rumped Sunbird, and Indian Robin. Informal interviews and field records were made to assess the human impact on plants which affected the breeding of birds in the mixed dry deciduous and scrub forests.

CHAPTER 1

INTRODUCTION

1.1. General Introduction

Community ecology is the study of 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 (Wiens 1989). Many valuable literature in different fields of community studies have been available since the nineteenth century. Studies of Lack (1933), Kendeigh (1934) and Odum (1950) made remarkable contributions in the field of community ecology.

According to Cody (1974, 1978) bird communities have a direct relation with the structure of habitat and thereby act as indicators of environmental changes with the changing habitats. Also, birds are one of the best indicators of environmental quality of any ecosystem (Ripley 1978). Although many taxa of animals were used to assess the habitat quality, others such as plants (Cronk 1988), butterflies (Brown 1991, Kremen 1992,1994), tiger beetle (Rodriguez *et al.* 1998), birds (Debinski & Brussard 1994, Kremen 1994) and mammals (Mittermeier 1988) were extensively used as indicators for assessment of biological diversity. The council of Environmental Quality (USA) identified birds as the commonly used indicator of environmental changes (Morrison 1986). Being ecologically diverse and sensitive to various kinds of perturbation, bird community acts as a better predictor of the quality and health of the habitat than a single species (Javed 1996). Indicator species can be a valuable tool for conservation research. Their use has been in two ways: (a). inventory studies and (b). monitoring studies (Kremen 1992). The present study tries to cover both the aspects.

The population studies have 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 natural and human-caused environmental changes (Wiens 1989). This richness in breeding species is high in natural and heterogeneous landscapes and in relatively open canopies in Southeastern Idaho, U.S.A. (Saab 1999). Trezcinski *et al.* (1999) studied the relative importance of the independent effects of forest cover and fragmentation on the distribution of forest breeding birds. Hobson and Schieck (1999) studied the impact of wildfire and harvesting on the forest bird communities in north central Alberta, Canada and suggested that harvest practices would be better processes and are more likely to conserve biodiversity. In the same place Schieck *et al.* (2000) brought out an interesting result that the retention of snags and residual trees in clumps would maintain the diversity of bird as in an old undisturbed natural forest.

1.2. Indian Literature

Khan (1980) gave a comparative account on the bird fauna of shola forest and plantation area in the Nilgiris. Ramakrishnan (1983) made a comparative study of the bird communities in four forests in the Malabar area of South India.

Moreover, he explained the relationship between the plant diversity and bird diversity, and found that the bird diversity was higher in Silent Valley. Although the diversity was high in Silent Valley it was the highest in the disturbed semi-evergreen forest (Pramod 1999). Jayson and Mathew (2000) studied diversity, abundance and distribution of bird species in the evergreen and moist deciduous forests of Silent Valley, Kerala. Gandhi (1986) compared the bird community structure of scrub forest with that of monoculture plantations, and pointed out that the bird diversity was higher in the scrub forest than in monoculture plantation. Johnsingh *et al.* (1987) recorded the edge effect on the bird fauna and the correlation of the abundance of insects and fruits with that of bird fauna in Wolf Hill, a thorn scrub habitat in South India.

Diversity of birds and plants in Mudumalai Wildlife Sanctuary showed a positive correlation (Manoharan 1988). Daniels (1989) did an indepth study on the birds of Uttara Kannada district and explained the factors that influenced the local bird assemblage and diversity, and the biogeographic influences and patterns of diversity. Price and Jamdar (1990) recorded the breeding bird community of Overa Wildlife Sanctuary. Zacharias and Gaston (1999) studied the distributions and status for all species endemic to South Asia from 24 forest areas in Kerala State. Sultana and Khan (1999, 2000) surveyed 19 patches of oak forests in three districts of Kumaon Himalaya to document avian community and the status of birds.

The impact of environmental degradation on the avifauna, and the bird community structure and seasonality of the Eastern Ghats were investigated thoroughly by various authors (Ripley 1978; Price 1979; Beehler *et al.* 1987; Rathinasabapathy 1988; Alagarrajan 1989). Katti (1989) explored the relationship between bird community structure and vegetation in Lower Dachigam Valley, Kashmir. Gaston (1978b, 1978c, 1983) studied the seasonal occurrence and distribution of birds in the Ridge area of New Delhi and also documented the effect of grazing on the abundance and diversity of birds in scrub vegetation at Nathwara, Rajasthan. Further, Gaston (1981) reported the timing of breeding among Indian birds of dry deciduous forest in North India. The ecology of terrestrial birds (Sundaramoorthy 1991), seasonal abundance of land birds (Vijayan 1990) and ecological study of Keoladeo National Park had been described (Ali and Vijayan 1986). The impact of disturbances on different habitats in the Nilgiri Biosphere Reserve has been brought out by Vijayan *et al.* (1998 & 1999). Gokula (1998) analyzed the structure of bird communities in the dry deciduous and thorn forests in Mudumalai Wildlife Sanctuary. He described in detail the structure and functional aspects of the community structure in Mudumalai Wildlife Sanctuary. The impact of habitat disturbances on bird and butterfly communities was studied in Khanchendzonga Biosphere reserve (Chettri 2000). Raman (2001) studied the communities of birds in different altitudes of Kalakkadu- Mundanthurai Tiger Reserve and found that the bird species were higher in low altitude than in high altitude evergreen forest.

Although 81% of land birds were recorded out of 1295 species of birds in the subcontinent (Inskipp *et al.* 1996), ecology and biology of only a few species have been studied in detail. Ecological study of the Weaver bird (Mathew 1975), Indian Peafowl (Johnsingh and Murali 1980), Black and orange Flycatcher (Khan 1980) and Norcondam Hornbill (Hussain 1984). Black Drongo (Shukkur and Joseph 1980), Bulbuls (Vijayan 1980), Cukoos (Becking 1981), Racket-tailed, Bronzed and White-bellied Drongos (Vijayan 1984), Barbets (Yahya 1988), Yellow-browed Leaf warbler (Price and Jamdar 1991) Nilgiri Laughing thrush (Islam 1994), Southern Crow-Pheasant (Natarajan 1997), Fantail Flycatcher (Gokula 1998) Purple Sunbird (Kumar *et al.* 1999), and Malabar Grey Hornbill (Mudappa 2000) were recorded as a few biological study of land birds from India. Ali (1979) reported that the study of birds in relation to habitats would give valuable data for forest management. It is apparent that the study of ecology of bird communities and interactions with habitat were covered in bits and pieces from India.

Though India is rich with diverse sets of habitat types, our knowledge of general bird ecology is still elementary (Ali and Ripley 1987). What we know today of bird community structure and dynamics is largely based on works in temperate forest and a comparative study is needed for a better understanding of bird community structure in other climatic areas. It is also interesting to note that in India most of the community studies have been conducted in the protected areas. Area outside protected area network is also equally important for birds and biodiversity conservation (Prasad *et al.* 1998). Hence, a study was designed to determine the ecology of the bird communities in the mixed dry deciduous forest and scrub forest (SalimAli Centre for Ornithology and Natural History) in

Anaikatty Reserve Forest, foothills of Nilgiri Biosphere Reserve, Coimbatore, South India.

1.3. Foreign Literature

Tropical areas have substantially greater diversities than temperate forests of the same size (MacArthur 1965, Howel 1971, Karr 1971). MacArthur and MacArthur (1961) and Recher (1969) discussed the factors that influence local vegetation diversity and the assemblages of birds.

Whittaker (1975) states that communities are assemblages of populations of species, which occur together in space and time. The cause-effect relation of such assemblages led to an increased interest in studies on bird communities (MacArthur 1957, Cody and Diamond 1975, Cody 1974, Ricklefs 1975, Diamond 1978, Hutchinson 1978, Pianka 1981). Wiens (1974) provided special impetus to the investigations on bird communities and brought out a compendium in two volumes in 1989.

MacArthur (1958) studied the population ecology of five species of Warblers of Northeastern coniferous forests to determine the factors contributing to the abundance of species. Various aspects of bird communities of Neotropical forests were studied extensively by Terborgh (1971, 1977, 1980a, 1980b, 1985a, 1985b, and 1990). Karr *et al.* (1982) reported that the composition and abundance of a tropical forest avifauna changed over time. Recher (1986) emphasized patterns of species richness, avian abundance and community structure in eucalypt-forest. Helle (1986) studied the forest bird communities and habitat utilization in mature and succession phases. Pearson (1977) compared the bird community structure on six lowland forests. Karr *et al.* (1990), Robinson and Holmes (1982, 1984), Robinson *et al.* (1988,1990), Robinson and Terborgh (1990), Thiollay (1994) and MacNally (1994a,b) studied bird communities in the forests of Australia.

1.4. Bird community and its association with habitat

Many studies were conducted to reveal the complexity of bird-vegetation association. Rice *et al.* (1984) studied the importance of different habitat attributes such as density of vegetation, foliage height diversity (FHD), and patchiness to avian community organization. Ali (1979) opined that the study of birds in relation to habitats would give valuable data for forest management. Although the vegetation determined the distribution and abundance of most terrestrial bird species, correlation analysis of various communities, resource and habitat parameters provide no sure guidance to underlying causes for observed community pattern (Gilbert 1984). Many factors are thought to play a secondary role in determining the distribution and abundance. In recent years birds have been receiving due attention since the pioneering work on relationship between habitat structure and bird community by MacArthur and MacArthur (1961), and MacArthur (1964) in the temperate region. Avian community is directly related to the resources and the ways in which they are partitioned (Cody 1974).

Ample literature is available to support that the vertical layering of foliage influences the richness of bird species (MacArthur *et al.* 1962, MacArthur *et al.*

1966, Recher 1969, Cody 1970, Erdelen 1984, and Verner *et al.* 1989). However, a few studies in tropical forests did not find any such relationship between bird community and vegetation (Pearson 1982, Wiens 1983). But bird species diversity was found to have positive and linear relationship with the foliage height diversity and curvilinear relationship with the percentage of ground cover vegetation (Karr 1968 and Wilson 1974). Theberge (1976) studied bird population with special reference to vegetation and fire in the Kluane Mountains, southwest Yukon. Young (1977) explained the relationship of tree diameter diversity with bird community. Javed (1996) in his study from Rajaji National Park tested the relationship of bird species diversity with foliage height diversity.

Various aspects of vegetation structure other than foliage height diversity were studied elsewhere. Foliage volumes (Karr and Roth 1971), total crown volume (Verner and Larson 1989), percent vegetation cover (Karr 1968, Karr and Roth 1971, Wilson 1974), patchiness of shrub distribution, and crown cover (Crawford *et al.* 1991, Wiens and Rotenberry 1981) were studied. James and Wamer (1982) studied the correlation of the bird species diversity with plant species diversity and showed that the diversity of birds is high at intermediate levels of tree species richness. Moreover, bird species richness and diversity is highly influenced by some special habitat components. Those components are plant taxa (Balda1969, Holmes *et al.* 1979, Wiens and Rotenberry 1985, Sherry and Holmes 1996, Terborgh 1985), tree species richness and diversity (Orians 1969, Lovejoy 1975, Winternitz 1976, Young 1977, James and Wamer 1982), size of the study area (Verner and Larson 1989), and habitat heterogeneity

(Wiens 1973,1974): Although these components influence, all the species seen in a forest community are not equally represented; some species are rare (Karr 1971). Therefore extinction selectively suggests that certain habitats and species are more at risk (Slobodkin 1986), which has to be given more attention.

1.5. Bird community and its association with food

Various components such as the type of resource, quantity of resource and spatial and temporal distribution of resources play a major role in determining the community structure (MacArthur 1972). Seasonal variation in the food availability also determines the regular pattern of migration and local movements. Food availability is the major factor determining the seasonality of breeding (Lack 1968, Beals 1970, Dingle and Khamala 1972, Vijayan 1975, Vijayan 1984, Gokula 1998, Vijayan *et al.* 1999), and moult (Fogdon 1972) in birds. Cody (1968) explored the resource division in grassland bird communities and found that the influx of migratory bird population was due to the availability of arthropods (Greenberg 1995).

Phenology of the vegetation has considerable effect on the structure of avian community (Feisinger 1978, Gokula 1998, and Vijayan *et al.* 1999). However, in some cases food resources increase the bird diversity (Wolf 1975, Stiles 1978, Ford and Paton 1985, Terborgh 1985). A few studies have attempted to establish the relationship between the breeding seasons of birds and insect seasonality (Vijayan 1975, 1980, Shukkur and Joseph 1980, Gaston 1978a, Shukkur 1978, Vijayan 1984, Vijayan 1991, Sundaramoorthy 1991).

1.6. Impact of disturbance on bird community

Disturbance is an important component and variations in disturbance regime can affect community structure and ecosystem functioning either by damaging the natural habitat or by bringing about subtle changes (Block 1989, Sundriyal *et al.* 1994, Sundriyal and Sharma 1996). Anthropogenic influence on natural resources is the largest single cause of loss of biological diversity (Hannah *et al.* 1995). Species therefore differ in response to changes in their habitat that may result from human activities. Minor disturbances such as tree falls bring about canopy openings which increase the heterogeneity in a habitat which in turn paves way for higher bird diversity (Schemske and Brokaw 1981). 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), structural complexity of vegetation (Robinson and Holmes 1982,1984), substrate (Fitzpatrick 1980), plant species (Holmes and Robinson 1981), and degree of human modification (VanderWerf 1994). However, disturbances such as lopping of trees for firewood and fodder, grazing, trampling and uprooting of medicinal plants affect the vegetation structure (Khadka *et al.* 1984, Mahat *et al.* 1987,Hobbs and Huenneke 1992, Gill *et al.* 1996, Sundriyal and Sharma 1996, Vijayan *et al.* 1999).

Although disturbance helps plant communities and species in regeneration (Picket and White 1985), diversity (Dolman and Sutherland 1991) and species composition (Harrison 1981), they act as an 'intermediate disturbance stage' for most of the communities and species (Fox 1979). Since the disturbance components themselves are not in balance and each component has individual effects in different physiography, this may be fatal to the plant community and to the individual species (Cole 1995, Hobbs and Huenneke 1992). Contribution of Aigner (1996) and Aigner *et al.* (1998) was focused on bird community and the response of species to habitat change as a result of firewood extraction. Restrepo *et al.* (1999) reported the response of understorey birds to anthropogenic edges in a Neotropical montane-forest of Columbia. Gokula (1998), Vijayan and Gokula (1999) and Vijayan *et al.* (1998,1999) have brought out the impact of disturbances on birds in the Nilgiri Hills, South India.

1.7. Objectives

The present study was initiated with the following major objectives:

- To determine the structure of bird communities in different habitats (mixed dry deciduous forest and scrub forest) in Anaikatty Reserve Forest;
- To assess the seasonality of birds in these two habitats
- To analyze the impact of disturbance in these two habitats, especially on bird communities, and
- To investigate the general ecology of select bird species.

CHAPTER 2

STUDY AREA

The Western Ghats is one of the 24 Bio-diversity hot spots in the World (Mittermeir *et al.* 1998). There are 508 species of birds in it, only a few species have been studied in detail (Ali and Ripley 1987, Gaston 1972, Johnsingh *et al.* 1982, Vijayan 1980, Vijayan 1984 and Gokula 1998, 1999). It has 324 species of resident birds (Daniels 1997) of which 17 are endemic including one subspecies as referred by Ali & Ripley (1987). However Stattersfield *et al.* (1998) have suggested that only 16 species are endemic (Stattersfield *et al.* 1998). It also has a topographically complex reserve namely Nilgiri Biosphere Reserve 5525km^2 with wide range of rainfall zones between 500 and 7000 mm annually and it extends up to Anaikatty hills. The present study was taken-up in the highly degraded and regenerating area (Scrub forest) and the mixed dry deciduous forest of Anaikatty, Coimbatore. In the Anaikatty Reserve Forest, there are areas with different grades of disturbance. Balasubramanian *et al.* (2001) have reported the vegetation of disturbed habitats at Moongilpallam area in Anaikatty.

2.1. Location and Topography

The study was undertaken in Anaikatty hills, the foothills of the Nilgiris in the Nilgiri Biosphere Reserve (NBR), which lies in Western Ghats. It is the campus of Salim Ali Centre for Ornithology and Natural History (SACON) and the adjacent Anaikatty Reserve Forest at an elevation of about 610-750m above mean sea

Figure 2.1. Map showing the intensive study area (Source: Survey of India - Topo sheet 1971

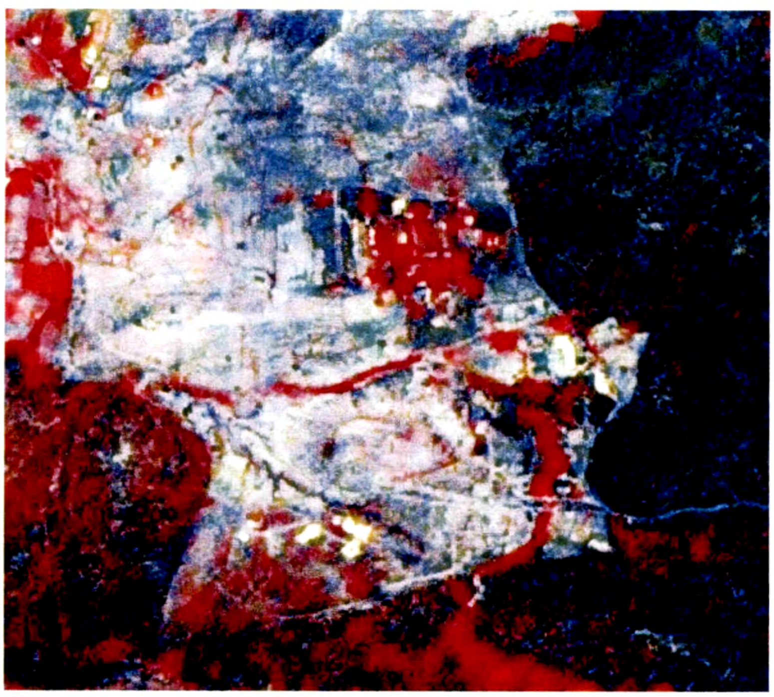


Plate 1. Habitats showing different vegetation type in the Anaikatty hills

level. This area is situated between $76^{0}39'$ and 76^{0} 47'E and from 11^{0} 5' to 11^{0} 31'N. Nilgiris south division and Sathyamangalam division is adjacent to the study area on the north, Erode division on the south by, Indira Gandhi Wildlife Sanctuary on the east and Palghat forest division, Kerala State on the west. Anaikatty Reserve Forest is divided into north and south divisions. The total area of Anaikatty Reserve Forest is 4447.74 ha (2292.08 ha of south division and 2155.66 ha of north division) (Figure 2.1).

The study site of campus which is scrub forest (Plate 1) located at Moongilpallam which is close to Anaikatty (6 km) and 25 km north-west of Coimbatore city and is seen in the south reserve forest of Coimbatore range under Coimbatore division. The campus, formerly a private land, stretches to 55 acres. On one side it abutts on the Anaikatty Reserve Forest and the other side it touches the private land on two sides each.

On the western side of SACON, a non-perennial stream called Perumpallam flows. Water flow is restricted to the rainy season and is for about 5-6 months a year (Soundarapandian 1992). Forest is an undulating terrain with seasonal waterfalls. The hills on the north and south rise from an elevation of 560 to 1600m above mean sea level (Plate 1).

Rock formation in the study area is gneiss of Archaean age group, comprising variety of rock types. Soil type of this forest is generally hard gravel in major portions and red loamy soil in some patches. Red loamy and sandy soil, reddish brown and brown soil and clayey soils mostly cover the plains. Mostly the soil is devoid of humus (Soundarapandian 1992).

2.2. History

The Anaikatty forest ranges were working under permit system till 1905 for felling trees for local demands. Simple coppice system operated in this area till1983 whereby trees in a particular area were felled and the resultant coppice was allowed to grow for 20 years. This cycle was repeated. This was adopted for a particular area and was repeated periodically in the other areas also. The Tamil Nadu Forest Department has implemented Afforestation in this forest since 1990 mostly for filling the gaps or the open areas. Now the existing forest is a secondary forest that was formed by secondary succession (Soundarapandian 1992). Part of the cleared area is private land.

2.3. Land-use

The tribals of the surrounding villages (Doomanur, Sembukkarai, Kondanur, Kondanurpudhur, Aalamaramedu, and Moongilpallam) collect firewood and minor forest produces from this forest. Elephant, cattle, goat and sheep graze here. 17 elephants and 67 cattle use this area frequently. The degraded area is mostly private land and is partly allowed to regenerate naturally, also by plantation.

2.4. Abiotic Factors

2.4.1. Climate

In general the climate is moderate and pleasant for most part of the year except summer which is relatively hot and dry. Weather is pleasant especially during monsoon and winter (Sounderapandian1992). The climate varies considerably in different seasons. The foothills are hot and dry while the upper regions of the hills enjoy a mild cool climate.

2.4.2. Seasons

Based on the climate, different seasons were observed during the study period (1999-2001) and are classified into the following four:

Southwest monsoon (June, July and August): The study area received 5% of the total annual rainfall during this season. The mean rainfall received was around 40 mm. The season had the moderate temperature and next to the least of relative humidity among the seasons. This season is peculiar in having the fast windspeed.

Northeast monsoon (September, October and November): The study area received more than half (69%) of the total annual rainfall during this season. The mean rainfall received was around 500 mm. The season had the lower temperature when compared to the southwest monsoon and maximum relative humidity among the seasons.

Winter (December, January and February): It was the least rainy period of the year with the annual rainfall of 34 mm. This season was the colder period with the minimum temperature falling to 18^0C and also with the lowest windspeed.

Summer (March, April and May): This area received 21% of the annual rainfall in this season from the pre-monsoon showers. This was the period of maximum temperature, which leaped up to 37^0 C with low relative humidity.

2.4.3. Rainfall

This area receives rainfall from both the monsoons but comparatively higher during northeast monsoon. The monthly mean rainfall is about 75 cm in the plains and along the foothills and increasing to about 120 cm towards the higher elevations (Balasubramanian 1996). The northeast monsoon normally commences in the latter part of August or in early September and lasts till the beginning of December with occasional pauses. The southwest monsoon is during June-August. The area had an average annual rainfall of 688 mm during the 10-year period from 1991-2000 (Figure2.2). The mean annual rainfall of the area was lower than that of the moist deciduous forest zone of the country but was comparable to that of the mixed dry deciduous forest zone (Champion and Seth 1968).

Rainfall trend for ten years showed significant variation between the years (standard deviation = 80). The highest (994 mm) and lowest (324 mm) annual rainfall during these 10 years were recorded in 1997 and 1991 respectively. The rainfall was higher during the first year of the study period (700 mm) than the second year (641-mm). The highest rainfall was in October (418 mm) during 1999-2000 and September during 2000-2001. Monthly total rainfall from 1999-

Figure 2.2. Annual rainfall from1991 to 2000

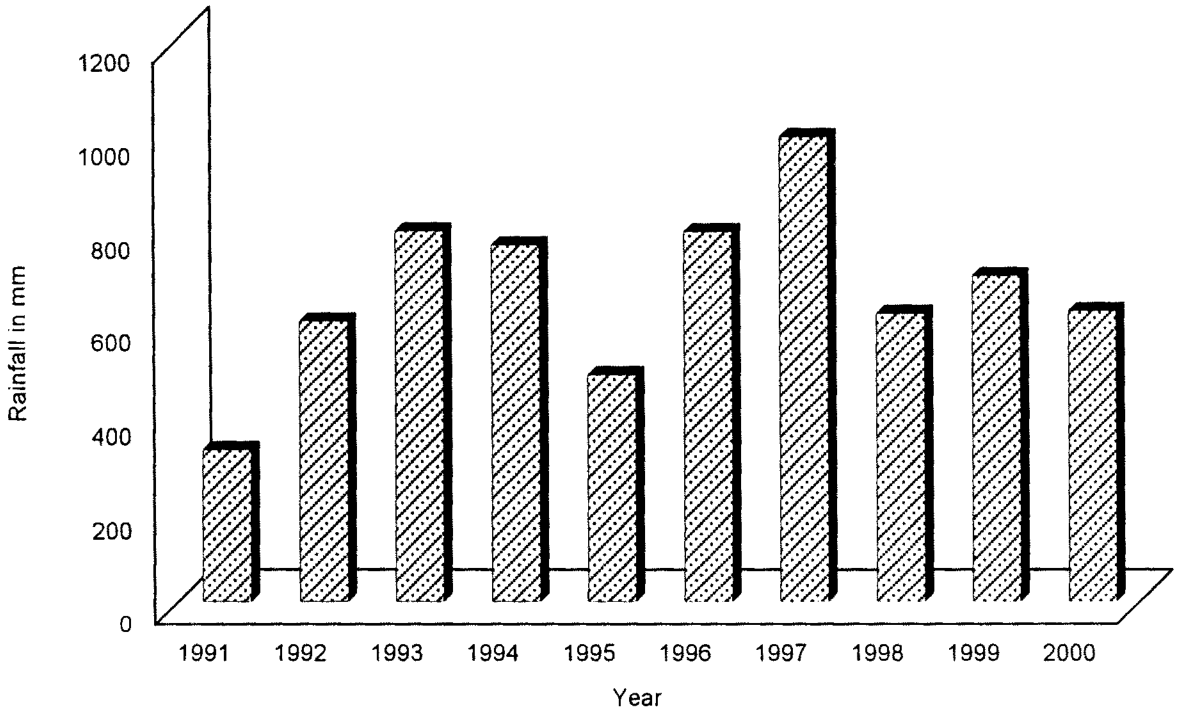
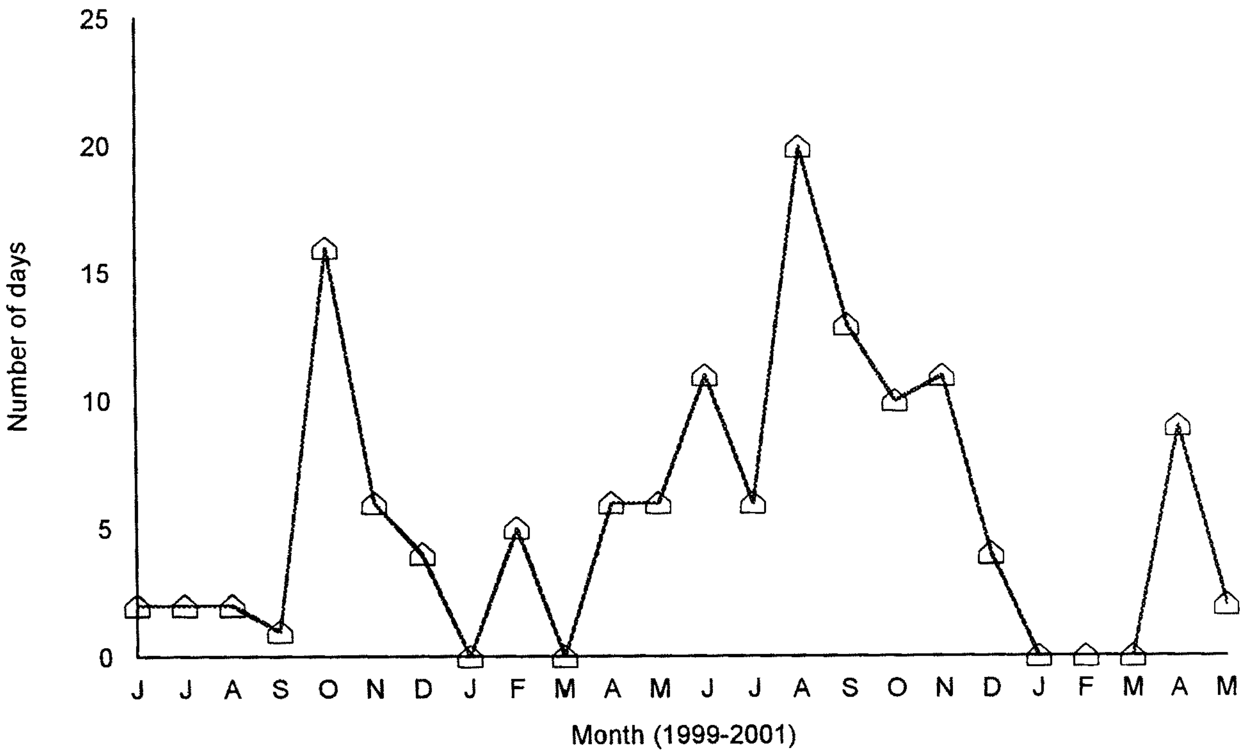


Figure 2.3. Rainy days during 1999-2001



2001 showed the highest during northeast monsoon season and lowest in the winter (Table 2.1).

Table 2.1. Monthly total rainfall in mm from 1999 to 2001

Month	First year (1999-2000)	Second year (2000-2001)
Jun	12.7	15
Jul	17.7	7.8
Aug	6.9	12.1
Sep	8.2	192.7
Oct	418.1	127.8
Nov	127.8	60.7
Dec	25.5	27.3
Jan	2.4	0.2
Feb	11.7	0.1
Mar	0	2.5
Apr	45.4	181.2
May	23.7	13.8

The number of rainy days during 1999-2001 showed an increase in number of rainy days in October 1999 and reached the peak in August 2000 (Figure 2.3). Number of rainy days was also more during 2000-2001 (86 days) than in 1999-2000 (50 days). There were no rainy days in January and March in both the years. Maximum rainfall was in October in the first year and September in the second year (Table 2.1 & Figure 2.3). Only northeast monsoon brings higher precipitation to Anaikatty hills.

2.4.4. Temperature

Maximum temperature varied between 28 °C and 36 °C during the study period. There was no significant difference between the years in maximum and minimum temperatures (Max.33 and Min.22). Difference in maximum temperature between the coldest month (28.7 °C) and warmest month (35.8 °C) was only 7.1 °C. The highest maximum temperature was observed during April and lowest maximum in December in both the years. The highest minimum temperature was in April for both the years and lowest minimum was in January in the first year and December in the second year (Table 2.2).

Table 2.2. Monthly mean maximum and minimum temperature in Celsius from 1999 to 2001

Month	First year (1999-2000)		Second year (2000-2001)	
	Max.	Min.	Max.	Min.
Jun	32.5	22.2	32.3	22.0
Jul	31.5	21.9	32.3	21.9
Aug	32.6	22.2	31.2	21.7
Sep	34.0	22.3	32.3	22.1
Oct	31.0	21.9	31.6	21.5
Nov	29.7	20.6	31.0	20.8
Dec	28.7	19.2	29.5	18.0
Jan	30.6	19.0	31.2	19.7
Feb	32.5	20.9	31.2	21.0
Mar	34.9	21.6	34.5	22.4
Apr	35.8	23.4	36.2	23.5
May	35.8	23.5	35.5	23.6

Table 2.3. Monthly Mean RH in % from 1999 to 2001

Month	First year(1999-2000)		Second year(2000-2001)	
	RH at 8.30 hr	RH at17.30 hr	RH at 8.30 hr	RH at17.30 hr
Jun	80	64	82	66
Jul	82	68	79	60
Aug	81	61	85	70
Sep	79	57	86	70
Oct	89	75	82	67
Nov	82	62	81	56
Dec	87	58	80	50
Jan	84	46	81	42
Feb	83	45	75	27
Mar	78	31	72	32
Apr	79	52	80	47
May	77	50	77	54

2.4.5. Humidity

Humidity was the maximum during October in the first year and September in the second year of the study periods corresponding to the total rainfall (Table 2.3). But the humidity showed minimum during summer (March). The monthly mean of the relative humidity of the atmosphere recorded during the study period showed fluctuation between 31-75 (at 8.30 hours) and 72-89 (at 17.30 hours).

2.4.6. Windspeed

Windspeed was recorded during the study period and there existed a regular pattern of seasonality (Table 2.4). Windspeed was the maximum during southwest monsoon in both the years of the study. The monthly mean windspeed recorded during the study period showed fluctuation between 3 and 14 km/h (Table 2.4). Very low windspeed was observed in December and the highest windspeed were recorded in July.

Table 2.4. Monthly mean windspeed from 1999 to 2001

Month	Windspeed in km/h	
	1999-2000	2000-2001
Jun	13	13
Jul	14	14
Aug	13	11
Sep	12	9
Oct	5	7
Nov	5	5
Dec	3	4
Jan	5	6
Feb	6	6
Mar	6	8
Apr	9	4
May	11	11

2.5. Vegetation types

The Anaikatty Reserve Forest in and around the study area comes under the Southern Tropical mixed dry deciduous forest type (Champion and Seth 1968). The major forest types in Coimbatore division are 47% of southern mixed dry deciduous, 29% of southern thorn forest, 8% of semi evergreen forest and 2% of wet evergreen forest. Nearly 8% of this area consisted of plantations of various types (Nagarajan *et al.* 1993). The degraded area lies inside SACON premises with a few regenerated tree species and dominated by tall shrubs such as *Lantana camara* and *Chromolaena odorata*.

2.5.1. Mixed dry deciduous forest

This forest was cleared by the forest department during the early 1980s and left for regeneration for the secondary succession. Mixed dry deciduous forest species dominated this reserve forest. This area consists of trees, herbs and mostly shrubs. It consists of the combination of trees such as *Acacia leucophloea, Ziziphus mauritiana, Chloroxylon swietenia, Albizia amara, Tamarindus indicus, Albizia lebbeck, Acacia polyacantha, Diospyros ferrea, Cassia fistula, Commiphora caudata.* Dominant shrubs available in this forest are *Chromolaena odorata, Clausena indica, Elaeodendron glaucum, Flacourtia indica, Lantana camara, Lantana wightiana, Randia dumetorum, Premna tomentosa, Pavetta indica* and *Mundulea sericea.* Succulents such as *Opuntia dillenii* and *Euphorbia antiquorum* are also common. Since many villagers are dwelling in and around this vegetation type, anthropogenic pressures mostly affect it. The tribals of the surrounding villages collect firewood and other minor forest produces from this forest. Elephants, grazing cattle and goat frequently visit this area (Plate 2).

2.5.2. Scrub forest

This scrub forest was degraded because of extensive clearing and since 1996 SACON allowed a few acres of this land to be regenerated by planting trees and providing them protection. Studies are conducted to understand the structure of the existing plant and bird community and also to monitor the changes in a long-term basis. This area consists of the regenerating trees such as *Albizia amara, Diospyros ferrea, Elaeodendron glaucum* and *Cassia fistula*. Dominant shrubs available in this area are *Mundulea sericea Chromolaena odorata, Clausena indica, Flacourtia indica, Lantana camara, Lantana wightiana, Randia dumetorum, Premna tomentosa* and *Pavetta indica*. *Opuntia dillenii* is the common succulent and *Euphorbia antiquorum* is less common. Elephants and cattle frequently, and goats occasionally visit this area (Plate 2).

2.6. People and their livelihood

People at Anaikatty Hills are mostly scheduled tribes (71%). Irulas are the only scheduled tribes in this division. 26% of them are other castes (OC), including Okkiliar, Muslim, Padyachi Goundar (Vanniar), Goundar, Valayar, Naidu and Chettiar. The smallest group of people in this area is scheduled caste (3%) is Sakkiliar. Their main income generating ways and means are brick works

PLATE 2. STUDY AREA

Scrub forest and abutting mixed dry deciduous forest in Anaikatty hills

Grazing by goat in Anaikatty hills

Cattle grazing in Anaikatty hills

Extracting bamboo

Photo by Sr. T. Nirmala

and agriculture (Village Administrative Officer, Veerapondy Panchayat, Thadagam). Cultivation is done in their own land and cattle grazing in the forest. People from the nearby village called Thadagam own the cattle. They also go for plantation work on daily wages. They have their own goats which go into the forest for grazing.

2.7. Wildlife in Anaikatty hills

2.7.1. Mammals

Anaikatty Reserve Forest harbour herbivores such as Asian Elephant (*Elephas maximus*), Gaur/Indian Bison (*Bos gaurus*), Sambar (*Cervus unicolor*), Chital (*Axis axis*), carnivores such as leopard (*Panthera pardus*), Wild dog (*Cuon alpinus*), omnivores such as Sloth bear (*Melurus ursinus*) and Wild boar (*Sus scrofa*), and primates such as Common Langur (*Presbytis/ Semnopithecus entellus*). Some of the small mammals living here are Common Mangoose (*Herpestes edwardsii*), Indian Three-striped Palm Squirrel (*Funambulus palmarum*), Black-naped Hare (*Lepus nigricollis*) and rats.

2.7.2. Birds

The avifauna of this forest consists of 196 as given in the appendix (1) and avifauna of SACON campus consists of 98 species (Nirmala and Vijayan 2000).

2.7.3. Herpetofauna

In addition to the above living organisms, Anaikatty hills support a considerable number of herpetofauna.

2.7.3.1. Reptiles

Indian Rock Python (*Python molurus*), Green Keel-back (*Macropisthodont plumbicolor*), Spectacled Cobra (*Naja naja*), Common Bronze-back Tree Snake (*Dendrēlaphis tristis*), Indian Rat Snake (*Ptyas mucosus*), Green Vine Snake (*Ahaetulla nasutus*) and Common Sand Boa (*Eryx conica*) are also seen.

2.7.3.2. Amphibians

Common Asian toad (*Bufo melanostictus*), Red Narrow-mouthed frog (*Microhyla rubra*) and Marbled baloon frog (*Uperodon systoma*) form the major species found here.

CHAPTER 3

VEGETATION

3.1. Introduction

A qualitative evaluation of vegetation is a pre-requisite for the study of forest efficiency that depends on the type, quality and stratification of vegetation (Saxena and Singh 1982a). Vegetation has been mostly studied by animal ecologists to correlate its availability with utilization by animals. MacArthur and MacArthur (1961) highlighted the importance of vegetation to birds, and since then studies on vegetation have been increasing in the field of avian ecology.

Substantial reduction of forest cover will be leading to serious ecological disasters such as soil erosion, landslides, and loss of soil fertility and catastrophic floods (Saxena and Singh 1982b). The tree species, their diversity and density, vegetation complexity and resource exploitation patterns have a direct impact on the wildlife (Wilson 1974, Bland 1998, Maratha and Louis 1998). There is a considerable increase in the number of studies on vegetation and bird communities (Infield 1988, Newmark and Leonard 1991, Newmark *et al.* 1993, Gokula 1998, Vijayan *et al.* 1999).

However, only a few studies in the Western Ghats have focused on avian use of disturbed forest such as those by Joshua and Johnsingh (1988) on edge effect and bird communities, Daniels (1996) on landscape ecology and conservation of birds, Gokula (1998) on the bird communities in the dry deciduous and thorn forests in Mudumalai with special reference to human disturbance on the breeding birds. Vijayan *et al.,* (1999) studied the impact of disturbances on the plant and bird communities in six major habitats in the Nilgiri Biosphere Reserve, namely scrub, dry deciduous, moist deciduous, shola, evergreen forests and grasslands. Vijayan and Gokula (1999) have analyzed the impact of disturbances on the populations of the two rare endemic birds. Gokula and Vijayan (2000) have described the foraging of birds in the thorn forest in Mudumalai. Quantification of plant resources will help us to find out whether any correlation exists between vegetation and bird communities. Several authors have highlighted the importance of plant resources to avifauna; Balasubramanian (1990) has discussed the importance of fleshy fruits in the diet of several bird species in a disturbed forest at Point Calimere. He has further stated that the fruiting phenology has correlation with bird abundance. Vijayan *et al.,* (1999) described the impact of human interference on vegetation and bird communities in different habitats. An attempt has been made in this study to identify i. the availability of plant resources, ii. to determine the importance of plant species in the community, iii. the seasonality of foliage height diversity, and iv. phenology of plants to compare them with abundance of bird species.

The present study was conducted in and around the forests of Anaikatty, Western Ghats. The vegetation of the forest here is of the southern mixed dry deciduous type and in the SACON campus it is scrub forest (Champion and Seth 1968).

3.2. Sampling Method

Chapman (1933) advocates the use of rectangular quadrats trather han the square and circular. Using non-destructive measures, belt transect method was adopted to obtain quantitative information about the structure and composition of terrestrial plant communities. A kilometer length of four transects, which are laid for bird census was used. Transects are designed to show graphically the changes in the composition of the vegetation along a selected line across the survey area and are a form of systematic sampling in which samples are arranged linearly and usually contiguously. The belt transect is a better method which employs a strip of vegetation rather than a line. Unless there is a great diversity of plant taxa over the area, one transect is generally sufficient and this is commonly used in ecological studies.

3.2.1. Size of the quadrats

Vegetation was sampled to estimate the diversity, density, dominance and Importance value index (IVI) in the two different habitats namely mixed dry deciduous and scrub forest. Size of the quadrats depends on the morphology of the species in the vegetation to be sampled and the homogeneity of the vegetation. In each transect, 10 x

20m plots were laid in both the habitats to estimate the trees. Mixed dry deciduous forest was sampled using 35 plots from three transects (10+10+15) and scrub forest was sampled using 35 plots in one transect. In total, 70 plots were laid in both the habitats. All the trees and shrubs present within the plots were identified upto species level. The height, girth at breast height (>14 cm) and number of species were estimated for all the tree species within the plot. To enumerate shrubs, within each tree quadrat, two sub-quadrats of 5 x 5m each were laid. Canopy cover of shrubs was also estimated. In the same plot, four quadrats of 1 x 1m were laid to estimate the ground cover.

3.2.2. Foliage Height Diversity (FHD)

Vertical distribution of foliage was sampled in each transect of 1 km in the mixed dry deciduous forest and in the scrub forest following the method of MacArthur and Horn (1969) with very little modification as adopted by Daniels (1996) for the Western Ghats and the method of Gokula (1998) for the Mudumalai Wildlife Sanctuary. At every 50-m interval, a circular plot of 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 5m interval on four cardinal directions was established. Ten such similar samples were repeated in all transects. A total of 520 points (10 plots in each transect and 13 points per plot) were made for the vegetation profile study in the forest and campus habitats. An aluminium rod (marked with 1m divisions up to 15 m) was placed vertically at every point. The percentage of foliage thickness covering the rod in each vertical stratum was recorded at every 1m interval. From these measurements, the foliage height diversity (FHD) in each stratum was determined using Shannon's index for both habitats. Similarly bird species diversity (BSD) was also calculated at each vertical stratum and correlated with foliage height diversity.

3.2.3. Plant phenology

Altogether, 51 species of plants comprising 255 individuals were marked for phenological studies. In the mixed dry deciduous forest, 36 species and in the scrub forest 27 species were selected mainly those which are common and preferred by birds (Plate 3). Five individuals of each species were marked with aluminium tag and monitored once in a fortnight for their phenology for two years (1999-2001). The vegetative phase (young leaf and matured leaf=100%) and reproductive phase (buds, flowers, unripe and ripe fruits=100%) of the marked plants were estimated separately in percentages. The data were averaged for each species and given the phenological status during the study period. This data was used to compare frugivore and nectarivore abundance.

PLATE 3. PREFERRED FRUITS OF BIRDS IN THE ANAIKATTY HILLS

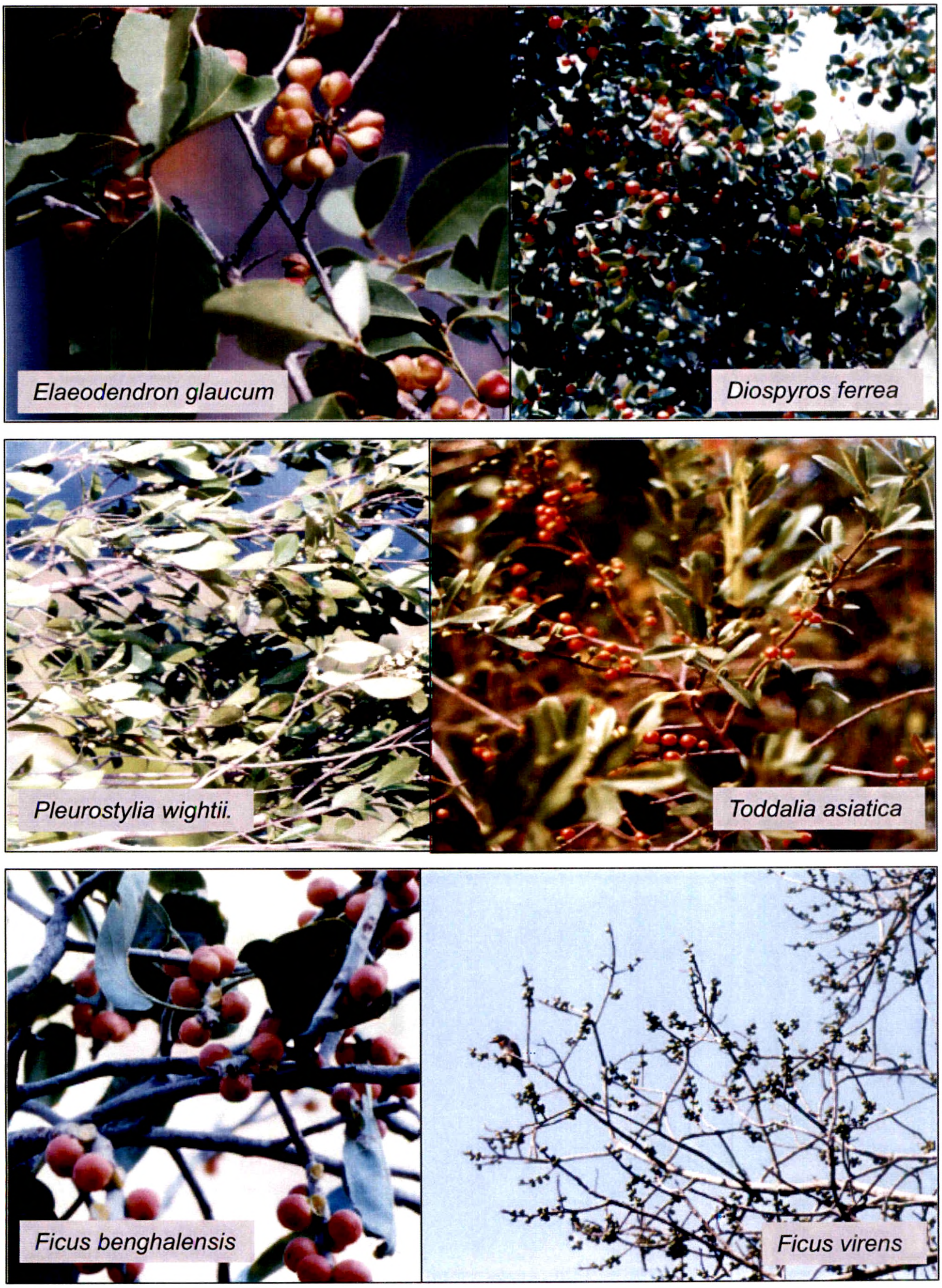


Photo by Sr. T. Nirmala

3.3. Data analysis

The relative values of density, dominance and frequency are determined for each species. Density refers to the number of individuals per unit area, dominance to the basal area or crown cover per unit area, and frequency to the fraction of sample plots containing the species. Importance value index gives an idea of the sociological structure of a species in its totality in the community but does not indicate its position separately with regard to other aspects such as frequency, density and so on. The vegetation data were quantitatively analyzed using standard analytical and statistical methods with computer software packages (Excel, SPSS and Vedas program). The following formulae were used for analysis.

Density per plot = $\frac{\text{Total number of individuals}}{\text{Total number of quadrats examined}}$

Relative density = $\frac{\text{No. of individuals of a species in all quadrats}}{\text{No. of individuals of all species in all quadrats}} \times 100$

Frequency (%) = $\frac{\text{No. of quadrats in which the species occur}}{\text{Total number of quadrats examined}} \times 100$

Relative frequency (%) = $\frac{\text{No. of occurrences of a species}}{\text{Number of occurrences of all species}} \times 100$

Shannon's Diversity index $H' = -\Sigma\, Pi \log_e Pi$

Where,

$Pi = n_i / N$

n_i = number of individuals of the i^{th} species and

N = total number of individuals of all the species in that sample area.

The higher the value of H, the greater the diversity.

Importance value index (IVI)
Relative values for density, dominance and frequency may be combined into a single importance value, which reflects these three somewhat different measures of the importance of the species in the community.
Importance Value Index = Relative density + relative dominance + relative frequency

Niche breadth
Niche breadth of all the plant species in Anaikatty were calculated using Levins's niche breadth formula (Levins 1969).
$B = 1 / \Sigma Pi^2$
$Pi = n_l / N$
Where,
B = Niche breadth
n_l = number of individuals of a species in one habitat
N = total number of individuals of a species in both the habitats (Σn_l).

3.4. Results and Discussion

3.4.1. Flora of the Anaikatty hills

Totally, 118 plant species belonging to 44 families were recorded from the belt transect in mixed dry deciduous and scrub forests. They consisted of tree (50), shrub (45), herb (9) and stragglers (14). Among them, 50 species are having medicinal value and are preferred for collection by the tribals (Appendix 2). Herbs are not studied here upto species level since Balasubramanian *et al.* (2001) have already reported 69 herb species in the degraded area of Anaikatty; only percentage cover is considered here.

3.4.2. Plant community in the mixed dry deciduous forest (MDDF)

The number of tree and shrub species found in 0.7ha of mixed dry deciduous forest was estimated. Vegetation profile of mixed dry deciduous forest consisted mostly of tree species of 2-6m height (Figure 3.1) and the upper stratum was thinned out with a few tall trees such as *Ficus* sp., *Tamarindus indica, Acacia polyacantha, Albizia amara, Canthium dicoccum, Celtis philippensis* and *Commiphora caudata*. Shrubs formed the lower stratum of the mixed dry deciduous forest at 0-2m (Figure 3.1). Shrubs occupied a predominant place from ground to 1m height in mixed dry deciduous forest than in scrub forest.

3.4.2.1. Species richness, density and diversity of plants

Shrub species richness and diversity (H') were more than the tree species richness and diversity (Table 3.1). Trees and shrubs were distributed with the same equitability. Although 370 individuals of 27 tree species were recorded (Table 3.2), only a few tree species viz., *Limonia alata, Diospyros ferrea, Cordia monoica, Atalantia monophylla, Albizia amara* and *Bauhinia rsacemosa* had >10 IVI. The relative density value of 23 tree species was <1 and only four tree species were having >1.

Table 3.1. Diversity of plant forms in the mixed dry deciduous forest.

Growth forms	Species richness	Diversity	Equitability
Tree	27	2.28	0.69
Shrub	40	2.53	0.69

Although 45 shrub species (Table 3.3) were recorded, only a few were having density values >1. viz., *Acalypha fruticosa, Carmona retusa, Pavetta indica* and *Acacia* sp.

Figure 3.1. Vegetation profile of the mixed dry deciduous forest

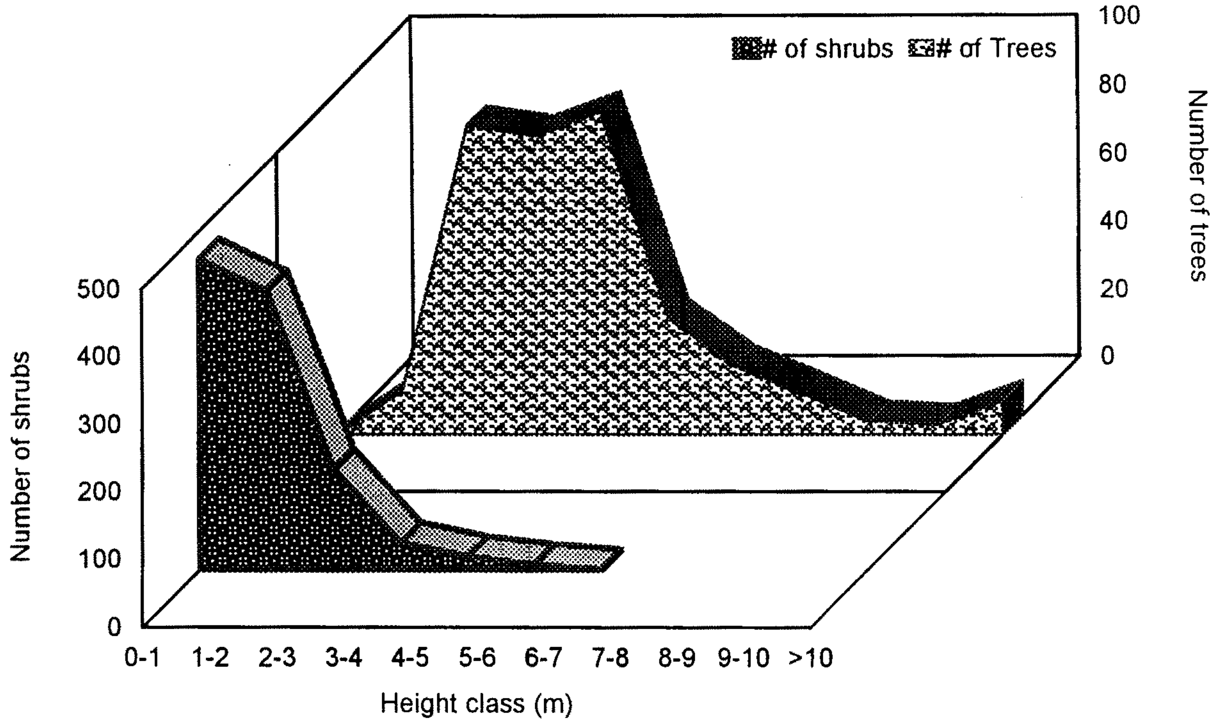


Figure 3.2. Vegetation profile of the scrub forest

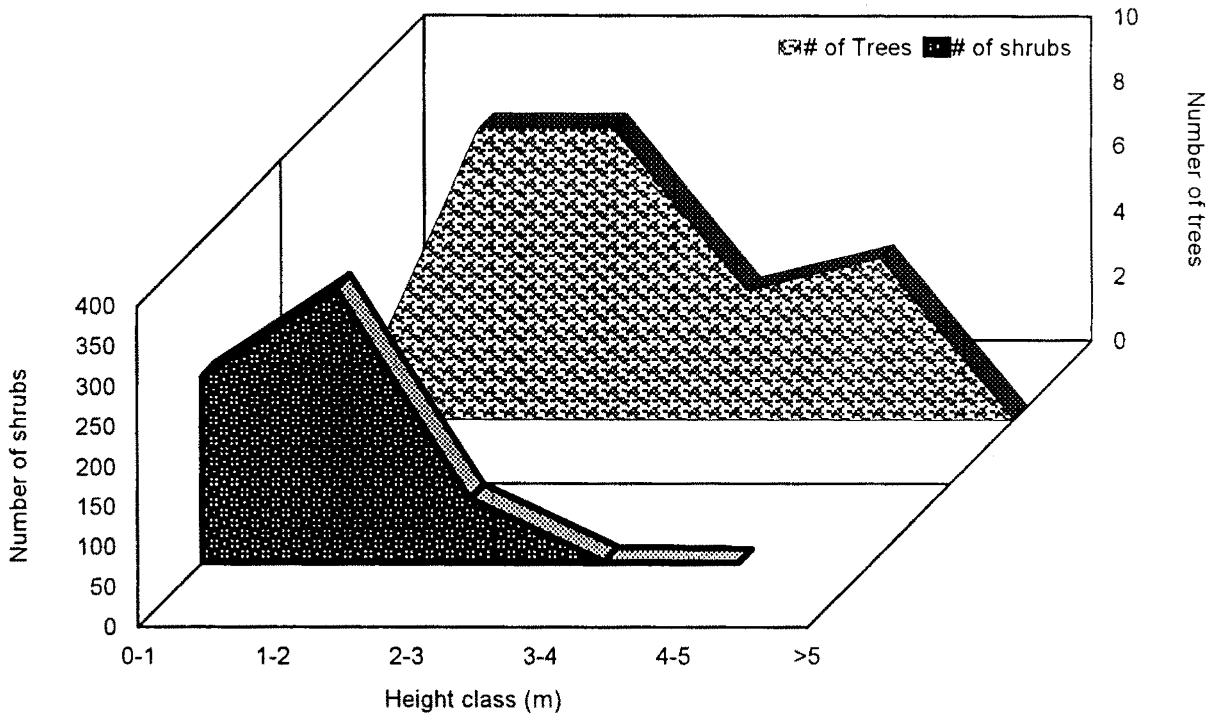


Table 3.2 Ecological values of tree species in the mixed dry deciduous forest

Species	Number of individuals	Frequency %	Abun-dance	Density	IVI	Basal area
Melia azadiracta	1	2.86	1.00	0.03	0.86	0.15
Gyrocarpus jacopinus	1	2.86	1.00	0.03	0.87	0.45
Ailanthus excelsa	1	2.86	1.00	0.03	0.89	1.20
Elaeodendran glaucum	1	2.86	1.00	0.03	0.90	1.42
Premna tomentosa	1	2.86	1.00	0.03	0.96	3.11
Prosopis juliflora	1	2.86	1.00	0.03	1.05	5.68
Bambusa sp	2	2.86	2.00	0.06	1.80	19.20
Euphorbia antiquorum	1	2.86	1.00	0.03	1.83	27.50
Flacourtia indica	2	5.71	1.00	0.06	2.18	13.60
Ixora pavetta	2	5.71	1.00	0.06	2.22	14.57
Mundulia sericea	6	8.57	2.00	0.17	3.52	4.86
Ficus benghalensis	2	5.71	1.00	0.06	3.71	56.41
Tamarindus indicus	1	2.86	1.00	0.03	3.77	82.05
Gardenia sp	5	8.57	1.67	0.14	3.96	24.73
Canthium dicoccum	4	11.43	1.00	0.11	4.04	18.33
Zizyphus mauritiana	5	14.29	1.00	0.14	4.72	13.63
Phyllanthus reticulata	9	14.29	1.80	0.26	5.90	16.40
Acacia polyacantha	4	8.57	1.33	0.11	7.27	125.60
Celtis philippensis	8	22.86	1.00	0.23	8.66	52.90
Chloroxylon swietenia	15	28.57	1.50	0.43	11.87	57.48
Bauhinia racemosa	7	20	1.00	0.20	17.25	318.14
Commiphora caudata	3	5.71	1.50	0.09	17.71	442.78
Atlantia monophylla	39	48.57	2.29	1.11	23.89	98.88
Albizia amara	30	51.43	1.67	0.86	25.83	205.78
Cordia monoica	40	51.43	2.22	1.14	27.61	180.05
Diospyros ferrea	61	65.71	2.65	1.74	37.97	230.26
Limonia alata	118	91.43	3.69	3.37	78.75	797.91

Table 3.3 Ecological values of shrub species in the mixed dry deciduous forest

Species	Number of individuals	% fre-quency	Abun-dance	Density	IVI
Carbata	1	1.43	1.00	0.01	0.31
Hyptis sp	1	1.43	1.00	0.01	0.31
Fluggea leucopyros	1	1.43	1.00	0.01	0.31
Glycosmis pentaphylla	1	1.43	1.00	0.01	0.31
Canthium dicoccum(s)	1	1.43	1.00	0.01	0.31
Celtis philippensis(s)	1	1.43	1.00	0.01	0.31
Diospyros ferrea	1	1.43	1.00	0.01	0.31
Mundulia sericea	1	1.43	1.00	0.01	0.31
Abutilon indica	1	1.43	1.00	0.01	0.31
Erythroxylum monogynum	2	1.43	2.00	0.03	0.40
Phyllanthus reticulata	2	1.43	2.00	0.03	0.40
Zizyphus mauritiana	2	2.86	1.00	0.03	0.63
Cardiospermum canescens	2	2.86	1.00	0.03	0.63
Securinega sp	2	2.86	1.00	0.03	0.63
Malvastrum sp	2	2.86	1.00	0.03	0.63
Maytenus emarginata	4	2.86	2.00	0.06	0.82
Scutia myrtina	3	4.29	1.00	0.04	0.95
Dichrostachys sp	4	4.29	1.33	0.06	1.04
Randia dumetorum	4	5.71	1.00	0.06	1.26
Pterolobium hexapetalum	4	5.71	1.00	0.06	1.26
Jasminum sp	6	7.14	1.20	0.09	1.67
Ruellia sp	11	5.71	2.75	0.16	1.90
Melia azadiracta	8	10	1.14	0.11	2.31
Andrographis sp	10	12.86	1.11	0.14	2.93
Flacourtia indica	14	11.43	1.75	0.20	3.08
Zizyphus oenoplia	13	14.29	1.30	0.19	3.44
Barleria sp.	14	15.71	1.27	0.20	3.75
Oscimum sp.	18	14.29	1.80	0.26	3.90
Carissa spinarum	21	15.71	1.91	0.30	4.39
Capparis grandiflora	19	18.57	1.46	0.27	4.66
Capparis sepiaria	16	21.43	1.07	0.23	4.83
Toddalia asiatica	20	21.43	1.33	0.29	5.20
Opuntia dillenii	57	27.14	3.00	0.81	9.50
Acacia sp.	44	47.14	1.33	0.63	11.43
Pavetta indica	78	52.86	2.11	1.11	15.46
Carmona retusa	95	55.71	2.44	1.36	17.47
Acalypha fruticosa	153	72.86	3.00	2.19	25.50
Chromolaena odorata	213	67.14	4.53	3.04	30.12
Lantana camara	232	92.86	3.57	3.31	35.90

3.4.3. Plant community in the scrub forest (SF)

The number of tree and shrub species found in 0.7ha of scrub forest was estimated. Vegetation profile of scrub forest consisted mostly of shrub species at 1-2m height (Figure 3.2) and the upper stratum was thin with a few regenerating trees >3m such as *Albizia amara, Diospyros ferrea, Erythrina indica* and *Cassia fistula.* Shrubs formed the lower stratum of the scrub forest at 0-2m. Shrubs occupied a predominant place from ground to 1m height here also.

3.4.3.1. Species richness, density and diversity of plants

Tree species richness was very low in scrub forest corresponding to that in MDDF (Table 3.8). Shannon's index showed higher diversity of shrubs than tree diversity. Eventhough shrub species were high they were not evenly distributed. But tree species were distributed with greater evenness (Table 3.4). Although 15 individuals of 6 tree species were recorded (Table 3.5), only *Premna tomentosa, Chloroxylon swietenia, Diospyros ferrea* and *Albizia amara* were common and their height was restricted to <4m.. Herb and grass coverage was 54%. Open space was comparatively low (46%) in the scrub forest (Table 3.7). Although 32 shrub species (Table 3.6) were recorded within the quadrat, only a few had having more than one as their density viz., *Lantana camara, Chromolaena odorata, Carmona retusa, Cassia auriculata* and *Pavetta indica.* The most common shrub species were *Lantana camara* and *Chromolaena odorata*. Low number of tree and shrub species was due to the felling of all plants. The species diversity and richness were low in this study as compared to the other tropical forests (Vijayan *et al.* 1999) due to the exploitation of plant resources by people and cattle. Similar observation was reported in Rewa Division at Madhya Pradesh (Rao and Mishra 1994).

Table 3.4 Diversity of plants in the scrub forest

Growth forms	Species richness	Diversity	Equitability
Tree	8	1.58	0.88
Shrub	32	2.41	0.7

Table 3.5 Ecological values of tree species in the scrub forest

Species	Number of individuals	% frequency	Abundance	Density	IVI	Basal area
Premna tomentosa	5	26.32	1.00	0.33	0.31	71.35
Mundulia sericea	1	5.26	1.00	0.07	0.31	0.53
Erythrina indica	1	5.26	1.00	0.07	0.31	16.04
Cassia fistula	1	5.26	1.00	0.07	0.31	16.04
Euphorbia antiquorum	1	5.26	1.00	0.07	3.44	6.50
Albizia amara	3	15.79	1.00	0.20	5.20	6.50
Diospyros ferrea	3	15.79	1.00	0.20	5.20	6.50
Chloroxylon swietenia	4	21.05	1.00	0.27	11.43	25.25

Table 3.6 Ecological values of shrub species in the scrub forest

Species	Number of individuals	% frequency	Abundance	Density	IVI
Acalypha fruticosa	4	13.33	1.00	0.13	0.21
Cordia monoica	1	3.33	1.00	0.03	0.21
Malvastrum sp	3	10	1.00	0.10	0.21
Justicia sp	6	13.33	1.50	0.20	0.27
Carmona retusa	41	63.33	2.16	1.37	0.31

Species	Number of individuals	% fre-quency	Abun-dance	Density	IVI
Elaeodendran glaucum	2	6.67	1.00	0.07	0.31
Acacia sp	5	16.67	1.00	0.17	0.40
Mimosa pudica	1	3.33	1.00	0.03	0.42
Fluggea leucopyros	1	3.33	1.00	0.03	0.42
Capparis grandiflora	2	6.67	1.00	0.07	0.63
Cassia auriculata	50	63.33	2.63	1.67	0.63
Toddalia asiatica	1	3.33	1.00	0.03	0.63
Diospyros ferrea	4	6.67	2.00	0.13	0.63
Chromolaena odorata	138	90	5.11	4.60	0.69
Carissa spinarum	4	13.33	1.00	0.13	0.82
Chloroxylon swietenia	3	6.67	1.50	0.10	1.04
Argyreia pomacea	9	30	1.00	0.30	1.26
Melia azadiracta	2	6.67	1.00	0.07	1.26
Mundulia sericea	2	3.33	2.00	0.07	1.27
Opuntia dillenii	16	30	1.78	0.53	1.67
Zizyphus mauritiana	6	16.67	1.20	0.20	1.96
Securinega sp	22	50	1.47	0.73	1.96
Calotropis gigantea	5	10	1.67	0.17	3.75
Ipomea sp	2	6.67	1.00	0.07	3.90
Scutia myrtina	7	23.33	1.00	0.23	4.39
Lantana camara	144	93.33	5.14	4.80	4.66
Pavetta indica	31	43.33	2.38	1.03	4.83
Grewia rhamnifolia	5	16.67	1.00	0.17	5.55
Randia dumetorum	13	13.33	3.25	0.43	5.89
Zizyphus oenoplia	1	3.33	1.00	0.03	17.47
Flacourtia indica	23	46.67	1.64	0.77	25.50
Capparis sepiaria	4	13.33	01.00	0.13	30.12

3.4.4. Ground cover

Herb and grass coverage for 140 m^2 was 38%. Open space on the ground was high ie.62% for the same area. Herb cover was high in scrub forest than in the mixed dry deciduous forest (Table 3.7) and this might probably be because of the highly disturbed area as noted in the study of Reddy (1998) in the tropical grasslands in Guntur.

Table 3.7. Proportion of ground cover in the mixed dry deciduous forest and scrub forest

Ground cover (%)	Mixed dry deciduous forest	Scrub forest
Grass cover	27	30
Herb cover	11	24
Barren ground	62	46

3.4.5. Niche breadth

In order to study the distribution of plant species comparing both the habitats, niche breadth of each plant species was calculated using Levins's formula (Levins 1969). The number of species having greater niche breadth was more in the mixed dry deciduous forest than in the scrub forest. Fifty one percent of plant species had <1niche breadth, and 19 species 2, 14 species 3 and 7 species >3 as their niche breadth (Table 3.8). Among this, the only tree that had more than three as its niche breadth which was more widely distributed was *Chloroxylon swietenia*, but the shrub species with >3 as their niche breadth were *Capparis sepiaria, Carmona retusa, Lantana camera, Pavetta indica, Acacia* sp., and *Acalypha fruticosa*. They invaded most of the area in the forest because of anthropogenic disturbances in this area as in other parts of NBR (Maya 2000).

Table 3.8 Niche breadth of trees and shrubs in the mixed dry deciduous forest and the scrub forest

Plant forms	Number of species in		Niche breadth
	MDDF	SF	
Tree	14	0	<1
	8	8	>1-2
	5	5	>2-3
	1	1	>3
Shrub	24	0	<1
	11	11	>1-2
	9	9	>2-3
	6	6	>3

3.4.6. Foliage Height Diversity (FHD)

In mixed dry deciduous forest, foliage was available up to 11-12 m and in scrub forest, only upto 5m height. Foliage Height Diversity was estimated for mixed dry deciduous forest upto 10m and for scrub forest upto 5m after which it became zero diversity (Figure 3.3-3.6).

Foliage Height Diversity was greater up to 6 m height class and decreased as the height increased because of the fewer number of tall trees. The higher strata were dominated largely by tree species such as *Acacia polyacantha, Albizia lebbeck, Tamarindus indicus* and *Ficus* species.

In scrub forest Foliage Height Diversity was greater up to 3 m height class and lower in the 3-4 m class. MacArthur and MacArthur (1961) related the foliage complexity with the bird species diversity and stated

Figure 3.3. Foliage Height Diversity (FHD) of the mixed dry deciduous and scrub forests in southwest monsoon

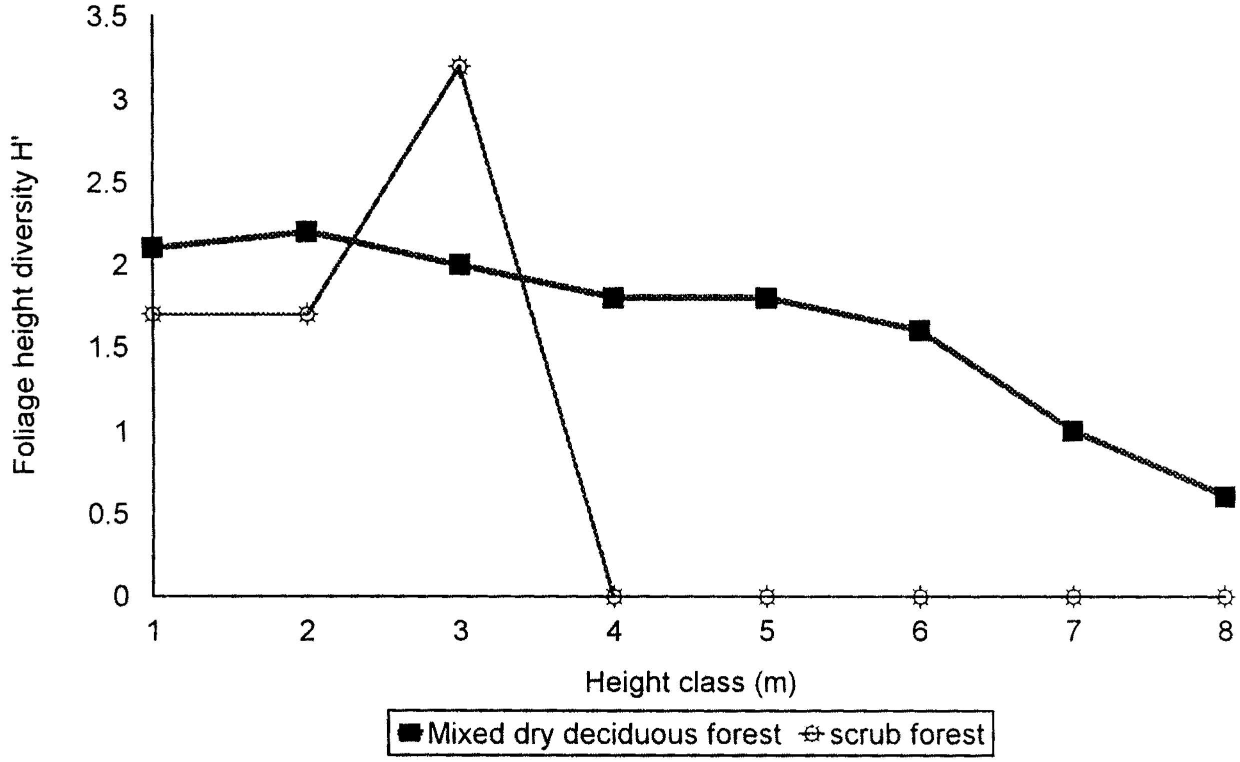


Figure 3.4. Foliage Height Diversity (FHD) of the mixed dry deciduous and scrub forests in northeast monsoon

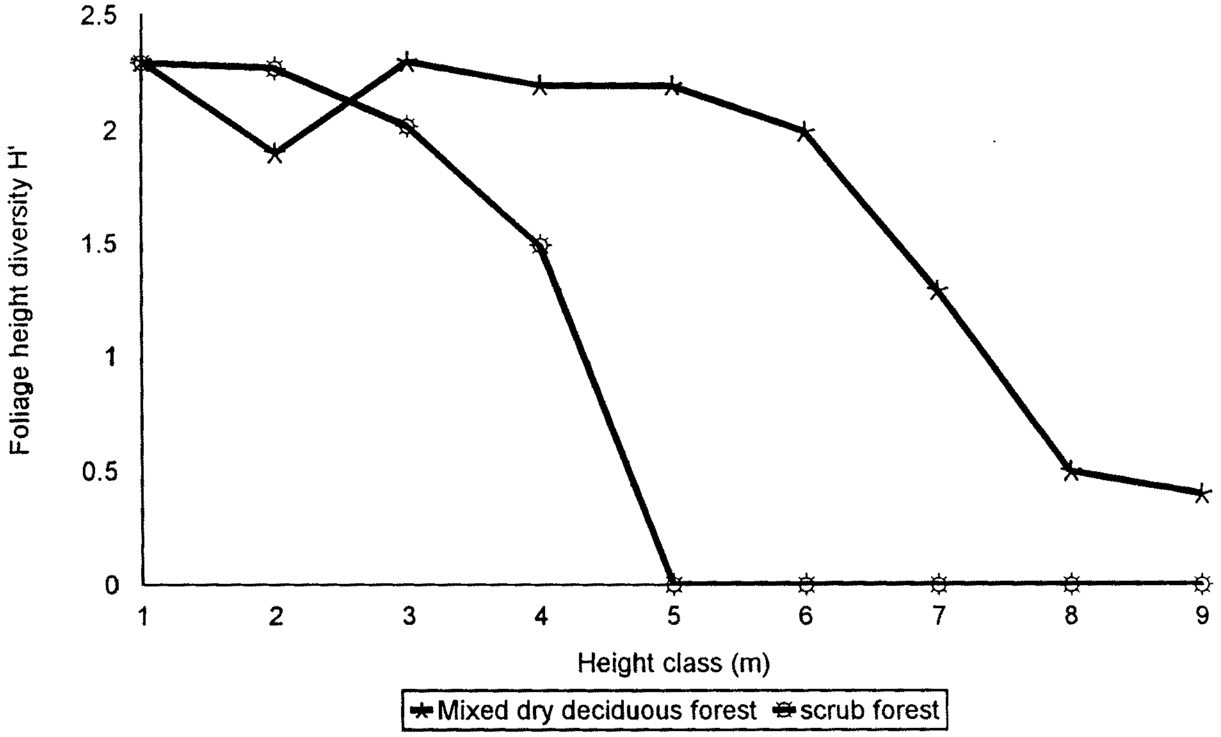
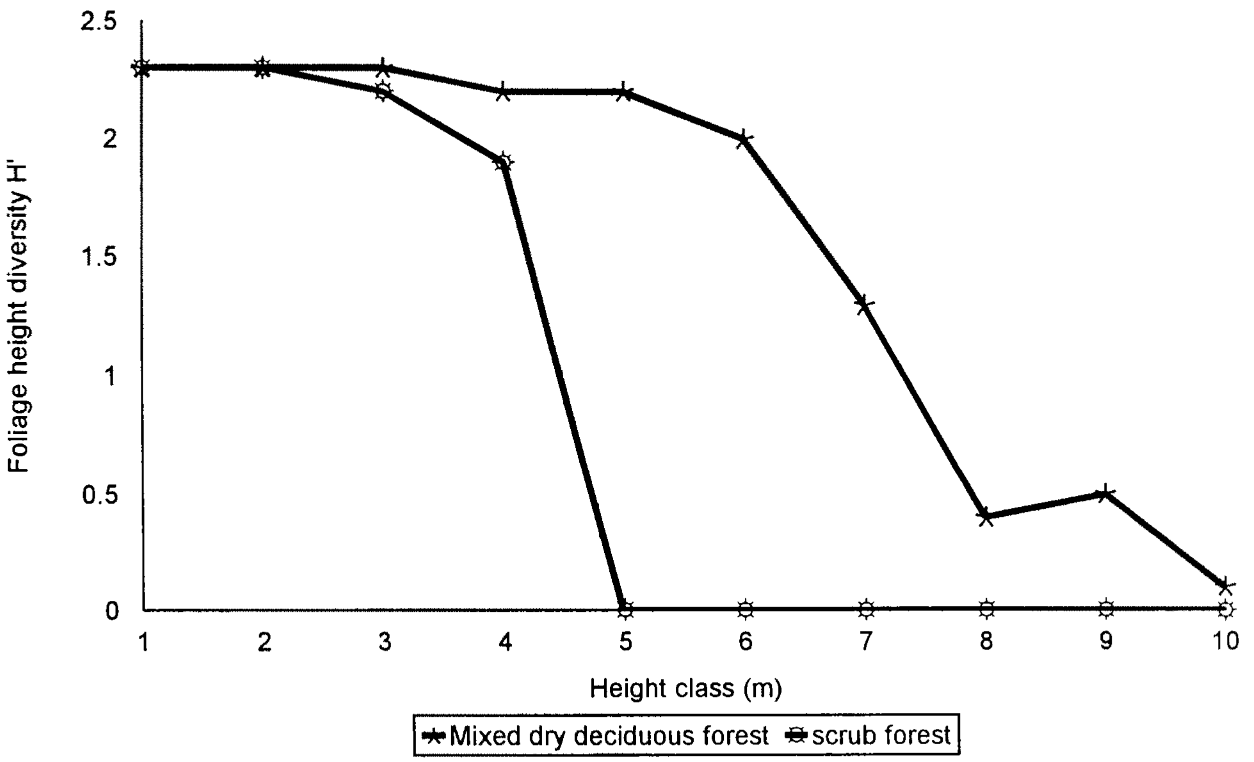


Figure 3.5. Foliage Height Diversity (FHD) of the mixed dry deciduous and scrub forests in Winter

Figure 3.6. Foliage Height Diversity (FHD) of the mixed dry deciduous and scrub forests in Summer



that higher foliage profile layers harboured more species. This is true with habitats of mixed dry deciduous forest and scrub forest in this study also and similar studies elsewhere (Johnsingh *et al.* 1987, Vijayan *et al.* 1999).

Foliage diversity was high during northeast monsoon and winter up to 3m in scrub forest and it extended upto 5m height where it reached nil diversity. This was because of the foliage bloom after the showers of southwest and northeast monsoon. But in summer and southwest monsoon it was lowered to zero at the same height level, which was due to less foliage on the height above 5m. During summer it went down even to 4m, and was due to foliage withering during hot (summer) season.

3.4.7. Phenology of plant species

3.4.7.1. Mixed dry deciduous forest

The maximum percentage of flower abundance was recorded in April in both the years while the minimum was in December. The maximum percentage of fruit abundance was recorded in December in both the years (Figure 3.7), whereas the minimum was in April. The phenological trend was the same for both the years.

3.4.7.2. Scrub forest

The phenological trend was the same for both the years and it showed two peak periods. The maximum percentage of flower was recorded in the first (April, May) and second peaks (October) in both the years. The minimum percentage of flower abundance was observed in

Figure 3.7. Abundance of flower and fruit in the mixed dry deciduous forest

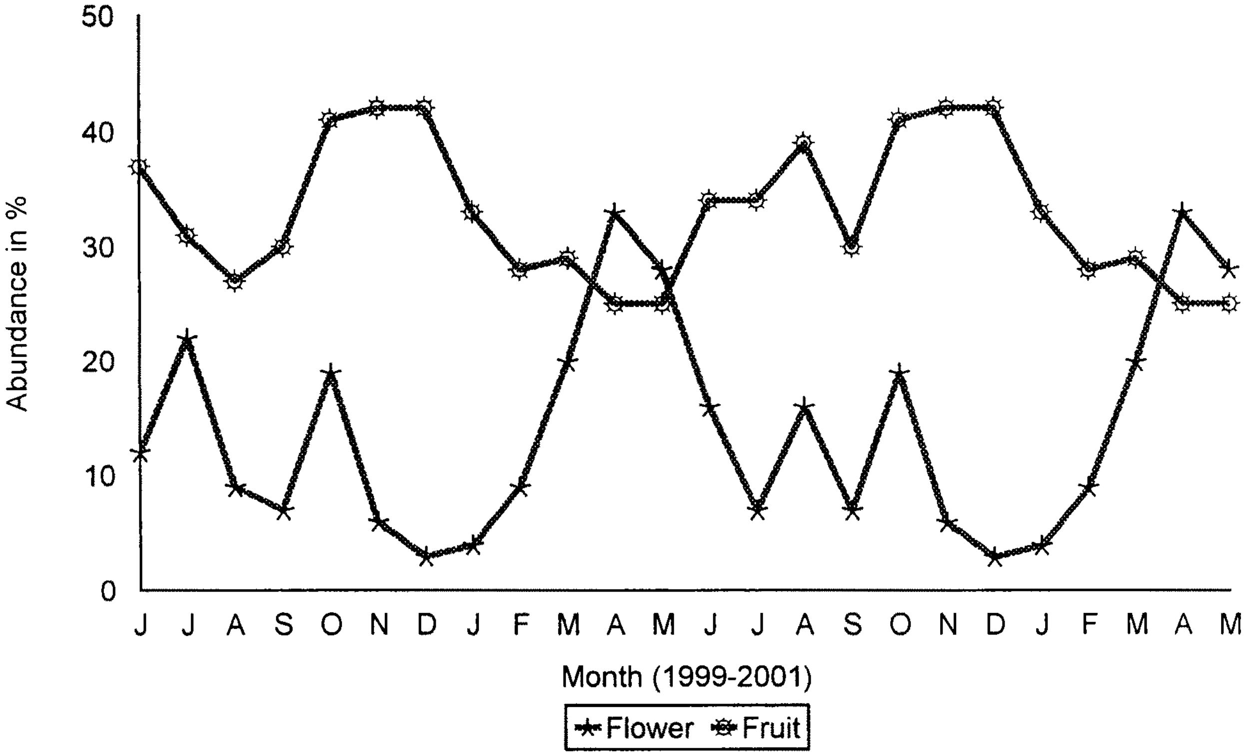
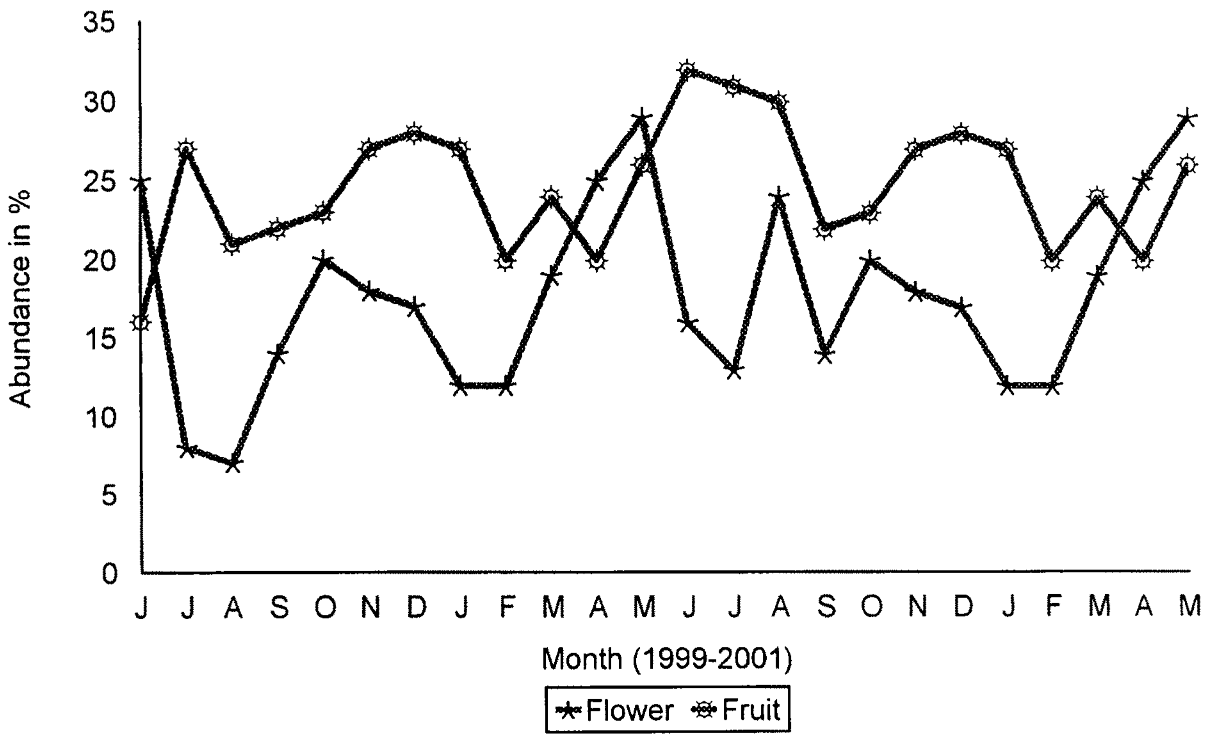


Figure 3.8. Abundance of flower and fruit in the scrub forest



July/August for both the years. The maximum percentage of fruit abundance was recorded in June/July for both the years (Figure 3.8) while the minimum was in April.

3.4.7.3. Fruiting seasonality of plants

In total, the mixed dry deciduous forest showed two peaks, the major one in December and the second in August. Scrub forest also showed two peaks, one in December and the other in May. Mostly fruiting increased after monsoon (Figure 3.9). Fruiting species were higher in mixed dry deciduous forest than scrub forest throughout the year.

3.4.7.4. Flowering seasonality of plants

Mixed dry deciduous forest had a large number of trees in flower during May and also a minor peak during October and August. The pattern was different in August during the two years; in the second year it was greater in the scrub forest. Scrub forest also showed the same peak period. Mostly flowering increased after winter and during monsoon (Figure 3.10) as in the study of Sun *et al.* (1996). Only during the peak periods (May and August) the flowering plants in mixed dry deciduous forest were higher than scrub forest. Seasonal variation in the flowering between the habitats was evident as in the study of Balasubramanian and Bole (1993). In spring (summer) flower was more in the MDDF while

Figure 3.9. Number of fruiting species in the mixed dry deciduous and scrub forests

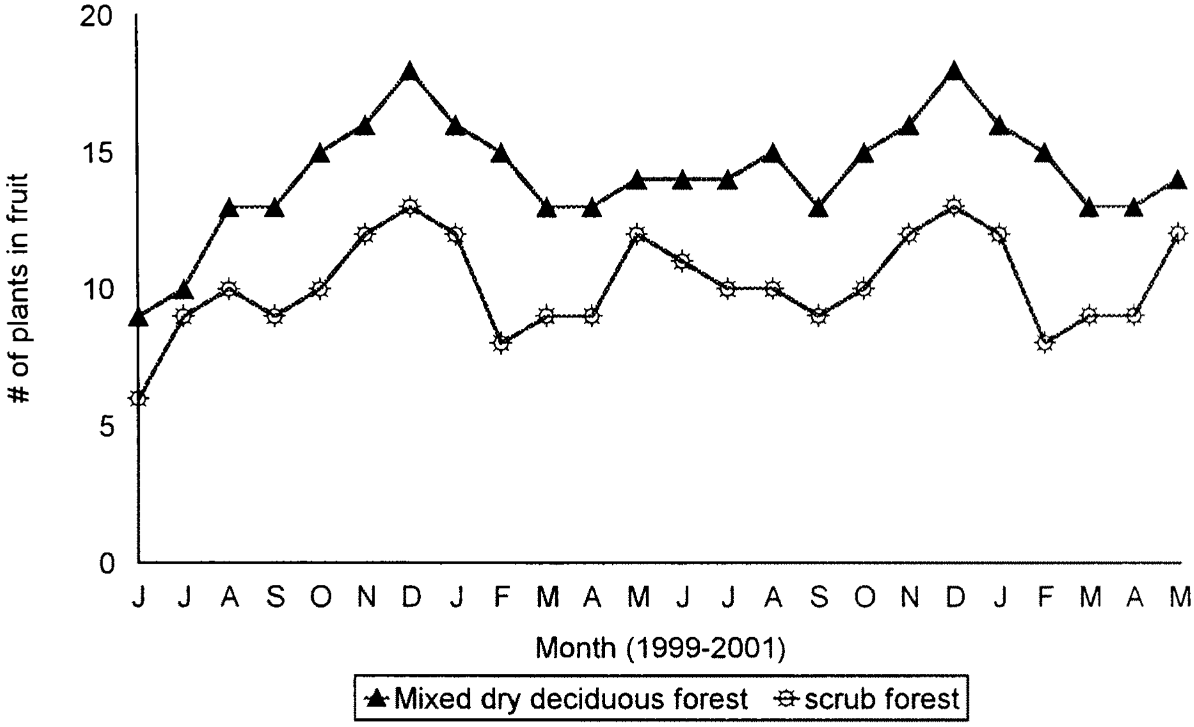
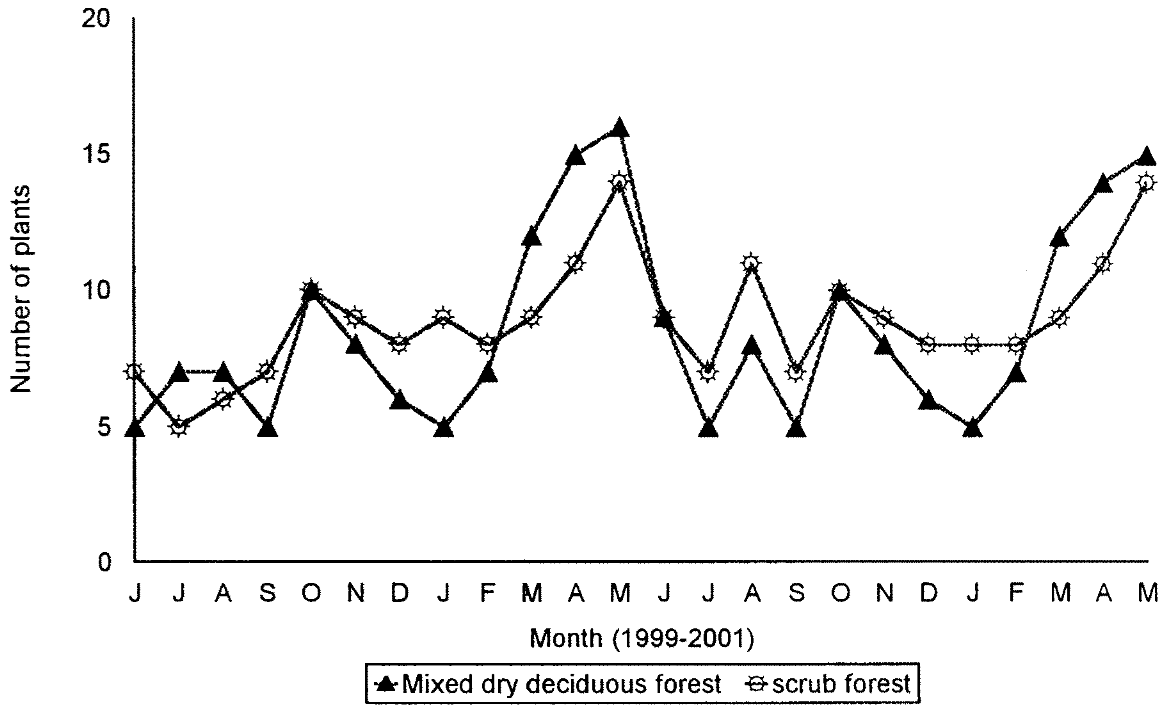


Figure 3.10. Number of terrestrial plant species in flower



during monsoons and winter it was more in the scrub forest where abundance of shrub was more.

Plant species were comparatively high in mixed dry deciduous forest than scrub forest. Even in shrub diversity, it was high in forest than in the scrub forest. This was due to the degradation of this area to a very high level leading to an increase in the number of weeds which had high adaptive attributes (Mathew 1990, Rawat *et al.* 1994). Shrub species were more owing to the open space created by cattle grazing, collection of branches and leaves for goat and sheep, uprooting of certain species of trees and branches for the construction of houses and fuel purpose.

3.5. Conclusion

The availability of tree and density were higher in mixed deciduous forest than scrub forest. Shrub availability was high in scrub forest. Foliage height diversity was high in the mixed dry deciduous forest than scrub forest; also foliage was available upto 11-12 m in the former while in the latter it was only upto 5m height.

Plant species were comparatively high in mixed dry deciduous forest than in scrub forest. Diversity of shrub was high in MDDF than in the SF. This is due to the degradation of this area to a very high level. Shrub species were more owing to the open space created by clearing the forest and later by cattle grazing, collection of branches and leaves for goats and sheeps, cutting of certain species of trees and branches for the construction of houses and fuel purpose.

In the mixed dry deciduous forest, maximum percentage of flower was recorded in April for both the years and minimum was seen in December. A definite phenological trend does exist and it is the same for both the years. The habitat heterogeneity was the factor responsible for the changes in the vegetation between the two habitats.

In the scrub forest phenological trend was the same for both the years and it showed two peak periods. The maximum fruit abundance was in June-July and flower abundance was recorded in April-May with a minor peak in October during both the years. Minimum abundance of flower was in August and minimum fruit abundance was in June.

The number of species of plants in flower and fruit as well as the abundance of flower and fruit was similar in both the years, but varied between the two habitats. Plant species in fruit were higher in mixed dry deciduous forest than scrub forest in all the seasons. Flowering was high during summer in both the habitats. Only during this major peak period (March, April and May) the plants in flower in mixed dry deciduous forest were higher than in the scrub forest.

Habitat degradation was mainly due to removal of trees. Later, regeneration has brought in many smaller shrubs, but with more open areas when compared to the reserve forest. Hence, the species richness and composition changed with the increase of open areas and scrub forest species in the degraded sites. Although a few such species are added to the whole area because of the habitat diversity with the addition of the degraded area, many of the forest species disappeared. Habitat diversity increased with moderate disturbance.

CHAPTER 4

BIRD COMMUNITY STRUCTURE

4.1. Introduction

The community is an assemblage of species populations, which occur together in space and time (Wiens 1989). According to Smith (1986) community is an assemblage of plants and animals found living together with some degree of permanence. Here the study of bird community refers to the search for relations among measurable aspects of sets of bird species. There may be patterns, as of size or relative abundance, among the species within a community, and there may be patterns, as of number of species, that vary regularly from community to community (MacArthur 1971).

The simplest measure related to diversity in an area is to find out the species richness. But the species richness alone will give very little information about the community structure (Wiens, 1989). This view suggested that diversity should be estimated to compare the communities. Also diversity may be measured most directly as number of species and expressed as an index that incorporates the interplay of species richness and relative abundance of species into a single value for a given community (Wiens, 1989). Moreover, it may vary depending upon the number of samples and the area sampled. Hence, ecologists developed various diversity indices to compare the different communities. Diversity index is dependent on sample size, Pielou (1975) and

Grassle *et al.* (1979) have discussed the ecological diversity in detail. Shannon's diversity index is the most widely used index of community ecology.

Quantitative and qualitative information on abundance of bird species in different habitats is necessary for solving many fascinating ecological problems. Studies on the ethology and ecology of birds in different habitats will give valuable input for forest management. Indian subcontinent is known for its diverse and rich bird species whose taxonomy, distribution, habitat and their general characteristics are well-documented (Jerdon 1862-64, Bates and Lowther 1952, Ali and Ripley 1987). However only very little is known about Indian bird community structure and their dynamics (Beehler *et al.* 1987), Johnsingh *et al.* (1987) studied the edge effect in the forest. Sundaramoorthy (1991) documented the bird communities in different habitats in Keoladeo National Park, Bharatpur. Gokula (1998) studied the bird community structure in moist deciduous forest at Mudumalai Wildlife Sanctuary, Jayson and Mathew (2000) studied the seasonal changes of forest birds in Silent Valley. This study was conducted in Southern tropical mixed dry deciduous forest and scrub forest of Western Ghats. As population study has been used traditionally to monitor long-term changes in avian population, this study was designed

- to understand the structure of bird community, species composition, alpha diversity and evenness
- to assess the factor affecting the bird communities in mixed dry deciduous forest and scrub forest.

4.2. Method

Bird population was estimated using variable width line transect method following Bibby *et al.* (1993). Line transect was used to estimate the composition, relative abundance and density of birds. It satisfies its own unique assumptions (Manual and Carey 1991) as

1. All birds on the transect line are detected.
2. Distances are measured accurately.
3. Detections of birds are independent events.
4. Birds do not move before being detected; none are counted more than once.

Variable-width transect was selected because of its robustness and sampling efficiency (Burnham *et al.* 1980), detection of more species and individuals (Wilson *et al.*1994), providing the greatest potential for the national survey (Langbein *et al.* 1999), ease of sampling compared to other methods (Verner 1985, Sundaramoorthy 1991, Javed 1996) and has worked well in many areas (Carey 1983). Because of variable width line transect method, the following benefits are encountered: 1. All the birds are counted 2. Different species are counted on different scales because of differing detectabilities. 3. Adds more records of the conspicuous species.

A kilometer length of four permanent transects were laid and marked at every 10m distance. Of four transects, three were in the mixed dry deciduous forest and one in the scrub forest which is in the campus of SACON. The area sampled in three transects at mixed dry deciduous forest is equal to one at scrub forest (10 ha) where the area is open. Census was carried-out thrice a month in each transect, early in the morning, half an hour after sunrise in all the seasons and time is limited to one hour. No census was made during foggy or rainy days. Distances perpendicular to the route are measured for all the birds. The height of the plant at which the bird was noticed and the activity of the birds was also recorded. During sampling, all birds seen or heard in each transect were recorded. The bird species, which were not seen and identified only by call, were considered as a single individual unless the call invariably differed and the approximate distance was recorded. Frequency of occurrence was used to identify the species that were restricted to specific habitat following Hagan *et al.* (1997). Species diversity and evenness, species richness, relative abundance and density were determined for each habitat.

4.3. Data analysis

In the present study, since the number of samples and the area sampled in different habitats were equal, the abundance of birds observed was comparable.

4.3.1. Species richness and abundance

Characterization of a community in a simple way is to count the various species found in an area. The number of species recorded is expressed as species richness (Margalef species richness). The total number of birds recorded is generally expressed as abundance of birds. The total number of birds recorded divided by number of counts conducted is expressed as the average number of birds and is considered here in this study as abundance of birds.

4.3.2. Species diversity and Evenness

Species diversity has two components: The species richness in the community and Species evenness or equitability (Ludwig and Reynolds, 1988). Although diversity may be measured most directly as number of species and expressed as an index, it incorporates the interplay of species richness and relative abundance of species into a single value for a given community (Wiens, 1989). Species diversity and evenness determine heterogeneous community. Evenness is a measure of the even allotment of individuals among the species. A number of indices have been used to calculate diversity. Among them, most widely used one is the Shannon-Weaver index (1963) given as follows:

$$H' = -\sum_{i=i}^{s} P_i \log_e P_i$$

$\log_e = \ln$; $P_i = n_i / N$

Where H' = Diversity

S = Number of species

Pi = Proportion of individuals of the total sample belonging to the i th number.

4.3.3. Evenness index

A number of indices have been used to quantify evenness component of diversity. Evenness1 is used here, which expresses the ratio of Hill's number (Alatalo 1981).

Evenness index1 (Pielou1975, 1977) $$E1 = \frac{H'}{\ln(s)} = \frac{\ln(N_1)}{\ln(N_0)}$$

4.3.4. Commonness index

The commonness of each bird species in different habitats was found out by calculating commonness index, which is the average sighting frequency of a species in one sample.

4.3.5. Dominance index

The relative dominance of each bird species in the two habitats was determined by calculating Dominance index using the following formula.

Relative dominance = n_i * 100 / N

Where n_i number of individuals in i^{th} species
N means the total number of individual of all species seen during the study period.

4.4. Results

4.4.1. Distribution of avifauna

Anaikatty hills harboured a variety of birds with 17 orders of 45 families with 194 species (Nirmala and Vijayan 2001). One hundred and eighty seven species of birds were observed during the study period, 1999-2001. A total of 129 species were recorded in the study area during census which was 69% of the total species observed in the area which is greater than that in the other studies. The number of individuals counted in the study area was higher during the second year (23999) than in the first year (23759). On the contrary, the number of bird species in the study area was higher during the first year (129) than in the second year (122). The number of species decreased but the abundance increased during the second year. Of the 129 species, 35% were restricted to the forest and 12% to the scrub forest. The species common to both the habitats were 53% (Figure 4.1) and this was vindication of the scrub forest (SACON) in contiguous with mixed dry deciduous forest. The list of the birds from these two habitats with their status and guild is annexed (Appendix1).

4.4.2. Numerical Status of birds

Birds recorded at the time of census were classified into six classes according to their presence in the study area during the period 1999-2001. Birds that were recorded <5 are grouped into the first category, very rare (21%), from 6-20 formed the second class, rare (24%), between 21 and 50 formed the third class, occasional (14%) (Table 4.1). Anaikatty hills had majority of species with rare sightings (24%) and 20% of common species (Table 4.1). 0

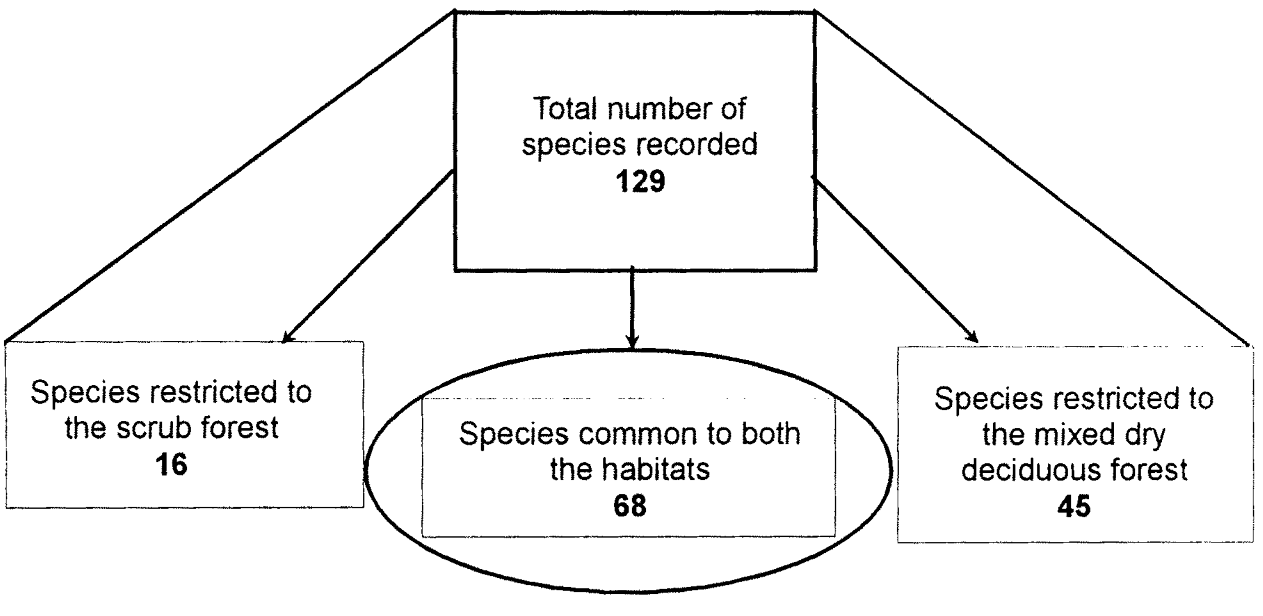
Table 4.1. Status of the birds based on their presence during the study period (1999-2001).

Classes	Number of Species	% of species occurrence	Status
1-5	28	21	Very rare
6-20	32	24	Rare
21-50	18	14	Occasional
51-100	12	10	Frequent
101-500	25	20	Common
>501	14	11	Very common
Total	129		

4.4.3. Migratory status

Bird species were classified based on the migratory status following Daniels (1997). The migratory status of bird species showed 63% residents, 25% resident and local migrants and 12% winter visitors in Anaikatty hills (Table 4.2). In general, residents, resident with local migrants and winter visitors from mixed

Figure 4.1. Distribution of birds in the Anaikatty hills



dry deciduous forest showed higher number of species than from scrub forest. Resident birds were the dominant group and were rather high in Anaikatty hills than the Western Ghats 59% (Daniels 1997).

4.4.3.1. Mixed dry deciduous forest

Winter visitors constitute 12.4% of the total birds observed in mixed dry deciduous forest (Table 4.2). Of the 14-winter visitor species seven were sighted as restricted to the mixed dry deciduous forest.

4.4.3.2. Scrub forest

Percentage of winter visitor sighted in scrub forest was 9.5% (Table 4.2). Eight species have been sighted and Great Reed Warbler was the only winter visitor restricted to this area (Appendix 2).

Table 4.2. Migratory Status of Bird species in the Anaikatty hills

Area	Status			Total Number of species
	Winter visitor	Resident with local migrant	Resident	
Mixed dry deciduous forest	14	28	71	113
Scrub forest	8	21	55	84
Anaikatty hills	15 (12%)	32 (25%)	82 (63%)	129

4.4.4. Guild

Birds were classified into guilds following Ali & Ripley (1987). Insectivore bird species dominated the Anaikatty hills. The number of species in all the guilds was higher in the mixed dry deciduous forest than in the scrub forest except granivores. The first four category of guilds were same for both the areas and in mixed dry deciduous forest nectarivore formed the fifth category whereas in scrub forest it was granivore.

In MDDF, 48% of the bird species was insectivores while in SJ, 46%. The guild formed the hierarchy as follows in mixed dry deciduous forest: Insectivore> Omnivore>Frugivore>Carnivore>Nectarivore>Granivore. Scrub forest exhibited the hierarchy of guild-wise species of birds as follows: Insectivore> Omnivore> Frugivore> Carnivore> Granivore >Nectarivore (Figure 4.2).

The bird abundance hierarchy showed variation from bird species hierarchy. Frugivores are the dominant guild in both the habitats and also in Anaikatty hills in general. The hierarchy of abundance in mixed dry deciduous forest was Frugivore > Insectivore > Omnivore > Nectarivore > Granivore > Carnivore and scrub forest was Frugivore > Insectivore > Omnivore > Granivore > Nectarivore > Carnivore (Figure 4.3). In total, the Anaikatty hills showed similar hierarchy as mixed dry deciduous forest. Granivore abundance was higher than the nectarivore abundance in scrub forest and Granivore abundance was comparatively higher than the granivores of mixed dry deciduous forest.

4.4.5. Species Composition

Of the 129 species, 113 species of birds belonging to 38 families were recorded in mixed dry deciduous forest and 84 species belonging to 34 families were recorded in the scrub forest. Species belonging to the families of Pycnonotidae, Muscicapidae, Irenidae and Centropodidae were sighted more frequently in these areas. They are: Crow-pheasant, Gold-mantled Chloropsis,

Figure 4.2. Guild wise species richness of birds in the Anaikatty hills

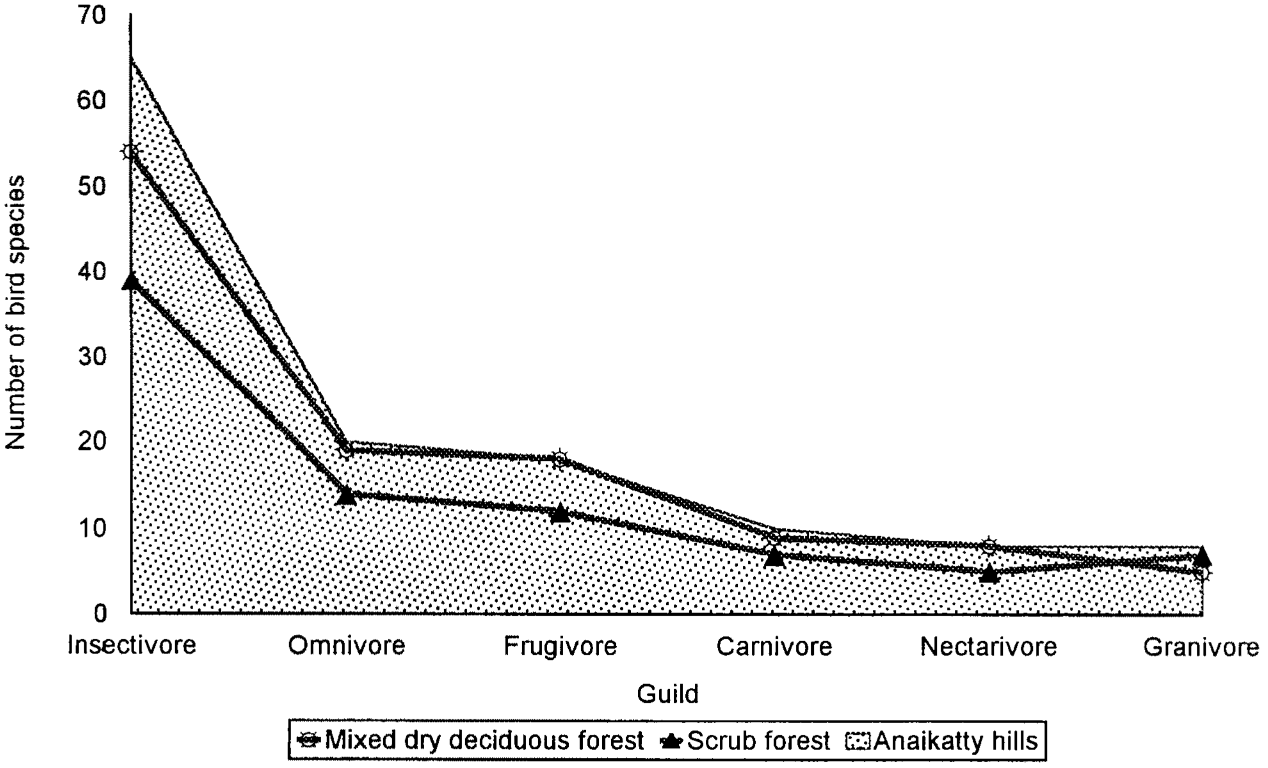
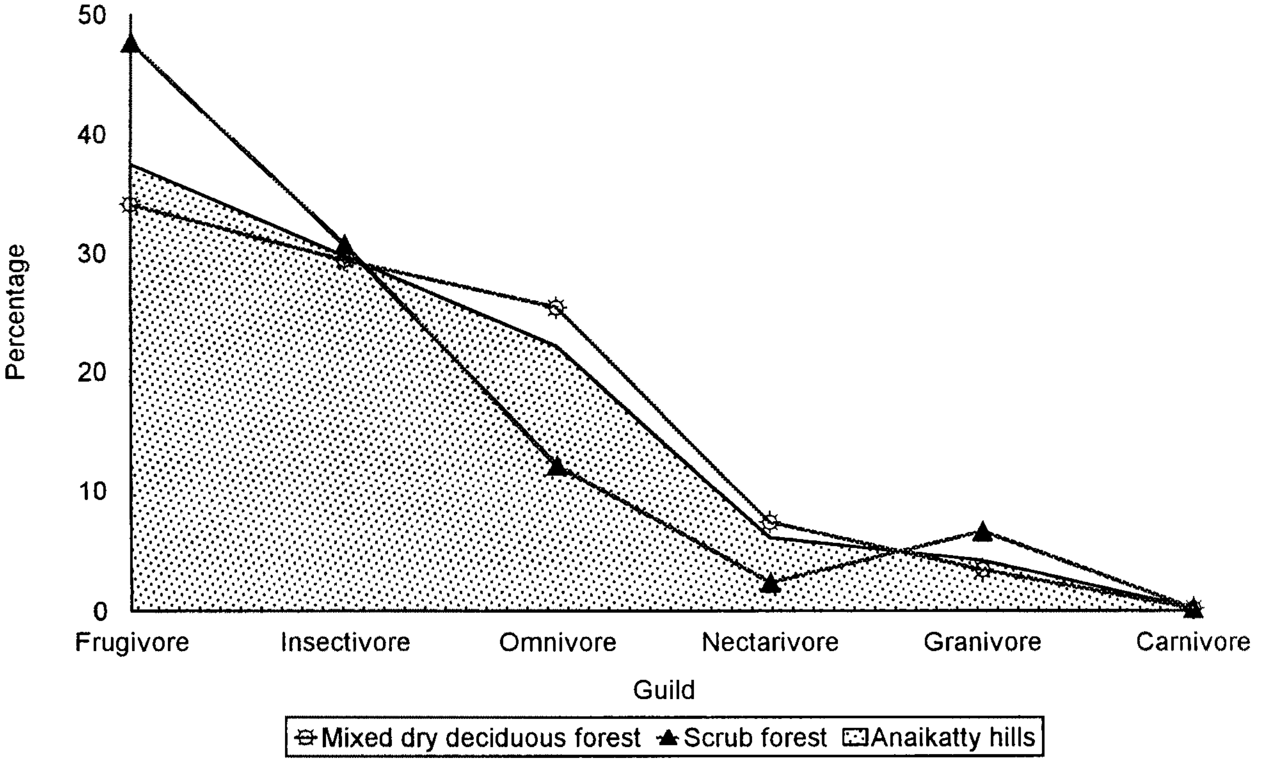


Figure 4.3. Guild-wise abundance of birds in the Anaikatty hills



Gold-fronted Chloropsis, Common Iora, Flycatchers, Warblers and Babblers. Ploceidae was not seen in mixed dry deciduous forest and Oriolidae and Sylviidae were not observed in scrub forest. Species composition in both areas varied significantly (Table 4.3).

Table 4.3. Bird species composition (family-wise) in mixed dry deciduous and scrub forests.

Family	Mixed dry deciduous forest		Scrub forest	
	# of species	Abundance	# of species	Abundance
PHASIANIDAE	6	20	5	3
COLUMBIDAE	6	15	3	7
PSITTACIDAE	4	13	2	6
CENTROPODIDAE	1	30	1	3
CUCULIDAE	4	8	3	1
APODIDAE	2	2	3	5
UPUPIDAAE	1	2	1	0
MEGALAIMIDAE	4	10	2	0
PICIDAE	8	3	4	1
HIRUNDINIDAE	2	2	2	3
LANIIDAE	3	1	1	1
ORIOLIDAE	2	4	0	0
DICRURIDAE	4	6	3	0
STURNIDAE	4	14	4	14
CORVIDAE	2	6	2	2
CAMPEPHAGIDAE	3	1	1	0
IRENIDAE	3	55	1	3
PYCNONOTIDAE	5	132	4	60
SYLVIIDAE	2	23	1	6
SYLVIIDAE	1	7	0	0
MUSCICAPIDAE	19	105	11	37
DICAEIDAE	2	10	2	1
NECTARINIIDAE	3	21	3	4
PLOCEIDAE	0	0	3	1
FRINGILLIDAE	1	2	1	2

The total number of bird species recorded during census in the mixed dry deciduous forest fluctuated between 44 and 70, whereas in scrub forest it was only between 20 and 42. The maximum number of species in scrub forest did not reach even the minimum of the mixed dry deciduous forest. Diversity and richness were higher in the mixed dry deciduous forest and were lower in the scrub forest mainly due to the habitat degradation.

4.4.6. Similarity

The overlap between the areas at vertical height showed medium level of similarity at ground level and as the height increased the overlap decreased. Minimum overlap was observed in 3-4 m height (Table 4.4).

Table 4.4. Similarity index showing overlap between the habitats

Vertical Height Class	Jaccard index
0-1	0.5
1-2	0.4
2-3	0.3
3-4	0.2
4-5	0.0
5-6	0.0

4.4.7. Species richness and abundance of birds

In the mixed dry deciduous forest the highest peak in abundance of birds was observed in September (223). In the scrub forest the highest peak was in January (239) and a second peak in September (Figure 4.4). In both the habitats minimum abundance was in June-July. There was no significant variation between the years except during June to August. Scrub forest exhibited greater abundance than mixed dry deciduous forest in January and December.

Unlike abundance, species richness was high in mixed dry deciduous forest throughout the year and the highest peak in October (70) and a minor peak in March (64). There was a definite trend in the fluctuation of species richness in mixed dry deciduous forest(Figure 4.5). Scrub forest peaked in

Figure 4.4. Abundance of birds in the mixed dry deciduous and scrub forests

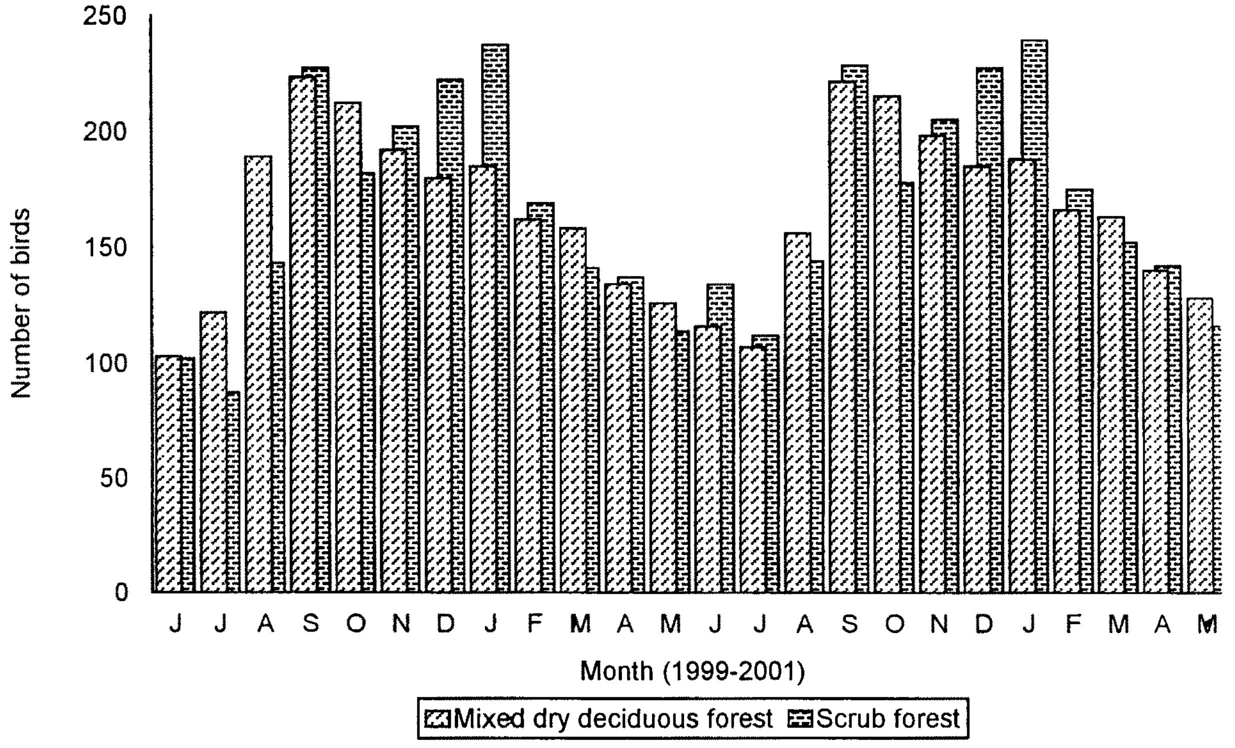
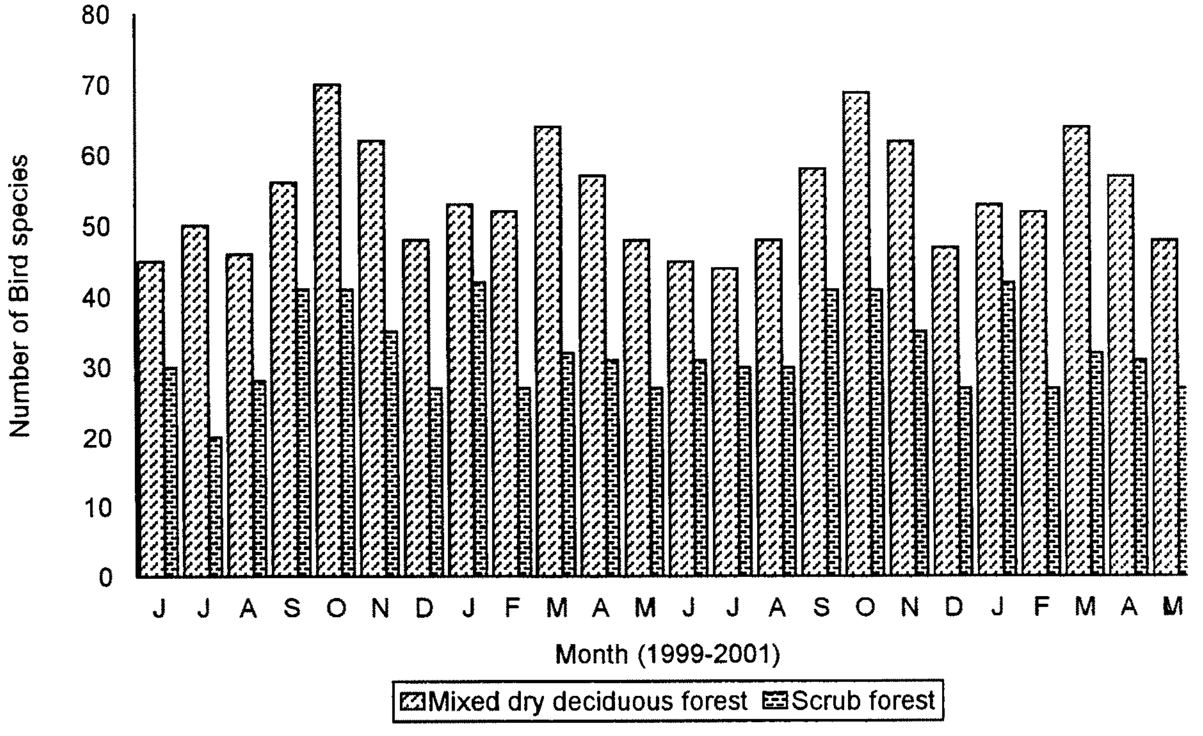


Figure 4.5. Bird species richness in the mixed dry deciduous and scrub forests



species richness during January (42) and September - October (41). Minimum number of species was observed during June (45) in the mixed dry deciduous forest and in the scrub forest in July (20).

Table 4.5 Species diversity and evenness in the mixed dry deciduous (MDDF) and scrub forests (SF).

Habitat	Parameters	Minimum	Maximum	Mean	Std deviation
MDDF	Shannon's diversity	2.81	3.27	3.09	0.16
	Evenness	0.74	0.83	0.78	0.03
	Richness	44	70	54.08	7.78
	Abundance	309	668	496	111
SF	Shannon's diversity	2.36	3.06	2.76	0.18
	Evenness	0.75	0.82	0.80	0.02
	Richness	20	42	32.29	6.13
	Abundance	262	716	502	141

Diversity was high in the mixed dry deciduous forest than in the scrub forest (Table 4.5 and figure 4.6). Bird population showed heterogeneity in nature with high species diversity. The maximum diversity was in January (3.27) and evenness or equitability was also high which denotes that the distribution was highly even (Figure 4.7). The minimum diversity was in June (2.81) also with less even distribution (0.74) with a few species in higher numbers.

In the scrub forest the maximum diversity was in October (3.06) with high evenness (0.82). The minimum diversity was in April and December (2.61) also with low evenness (0.76).

4.4.8. Bird Species Diversity (BSD) and Foliage Height Diversity (FHD)

There is a strong positive correlation for bird species diversity with FHD in both mixed dry deciduous forest ($r = 0.72$, $p<0.018$) and scrub forest ($r = 0.996$,

Figure 4.6. Diversity of birds in the mixed dry deciduous and scrub forests

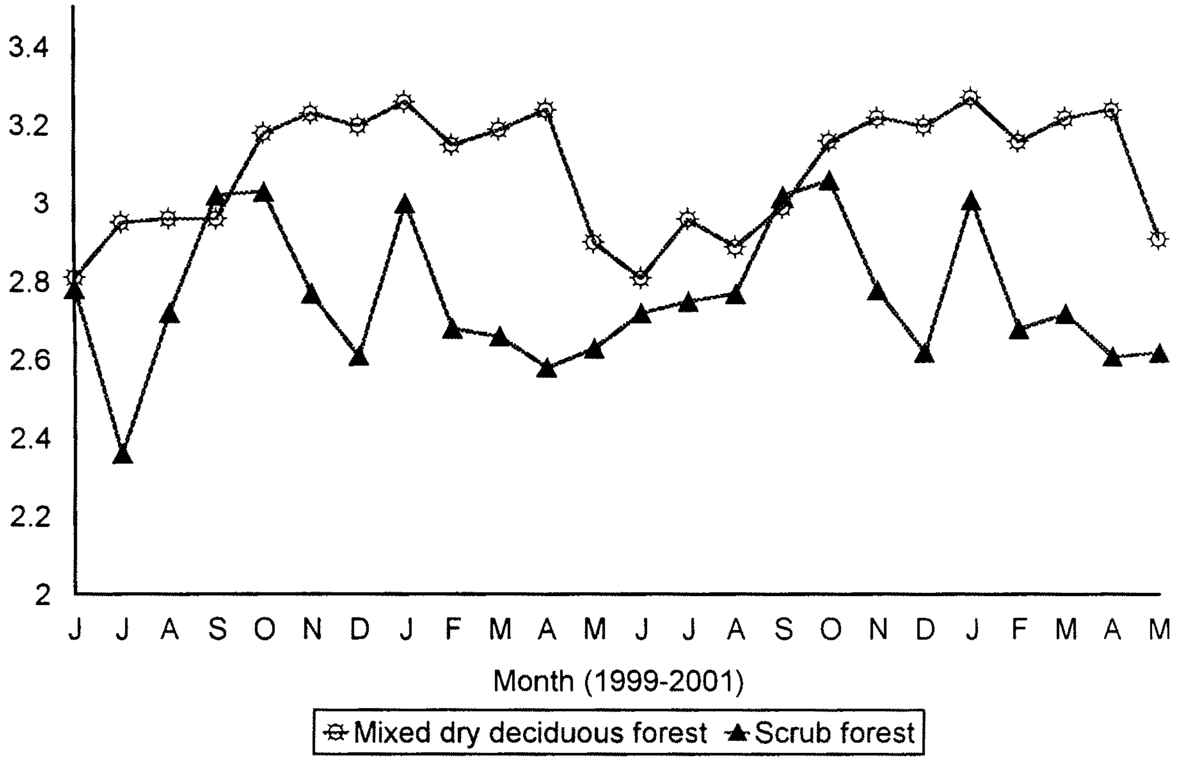
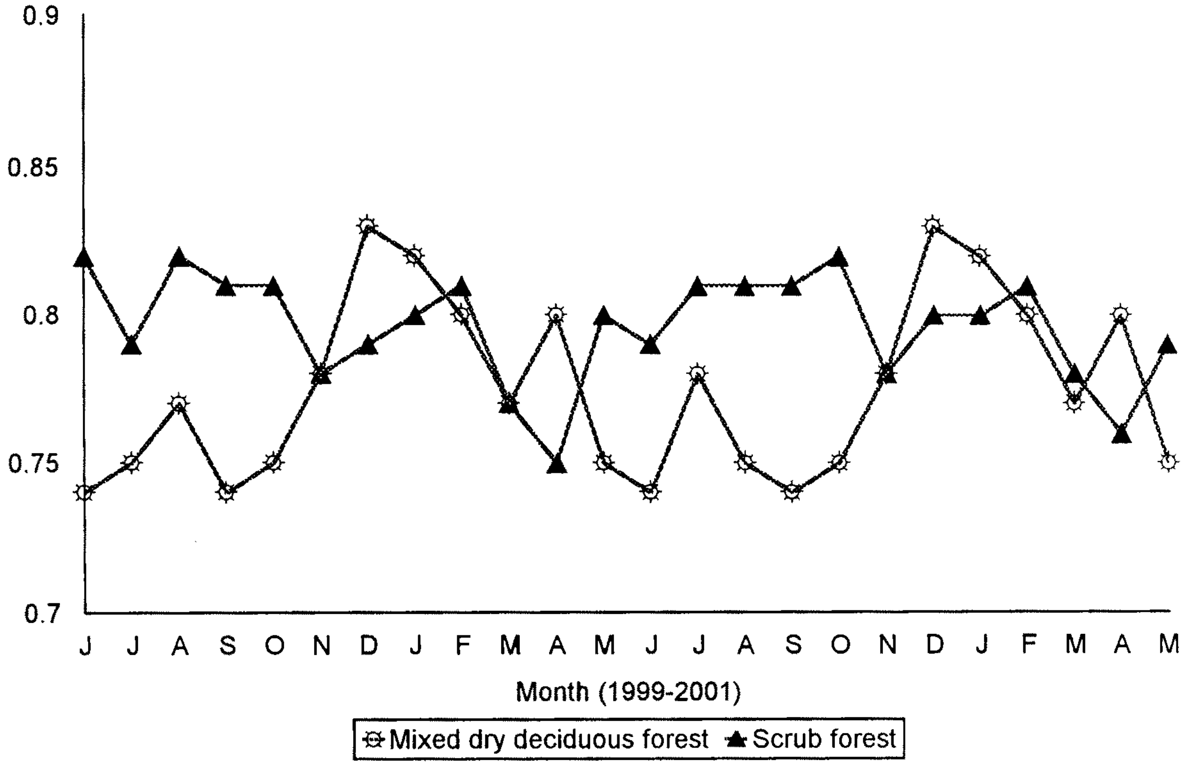


Figure 4.7. Evenness in the mixed dry deciduous and scrub forests



p<0.0001). Similar such studies where FHD showed significant correlation with foraging BSD in some other habitats were in Silent Valley and Mudumalai (Pramod 1995, Gokula 1998, and Vijayan *et al.* 1998, 1999, and 2000). However, some studies showed no correlation between FHD and BSD (Pearson 1982, Wiens 1983, Johnsingh and Joshua 1994).

4.4.9. Common bird species (Commonness index)

The most common species in Anaikatty hills with commonness index >25 were the White-browed Bulbul (49.9), Red-vented Bulbul (29.6) and Common Iora (28.8).

4.4.9.1. Mixed dry deciduous forest

The five most common bird species in mixed dry deciduous forest were the Whitebrowed Bulbul, Common Iora, Blyth's Reed Warbler, Southern Crow-Pheasant and Grey Forest Fowl. Commonness index value of five species was >11 and 18 species had >4 (Table 4.6). The list of species found in this habitat is given in Appendix 2. Among the migratory species Blyth's Reed Warbler was common. There was an endemic species, Bluewinged Parakeet that was common in this habitat (Table 4.6).

4.4.9.2. Scrub forest

The most common bird species in scrub forest was Red-vented Bulbul, White-browed Bulbul, Yellow-eyed Babbler and Blyth's Reed Warbler. Commonness index value of two species were >10 and of 13 species were >2

(Table 4.7). The list of species found in this habitat is given in Appendix 2. Among the migratory species Blyth's Reed Warbler was common.

Table 4.6 Common bird species in the mixed dry deciduous forest

Species name	commonness index
White-browed Bulbul	38.97
Common lora	26.99
Blyth's Reed Warbler*	20.89
Southern Crow-Pheasant	20.00
Grey Forest Fowl	11.90
Red-vented Bulbul	11.63
Indian Tailor Bird	11.11
Peninsular Forest Babbler	11.08
Red whiskered Bulbul	11.04
Indian Purplerumped Sunbird	10.83
Indian Spotted Dove	10.14
Tickell's Flowerpecker	6.60
Largebilled Leaf Warbler**	6.53
White-headed Babbler	6.44
Dullgreen Leaf Warbler*	6.03
Peninsular Spotted Babbler	5.90
Small Greenbilled Malkoha	5.06
Bluewinged Parakeet**	4.86

*Migrant **Endemic

Table 4.7 Common bird species in the scrub forest

Species name	commonness index
Red-vented Bulbul	17.99
White-browed Bulbul	10.93
Yellow eyed Babbler	8.94
Blyth's Reed Warbler*	5.22
Red-whiskered Bulbul	4.22
South Indian Blackbacked Robin	3.61
White-headed Babbler	3.60
Indian Tailor Bird	2.74
Indian Little Brown Dove	2.67
Indian Spotted Dove	2.40
Southern Forest Myna	2.36
Plain Wren-Warbler	2.35
Southern Crow-Pheasant	2.33

* Migrants

4.4.10. Dominant bird species (Dominance index)

The most dominant species in Anaikatty hills were White-browed Bulbul (15.9), Common Iora (8.18) and Red-vented Bulbul (8.17).

4.4.10.1. Mixed dry deciduous forest

The most dominant species in mixed dry deciduous forest were White-browed Bulbul and Common Iora; Peninsular Forest Babbler and Crow-Pheasant were the second dominant species. Species recorded during the study period were 113 in the mixed dry deciduous forest, of which 20 species had >1 and 14 species with >2 as their index value (Table 4.8) which were considered as dominant.

Table 4.8 Dominant species of birds in the mixed dry deciduous forest

Species Name	Dominance index
White-browed Bulbul	17.1
Common Iora	10.3
Peninsular Forest Babbler	6.7
Southern Crow-Pheasant	6.1
Blyth's Reed Warbler	4.6
Red-vented Bulbul	4.5
White-headed Babbler	4.5
Red Whiskered Bulbul	4.2
Indian Purplerumped Sunbird	3.7
Grey Forest Fowl	3.4
Indian Tailor Bird	2.8
Indian Spotted Dove	2.8
Southern Forest Myna	2.5
Bluewinged Parakeet	2.0

4.4.10.2. Scrub forest

The most dominant species in scrub forest were Red-vented Bulbul, White-browed Bulbul, Yellow-eyed Babbler, White-headed Babbler and Southern Forest Myna. Species recorded during the study period were 84 in scrub forest, of which 22 species had >1 and the most dominant 14 species had >2 as their index value (Table 4.9).

Table 4.9 Dominance index in the scrub forest

Species Name	Dominance index
Red-vented Bulbul	18.9
White-browed Bulbul	12.8
Yellow-eyed Babbler	8.2
White-headed Babbler	6.5
Southern Forest Myna	5.2
Red-whiskered Bulbul	4.2
Blyth's Reed Warbler	3.4
South Indian Blackbacked Robin	2.8
Southern Blossom-headed Parakeet	2.7
Indian House Swift	2.6
Indian Little Brown Dove	2.3
Black-headed or Brahminy Myna	2.1
Rufous-bellied Babbler	2.1
Indian Tailor Bird	2.1

4.5. Discussion

Species restricted to mixed dry deciduous forest were three-fold higher when compared to the species restricted to the scrub forest, which was due to the lower vegetation structure as in the study of Francis (1908), Prabhakar and Gadgill (1994). Resident birds were more than that reported (59%) by Daniels (1997) and hence more common which was probably because of their adaptability to feed on any available food and so coexisting. This is similar to the study of Gokula (1998). The most dominant species was White-browed Bulbul in both the areas and is a resident bird.

Insectivore bird species dominated the Anaikatty hills as in many other studies. In all disturbed forest insectivores are comparatively more (Pramod 1999, Johnsingh *et al.* 1987). The number of species in all the guilds was higher in the mixed dry deciduous forest. The bird abundance also was higher in mixed dry deciduous forest. Granivore abundance was higher than the nectarivore abundance in scrub forest and Granivore abundance was comparatively higher in scrub forest than in mixed dry deciduous forest because of the availability of more open ground for their foraging as observed by Gokula (1998).

Diversity was high in mixed dry deciduous forest in all the months compared to scrub forest except September with high equitability mainly because of the habitat structure with high foliage height diversity. The highest diversity was recorded during January in mixed dry deciduous forest. This high diversity was due to the increase of resident birds such as Paradise Flycatcher, Purple-rumped Sunbird, Spotted Dove and Yellow-eyed Babbler. The inflow of resident & local migrant species such as Black Bulbul, Blossom-headed Parakeet, Red-whiskered Bulbul and winter visitor such as Blyth's Reed Warbler, Brown shrike, Largebilled Leaf Warbler, Lesser Whitethroat, Rosefinches and House Martin was profoundly seen during January where the diversity had a peak with maximum in mixed dry deciduous forest. Minimum diversity observed was in June, which was due to hot and dry period where food resource availability was also low.

The highest diversity was recorded during October in scrub forest. This was due to the inflow of winter visitor species such as Brown Shrike, Lesser Whitethroat and resident & local migrants such as Hoopoe, Little Brown Dove, Rufous Turtle Dove, Red Whiskered Bulbul, and Brain Fever Bird. Besides this, yellow-eyed Babbler, Loten's Sunbird, Brahminy Myna, Forest Bush Quail and yellow fronted Pied Woodpecker are a few residents responsible for the increased diversity. In scrub forest the diversity and evenness were high during January with shooting up of food resource such as insect abundance and fruit abundance. Similar results have been shown by Gokula (1998) but Sundaramoorthy (1991) studies revealed that species diversity was high in summer in mixed vegetation at Bharatpur Keoladeo National Park. Gaston's (1978) study on the New Delhi ridge also showed similar result where diversity was high during winter and low in summer. The species diversity was found to be greatest in the disturbed natural habitat studied by MacArthur (1969) and Pramod (1995) became true here in mixed dry deciduous forest also.

Abundance was higher in scrub forest than mixed dry deciduous forest, which fluctuated with very little conspicuousness. In the scrub forest, less species with more abundance were evenly distributed and in the mixed dry deciduous forest more species were less evenly distributed implying higher plant species diversity leading to increase of species (Pramod 1995). Abundance was high in mixed dry deciduous forest during September because of the local migrants such as the South Indian Black-headed Oriole, Southern Blossom-headed Parakeet, Crimson-breasted Barbet, Southern Forest Myna, Large green

Barbet, Lesser Golden-backed woodpecker, Palm Swift Flycatcher, Red-whiskered Bulbul, Small Green Barbet, Slatyheaded Scimitar Babbler, Southern Small Minivet, and migrants Lesser Whitethroat, Dullgreen Leaf Warbler, Peninsular Indian Paradise, Tree-pie, White-bellied Drongo, Indian Myna, Pariah Kite, Indian Crested Hawk-Eagle, Rose-ringed Parakeet and Eastern Swallow. Species richness was found to be greater in mixed dry deciduous forest than scrub forest with pronouncing difference. This low species richness in scrub forest was due to the degradation of this area and less tree species diversity and density. High species abundance during January in scrub forest was because of the increasing abundance of Southern Blossom-headed Parakeet, Bluewinged Parakeet, Hoopoe, Common Iora, Southern Forest Myna, Indian Little Brown Dove, Indian Alpine Swift, Rufous-bellied Babbler, Red-rumped Swallow, Red-vented Bulbul, Red-whiskered Bulbul, Indian Spotted Dove, Small Green Bee-eater, Indian Tree-pie, Yellow-eyed Babbler, Indian Myna, Crested Swift and Indian House Swift.

Anaikatty hills are diverse with both plants and birds. Tree GBH class density and height class abundance (Chapter 3) suggested that the mixed dry deciduous forest trees and scrub forest had a disproportionate distribution due to high pressure on lower GBH classes and short trees which were collected for fuel wood. Here the field observation revealed that the regeneration of canopy trees was poor due to grazing, fuel collection and trampling. Vegetation structure in scrub forest revealed that human pressure and high open space had reduced the quality of the species composition of birds and plants in scrub forest as observed in Mudumalai by Gokula (1998) and Vijayan *et al.* (1999).

The commonness and dominant species in Anaikatty hills have been determined. The most common resident species in mixed dry deciduous forest and scrub forest included White-browed Bulbul, Red-vented Bulbul and Common Iora. The most common bird species in mixed dry deciduous forest were confirmed as Whitebrowed Bulbul, Common Iora, Blyth's Reed Warbler, Southern Crow-Pheasant and Grey Forest Fowl. The most common bird species in scrub forest were Red vented Bulbul, White-browed Bulbul, Yellow eyed Babbler and Blyth's Reed Warbler.

The most dominant species in Anaikatty hills were White-browed Bulbul, Common Iora and Red-vented Bulbul. The most dominant species in mixed dry deciduous forest were White-browed Bulbul, Common Iora, Red-vented Bulbul, Peninsular Forest Babbler and Southern Crow-Pheasant. The most dominant species in scrub forest were Red-vented Bulbul, White-browed Bulbul, Yellow-eyed Babbler, White-headed Babbler and Southern Forest Myna.

4.6. Conclusion

Mixed dry deciduous forest and scrub forest show higher bird abundance. Diversity and evenness of birds are high during January in mixed dry deciduous forest and during October in the scrub forest. The resident birds are more than that reported in Western Ghats.

Insectivore bird species dominated the Anaikatty Hills as found in many other disturbed forests. The number of species in all the guilds is higher in the mixed dry deciduous forest. The bird abundance in guild wise is also higher in mixed dry deciduous forest. Granivore abundance is higher than the nectarivore abundance in scrub forest. Granivores are higher in scrub forest than in mixed dry deciduous forest.

Diversity was high in mixed dry deciduous forest in all the months compared to scrub forest except September with high equitability. Maximum diversity was recorded during January in mixed dry deciduous forest. Minimum diversity is observed in June. The highest diversity was recorded during October in scrub forest.

Abundance was high in the scrub forest than mixed dry deciduous forest. Abundance was high in the mixed dry deciduous forest during September with the increasing abundance of Southern Blossom-headed Parakeet, Rose-ringed Parakeet, Eastern Swallow Crimson-breasted Barbet, Southern Forest Myna, Large green Barbet, Palm Swift, Peninsular Indian Paradise Flycatcher, Dullgreen Leaf Warbler, Red-whiskered Bulbul, Southern Small Minivet, Lesser Whitethroat, Indian Tree-pie, Indian White-bellied Drongo, Indian Myna, Pariah Kite, Indian Crested Hawk-Eagle.

Species richness was found to be greater in mixed dry deciduous forest than scrub forest with pronouncing difference. This low species richness in scrub forest was due to the degradation of this area and less tree species diversity. Species abundance was determined to be high during January in scrub forest.

Anaikatty hills are diverse with both plants and birds. The mixed dry deciduous forest trees and scrub forest have a disproportionate distribution due to high pressure on lower GBH classes and short trees. Vegetation structure in scrub forest revealed that human pressure and high open space has reduced the quality of the species composition and density of birds and plants in scrub forest.

The commonness and dominant species in Anaikatty hills have been determined. The most common resident species in mixed dry deciduous forest and scrub forest include White-browed Bulbul, Red-vented Bulbul and Common Iora. The most common bird species in mixed dry deciduous forest are Whitebrowed Bulbul, Common Iora, Blyth's Reed Warbler, Crow-Pheasant and Grey Junglefowl. The most common bird species in scrub forest are determined as Red vented Bulbul, White-browed Bulbul, Yellow eyed Babbler and Blyth's Reed Warbler.

The most dominant species is in Anaikatty hills are White-browed Bulbul, Common Iora and Red-vented Bulbul. The most dominant species in mixed dry deciduous forest are White-browed Bulbul, Common Iora, Red-vented Bulbul, Peninsular Forest Babbler and Southern Crow-Pheasant. The most dominant species in scrub forest are Red-vented Bulbul, White-browed Bulbul, Yellow-eyed Babbler, White-headed Babbler and Southern Forest Myna.

CHAPTER 5

SEASONALITY OF BIRDS AND INSECTS

5.1. Introduction

Stable population (Wright 1970, Kricher 1975) and seasonally fluctuating population (Anderson 1972, Morrison *et al.* 1980, Pyke 1984, Jayson and Mathew 2000) have been reported on forest birds. Seasonal fluctuation of forest birds is influenced by the availability of fruits (Terborgh 1986, Wheelwright 1986b, Levey 1988) and insects (Koen and Crowe 1987). Seasonality of bird community in relation to climatic factors (Price 1979, Vijayan 1984) time and space (Karr 1971, Greenberg 1981, Loiselle 1988, Blake and Loiselle 1991) has been documented. Seasonal variation in the abundance of a species is an adaptive phenomenon (Koen 1992) evolved through ages to take maximum advantage from the ambient environmental conditions. These environmental factors are mainly biotic and abiotic, which influence the seasonality of food abundance (Jansen and Schoener 1968, Vijayan 1984, Sundaramoorthy 1991, Arun 2000) and in turn, the dependent, living organisms (Borchert 1998, Vijayan 1984). Seasonality of birds has been reported from many other countries (Anderson 1972, Morrison *et al.* 1980, Pyke 1984).

Tropical forests support a stable population of birds in all seasons, whereas marked seasonal fluctuations have been noted in temperate forests (Kricher 1975). Although most of the forest birds are classified as mainly insectivores or mixed feeders (Koen 1988a, Pramod 1995), fruit is an important food source for many species in the climatic regions where fruit production is limited to part of the year and insect abundance fluctuates seasonally (Sorensen 1981, Loman 1982, Levings and Windsor 1985, Koen and Crowe 1987). The community composition and densities of bird populations showed spatial and temporal variation where fluctuation in food resource availability in forests is conspicuous (Crome 1978, Hilty 1980, Woinarski and Cullen 1984, Pyke 1985, Levey 1988, Innes 1989, Koen 1992 and Poulin *et al.* 1994).

Apart from these, the seasonality of animals is regulated by the biotic factors especially composition of trees in a forest (Pekelharing *et al.* 1998). Age of the forest and size of the forest area may also affect seasonality, as in the case of birds in Hong Kong (Kwok and Corlett 1999). In the natural conditions, all these major factors often affect the abundance and diversity of organisms indirectly (Jansen and Schoener 1968) by regulating the insect abundance and seasonality as in many of the studies (Subramanyam and Hagstrum 1993, Pollard and Moss 1995, Lale *et al.* 1996, Posonby and Copland 1996). Among the abiotic factors, the most important factors that are closely associated with the seasonality of organisms are temperature (Pollard 1988) and rainfall which determine the seasonality of plants (Borchert 1998), humidity (Vijayan 1984) and windspeed (Mccarty *et al.* 1999) that affect the folivorous insects and finally their predator, the birds.

5.2. Seasonality of Insects

The abundance and seasonal fluctuation of insects play a major role in determining the seasonality and biological cycle of the organisms, which are dependent on them for food. Since 50% of the terrestrial birds are insectivorous it becomes all the more important to assess the abundance of insects in the study area. Various authors have studied seasonality of terrestrial arthropods (Basset 1991, Simandal 1993, Schowalter and Ganio 1998) in temperate forest. Most of the long-term monitoring studies on insect populations other than butterflies are carried out using only the light trap method, and are mostly done in the temperate countries (Wolda 1978a, Holloway 1987).

Many authors have highlighted the importance of abiotic factors on insects such as temperature (Saulich *et al.* 1994, Yoshio and Ishii 1994), humidity (Pollard and Moss 1995, Lale *et al.* 1996, Posonby and Copland 1996), rain (Wolda 1978a, Pollard 1988), day length (Danilevskii 1996), and diet (Feeny 1970, Assad *et al.* 1997). The floral species diversity (Sparks and Parish 1995, Arun 2000), bird (Vijayan *et al.* 1999) and arthropod abundance (Gunnersson 1996, Arun 2000) explicit the role of biotic environment associated with insect and bird seasonality. In most cases a combination of different factors described above explain the effect of insect population on the abundance of bird which depend on insects (Turner and Mccarty 1998).

However, insects being a stable diet of most birds (Koen 1988a), a few ecological studies on birds have documented the insect abundance of different forest areas (Vijayan 1975, 1984, Sundaramoorthy 1991). Records of the ornithological reports established the significance of seasonal abundance of insects on the breeding birds (Vijayan 1975, 1980, Gaston 1978a, Shukkur 1978, Vijayan 1984, Vijayan 1991, Sundaramoorthy 1991). There was no correlation between insect and bird abundance in their studies except caterpillar abundance on breeding birds (Vijayan 1984). Since 50% of the birds of Anaikatty hills were insectivorous birds, an attempt has been made to assess the abundance and seasonality of birds and insects.

Seasonality of birds was scarcely documented in Western Ghats (Jayson and Mathew 2000). Seasonality of insects was poorly documented in tropical countries because of lack of facilities for research and economic backwardness (Gadagkar *et al.* 1990). No intensive long-term study on the seasonality of insect populations in the natural conditions has been reported from India except the study of Arun (2000) in the moist deciduous forest of Siruvani. Moreover, the major food source of the birds in the study area being insects, quantitative sampling of insects was done using the standardised methods of Southwood (1971).

However, no information is available on the seasonality of birds with reference to its food abundance in the mixed dry deciduous forest (MDDF) and scrub forest (SF). An attempt has been made to monitor the seasonal changes of bird communities in the mixed dry deciduous forest and scrub forest with the following objectives.

- To determine the seasonality of bird communities and abundance of Insects.
- To compare the seasonal patterns in the abundance of birds and insects in a mixed dry deciduous forest and scrub forest, and
- To evaluate the role of various ecological factors in regulating the bird and insect abundance.

5.3. Methodology

Bird population was estimated using variable width line transect method as described in the fourth chapter. Phenology of plants (the percentage of flower, fruit and leaf) was studied as given in chapter 3.

5.3.1. Foliage Height Diversity

Explained as earlier in chapter 3.

The abiotic factors monitored during the study were minimum and maximum temperatures, relative humidity, sunshine hours, rainfall, and number of rainy days.

5.3.2. Insect abundance

The amount of present knowledge on the insects of the tropical forests is comparatively sparse than that of the temperate countries. However, the seasonal abundance of insect populations in natural conditions is rather less explored because it involves frequent sampling of insects using various sampling methods at regular intervals, which are often laborious and time consuming. The lack of scientific tradition and the moderate budgets are the two major causes attributed to this lack of knowledge (Gadagkar *et al.* 1990) on the insects of the tropical forests. However, any single method has been found insufficient to sample the arthropods efficiently (Kharboutli and Mack 1993); six standard sampling techniques as described by Southwood (1971) with slight modifications to suit the local environment were employed for the sampling of general invertebrate abundance. Abundance of butterflies was estimated using transect counting or visual count method (Pollard 1977, Ishii 1993).

5.3.3. Insect sampling methods

Six major sampling methods were used in the field for the regular sampling of insects, namely sweep sampling, visual count, mechanical knock down, light trap, aerial trap and pitfall trap for the estimation of canopy and ground arthropods and other invertebrates. The insects collected by different sampling devices per fortnight were identified upto order; other invertebrates were classified upto class and, released back into the environment. For the purpose of sorting the insects, the Imm's classification was followed (Richards and Davies 1977).

5.3.3.1. Sweep sampling

This method is specially adapted for sampling insects from ground layer vegetation. Sweep sampling was done from the herb and shrub layers of the vegetation using a sweep net fitted with a cotton net having a mouth diameter of 40cm and an approximate mesh size of 2 mm. The sweeps were done during the morning hours after 8.30 a.m. along a kilometre length of four transects (laid for bird census) in the mixed dry deciduous forest and scrub forest. In total, two hundred and fifty sweeps were taken from each transect at every 100m distance along the transects. This was done at every fortnight. The approximate area of coverage per sweep sampling was 1x10 m^2. The insects collected in the sweeping net were temporarily anaesthetised by putting the tail end of the net along with the insect trapped, into a bottle containing a piece of cotton soaked in 70% chloroform for approximately 10 seconds. The immobilised insects were classified into orders, counted and then released back at the same place.

5.3.3.2. Visual count /Transect count

Transect counting is the most popular and universally accepted method for monitoring butterfly population abundance. Various authors (Pollard 1977, Pollard and Yates 1993, Ishii 1993, Natuhara *et al.* 1996, Arun 2000) have tested the reliability of this method for estimating butterfly abundance. Transect counting method with slight modification was employed for estimating the relative abundance of butterflies. All the butterflies encountered within 10 x 5-m area were counted and the number was recorded. The count was made in the morning hours at every 100 m distance along transect. The total area covered by this sampling was 500 m^2 for each transect. The time of the count was fixed as between 08.30am and 11.30 am, based on the preliminary counts done at different times of the same day, which showed that this was the best time for counting lepidoptera. This method was employed earlier by Fogdon (1972), Vijayan (1975) and Sundaramoorthy (1991).

5.3.3.3. Knock down

Mechanical knockdown of the insects inhabiting the shrubs was made using a bamboo pole and the insects were collected on a tray (1m x 1m, made of thick white cloth supported by steel frame). The tray was placed underneath the selected shrub for sampling and the bush was beaten thoroughly with a bamboo pole. For uniformity, 10 beats were made as a standard for each sample to dislodge insects. The insects collected on the tray were identified, counted and released back immediately.

Ten such samples were collected from the fixed places (shrub) throughout the study period. This method was for sampling the less mobile and weak flying forms of insects, which are mostly shade loving. The unit sampling effort of this sampling method involved 10 samples in each transect. The monthly samples consisted of two such sampling efforts resulting in 20 samples per transect in a month. Major limitation of this sampling method was its inefficiency to sample active flying insects and the insects of herb layers.

5.3.3.4. Light trap

A fabricated light trap based on the design of Mathew (1990) was employed for the purpose of sampling the nocturnal insect abundance. The light source used in the trap was a fluorescent tube, powered by a 12-watts battery. A fluorescent tube was the light source and it emittted uniform light to all the sides of the trap. The insects attracted towards the light were collected in the collecting chamber of the trap where the insects were immobilised with chloroform vapour. The trap was operated only for an hour during the early night hours (19^{th} hour) at every fortnight. Keeping the light trap on for longer periods might lead to gradual reduction in the efficiency of the trap due to the accumulation of insects within the collection chamber (Trematerra *et al.* 1996). The light trap is a special sampling device for the sampling of nocturnal flying insects.

5.3.3.5. Aerial trap

Plastic containers filled partly with water and preservative were hung in the canopy for two days (48 hours). 10 such traps per transect were used to collect aerial arthropods.

5.3.3.6. Pit-fall trap

Plastic containers filled partly with water and preserving solution were placed on the surface of the ground to get surface dwelling arthropods. 10 such traps were installed per transect.

5.3.4. Data Analysis

The various seasons noticed in Anaikatty were as in chapter 2. Major statistical tests were employed in analysing the data using the statistical package SPSS (Spss for MS windows, Release 6.0) and SPDIVERS.BAS. Multivariate Analysis of Variance and Kruskal-Wallis one way ANOVA were used to test the significance of difference in bird and insect abundance between the habitats. Friedmann's two way ANOVA and Kendalls coefficient of concordance were used to test the significance of rank order of abundance between variables and hierarchical pattern of abundance between seasons and habitats.

The Pearson correlation coefficients were calculated to find out relation between two variables directly. The linear multiple regression was used to examine the relationship between bird and insect abundance and with environmental factors. Significance of the difference in bird and insect abundance between seasons and habitats was tested using the significance of the F ratio obtained from ANOVA. Multiple (step-wise) linear regression procedures were used to explain the interrelations between the bird and insect abundance and other ecological factors such as, fruit and flower abundance, relative humidity, temperature, rainfall.

5.4. Results

5.4.1. Seasonality of birds

Bird abundance was high during north-east monsoon and winter and low during south-west monsoon in MDDF and SF respectively (Figure 5.1). Total number of species during south-west monsoon shared by MDDF was 63% and by SF was 37% only. The main winter visitors were Lesser Whitethroat, Dull Green Leaf-warbler, Blyth's Reed-warbler and Brown Shrike. This was followed by the flocks of altitudinal migrants such as Black Bulbul, Grey-headed Myna, Rosy Pastor, and Blossom-headed Parakeet, and a few locally moving Grey Drongo and Verditor Flycatcher and the resident birds such as Red-whiskered Bulbul, Purple Sunbird, Loten's Sunbird and Paradise Flycatcher which breed here during north-east monsoon. In SF, abundance was high in winter which was due to the entry of Rosefinches, Blyth's Reed Warbler, Largebilled Leaf Warbler,

Figure 5.1. Seasonal fluctuations of bird abundance in the mixed dry deciduous and scrub forests

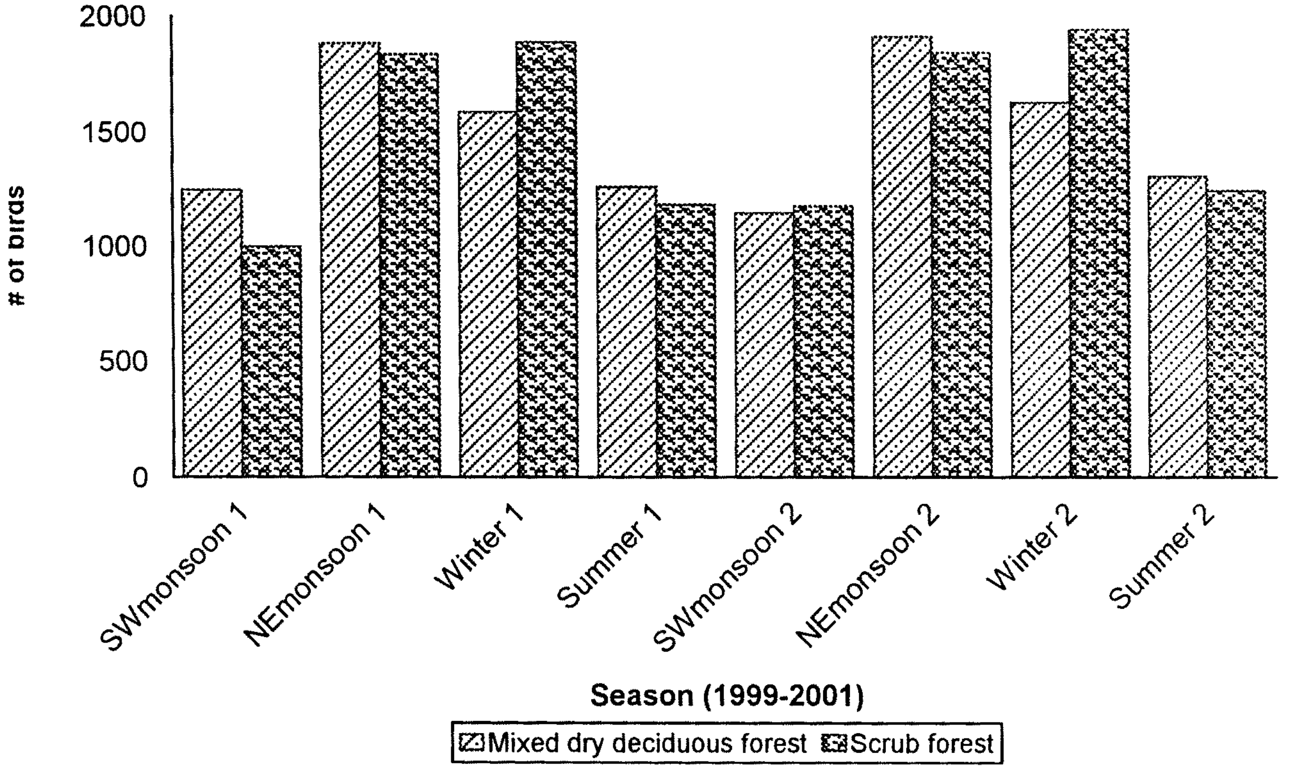
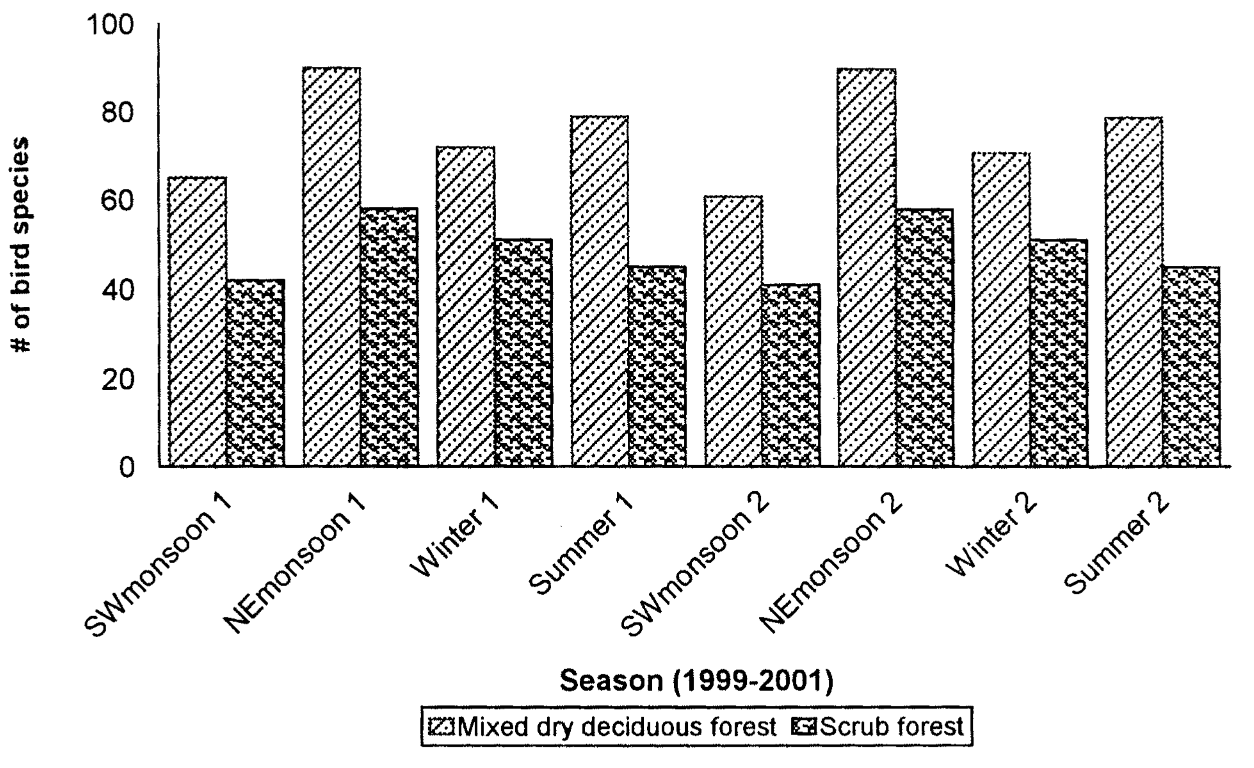


Figure 5.2. Seasonal fluctuations of bird species richness in the mixed dry deciduous and scrub forests



Paradise Flycatcher, Grey-headed Myna, Black Bulbul and Crested Hawk-Eagle and breeding of Spotted Munia and Pied Bushchat.

Species richness was higher during northeast monsoon (Figure 5.2) in both the habitats. Bird Species diversity was found to be greater in MDDF than in SF (Figure 4.6). Diversity index showed high value during winter (H' = 3.34) and north-east monsoon (H' = 2.94) for MDDF and SF respectively and was low in SW monsoon in both the habitats.

5.4.2. Seasonality of birds based on migratory status

The number of species increased consistently to reach the peak (MDDF 90, and SF 58) during northeast monsoon and found lowest in summer for both the habitats (Table 5.1). In general, resident (with local movement) species were the highest during northeast and lowest during southwest. In mixed dry deciduous forest, resident (with local movement) species were the highest during summer while in scrub forest it was during northeast monsoon. Winter visitors were high during northeast in both the habitats. No winter visitor was recorded during southwest monsoon 2 for both the habitats and in the southwest monsoon1 for MDDF. Total abundance of birds during different seasons was positively correlated with the increasing residents ($r = 0.836$, $p < 0 .01$, $N = 8$).

In SF an immigrant Rosefinche visited the Anaikatty hills during southwest monsoon. In MDDF Common Iora was the most abundant species during southwest 1, Whitebrowed Bulbul was the first dominant species during northeast 1 and 2, summer 1 and 2 and southwest 2 and Blyth's Reed Warbler was the dominant species during winter 1 and 2. In SF, the indicator White-browed Bulbul was the first dominant species during southwest monsoon 1 and 2 and Red-whiskered Bulbul was dominant in the other seasons. Abundance of birds during different seasons was positively correlated with increasing winter visitor (r = 0.993, p = .001) and resident with local movements (r = 0.862, p = .006).

Table 5.1. Status of birds during different seasons in the MDDF and SJ.

Season	Status (in number of species)					
	Resident		Resident with Local movement		Winter Visitor	
	MDDF	SJ	MDDF	SJ	MDDF	SJ
South West monsoon 1	51	34	14	7	0	1
North East monsoon 1	61	38	18	14	11	6
Winter 1	49	33	14	12	9	6
Summer 1	48	32	21	10	10	3
South West monsoon 2	46	35	15	6	0	0
North East monsoon 2	61	38	18	14	11	6
Winter 2	48	33	14	12	9	6
Summer 2	48	32	21	10	10	3

MDDF-Mixed dry deciduous forest, SJ- Scrub jungle, 1-First year, 2-Second year

5.4.3. Seasonality of bird abundance on feeding guild composition

The avifauna of the MDDF was largely dominated by insectivore guild through out the study period and followed by omnivore and frugivore. A definite seasonal pattern existed in all the six guilds (Figure 5.3). Insectivores occurred all through the seasons with the maximum during winter and minimum during northeast monsoon. Omnivores and carnivores were highly abundant during southwest monsoon and summer and lowest during winter. Frugivores were highly abundant during northeast monsoon and low during southwest monsoon. On the contrary, granivores were abundant during southwest monsoon and lowest during northeast monsoon. Nectarivores were found low during winter and

Figure 5.3. Guild-wise composition of bird species in the mixed dry deciduous forest

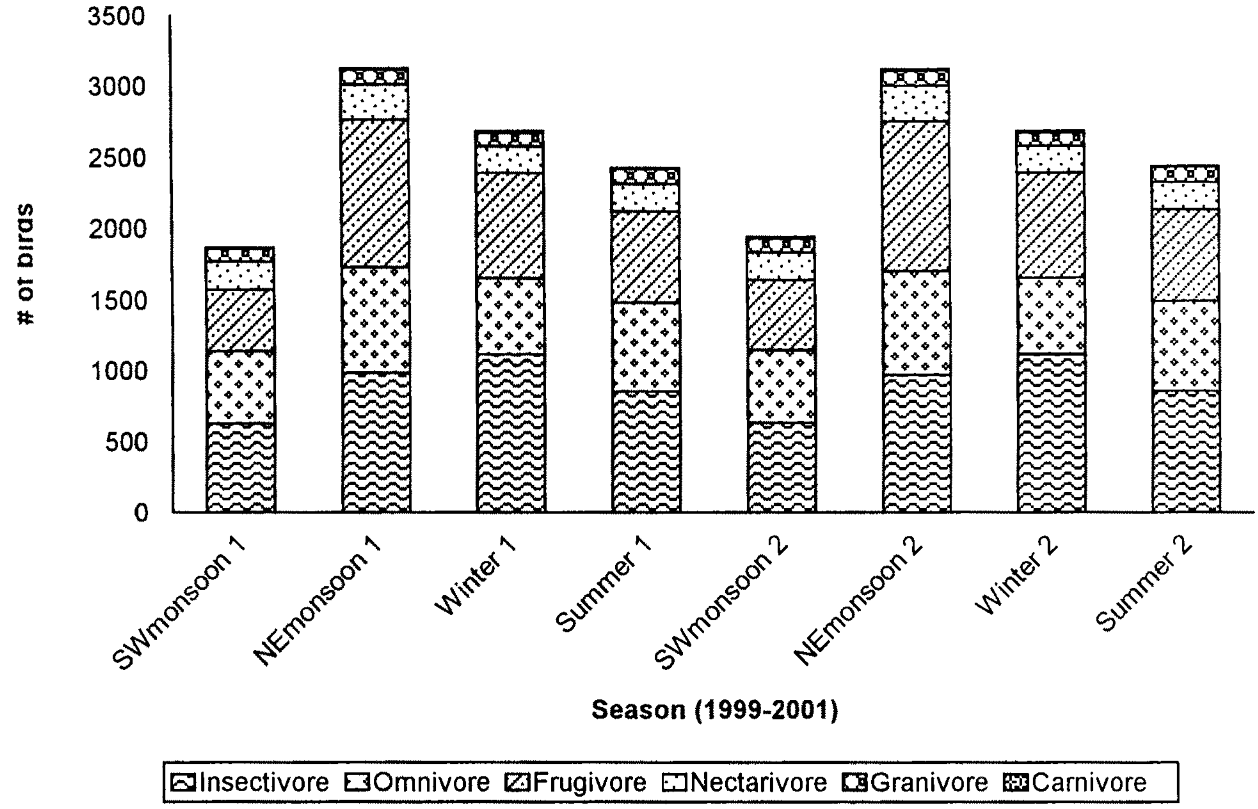
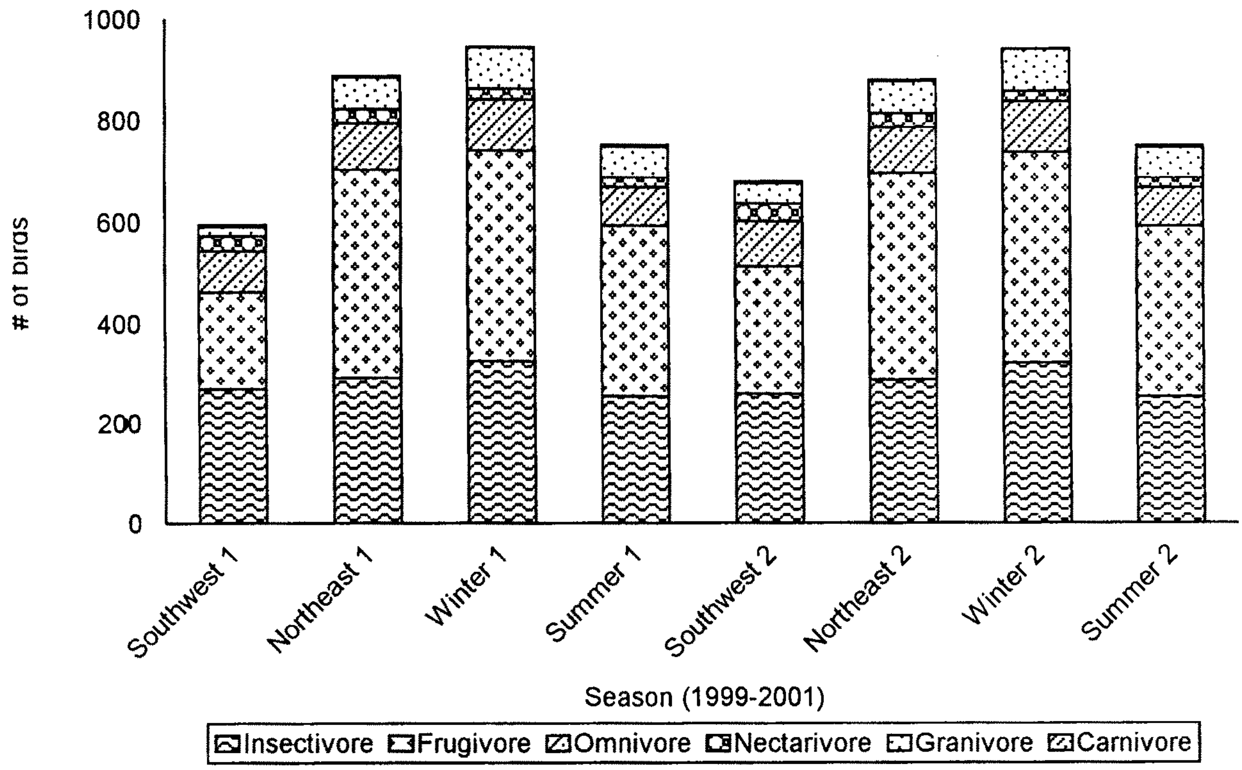


Figure 5.4. Guild-wise composition of bird species in the scrub forest



high during southwest monsoon. Variation in the total abundance of birds was correlated with the abundance of different guilds in various seasons. Nectarivores ($r = 0.795$, $p = .018$), insectivore ($r = 0.726$, $p = .041$) and frugivore ($r = 0.952$, $p = .0001$) were positively correlated with the total abundance of birds while the other guilds such as granivore, carnivore and omnivore had no such significant correlation.

In SF, the avifauna was dominated by frugivores followed by insectivores. Frugivore abundance was high during northeast monsoon and low during southwest monsoon. As frugivores were high, insectivores and omnivores were found to be low during northeast monsoon (Figure 5.4). Distinct pattern was evident in all the guilds. Feeding guild composition differed significantly between seasons. Carnivores were fewer in negotiable number (1-4), lowest during winter and high during summer. In both the habitats nectarivore was high during southwest monsoon and low during winter and it was just contrary to the granivores. Variation in the total abundance of birds was high and was similar to that of many guilds in various seasons; granivore ($r = 0.816$, $p = .014$), insectivore ($r = 0.873$, $p = .005$), frugivore ($r = 0.904$, $p = .002$) and omnivore ($r = 0.837$, $p = .010$) were positively correlated, whereas carnivore ($r = -0.843$, $p = .009$) showed significant negative correlation.

5.4.4. Abundance of invertebrates in the Anaikatty hills

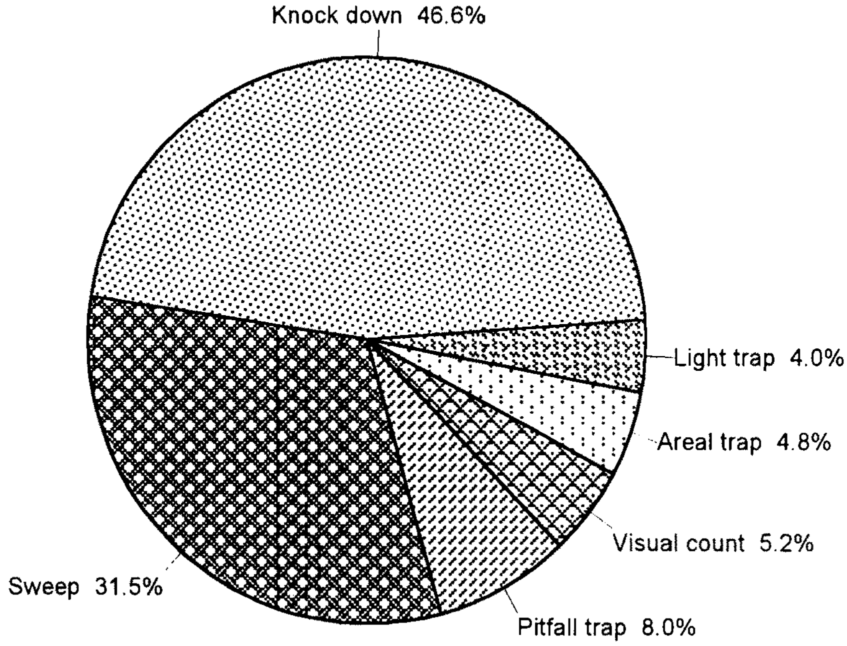
The invertebrates obtained by six sampling methods showed much variation in the composition and abundance of insect orders including arachnid. Of 29 orders of insects under the class Insecta (Richards and Davies 1977), the following 16 groups were encountered during the six various sampling techniques employed in the field. Diptera (flies and mosquitoes), Hymenoptera (ants, bees and wasps), Lepidoptera (butterflies and moths), Hemiptera (bugs), Orthoptera (grasshoppers), Isoptera (termites), Dictyoptera (cockroaches), Coleoptera (beetles), Odonata (dragonflies and damselflies), Phasmida (leaf insects), Ephemeroptera (mayflies), Mecoptera (scorpion flies) Neuroptera (lacewing), Plecoptera, Dermaptera and Psocoptera. Other invertebrates were grouped under four different classes Arachnida, Gastropoda, Diplopoda and Chilopoda. Insects belonging to orders of insignificant numbers were recorded as others and invertebrate group as miscellaneous for analysis.

The maximum insect abundance per sampling effort in Anaikatty hills was recorded in Knock down sampling (47%) followed by sweep sampling (32%), and the remaining 22% was contributed by the other 4 methods viz. visual counting, pitfall trap, aerial trap and light trap (Figure 5.5). These sampling efforts showed high correlation between them except the light trap. Knockdown with sweep and visual count samplings were significant at 99% confidence interval r = 0.778*, p = .0001, r = 0.914, p = .0001 respectively. The hierarchy in abundance of insects by sampling methods was Knock down> sweep sampling> pitfall trap> visual count > aerial trap > light trap.

Table 5.2 Mean abundance ranks obtained for different arthropod groups in Anaikatty hills

Arthropod group	Mean Rank
ARACHNID	20.69
HYMENOPTERA	20.33
DIPTERA	18.92
LEPIDOPTERA	18.50
HEMIPTERA	17.59
COLEOPTERA	16.93

Figure 5.5. Percentage contribution of insects by different sampling methods in Anaikatty hills (n=88325)



Kendall's Coefficient of Concordance in the first six arthropod groups revealed a significant unique abundance hierarchy among the different arthropod groups from six sampling methods (Kendall's W=0.84, P<0.001, D.F. = 22).

Arachnid > Hymenoptera > Diptera > Lepidoptera > Hemiptera > Coleoptera (Table 5.2).

There was a significant consistency of abundance hierarchy among the six sampling methods (Kendall's coefficient of concordance W = 0.793, χ^2= 174.5, P= <0.001). The highest mean rank was obtained for the knockdown samples followed by sweep, pitfall trap, visual count, aerial trap and light trap samples (Table 5.3). The percentage variation from the mean monthly abundance was used for comparing monthly fluctuations in the arthropod abundance of different sampling methods. The highest monthly variation in abundance (72%), was observed in the sweep sampling followed by the knockdown method indicating a greater amount of fluctuation in the abundance of arthropod in these methods than the other four methods (Table 5.3). Pitfall trap showed the least variation among the methods with the standard deviation being 26% from the mean.

Table 5.3 Comparison of insect abundance data from different sampling techniques

Methods	Mean abundance/month	Std. Deviation	%variation from mean	Minimum	Maximum	Mean rank
Knock down	2647.61	1859.3	70	589	6942	5.61
Sweep sampling	2049.07	1473.3	72	270	5730	5.02
Visual Counting	645.68	410.7	64	92	1388	3.3
Pitfall Trap	562.93	147.4	26	258	847	3.45
Areal trap	415.25	151	36	176	712	2.61
Light Trap	107.55	40.7	38	28	173	1
Kendall's W = 0.793, Chi-square = 174.54, D. F. = 5, Significance at 99% (P<0.001)						

MDDF showed higher percentage in knock down. The maximum insect abundance per sampling effort in MDDF was recorded in knock down sampling (53%) followed by sweep (31%), and visual count, pitfall trap, aerial trap and light trap (Table 5.3). The dominating order of insect group in all these sampling methods were Orthoptera>Diptera>Lepidoptera>Coleoptera> Hymenoptera.

The sampling effort in SF was recorded in knock down sampling (32%) followed by sweep (32%), pitfall trap, aerial trap, light trap and visual count.

The order of abundance of different insect groups differed among sampling methods. The MDDF showed dominant order of insect groups from knock down, sweep, visual count, light trap, aerial trap and pitfall trap as Orthoptera, Diptera, Lepidoptera, Coleoptera and Hymenoptera respectively. While sweep, visual count and aerial trap showed Hemiptera, Lepidoptera and Diptera as a dominant order of insect group. The SF showed dominant orders of insect groups from knock down sampling, light trap and pitfall trap as Hymenoptera. While sweep sampling, visual counting and aerial trap samplings showed Hemiptera, Lepidoptera and Diptera respectively as a dominant orders of insect groups. Knock down sampling was predominated by arachnid among the invertebrates in both the habitats.

5.4.5. Abundance of invertebrates of different size classes

Invertebrates of small size (0 -0.5 cm) was the highest in both the habitats followed by medium size (0.6-2 cm) and large size (>2 cm length). Large sized invertebrates were very few, only 4% in MDDF (Figure 5.6) and 2% in SF (Figure 5.7). Small sized insects were abundant in Anaikatty hills.

Figure 5.6. Size-wise sampling of invertebrates in the mixed dry deciduous forest (n=30296)

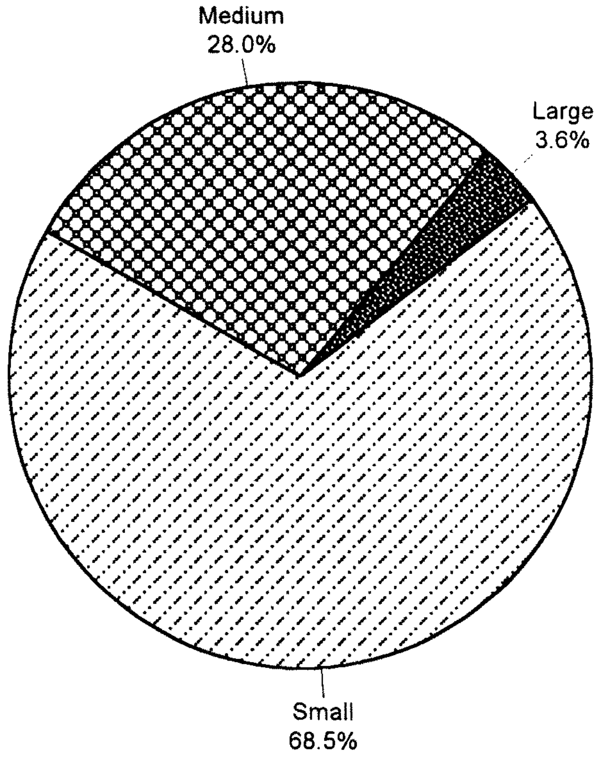
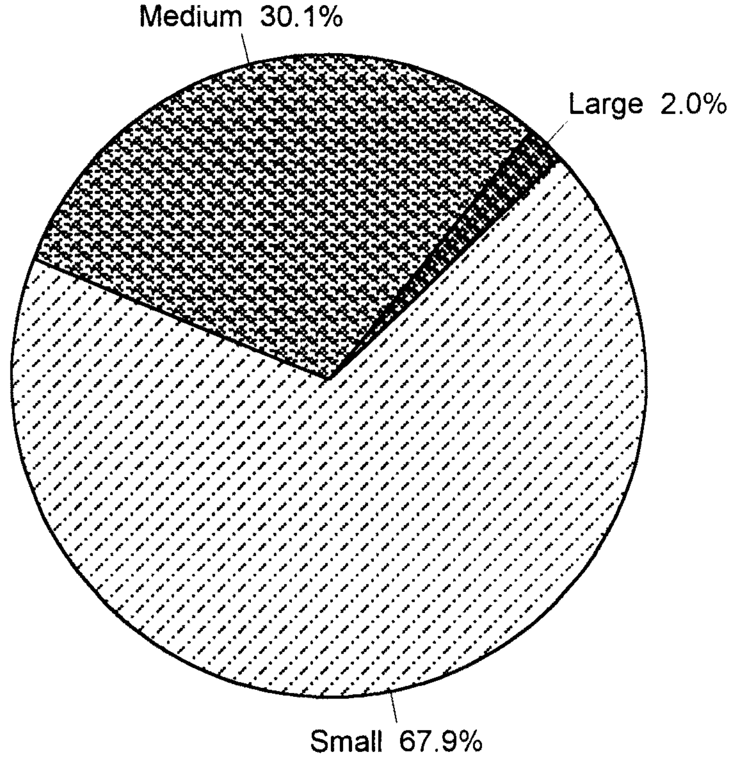


Figure 5.7. Size-wise sampling of invertebrates in the scrub forest (n=13867)



5.4.6. Composition of insects in the Anaikatty Hills

The general insect abundance from the pooled data of six sampling methods in MDDF showed that Arachnida was responsible for 21% of invertebrate abundance. The major contribution among the insect groups was of Lepidoptera followed by Orthoptera, Diptera and Hymenoptera (Figure 5.8). In SF, Hymenoptera was responsible for 26% of invertebrate abundance followed by Arachnida, Hemiptera, Diptera, Lepidoptera and Orthoptera (Figure 5.9). This hierarchy of abundance was statistically significant (Kendall's $W = 0.844$, $P < 0.0001$).

Among the insect groups, the first two higher abundant groups Lepidoptera differed in the two habitats, and Orthoptera in MDDF and Hymenoptera and Hemiptera in SF.

5.4.7. Seasonal abundance of insects

The overall invertebrate abundance fluctuated much and showed a definite trend in the years 1999-2001. The invertebrate abundance was maximum during winter, which accounted for 35% of the total abundance and minimum during southwest monsoon (Figure 5.10). Summer and north-east contributed 28% and 24% of the total invertebrate abundance respectively. All the sampling methods together showed a definite trend and peak during January in the mixed dry deciduous forest, scrub forest and Anaikatty hills (Figure 5.11). Seasonal fluctuation was similar for both the habitats. The total abundance from all the habitats together showed significant variation between the seasons (F =

Figure 5.8. Percentage composition of the Arthropod community in the mixed dry deciduous forest (n=60591)

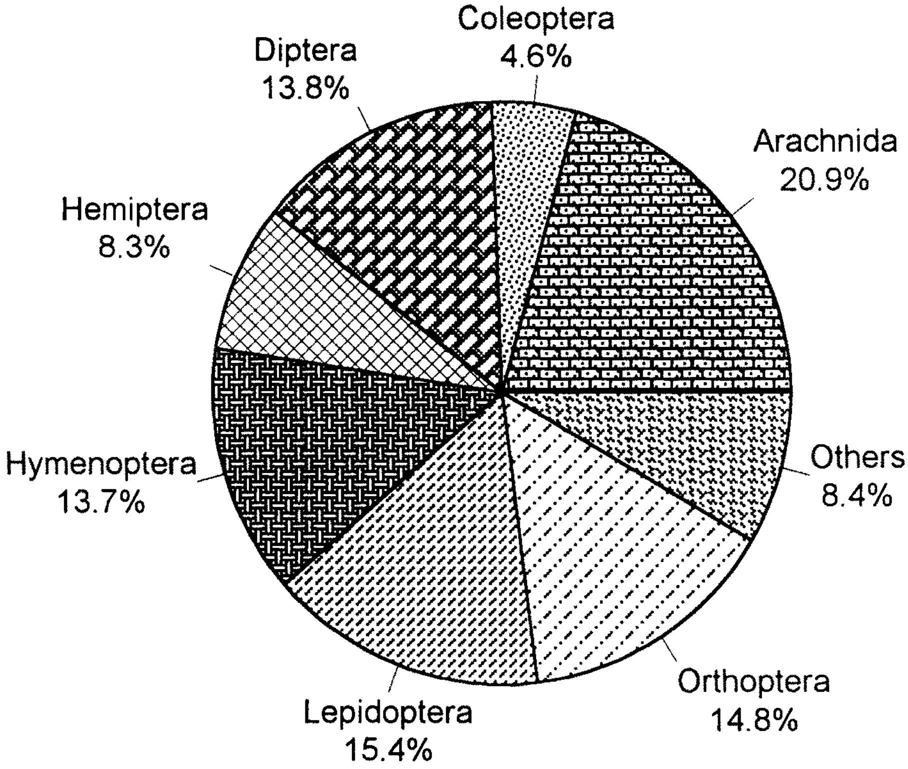


Figure 5.9. Percentage composition of the Arthropod community in the scrub forest (n=27734)

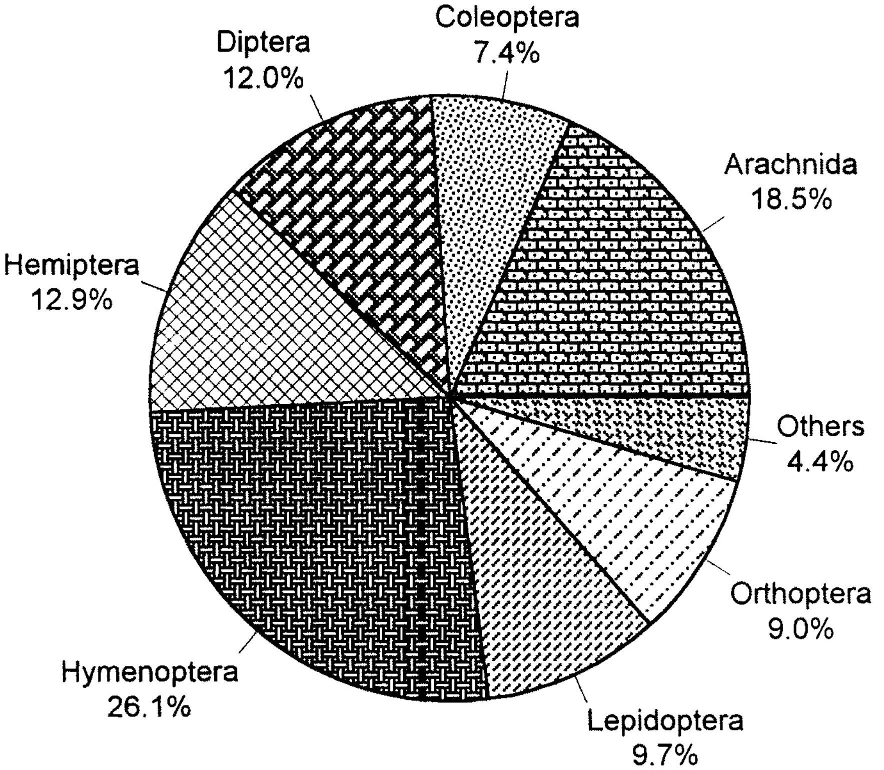


Figure 5.10. Invertebrate abundance in various seasons (n=88235)

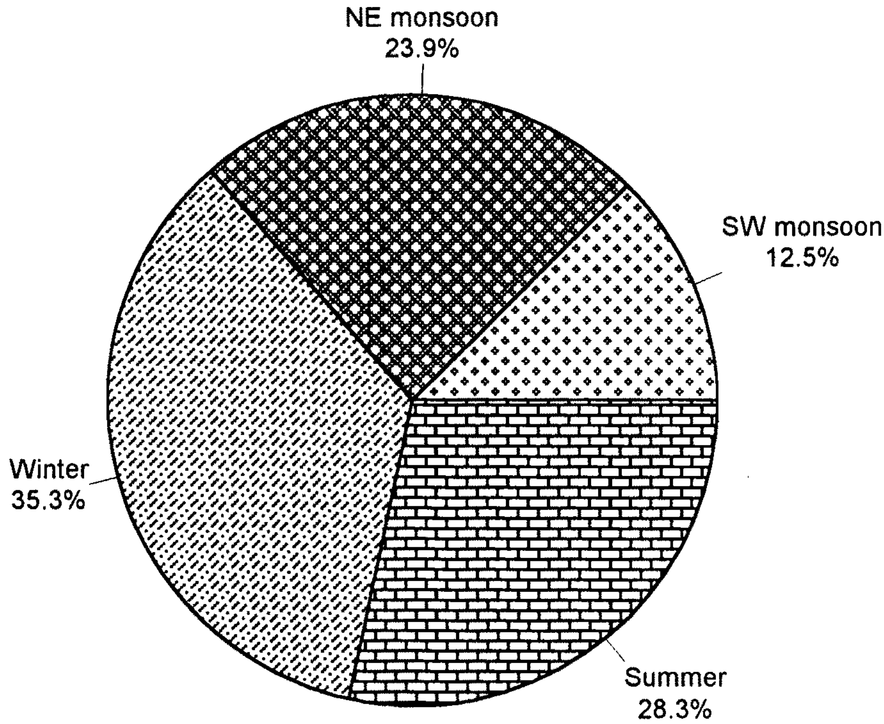
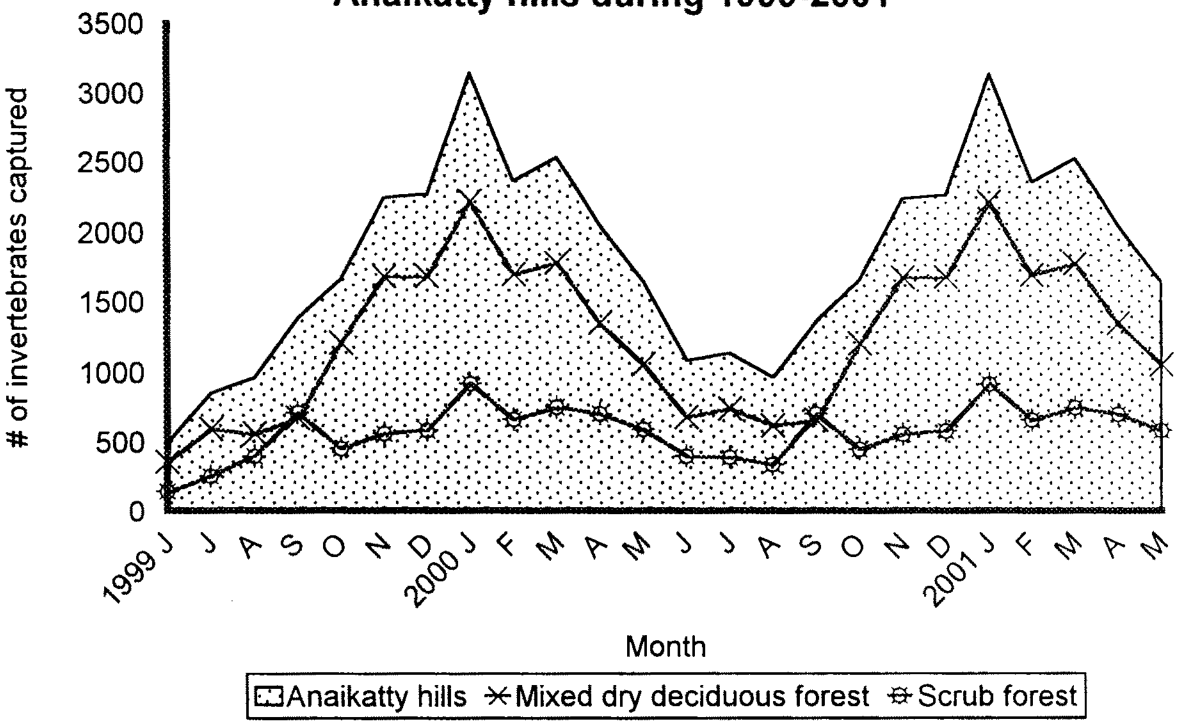


Figure 5.11. Temporal fluctuations of invertebrates in the Anaikatty hills during 1999-2001



1567.58, $P < 0.001$) and between years ($F = 24.05$, $P < 0.001$); the fluctuations in both the habitats were significantly correlated ($F = 287.01$, $P < 0.001$).

The peak was in January with a minor peak in September in SF (Figure 5.11). The lowest abundance recorded was in June and August. Lowest abundance in the first year (June and July 1999) was due to usage of only three sampling methods and in the other months all the six sampling techniques were used.

Lepidoptera, Orthoptera and Diptera were significantly higher in the mixed dry deciduous forest during winter, whereas Hymenoptera was the highest during north-east monsoon and Hemiptera was high during summer (Figure 5.12). In the scrub forest Hymenoptera was high during north-east monsoon as in the mixed dry deciduous forest while Diptera and Hemiptera were significantly high during winter (Figure 5.13).

5.4.8. Role of ecological factors on Insect

Among the six abiotic factors namely minimum temperature, maximum temperature, rainfall, rainy days, mean relative humidity and windspeed, only the minimum temperature, mean relative humidity and windspeed showed a significant negative correlation with the monthly abundance of insects in SF (Table 5.4). In MDDF, only mean relative humidity showed significant positive correlation. In scrub forest, sunshine duration exerted significant positive correlation with the abundance of insects ($r = 0.425$, $p = .038$), concurring that more open areas with herbs and shrubs yield higher insect abundance with sunshine duration. The abundance of insects was influenced by the biotic factors

Figure 5.12. Seasonality of invertebrate groups in the mixed dry deciduous forest

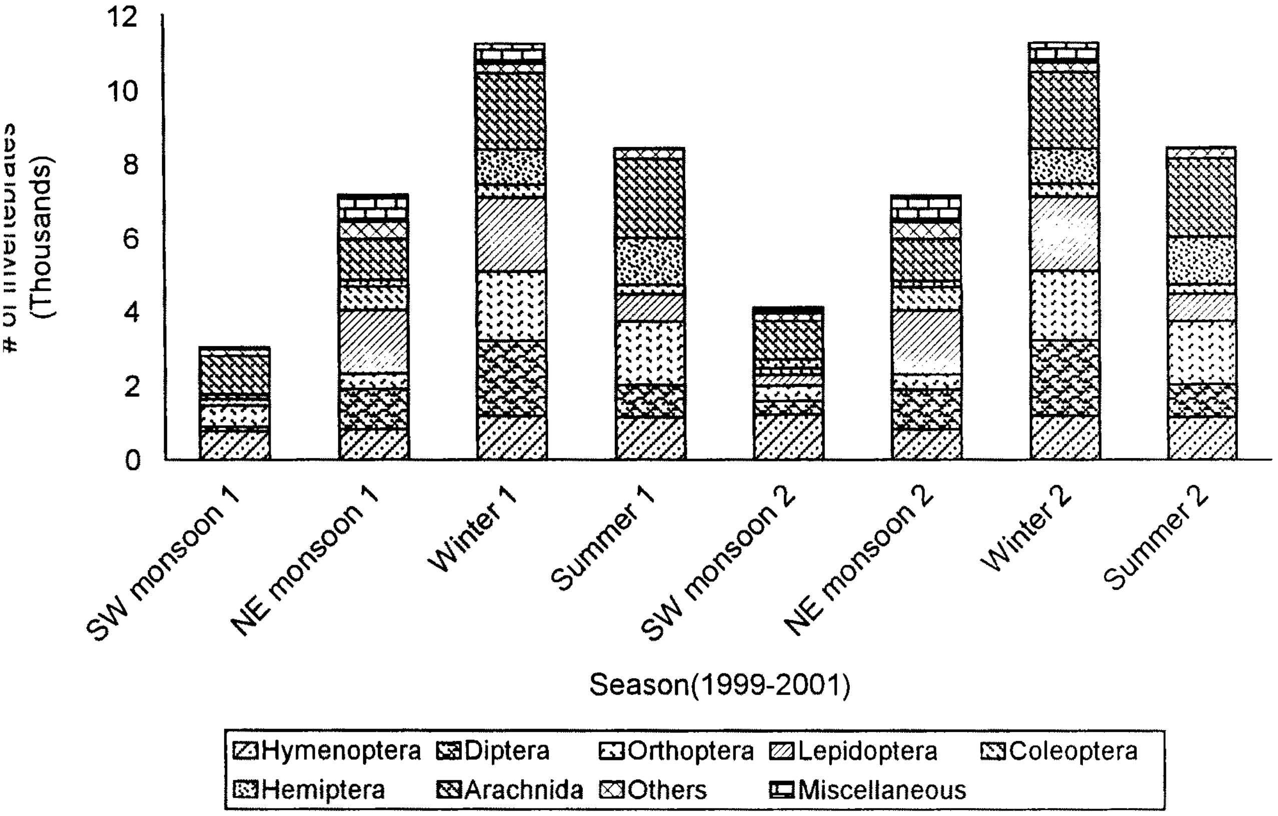
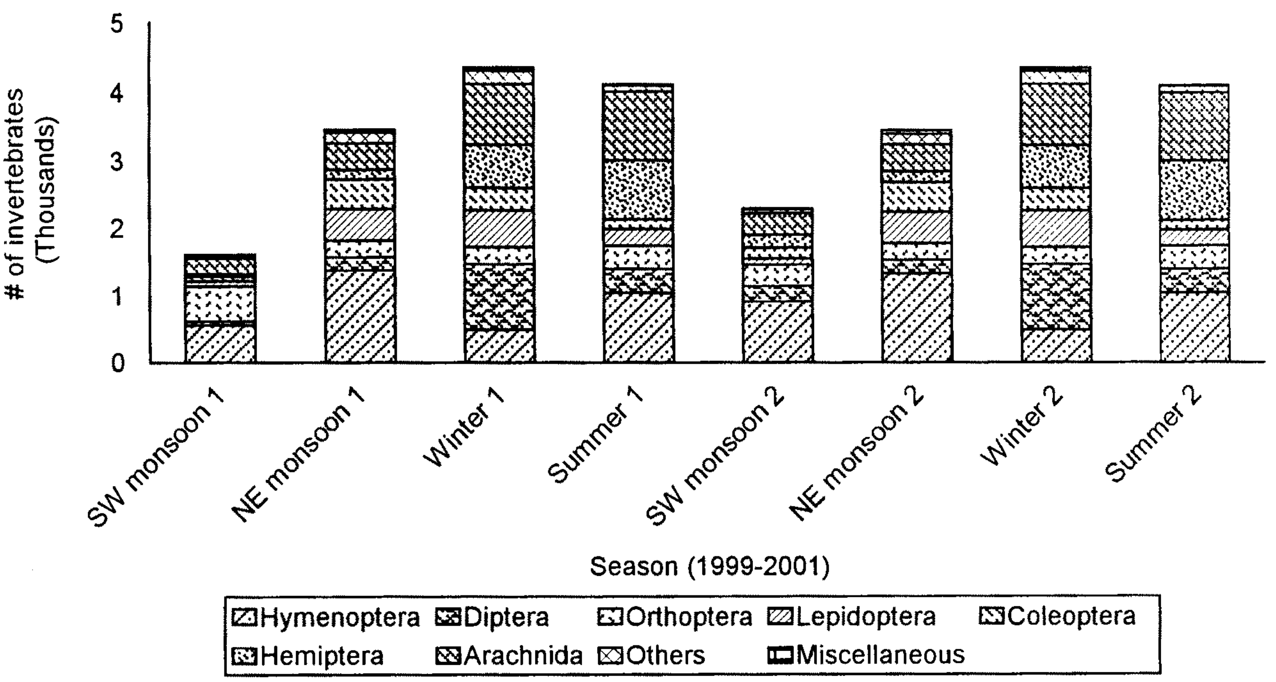


Figure 5.13. Seasonality of invertebrate groups in the scrub forest



such as plant species in fruit that showed significance positively with the abundance of insects (Table 5.4). Plant species in flower and phenology of young leaf showed significant negative correlation with the abundance of insects in both the habitats which depicts that when young leaves are more, insects are low and the vice versa took place in Anaikatty hills. The effect comes after flushing of leaves and increase of invertebrates occurred with a lag period after rain during north-east monsoon which might be the reason for their peak during winter. As the fruit increased in abundance, the insect also increased simultaneously in SF ($r = 0.502$, $p = .012$), but not in MDDF. Windspeed was negatively correlated in the SF. The abundance of insects influenced the bird species richness significantly (Table 5.4).

Table 5.4. Pearson correlation coefficients between insect abundance and environmental variables

Variables	MDDF	SJ	MDDF	SJ
	Correlation Coefficients (r)		Significance level (p)	
Insect abundance	1.000	-	1.000	-
Temperature-minimum (°C)	-	-0.333*	-	.021
Wind speed (kmph)	-	-0.526**	-	.0001
Mean relative humidity (%)	0.366*	-0.462**	.011	.001
Plants in fruit	0.286*	0.449**	.049	.0001
Plants in flower	-0.373**	-	.009	-
Phenology of young leaf (%)	-0.713**	-0.577**	.0001	.003
Bird species richness	0.300*	0.692**	.038	.0001

Correlation is significant at .05 level (2 tailed), **Correlation is significant at .01 level (2 tailed)

5.4.9. Bird and ecological factors

5.4.9.1. Role of abiotic factors on birds

Among the six abiotic factors, maximum temperature, minimum temperature and windspeed showed significant negative correlation with both species abundance and richness in both the habitats (Table 5.5). Rainfall showed positive correlation with abundance of birds in mixed dry deciduous forest alone (r= 0.407, p= .048). Also rainfall showed significant positive correlation with richness of birds in both the habitats namely MDDF (r = 0.605, p = .002) and SF (r = 0.434, p = .034).

Table 5.5. Pearson correlation coefficients between bird abundance and environmental variables

Parameters	Correlation Coefficients (r)		Significance level (p)	
	MDDF	SJ	MDDF	SJ
Bird abundance	1.000	-	1.000	-
Maximum Temperature (°C)	-0.406*	-0.535**	.049	.0001
Minimum Temperature (°C)	-0.409*	-0.693**	.047	.0001
Rainfall (mm)	0.407*	-	.048	-
Wind speed (kmph)	-0.509*	-0.653**	.011	.005
Insect	-	0.605**	-	.002
Plants in fruit	0.473*	0.429*	.020	.036
Plants in flower	0.473**	-0.478*	.010	.018
Phenology of fruit (%)	0.361*	-	.041	-
Phenology of flower (%)	-0.482*	-	.017	-
Bird species richness	0.586**	0.646**	.003	.001

* Correlation is significant at .05 level (2 tailed), **Correlation is significant at .01 level (2 tailed)

5.4.9.2. Role of biotic factors on bird community

5.4.9.2.1. Bird and insect

Bird and insect abundance fluctuated highly in Anaikatty hills (Figure 5.14). Anaikatty birds (44%) depend on the insects. Bivariate test of Pearson correlation coefficient was used to test the relation between bird and insect abundance. They showed significant positive correlation (r = 0.438, P = .032) suggesting that insect abundance positively influenced the abundance of birds.

Figure 5.14. Monthly fluctuation of bird and insect abundance in the Anaikatty hills

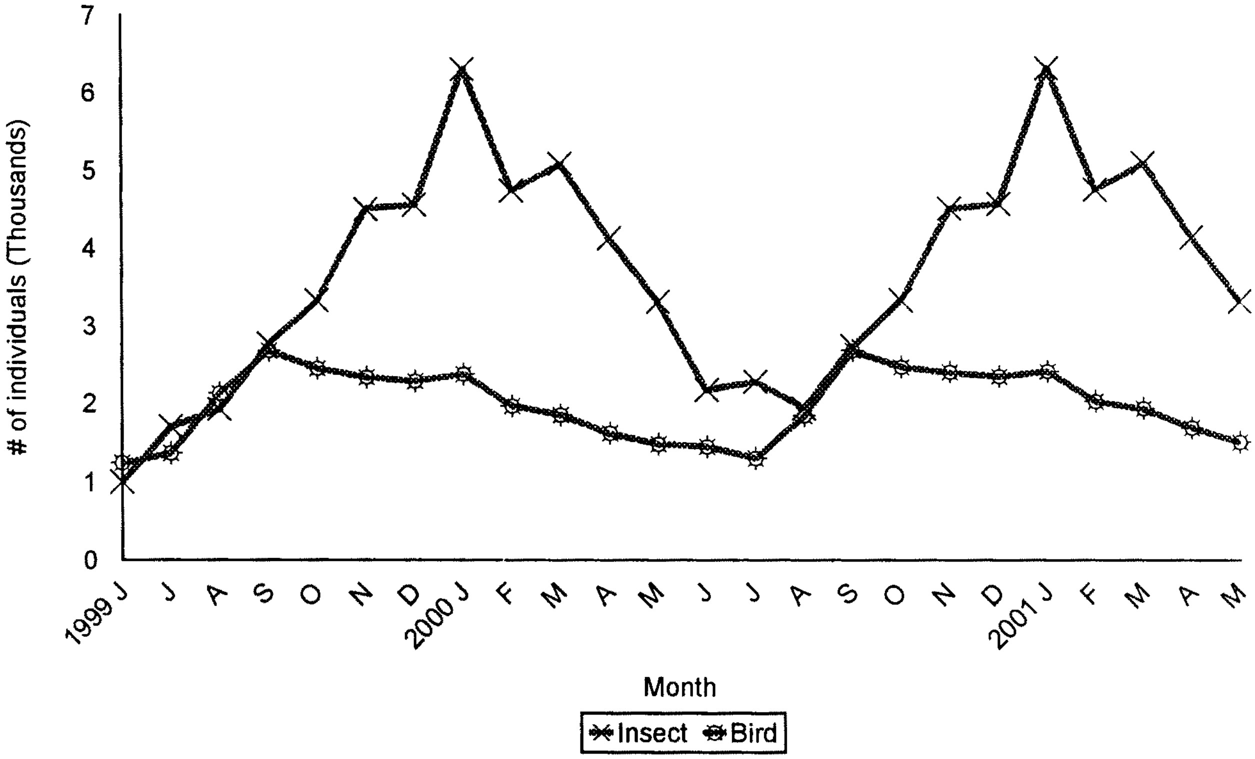
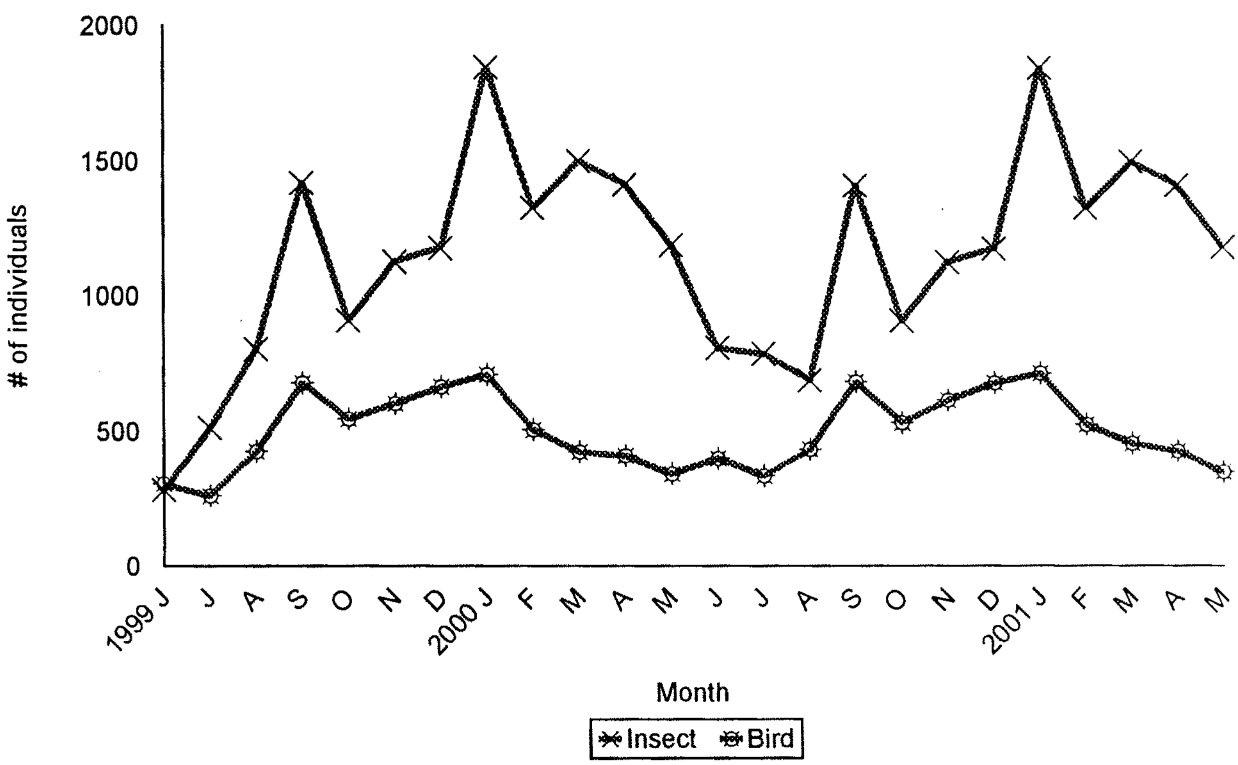


Figure 5.15. Monthly fluctuation of bird and insect abundance in the scrub forest



Similar relation was found in the scrub forest (Figure 5.15) with a significant positive correlation ($r = 0.605$, $P = .002$). However there was no such significance in MDDF mainly because the frugivore bird species was equally dominant there and this was tested by correlating Insectivore bird species with insects in MDDF which showed positive correlation with total insect abundance ($r = 0.851$, $p = .0001$). Whereas insectivore bird species abundance in SF showed significant positive correlation with lepidoptera ($r = 0.542$, $p < 0.007$) and insignificant with total insect abundance. Each insectivore bird species was correlated with each insect order and the results are given in Appendix 3.

5.4.9.2.2. Bird and vegetation

Increase of fruiting plants also increased the abundance of birds in Anaikatty hills (Table 5.5) as total abundance of birds in MDDF correlated significantly with frugivores ($r = 0.952$, $p = <0.0001$). Fruiting plants (Figure 5.16) and abundance of fruits (Table 5.5) showed negative correlation with abundance of flower. In SF also, the significant result was obtained with abundance of birds ($r = 0.904$, $p = .002$) and plants in fruit ($r = 0.429$, $p = <0.036$). Young and mature leaf had no significant correlation with bird abundance.

Abundance of birds in SF showed significant positive correlation with the number of plants in fruit (Figure 5.17) but with plants in flower it showed significant correlation negatively. Abundance of fruit and flower were insignificant to the abundance of birds. In mixed dry deciduous forest, fruiting reached a peak during the north-east monsoon in Anaikatty hills. The abundance of frugivores of

Figure 5.16. Abundance of birds and number of plant species in fruit in the mixed dry deciduous forest (r=0.473, p=0.020)

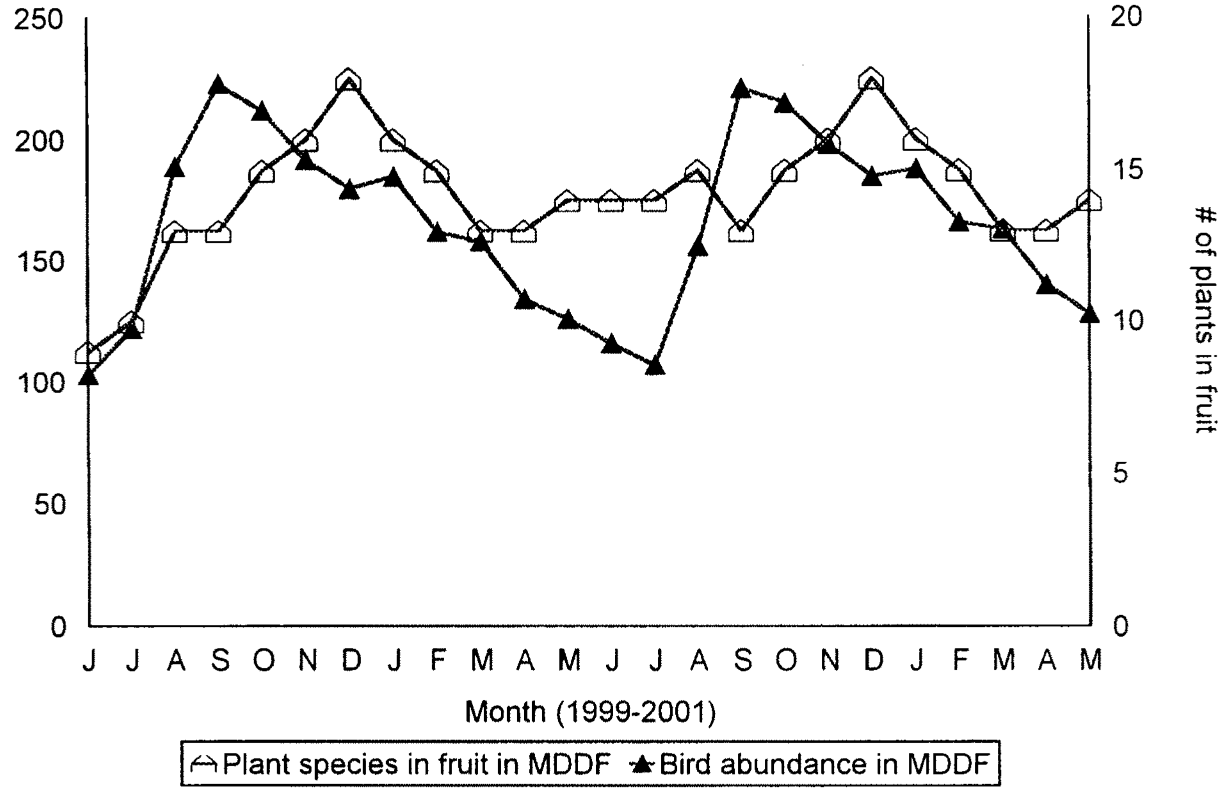
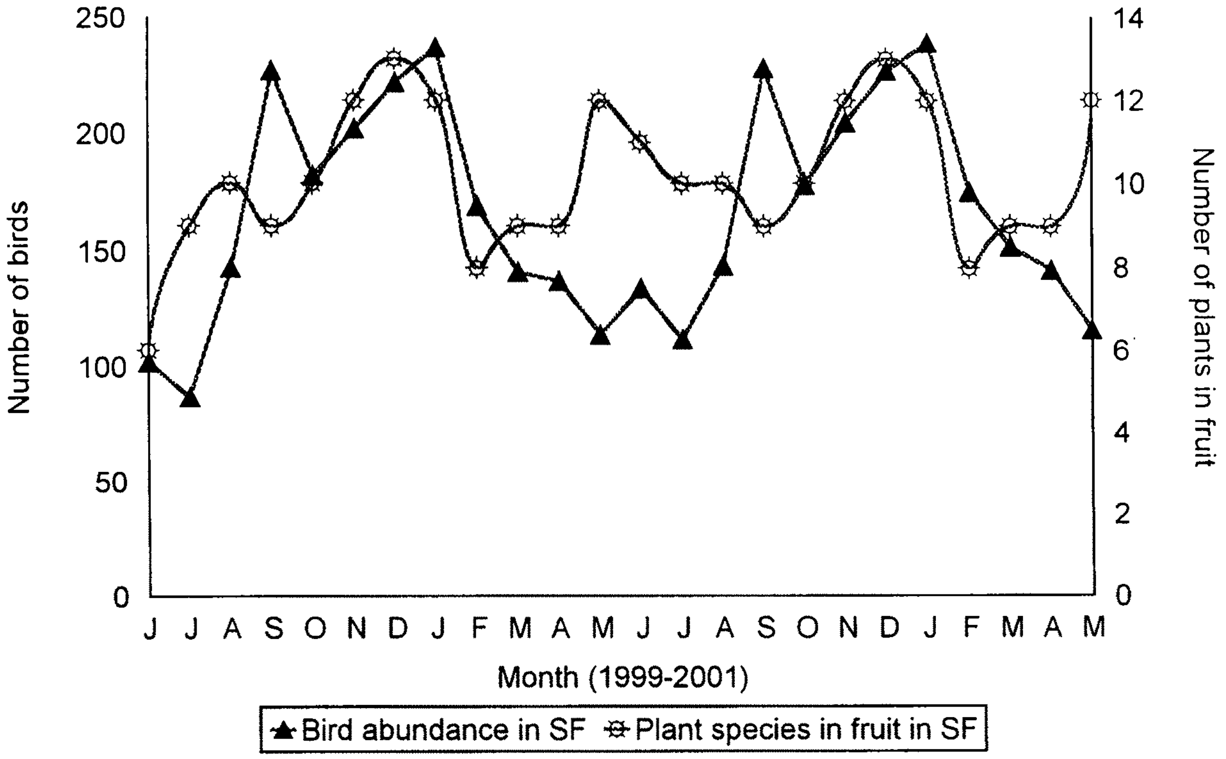


Figure 5.17. Abundance of birds and number of plant species in fruit in the scrub forest (r=0.429, p=0.036)



mixed dry deciduous forest synchronised with the abundance of fruits in that habitat (r = 0.449, p = <0.028) but not in SF.

5.4.10. Foliage Height Diversity (FHD) and Bird Species Diversity (BSD)

To relate bird community structure with habitat, vertical distribution of the foliage was sampled following MacArthur and Horn (1969). Foliage thickness was recorded at different strata seasonally and FHD was calculated for each stratum. Indices of BSD and FHD was correlated to test its dependency on FHD and test the hypothesis "Higher foliage profile layers harbour more species".

There was a positive significant correlation between FHD and BSD in all the seasons except summer (Table 5.6). All the other seasons showed significant result towards the influence of BSD by FHD. SF was highly significant ie. at 99% confidence interval. Moreover, the BSD and FHD significantly correlated altogether with MDDF (r=0.723*, p= .018) and SF (r=0.986**, p= .0001) habitats individually as well as wholly in Anaikatty hills (r=0.763***, p= .010). Foraging data was stratified according to the height and diversity was estimated to correlate with FHD, and it resulted with significant correlation (Table 5.6). This hypothesis became true with habitat SF and MDDF, where the Pearson correlation coefficients gave significant result positively.

Table 5.6. Pearson correlation coefficients between FHD and BSD

	Correlation Coefficients (r)		Significance level (p)	
Parameters	**MDDF**	**SJ**	**MDDF**	**SJ**
BSD / FHD	0.723*	0.986**	0.018	.000
Foraging BSD / FHD	0.639*	0.936**	0.047	.000
Southwest monsoon1	0.840**	0.936**	0.002	.000

Parameters	Correlation Coefficients (r)		Significance level (p)	
	MDDF	SJ	MDDF	SJ
Northeast monsoon1	0.644*	0.998**	0.044	.000
Winter1	0.731*	0.862**	0.016	.001
Summer1	0.020	0.997**	0.847	.000
Southwest monsoon2	0.633*	0.998**	0.049	.000
Northeast monsoon2	0.720*	0.993**	0.006	.000
Winter2	0.721*	0.799**	0.019	.006
Summer2	0.096	0.998**	0.516	.000

1- First year, 2- Second year, FHD- Foliage height diversity, BSD- Bird species diversity.

5.4.11. Insectivore birds and insects

Bird species such as Ashy Drongo, Blyth's Reed Warbler, Common Flame-back Common Iora and Pied Bushchat increased along with insect abundance in SF. Large-Billed Leaf Warbler, Greenish Warbler, Plain Prinia, Brown Shrike and Oriental Magpie Robin were affected directly by the insect abundance in MDDF (Appendix 3). Asian Paradise Flycatcher, Blyth's Reed Warbler and Brown Shrike were consistently increased in both the habitats with insect abundance. Shrikes, Warblers, Flycatchers, Drongos, Common Iora, Yellow-eyed Babbler, Oriental Magpie Robin, White-browed Wagtail, Chestnut-Headed Bee-Eater, Plain Prinia, Black-rumped Woodpecker, Rufous Woodpecker, Asian Paradise Flycatcher, Bee-eaters, Swifts and Swallows significantly increased with insect abundance (appendix 3).

5.5. Discussion

Seasonal fluctuation in birds is a phenomenon found in various habitats as discussed earlier in bird community structure. In drier habitats bird species richness and abundance initiated during monsoon as found by Johnsingh and

Joshua (1994) as against the wet forests found by Jayson and Mathew (2000). During northeast monsoon the species richness and abundance was high in MDDF whereas low in Mukkali (ibid) showing that there is a possibility of the birds to migrate locally from there to MDDF for example Black Bulbul, Grey-headed Bulbul, Pigeon etc. as suggested by Raman (1999) in Kalakkad - Mundanthurai Tiger reserve and Jayson and Mathew (2000) in Silent Valley. So MDDF becomes a wintering place for the high altitudinal birds since they found this area suitable during unfavourable climatic condition elsewhere. Gaston's (1978c) study on the New Delhi ridge also showed similar results where diversity was high during winter and low in summer.

The present result showed that population of avifauna considerably changes between seasons in both the habitats. Species abundance was more during north-east monsoon than during the winter season. Species richness was more during north-east monsoon in MDDF and during winter in SF than during south-west monsoon as reported in the moist deciduous forest (Gokula 1998, Vijayan *et al* .1999). Presence of locally moving birds and winter visitors are one of the major factors responsible for the higher diversity in the north-east monsoon. Food availability was also high during this season.

It could be discussed that the abundance of insects, availability of fruits and rainfall attracted more birds during September. The seasonal variation in the occurrence of birds could be due to fluctuation in the abundance of food as insect numbers relates with rainfall as studied by Karr (1976b), Vijayan (1984) and Vijayan *et al.* (2000). But not with leaf flush as in the studies of Price (1979) and

Johnsingh *et al.* (1987). As it has been established in the insect herbivores of the tropical savannas (Price *et al.* 1995) and leaf miners of Mexico (Nestel *et al.* 1994), in this study also, the overall insect abundance of the area did not show a direct significant relation with the plant phenology. But when the young leaves are few and tender, the insect abundance was high. However, small sized insects were profoundly abundant in Anaikatty hills. Birds of Anaikatty are small and they are capable of feeding on smaller sized insects (Vijayan 1984). 44% of bird are dependent on insect alone. Avifauna of MDDF becomes stable which shows frugivore and insectivore are the major guild forming community, which depends on fruits and insects. It is not the case with SF, where these guilds are moving to any available food and doesn't show correlation with the abundance of fruits, insects and flowers. However, insectivores of MDDF were depending on insects 60%, whereas in SF it was 50% on lepidoptera as found by Vijayan (1984).

In general, the insectivores and frugivores were the dominant groups in both the habitats, and showed distinct seasonal fluctuations in their abundance. Insectivores were invariably high during winter in both the habitats; this was due to the greater abundance of insect during this season. Abundance of more insectivores in winter season was also because of the migrants, most of whom are insectivores. Although the arrival of migrants started from September they stayed till early May; the abundance of warblers and flycatchers were more as they largely obtained their insect-food from shrubs. Moreover, the availability of migrants was higher in both the habitats as reported by Katti and Price (1996) in

Nilgiri and Vijayan *et al.* (2000) in Siruvani. The greater availability of foraging substrate and less inter-specific competition on foraging substrate might influence the population of warblers and flycatchers, which contributed to an increase in the overall insectivore population during winter as found in Mudumalai by Gokula (1998). Nectarivore, carnivore and frugivore species were fewer in the habitats as witnessed by Sundaramoorthy (1991), Gokula and Vijayan (1996), Gokula (1998) and Vijayan *et al.* (2000).

The insects emerged in relation to rainfall and their abundance increased as the rainy season progressed in Anaikatty hills as in the study of Murali and Sukumar (1993) in deciduous forest of Mudumalai Wildlife Sanctuary. Bird species such as Asian Paradise Flycatcher, Blyth's Reed Warbler and Brown Shrike were consistently increased in both the habitats with insect abundance. Shrikes, Warblers, Flycatchers, Drongos as in (Vijayan 1984), Common Iora, Yellow-eyed Babbler (Nirmala and Vijayan 2000), Oriental Magpie Robin, White-browed Wagtail, Chestnut-headed Bee-Eater, Plain Prinia, Black-rumped Woodpecker, Rufous Woodpecker, Asian Paradise Flycatcher (Gokula 1996, 1998).

In mixed dry deciduous forest, fruiting reached a peak during the north-east monsoon in Anaikatty hills as in the report of Balasubramanian *et al.* (1998) unlike the study of Poulin and Lefebvre (1997) where the peak is during fall in Central Panama. The abundance of frugivores synchronised with the availability of fruits in mixed dry deciduous forest but not in the scrub forest because of more frugivores in MDDF than in SF. It is apparent from the above discussions that the abundance of food and its availability regulate the number of birds as in Karr *et al.* (1992) and Pramod (1995).

The increase in abundance of birds in MDDF was because of the increase of endemic birds (Malabar Parakeet and Rufous Babbler), winter visitors and local migrants. High influx of species was because of immigration. Low species richness during southwest monsoon was due to emigration of migrants. Variation in the seasons was found in the region of Silent valley and Mukkali (Pramod 1995) where the diversity was profoundly high during summer. This variation was due to the habitat change in MDDF having more plants and foliage cover in the canopy. In mixed dry deciduous forest, fruiting reached a peak during the north-east monsoon in Anaikatty hills as in the report of Balasubramanian *et al.* (1998). which is also a cause added to the abundance of birds.

5.6. Conclusion

The communities of avifauna considerably change between seasons in both the habitats. The seasonal variation in the occurrence of birds was due to fluctuation in the abundance of food as insect abundance and fruiting species increased with rainfall. It could be ascertained that the abundance of insects, availability of fruits and rainfall attracted more birds.

Southwest monsoon was only for a few days but more number of rainy days was in northeast monsoon which resulted in blooming of insects and increasing insectivores. Frugivores increased with more number of fruiting species. Among the arthropod groups, Arachnida, Hymenoptera, Diptera and

Lepidoptera were the most abundant groups and were consistently high during winter. Seasonality pattern varied among insect orders. More number of rainy days were found to favour the insect abundance, which differed significantly among the seasons. Mixed dry deciduous forest recorded the highest arthropod abundance and this was determined by the habitat condition.

There exists a definite trend in both the habitats and peak of frugivore during north-east monsoon, insectivore during winter, nectarivore and granivore during south-west monsoon. Insectivores are dominant group and formed 50% in both the habitats, and showed distinct seasonal fluctuations in their abundance. Insectivores were invariably high during winter in both the habitats; this was due to the more insect abundance during this season. The greater availability of foraging substrate and less inter-specific competition on foraging substrate influenced the population of warblers and flycatchers, which contributed to an increase in the overall insectivore population during winter. Fruiting reached a peak during the north-east monsoon in Anaikatty hills. The abundance of frugivores of mixed dry deciduous forest and scrub forest synchronised with the availability of fruits. The abundance of frugivores of mixed dry deciduous forest synchronised with the availability of fruits in that habitat. No distinct pattern was found in nectarivores. Birds of Anaikatty were small and they were found corresponding to the abundance of small sized arthropods.

When young leaves are more, insects are low in Anaikatty hills. 44% of birds are dependent mainly on insects. Avifauna of MDDF showed frugivore and insectivore were the major guild, which depended on fruits and insects. It was not the case with SF, where these guilds were moving to any available food and did not show correlation with the abundance of fruits, insects and flowers.

Insectivores such as Ashy Drongo, Blyth's Reed Warbler, Common Flame-back Common Iora and Pied Bushchat in SF and Large-Billed Leaf Warbler, Greenish Warbler, Plain Prinia, Brown Shrike, Oriental Magpie Robin, Asian Paradise Flycatcher, Blyth's Reed Warbler and Brown Shrike in MDDF consistently increased with insect abundance. Shrikes, Warblers, Flycatchers, Drongos, Common Iora, Yellow-eyed Babbler, Oriental Magpie Robin, White-browed Wagtail, Chestnut-headed Bee-eater, Plain Prinia, Black-rumped Woodpecker, Rufous Woodpecker, Asian Paradise Flycatcher, Bee-eaters, Swifts and Swallows also increased significantly with insect abundance. These species directly depended on insects in Anaikatty hills.

CHAPTER 6

FORAGING BEHAVIOR

6.1. Introduction

Group of species that exploit the same class of resources in a similar way is known as guild (Root 1967). An understanding of patterns of foraging by organisms is central to the study of community organisation (Rosenberg 1990). It has been observed that birds prefer some specific habitats and coexist as guilds with the available pattern of food resources (Davies 1978). These coexisting birds are abundant in one habitat while some other coexisting birds are abounding elsewhere, and may fluctuate seasonally. The seasonality of food resources has impact on the spatial and temporal distribution and abundance of birds (Poulin *et al.* 1994). Breaking assemblages into functional groups forms one of the main techniques in ecology to understand the community structure and dynamics.

Members of a guild segregate themselves into specific ecological niches by adopting foraging behaviour. They differ in microhabitat use and foraging tactics (Wiens 1989). The foraging tactics include various methods to exploit the resources. Insectivore birds exhibit different methods of exploiting resources such as gleaning, sallying, probing, pouncing and hawking (Crome 1978, Holmes *et al.* 1979, Gokula 1998).

We use the foraging methods of birds from temperate forest (Crome 1978, Recher *et al.* 1985, Holmes 1990, and MacNally 1994), since no such studies are available in India except the study of Gokula (1998) in the thorn and dry deciduous forests in Mudumalai. Feeding methods of waterfowl community have been studied in detail in Keoladeo National Park, Bharatpur (Bhupathy 1991). Foraging of birds was discussed in community studies (Beehler *et al.* 1987, Johnsingh *et al.* 1987, Daniels 1989, Sundaramoorthy 1991, Johnsingh and Joshua 1994) mainly based on the information given by Ali and Ripley (1987). Vijayan *et al.,* (1999) and Gokula and Vijayan (2000) studied the foraging pattern of birds during the breeding season in thorn forest and found that the foraging overlap was low among the birds.

Niche overlap is 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, Alatalo 1981, 1982, Rolando and Robotti 1985, Szekely 1985). Moreover, knowledge of the ways in which birds exploit resources within a forest will increase the understanding of their habitat use and the essential requirements for their survival. This information would help in developing scientific conservation and management plan for any forests. This chapter will analyse the pattern of feeding behavior, microhabitat use by birds in the mixed dry deciduous and scrub forests and comparative study of foraging behavior of a few select species in both the habitats.

6.2. Methodology

Foraging records were made during May 1999 to May 2001. Twelve days in a month were spent to record foraging behavior of birds from the mixed dry deciduous and scrub forests. Most of the observations were done within four hours after sunrise. This is the most active foraging time for birds (Bibby *et al.* 1993). Only one foraging observation (initial record) was taken from any individual encountered as done by MacNally (1994). Initial observation is reported to provide precise estimate of foraging location rather than that of the subsequent ones (Bell *et al.* 1986).

For each foraging attempt microhabitat details such as the height above ground, substrate, foraging method and the plant species at which the prey was found were recorded.

Foraging attempts were assigned to 12 height categories: ground (considered as 0 m), at every 1 meter interval up to 10, and >10 m based on the general physiognomy of the vegetation (Gokula 1998). Select trees in both the habitats were marked with aluminium tags at different heights for reference.

A substrate is the place from where food is taken by birds. Substrate was classified as (1) ground - including grass, litter and barren ground, (2) trunk - the main axes of trees, (3) foliage - leaves including leaf-blades and petioles, (4) twigs - small branches to which leaves were attached, (5) flower, (6) fruits and (7) air. The plants were identified upto species or genus level.

6.2.1. Foraging methods

Foraging methods of birds were categorized as, (1) 'glean'; a stationary food item is picked up from its substrate by a standing or hopping bird. (2) 'Probe'; as glean but, 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 flies into air to catch flying prey. To cluster the species on a micro level, the sally, probe and glean were classified further into finer levels based on the substrate, which is given in Table 6.1. Moreover, the fruit and flower classification were used to record all behavior of frugivores and nectarivores since the use of plants by omnivorous birds was of relevance in comparison to their insectivorous behavior (Wheeler and Calver 1996). In total, 20 categories were used to collect information on foraging (Table 6.1) which encompasses the behaviors described by Crome (1978) and expanded by Holmes *et al.*, (1979), Ramsen and Robinson (1990) and MacNally (1994a).

6.2.2. Position in the canopy

The canopy layers used by the bird species were classified into ten as follows: These ten different canopy layers were possibly distinguished from three layers namely lower canopy, middle canopy and upper canopy (Figure 6.1) a). lower canopy was further distinguished as center lower, middle lower

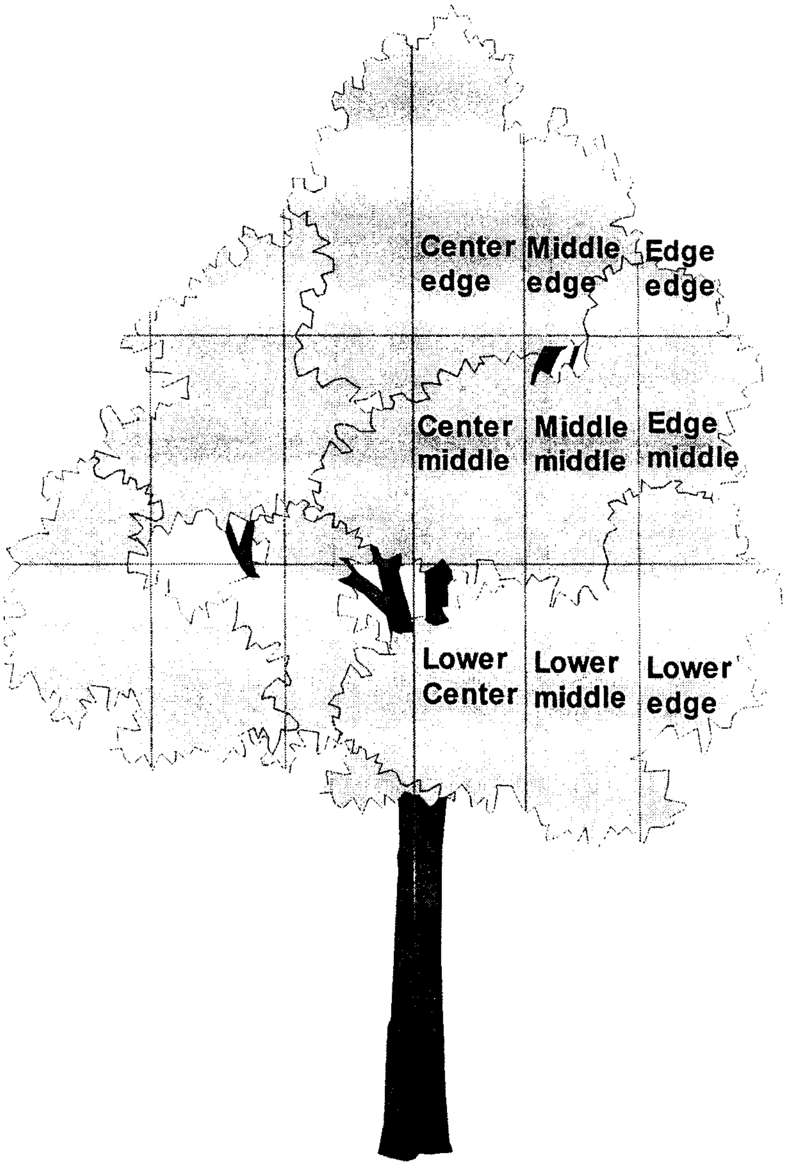


Figure 6.1. Diagrammatic representation of the canopy layers of a plant

and edge lower. b). Middle canopy was classified further into center center, middle middle and edge middle. c). Upper canopy was classified as center edge, middle edge and edge edge. d). Birds, which do not use plant at all for its prey was grouped under ground or air/ under canopy.

Table 6.1. Definition of foraging activities used to assess guild structure of avifauna

Foraging method	Sub categories
Sally	Above canopy-sally
	Below canopy-sally
	Herb-sally
	Shrub-sally
	Sally (sally to the ground)
Glean	Flower-glean
	Fruit-gleaning
	Ground-gleaning
	Litter-gleaning
	Main trunk-gleaning
	Secondary branch-gleaning
	Twig-glean
	Leaf-glean
Pounce	Ground-pounce
Probing	Ground-probing
	Litter-probing
	Main trunk-probing
	Secondary branch-probing
Tear	Leaf-tear
Hover	Hovering

For the purposes of getting sufficient sample size, the information was pooled irrespective of seasons and years. As thirty independent observations are recommended to represent the behavior of a bird accurately (Morrison 1984). Species with more than 30 observations were taken for analysis.

6.3. Statistical analysis

6.3.1. Specialist-Index *J'*

The foraging specialization of each bird category for each foraging dimension (Dimension includes method, substrate, vertical layer and canopy) was analyzed using the Shannon-Weaver index $H' = -\sum pi \ ln \ pi$ (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 maximum H' value obtained when the observations are distributed equally across all subsets of the foraging dimension) following Crome (1978) and Recher *et al.* (1985). *J'* value ranges between one and zero, with foraging specialization increasing as *J'* falls.

6.3.2. Niche overlap

Pianka (1981) defines ecological niche as "the sum total of the adaptations of an organismic unit or as all of the various ways in which a given organismic unit conforms to its particular environment". The resource gradient along with species showing partially non-overlapping distributions is a niche dimension (Cody 1974). The extent to which resource use overlaps between species pairs is niche overlap. The degree of species overlap in niche utilization for the different categories recorded (foraging method, substrate, canopy and foraging height) has been quantitatively expressed using Horn's (1966) equation:

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

where X and Y are the total number of observations for the two 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.

6.3.3. Cluster analysis

To compare foraging behavior (substrate, height, canopy use and method adopted) by various species, cluster analyses were performed on a data matrix (species * characteristics), following Holmes *et al.* (1979). This analysis used the unweighted pair group clustering method with arithmetic averages (UPGMA) and Squared Euclidean Distance (Legendre and Legendre 1983, Rohlf 1987). The SPSS statistical software (Norusis 1990) release 6.0 was used for the data analysis.

6.4. Results

Of the 194 species from Anaikatty Hills, 5550 foraging observations were made on 42 species of birds. Of this, 36 species in mixed dry deciduous forest, 22 species in scrub forest have more than 30 records and were taken for analysis (Table 6.2). Sixteen species were recorded from both the habitats and was taken for the comparative study of foraging.

Table 6.2. Number of foraging records made in the mixed dry deciduous and scrub forests during 1999-2001(* = <30 records).

S. code	Name of the species	Family	Number of observations in MDDF	Number of observations in SF	Total
301	GREY JUNGLEFOWL	Phasianidae	94	*	94
311	INDIAN PEAFOWL	Phasianidae	36	46	82
541	LAUGHING DOVE	Columbidae	*	39	39
558	BLOSSOM-HEADED PARAKEET	Psittacidae	45	122	167
564	MALABAR PARAKEET	Psittacidae	225	*	225
566	VERNAL HANGING PARROT	Psittacidae	53	-	53
595	BLUE-FACED MALKOHA	Cuculidae	74	*	74
744	CHESTNUT-HEADED BEE-EATER	Meropidae	56	-	56
750	GREEN BEE-EATER	Meropidae	42	39	81
765	COMMON HOOPOE	Upupidae	35	*	35
808	STREAK-THROATED WOODPECKER	Picidae	28	28	56
927	REDRUMPED SWALLOW	Hirundinidae	49	37	86
958	BLACK-HOODED ORIOLE	Oriolidae	41	-	41
963	BLACK DRONGO	Dicruridae	73	-	73
965	ASHY DRONGO	Dicruridae	33	*	33
967	WHITE-BELLIED DRONGO	Dicruridae	103	-	103
987	CHESTNUT-TAILED STARLING	Sturnidae	-	37	37
1006	COMMON MYNA	Sturnidae	-	100	100
1010	JUNGLE MYNA	Sturnidae	72	179	251
1100	COMMON IORA	Irenidae	368	54	422
1107	BLUE-WINGED LEAFBIRD	Irenidae	115	-	115
1120	RED-WHISKERED BULBUL	Pycnonotidae	84	36	120
1128	RED-VENTED BULBUL	Pycnonotidae	102	197	299
1138	WHITE-BROWED BULBUL	Pycnonotidae	333	149	482
1149	BLACK BULBUL	Pycnonotidae	74	-	74
1221	TAWNY-BELLIED BABBLER	Muscicapidae	125	55	180
1231	YELLOW-EYED BABBLER	Muscicapidae	*	106	106
1262	JUNGLE BABBLER	Muscicapidae	240	*	240
1267	YELLOW-BILLED BABBLER	Muscicapidae	189	48	237
1460	ASIAN PARADISE FLYCATCHER	Muscicapidae	82	*	82
1535	COMMON TAILORBIRD	Muscicapidae	40	37	77
1556	BLYTH'S REED WARBLER	Muscicapidae	128	44	172
1601	LARGE-BILLED LEAF WARBLER	Muscicapidae	147	-	147
1602	GREENISH WARBLER	Muscicapidae	159	*	159
1720	INDIAN ROBIN	Muscicapidae	*	59	59
1891	BROWN-HEADED BARBET	Capitonidae	31	*	31
1899	PALE-BILLED FLOWERPECKER	Picidae	124	*	124
1902	PLAIN FLOWERPECKER	Dicaeidae	74	-	74
1907	PURPLE-RUMPED SUNBIRD	Nectariniidae	361	74	435
1911	LOTEN'S SUNBIRD	Nectariniidae	90	*	90
1917	PURPLE SUNBIRD	Nectariniidae	57	45	102
1957	BAYA WEAVER	Ploceidae	-	37	37

6.4.1. Foraging patterns of bird species in the mixed dry deciduous forest

6.4.1.1 Foraging height

All the 12 height categories such as ground (0m), every meter class above ground upto 10m, and >10m were utilized by 36 bird species in the mixed dry deciduous forest (Table 6.3). Although most species fed 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 partitioned as three layers of strata; ground (0m), shrub/short trees (0.1-3), and tree layers (>3). In the community as a whole, a higher percentage of foraging manoeuvre were recorded in different height categories on trees. Other than shrub/short trees, mainly the birds utilized the layers of 3-6m.

Six species foraged mainly on or near the ground. Among them, Grey Junglefowl absolutely used the ground layer while Jungle Myna, Yellow-billed (White-headed) Babbler, Indian Peafowl, Common Hoopoe, and Jungle Babbler showed variety in their height preference

The 0.1-3m height category of shrub and short tree layers were utilized by nine species, which can be considered as lower canopy. Of the nine species, only Blossom-headed Parakeet used this layer extensively while Tawny-bellied (Rufousbellied) Babbler, Loten's Sunbird, Common Tailorbird, Red-vented Bulbul, White-browed Bulbul, Blyth's Reed Warbler, Purple-rumped Sunbird, Asian Paradise Flycatcher showed variation in their usage of vertical strata.

Table 6.3. Height distribution of birds in the mixed dry deciduous forest (%)

S. code	Name of the bird species	Vertical strata													
		0	0.1-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	H'	J'
301	GREY JUNGLEFOWL	100	-	-	-	-	-	-	-	-	-	-	-	0.0	0.00
311	INDIAN PEAFOWL	77	23	-	-	-	-	-	-	-	-	-	-	1.5	0.56
558	BLOSSOM-HEADED PARAKEET	-	88	-	-	-	-	-	-	-	-	2	9	0.3	0.11
564	MALABAR PARAKEET	-	3	2	3	32	28	12	4	7	3	4	3	1.2	0.44
566	VERNAL HANGING PARROT	-	-	-	-	2	-	2	2	34	8	53	-	0.9	0.33
595	BLUE-FACED MALKOHA	19	14	3	5	20	23	8	4	-	3	-	1	2.3	0.85
744	CHESTNUT-HEADED BEE-EATER	2	5	7	2	2	16	16	13	13	-	2	23	2.7	1.00
750	GREEN BEE-EATER	-	19	-	-	52	7	-	-	-	-	-	21	0.7	0.26
765	COMMON HOOPOE	91	-	-	3	-	-	3	3	-	-	-	-	1.9	0.70
808	STREAK-THROATED WOODPECKER	-	-	7	21	57	-	11	-	4	-	-	-	0.3	0.11
927	REDRUMPED SWALLOW	-	-	-	2	-	29	-	-	-	-	59	10	0.6	0.22
958	BLACK-HOODED ORIOLE	-	-	-	-	10	51	17	7	2	2	-	10	1.4	0.52
963	BLACK DRONGO	8	3	1	3	4	-	21	10	22	3	7	19	2.4	0.89
965	ASHY DRONGO	-	-	-	-	3	15	30	15	3	-	18	15	1.9	0.71
967	WHITE-BELLIED DRONGO	4	1	-	1	13	22	14	17	12	10	4	4	2.1	0.78
1010	JUNGLE MYNA	39	19	-	-	-	-	21	3	18	-	-	-	1.5	0.56
1100	COMMON IORA	0	3	13	17	22	17	15	7	2	-	2	2	0.9	0.33
1107	BLUE-WINGED LEAFBIRD	-	-	-	5	30	39	17	5	2	1	1	-	1.4	0.52
1120	RED-WHISKERED BULBUL	-	14	19	24	8	12	12	7	1	1	1	-	2.2	0.81
1128	RED-VENTED BULBUL	-	40	15	6	14	1	4	5	1	3	-	12	1.8	0.67
1138	WHITE-BROWED BULBUL	2	16	30	22	17	12	1	1	1	-	-	-	0.9	0.33
1149	BLACK BULBUL	-	-	-	26	-	3	38	24	-	-	9	-	1.5	0.54
1221	TAWNY-BELLIED BABBLER	-	72	24	4	-	-	-	-	-	-	-	-	0.7	0.26
1262	JUNGLE BABBLER	81	6	4	4	1	1	2	-	-	-	-	-	0.7	0.26
1267	YELLOW-BILLED BABBLER	97	2	-	-	-	-	1	-	-	-	-	-	0.4	0.15
1460	ASIAN PARADISE FLYCATCHER	-	18	26	45	5	5	1	-	-	-	-	-	1.4	0.52
1535	COMMON TAILORBIRD	-	48	30	10	8	5	-	-	-	-	-	-	0.9	0.33
1556	BLYTH'S REED WARBLER	-	27	30	18	15	8	2	-	-	-	1	-	1.5	0.54
1601	LARGE-BILLED LEAF WARBLER	-	1	6	12	19	28	22	7	3	2	1	-	1.5	0.56
1602	GREENISH WARBLER	-	-	1	8	16	25	18	6	16	3	2	7	1.5	0.56
1891	BROWN-HEADED BARBET	-	-	6	29	10	6	19	16	10	-	-	3	2.3	0.85
1899	PALE-BILLED FLOWERPECKER	-	4	9	10	27	16	21	4	3	3	3	1	1.9	0.70
1902	PLAIN FLOWERPECKER	-	-	8	14	15	42	13	-	8	-	-	-	1.8	0.67
1907	PURPLE-RUMPED SUNBIRD	-	22	18	9	14	16	11	6	3	1	1	1	0.9	0.33
1911	LOTEN'S SUNBIRD	-	44	11	2	8	19	8	6	2	-	-	-	1.7	0.63
1917	PURPLE SUNBIRD	-	5	23	2	19	7	28	-	11	-	5	-	2.2	0.81

The tree layer (>3m) was used by 21 bird species. Within the tree layers, higher percentage of foraging manoeuvre was recorded in the 3-6m category, which can be considered as middle canopy. A few species such as the Ashy Drongo, Large-billed Leaf Warbler, Black Drongo, Vernal Hanging Parrot (Lorikeet) and the Red-rumped Swallow preferred feeding from the upper strata (>6m). For the avian community as a whole in mixed dry deciduous forest, a higher percentage (58%) of foraging manoeuvre were recorded in the tree layers (>3m height).

6.4.1.2. Foraging substrate

More number of bird species (7) used air (19%) and only two species (6%) used trunk (Table 6.4). Birds exploited flower and fruit equally (17% each), while ground, twigs, and foliage were used 14% each by these guilds (Table 6.4).

Ground: The ground-foraging guild was with five species namely Jungle Babbler, Grey Junglefowl, Indian Peafowl, Common Hoopoe and Yellow-billed Babbler which fed predominantly from the ground. Among these five species, none was restricted to the ground **substrate absolutely .**

Trunk: Streak-throated (Little Scaly-bellied Green) Woodpecker and Black-Hooded (Headed) Oriole largely obtained their prey from the trunk. In addition to this substrate, these birds also used twigs and fruits.

Table 6.4. Percent use of substrate by birds in the mixed dry deciduous forest

S. Code	Name of the bird species	Ground	Trunk	Foliage	Twigs	Flower	Fruit	Air
301	GREY JUNGLEFOWL	97	0	3	0	0	0	0
311	INDIAN PEAFOWL	74	0	3	0	0	23	0
558	BLOSSOM-HEADED PARAKEET	0	0	0	0	7	93	0
564	MALABAR PARAKEET	0	0	0	0	2	98	0
566	VERNAL HANGING PARROT	0	0	0	0	100	0	0
595	BLUE-FACED MALKOHA	24	8	9	35	0	23	0
744	CHESTNUT-HEADED BEE-EATER	0	0	13	0	0	0	88
750	GREEN BEE-EATER	0	0	21	0	0	0	79
765	COMMON HOOPOE	91	6	0	3	0	0	0
808	STREAK-THROATED WOODPECKER	0	93	0	7	0	0	0
927	REDRUMPED SWALLOW	0	0	0	0	0	0	100
958	BLACK-HOODED ORIOLE	0	66	0	32	0	2	0
963	BLACK DRONGO	0	0	1	0	0	0	97
965	ASHY DRONGO	0	0	0	0	24	0	76
967	WHITE-BELLIED DRONGO	0	0	2	0	0	0	98
1010	JUNGLE MYNA	39	3	0	0	53	6	0
1100	COMMON IORA	0	0	27	72	0	0	0
1107	BLUE-WINGED LEAFBIRD	0	0	56	17	20	8	0
1120	RED-WHISKERED BULBUL	1	4	1	24	0	70	0
1128	RED-VENTED BULBUL	2	12	4	12	0	71	0
1138	WHITE-BROWED BULBUL	2	0	1	15	0	77	5
1149	BLACK BULBUL	0	1	45	49	0	5	0
1221	TAWNY-BELLIED BABBLER	0	0	14	85	0	1	0
1262	JUNGLE BABBLER	81	2	0	17	0	0	0
1267	YELLOW-BILLED BABBLER	97	0	1	2	0	0	0
1460	ASIAN PARADISE FLYCATCHER	0	0	12	0	0	0	88
1535	COMMON TAILORBIRD	3	0	35	58	0	5	0
1556	BLYTH'S REED WARBLER	0	0	56	44	0	0	0
1601	LARGE-BILLED LEAF WARBLER	0	0	90	10	0	0	0
1602	GREENISH WARBLER	0	9	27	64	0	0	0
1891	BROWN-HEADED BARBET	0	6	6	0	0	87	0
1899	PALE-BILLED FLOWERPECKER	0	0	15	21	64	0	0
1902	PLAIN FLOWERPECKER	0	0	46	40	14	0	0
1907	PURPLE-RUMPED SUNBIRD	0	0	5	7	87	1	0
1911	LOTEN'S SUNBIRD	0	0	0	6	93	1	0
1917	PURPLE SUNBIRD	0	7	16	4	74	0	0

Foliage: Five bird species such as Blyth's Reed Warbler, Bluewinged Leafbird (Goldmantled Chloropsis), Plain Flowerpecker, Black Bulbul and Large-billed Leaf Warbler formed this guild and predominantly used this substrate. Twigs were the second dominant substrate (Table 6.4) used by the members of this guild.

Twigs: This guild was also formed of five species namely, Blue-faced (Green-billed) Malkoha, Greenish Warbler, Tawny-bellied Babbler, Common Tailorbird and Common Iora. All these species did not use this substrate (Table 6.4)**exclusively**. Foliage was the second dominant substrate used by these birds.

Flower: Six bird species exploited this substrate predominantly. Only Vernal Hanging Parrot alone used this substrate while other species used other substrates also (Table 6.4).

Fruit: Six bird species formed this guild, of which none was restricted to this substrate. Parakeets (Table 6.4) used this predominantly with a little overlap of flower. Other species such as Bulbuls and Large Green Barbet used this substrate and also other substrates for their prey.

Air: Seven species formed this guild (Table 6.4). Red-rumped Swallow obtained its prey absolutely from air. Drongos predominantly used air for their prey and in addition, they also used foliage to a less extent.

6.4.1.3. Foraging methods

Only three major techniques were possibly distinguished from the five major prey attack manoeuvre, while 20 minor techniques (Table 6.1) were distinguished from the major classified foraging manoeuvre for 36 bird species in the mixed dry deciduous forest. The major prey attack manoeuvre were sallying, pouncing, gleaning, hovering and probing (Table 6.5). Birds such as gleaner (88%), sallier (10%), prober (1%), pouncer and hoverer (1%) were recorded from this habitat.

Gleaning: Twenty-nine species were recorded as gleaner (Table 6.5), of which 24 species predominantly used (100%) this method.

Sallying: Six species such as Asian Paradise Flycatcher, White-bellied Drongo, Green Bee-eater, Black Drongo, Ashy Drongo and Chestnut-headed Bee-eater used this method to obtain their prey. Except Ashy Drongo, all other birds of this guild used sally as the only prey attacking manoeuvre.

Hovering (aerial capture): Red-rumped Swallow was recognized as hoverer, which used this method only as the prey-attacking manoeuvre.

6.4.1.4. Prey attack manoeuvre by gleaners

Since gleaning formed the major method adopted by the birds of Anaikatty hills, this method was further **divided** into other types (Table 6.1) used by them. In total, gleaning of flower (21%), fruit (21%) and twig (21%)

Table 6.5. Percent prey attack manoeuvre by birds in the mixed dry deciduous forest

S. code	Name of the bird species	Glean	hover	Pounce	Probe	Sally
301	GREY JUNGLEFOWL	95	-	-	5	-
311	INDIAN PEAFOWL	67	-	-	33	-
560	VERNAL HANGING PARROT	100	-	-	-	-
564	MALABAR PARAKEET	100	-	-	-	-
595	BLUE-FACED MALKOHA	99	-	-	1	-
695	ASHY DRONGO	24	-	-	-	76
744	CHESTNUT-HEADED BEE-EATER	-	-	-	-	100
750	GREEN BEE-EATER	-	-	-	-	100
765	COMMON HOOPOE	74	-	-	26	-
808	STREAK-THROATED WOODPECKER	71	-	-	29	-
927	REDRUMPED SWALLOW	-	100	-	-	-
958	BLACK-HOODED ORIOLE	83	-	17	-	-
963	BLACK DRONGO	-	-	-	-	100
967	WHITE-BELLIED DRONGO	-	-	-	-	100
1010	JUNGLE MYNA	97	-	-	3	-
1100	COMMON IORA	100	-	-	-	-
1107	BLUE-WINGED LEAFBIRD	100	-	-	-	-
1120	RED-WHISKERED BULBUL	100	-	-	-	-
1128	RED-VENTED BULBUL	99	-	1	-	-
1138	WHITE-BROWED BULBUL	95	-	-	-	5
1149	BLACK BULBUL	100	-	-	-	-
1221	TAWNY-BELLIED BABBLER	100	-	-	-	-
1262	JUNGLE BABBLER	100	-	-	-	-
1267	YELLOW-BILLED BABBLER	100	-	-	-	-
1460	ASIAN PARADISE FLYCATCHER	-	-	-	-	100
1535	COMMON TAILORBIRD	100	-	-	-	-
1556	BLYTH'S REED WARBLER	100	-	-	-	-
1601	LARGE-BILLED LEAF WARBLER	100	-	-	-	-
1602	GREENISH WARBLER	100	-	-	-	-
1891	BROWN-HEADED BARBET	100	-	-	-	-
1899	PALE-BILLED FLOWERPECKER	100	-	-	-	-
1902	PLAIN FLOWERPECKER	100	-	-	-	-
1907	PURPLE-RUMPED SUNBIRD	100	-	-	-	-
1911	LOTEN'S SUNBIRD	100	-	-	-	-
1917	PURPLE SUNBIRD	100	-	-	-	-
5580	BLOSSOM-HEADED PARAKEET	100	-	-	-	-

formed 63% of gleaning. Gleaning on ground (18%) and leaf (11%) was comparatively less, while on trunk (4%) and stem (4%) it was very little.

Flower Gleaning: Six species exploited the flowers for nectar. Vernal Hanging Parrot alone used this method only for feeding. Loten's Sunbird, Purple-rumped Sunbird and Purple Sunbird used this method predominantly while Pale-Billed (Tickell's) Flowerpecker and Jungle Myna used this method frequently (Table 6.6).

Fruit Gleaning: Only Malabar Parakeet, Blossom-headed Parakeet frequently used this method along with flower gleaning. Brown-headed (Large Green) Barbet, White-browed Bulbul, Red-vented Bulbul and Red-whiskered Bulbul also used this method along with other methods.

Ground Gleaning: Yellow-billed (White-headed) Babbler, Grey Junglefowl, Jungle Babbler, Indian Peafowl and Common Hoopoe formed this guild to get their prey from ground and overlap with litter gleaning as their second predominantly used method.

Leaf Gleaning: Large-billed Leaf Warbler, Blyth's Reed Warbler and Plain Flowerpecker used this method with twig and flower gleaning.

Trunk Gleaning: Streak-throated Woodpecker alone used this type of feeding along with gleaning on stem and twig.

Stem Gleaning: Black-hooded Oriole was the only bird species, which used this method. This species also used fruit, trunk and twig as substrate for collecting food.

Table 6.6. Percent prey attack manoeuvre by Gleaners in the mixed dry deciduous forest

S. Code	Name of the bird species	Flower Gleaner	Fruit Gleaner	Ground Gleaner	Leaf Gleaner	Litter	Trunk Gleaner	Stem Gleaner	Twig Gleaner
301	GREY JUNGLEFOWL	-	-	74	3	22	-	-	-
311	INDIAN PEAFOWL	-	33	54	4	8	-	-	-
558	BLOSSOM-HEADED PARAKEET	11	89	-	-	-	-	-	-
564	MALABAR PARAKEET	2	98	-	-	-	-	-	-
566	VERNAL HANGING PARROT	100	-	-	-	-	-	-	-
595	BLUE-FACED MALKOHA	-	23	7	10	16	-	8	36
765	COMMON HOOPOE	-	-	46	-	46	4	-	4
808	STREAK-THROATED WOODPECKER	-	-	-	-	-	65	25	10
958	BLACK-HOODED ORIOLE	-	3	-	-	-	9	50	38
1010	JUNGLE MYNA	54	6	40	-	-	-	-	-
1100	COMMON IORA	-	-	-	28	-	-	-	72
1120	RED-WHISKERED BULBUL	-	70	1	1	-	-	4	24
1128	RED-VENTED BULBUL	-	71	1	4	-	-	12	12
1138	WHITE-BROWED BULBUL	1	81	2	1	-	-	-	16
1149	BLACK BULBUL	-	32	-	-	-	-	2	66
1221	TAWNY-BELLIED BABBLER	-	1	-	14	-	-	-	85
1262	JUNGLE BABBLER	-	-	55	-	26	-	2	17
1267	YELLOW-BILLED BABBLER	1	-	93	1	4	-	-	2
1535	COMMON TAILORBIRD	-	5	3	35	-	-	-	58
1556	BLYTH'S REED WARBLER	-	-	-	56	-	-	-	44
1601	LARGE-BILLED LEAF WARBLER	-	-	-	90	-	-	-	10
1602	GREENISH WARBLER	-	-	-	27	-	-	9	64
1891	BROWN-HEADED BARBET	-	87	-	6	-	-	6	-
1899	PALE-BILLED FLOWERPECKER	67	-	-	14	-	-	-	19
1902	PLAIN FLOWERPECKER	16	-	-	45	-	-	-	39
1907	PURPLE-RUMPED SUNBIRD	88	0	-	5	-	-	-	7
1911	LOTEN'S SUNBIRD	93	1	-	-	-	-	-	6
1917	PURPLE SUNBIRD	74	-	-	16	-	-	7	4

Twig Gleaning: Six species including Common Iora, Greenish Warbler, Tawnybellied Babbler, Black Bulbul, Common Tailorbird and Bluefaced Malkoha were recognized as twig gleaners (Table 6.6).

6.4.1.5. Position in the canopy

The 10 Canopy layers used by the bird species in mixed dry deciduous forest were as follows: Different canopy layers were possibly distinguished from three layers namely under canopy, middle canopy and upper canopy for 36 bird species in the mixed dry deciduous forest. The major canopy layers were further divided into 10 categories (Table 6.7), of which 6 were common namely edge edge (58%), center middle (8%), center edge (3%), middle edge (3%) ground and air (28%). Center and middle denote the central axis of the plant and the distance between the center and the edge respectively.

Five major canopy layers out of 10 were possibly distinguished for 36 bird species in the mixed dry deciduous forest. The major canopy positions were Edge edge, center middle, center edge, middle edge and the birds from this habitat used ground or air also (Table 6.7).

Ground/Air (Under/over canopy): Bird species such as Grey Junglefowl, Red-rumped Swallow, Yellow-billed Babbler, Common Hoopoe, Jungle Babbler, Indian Peafowl, Green Bee-Eater, Jungle Myna, Chestnut-Headed Bee-Eater and Blue-Faced Malkoha used this to obtain its prey. Grey Junglefowl

Table 6.7. Percent of foraging canopy layers preferred by bird species in the mixed dry deciduous forest

S. code	Name of the bird species	Ground	Centre lower	Centre middle	Centre edge	Middle lower	Middle middle	Middle edge	Lower edge	Middle edge	Edge edge
301	GREY JUNGLEFOWL	100	-	-	-	-	-	-	-	-	-
311	INDIAN PEAFOWL	77	-	-	-	-	-	-	6	6	11
558	BLOSSOM-HEADED PARAKEET	-	-	-	12	-	-	21	-	-	67
564	MALABAR PARAKEET	-	-	4	18	-	-	9	-	9	59
566	VERNAL HANGING PARROT	-	-	2	26	-	-	32	2	4	34
595	BLUE-FACED MALKOHA	24	-	20	5	-	23	5	3	7	12
695	ASHY DRONGO	18	-	-	-	-	15	3	9	21	33
744	CHESTNUT-HEADED BEE-EATER	29	-	-	25	-	-	11	5	25	5
750	GREEN BEE-EATER	71	-	-	-	-	2	-	-	-	26
765	COMMON HOOPOE	91	-	-	3	-	-	-	-	6	-
808	STREAK-THROATED WOODPECKER	-	7	75	-	-	11	-	-	7	-
927	REDRUMPED SWALLOW	100	-	-	-	-	-	-	-	-	-
958	BLACK-HOODED ORIOLE	-	2	56	2	-	27	-	2	-	10
963	BLACK DRONGO	10	1	5	4	-	3	5	8	23	40
967	WHITE-BELLIED DRONGO	11	-	1	4	-	10	17	4	29	25
1010	JUNGLE MYNA	39	-	-	7	1	8	11	-	28	6
1100	COMMON IORA	-	-	4	13	1	18	10	3	20	31
1107	BLUE-WINGED LEAFBIRD	-	-	-	1	-	3	10	-	40	46
1120	RED-WHISKERED BULBUL	1	-	7	11	1	2	19	6	13	39
1128	RED-VENTED BULBUL	2	-	4	26	-	1	10	1	9	47
1138	WHITE-BROWED BULBUL	2	-	5	17	-	10	8	1	16	40
1149	BLACK BULBUL	-	-	-	35	-	19	9	1	-	35
1221	TAWNY-BELLIED BABBLER	-	3	32	4	1	14	7	-	10	30
1262	JUNGLE BABBLER	81	2	4	-	-	10	-	-	2	1
1267	YELLOW-BILLED BABBLER	97	-	2	-	-	-	1	1	-	1
1460	ASIAN PARADISE FLYCATCHER	9	2	9	1	10	10	4	16	18	22
1535	COMMON TAILORBIRD	3	5	15	23	5	5	8	8	13	18
1556	BLYTH'S REED WARBLER	-	-	5	7	2	16	16	5	17	31
1601	LARGE-BILLED LEAF WARBLER	-	-	2	3	-	16	15	6	29	29
1602	GREENISH WARBLER	-	-	8	8	-	17	10	3	31	23
1891	BROWN-HEADED BARBET	-	-	3	19	-	10	16	3	13	35
1899	PALE-BILLED FLOWERPECKER	-	-	2	10	-	9	21	3	11	45
1902	PLAIN FLOWERPECKER	-	-	4	14	-	7	6	1	19	49
1907	PURPLE-RUMPED SUNBIRD	-	-	1	22	1	2	11	4	11	49
1911	LOTEN'S SUNBIRD	-	-	1	18	-	4	11	-	10	56
1917	PURPLE SUNBIRD	-	-	5	18	2	11	12	4	23	26

and Red-rumped Swallow depend only on these strata and the other bird species extends overlap with other layers in the canopy (Table 6.7).

Center center (lower canopy): Bird species perched on the middle main axis of the plant canopy were Streak-throated Woodpecker, Black-hooded Oriole and Tawny-bellied Babbler. They also feed on the edge edge and middle middle canopy with other locations insignificantly. No species was restricted to any particular layer alone.

Middle edge (middle canopy): Bird species feeding on the upper canopy was White-bellied Drongo which feeds on the upper and middle canopy.

Center edge (upper canopy): Birds perched on the top of the main axis for preying over the upper canopy was Common Tailorbird. This exploits food from all the strata on the canopy of the plants (Table 6.7).

Edge edge (upper canopy): Twenty-one bird species (Table 6.7) were feeding on the top edge (upper canopy) position of the plant. Asian Paradise flycatcher exploited food from available canopies. They occupy the upper and middle canopy with a few species using air/ ground.

6.4.1.6. Specialist index

Among the four dimensions, specialization (J'= 0) was more in the substrates (2) and method (2) followed by feeding canopy (1) and height (1) categories (Table 6.8). Bird species such as Grey Jungle Fowl, Indian

Table 6.8. Extent of Specialization by birds in foraging dimensions (J') and diversity (H') in the mixed dry deciduous forest

S. code	Name of the bird species	Foraging Substrate		Foraging Canopy		Foraging Method		Foraging Height	
		H'	J'	H'	J'	H'	J'	H'	J'
301	GREY JUNGLEFOWL	0.14	0.09	0.00	0.00	0.87	0.52	0.0	0.00
311	INDIAN PEAFOWL	0.66	0.45	0.78	0.37	1.49	0.89	1.5	0.56
558	BLOSSOM-HEADED PARAKEET	0.25	0.17	0.84	0.40	0.25	0.15	0.3	0.11
564	MALABAR PARAKEET	0.09	0.06	1.23	0.58	0.09	0.05	1.2	0.44
566	VERNAL HANGING PARROT	0.00	0.00	1.36	0.64	0.00	0.00	0.9	0.33
595	BLUE-FACED MALKOHA	1.48	1.00	1.86	0.88	1.67	1.00	2.3	0.85
744	CHESTNUT-HEADED BEE-EATER	0.38	0.26	1.60	0.75	1.09	0.65	2.7	1.00
750	GREEN BEE-EATER	0.52	0.35	0.68	0.32	0.69	0.41	0.7	0.26
765	COMMON HOOPOE	0.35	0.24	0.35	0.17	1.53	0.92	1.9	0.70
808	STREAK-THROATED WOODPECKER	0.26	0.18	0.83	0.39	0.37	0.22	0.3	0.11
927	REDRUMPED SWALLOW	0.00	0.00	0.00	0.00	0.00	0.00	0.6	0.22
958	BLACK-HOODED ORIOLE	0.73	0.49	1.18	0.56	1.31	0.78	1.4	0.52
963	BLACK DRONGO	0.07	0.05	1.74	0.82	1.21	0.72	2.4	0.89
965	ASHY DRONGO	0.55	0.37	1.61	0.76	1.13	0.68	1.9	0.71
967	WHITE-BELLIED DRONGO	0.10	0.06	1.77	0.83	1.24	0.74	2.1	0.78
1010	JUNGLE MYNA	0.97	0.66	1.58	0.75	0.96	0.57	1.5	0.56
1100	COMMON IORA	0.61	0.41	1.78	0.84	0.61	0.37	0.9	0.33
1107	BLUE-WINGED LEAFBIRD	1.15	0.78	1.11	0.52	1.14	0.68	1.4	0.52
1120	RED-WHISKERED BULBUL	0.81	0.55	1.74	0.82	0.81	0.49	2.2	0.81
1128	RED-VENTED BULBUL	0.95	0.64	1.44	0.68	0.97	0.58	1.8	0.67
1138	WHITE-BROWED BULBUL	0.75	0.51	1.67	0.79	0.75	0.45	0.9	0.33
1149	BLACK BULBUL	0.93	0.63	1.33	0.63	0.93	0.56	1.5	0.54
1221	TAWNY-BELLIED BABBLER	0.46	0.31	1.69	0.80	0.46	0.28	0.7	0.26
1262	JUNGLE BABBLER	0.57	0.39	0.75	0.35	1.07	0.64	0.7	0.26
1267	YELLOW-BILLED BABBLER	0.14	0.09	0.18	0.08	0.29	0.17	0.4	0.15
1460	ASIAN PARADISE FLYCATCHER	0.37	0.25	2.08	0.98	1.03	0.62	1.4	0.52
1535	COMMON TAILORBIRD	0.93	0.63	2.12	1.00	0.93	0.56	0.9	0.33
1556	BLYTH'S REED WARBLER	0.69	0.47	0.45	0.21	0.69	0.41	1.5	0.54
1601	LARGE-BILLED LEAF WARBLER	0.33	0.22	1.66	0.78	0.33	0.20	1.5	0.56
1602	GREENISH WARBLER	0.87	0.59	1.74	0.82	0.86	0.51	1.5	0.56
1891	BROWN-HEADED BARBET	0.47	0.32	1.69	0.80	0.47	0.28	2.3	0.85
1899	PALE-BILLED FLOWERPECKER	0.90	0.61	1.54	0.73	0.90	0.54	1.9	0.70
1902	PLAIN FLOWERPECKER	1.00	0.67	1.48	0.70	1.00	0.60	1.8	0.67
1907	PURPLE-RUMPED SUNBIRD	0.49	0.33	1.45	0.68	0.47	0.28	0.9	0.33
1911	LOTEN'S SUNBIRD	0.28	0.19	1.27	0.60	0.27	0.16	1.7	0.63
1917	PURPLE SUNBIRD	0.82	0.55	1.83	0.86	0.82	0.49	2.2	0.81

Peafowl, Red-rumped Swallow and Vernal Hanging Parrot are specialists as their J' values were zero or very low in two or more dimensions.

6.4.1.7. Niche overlap

Niche overlap is one of the ways of measuring the extent to which foraging activities of the various species overlap with one another. This was calculated with foraging height (12 categories), foraging manoeuvre (20 categories), canopy (10 categories) and foraging substrate (7 categories). Overlap between species was calculated for each habitat and mean overlap of each species with others is presented. The results suggested that all the bird categories in this study overlapped with others atleast in one foraging dimension (Table 6.9). Among the three dimensions (foraging height, foraging method, foraging substrate), the highest mean overlap among species was found in foraging canopy (0.82) and the lowest in foraging method (0.14).

Height: Blue-faced Malkoha and Purple-rumped Sunbird had the highest niche overlap (0.75) while lowest (0.36) was found in Yellow-billed Babbler (Table 6.9).

Method: The mean overlap in feeding method was the highest in the White-browed Bulbul (0.83) while the lowest (0.14) was found in the Red-rumped Swallow (Table 6.9).

Canopy: The highest mean overlap was found in Brown-headed Barbet (0.82) while the lowest was found in Yellow-billed Babbler (0.42).

Table 6.9. Mean niche overlap for each species in the mixed dry deciduous forest

S. code	Name of the Bird	Height	Substrate	Canopy	Method	Overall
301	GREY JUNGLEFOWL	0.38	0.42	0.43	0.82	0.41
311	INDIAN PEAFOWL	0.56	0.55	0.65	0.73	0.59
558	BLOSSOM-HEADED PARAKEET	0.54	0.51	0.73	0.82	0.59
564	MALABAR PARAKEET	0.71	0.36	0.72	0.82	0.59
566	VERNAL HANGING PARROT	0.49	0.46	0.74	0.82	0.56
595	BLUE-FACED MALKOHA	0.75	0.61	0.76	0.82	0.70
695	ASHY DRONGO	0.68	0.54	0.80	0.56	0.67
744	CHESTNUT-HEADED BEE-EATER	0.71	0.47	0.73	0.26	0.63
750	GREEN BEE-EATER	0.64	0.47	0.66	0.26	0.59
765	COMMON HOOPOE	0.53	0.52	0.58	0.75	0.54
808	STREAK-THROATED WOODPECKER	0.70	0.51	0.57	0.74	0.59
927	REDRUMPED SWALLOW	0.53	0.36	0.49	0.14	0.46
958	BLACK-HOODED ORIOLE	0.69	0.54	0.61	0.77	0.61
963	BLACK DRONGO	0.66	0.43	0.81	0.26	0.63
967	WHITE-BELLIED DRONGO	0.69	0.40	0.80	0.27	0.63
1010	JUNGLE MYNA	0.61	0.50	0.73	0.82	0.61
1100	COMMON IORA	0.73	0.45	0.78	0.82	0.65
1104	BLUE-WINGED LEAFBIRD	0.66	0.57	0.71	0.81	0.64
1120	RED-WHISKERED BULBUL	0.74	0.54	0.80	0.82	0.69
1128	RED-VENTED BULBUL	0.68	0.52	0.77	0.82	0.65
1138	WHITE-BROWED BULBUL	0.66	0.47	0.80	0.83	0.64
1149	BLACK BULBUL	0.59	0.58	0.71	0.82	0.63
1221	TAWNY-BELLIED BABBLER	0.49	0.51	0.73	0.82	0.57
1262	JUNGLE BABBLER	0.51	0.42	0.53	0.82	0.48
1267	YELLOW-BILLED BABBLER	0.36	0.35	0.42	0.82	0.38
1460	ASIAN PARADISE FLYCATCHER	0.63	0.43	0.77	0.26	0.60
1535	COMMON TAILORBIRD	0.68	0.63	0.78	0.82	0.69
1556	BLYTH'S REED WARBLER	0.66	0.51	0.79	0.82	0.65
1601	LARGE-BILLED LEAF WARBLER	0.71	0.44	0.76	0.82	0.63
1602	GREENISH WARBLER	0.69	0.51	0.77	0.82	0.65
1891	BROWN-HEADED BARBET	0.73	0.55	0.82	0.82	0.69
1899	PALE-BILLED FLOWERPECKER	0.74	0.54	0.78	0.82	0.68
1902	PLAIN FLOWERPECKER	0.70	0.59	0.79	0.82	0.69
1907	PURPLE-RUMPED SUNBIRD	0.75	0.42	0.74	0.82	0.63
1911	LOTEN'S SUNBIRD	0.70	0.46	0.76	0.82	0.64
1917	PURPLE SUNBIRD	0.72	0.54	0.80	0.82	0.68

Substrate: The highest mean overlap was found in Blue-faced Malkoha (0.61) while the lowest was found in Yellow-billed Babbler (0.35) (Table 6.9).

Overall: All the dimensions together when combined, Yellow-billed Babbler showed the lowest overlap (0.38) while Red-whiskered Bulbul and Common Tailorbird (0.69) showed the highest overlap among the 36 species (Table 6.9).

6.4.1.8. Determination of foraging guilds

The guild formed in mixed dry deciduous forest based on the use of substrates, method and height and their relationships among the 36 bird species are summarized in the cluster diagram (Figure 6.2). Species were separated into a number of distinct groups whose members exploited food resources in similar substrates, method, canopy and height. Two distinct major guilds were arbitrarily recognized from the cluster diagram (Figure 6.2) as gleaner and sallier; the gleaner was further formed of three distinct guilds based on the substrate of gleaning, namely 1. Fruit 2. Flower, 3. Ground and 4. Stem (trunk and twigs).

Guild I consisted of birds that glean their prey on fruit. Guild II consisted of birds that glean their food from the flower. The guild III consisted of birds that largely obtained their food mainly insects or other invertebrates from all strata (ground, plant and air) (Figure 6.2). Within this guild, two major groups were obvious such as purely insectivore and omnivore. This was bifurcated

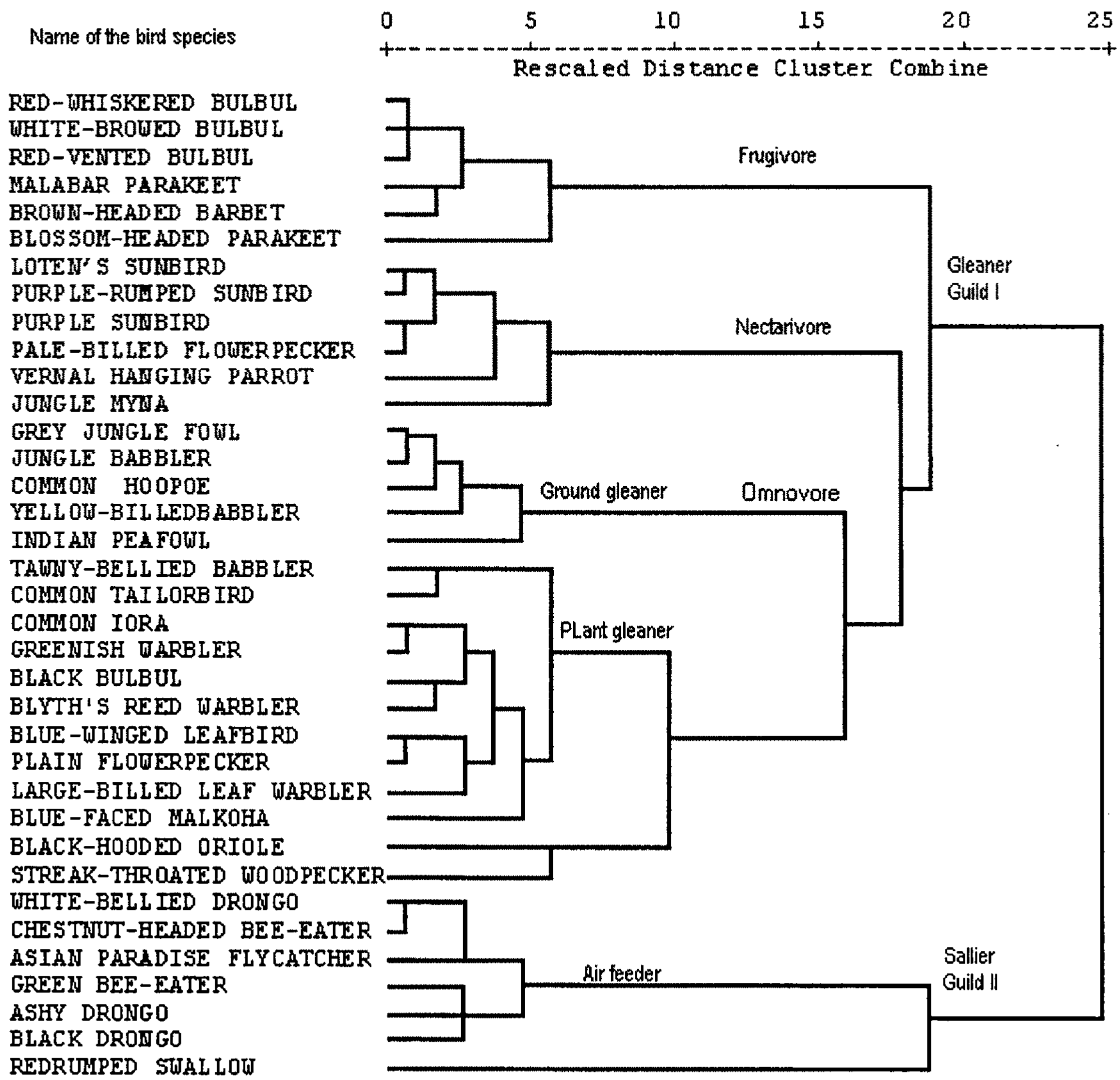


Figure 6.2. Dendrogram showing similarity among the 36 species in the use of the foraging method, substrate and height in the mixed dry deciduous forest

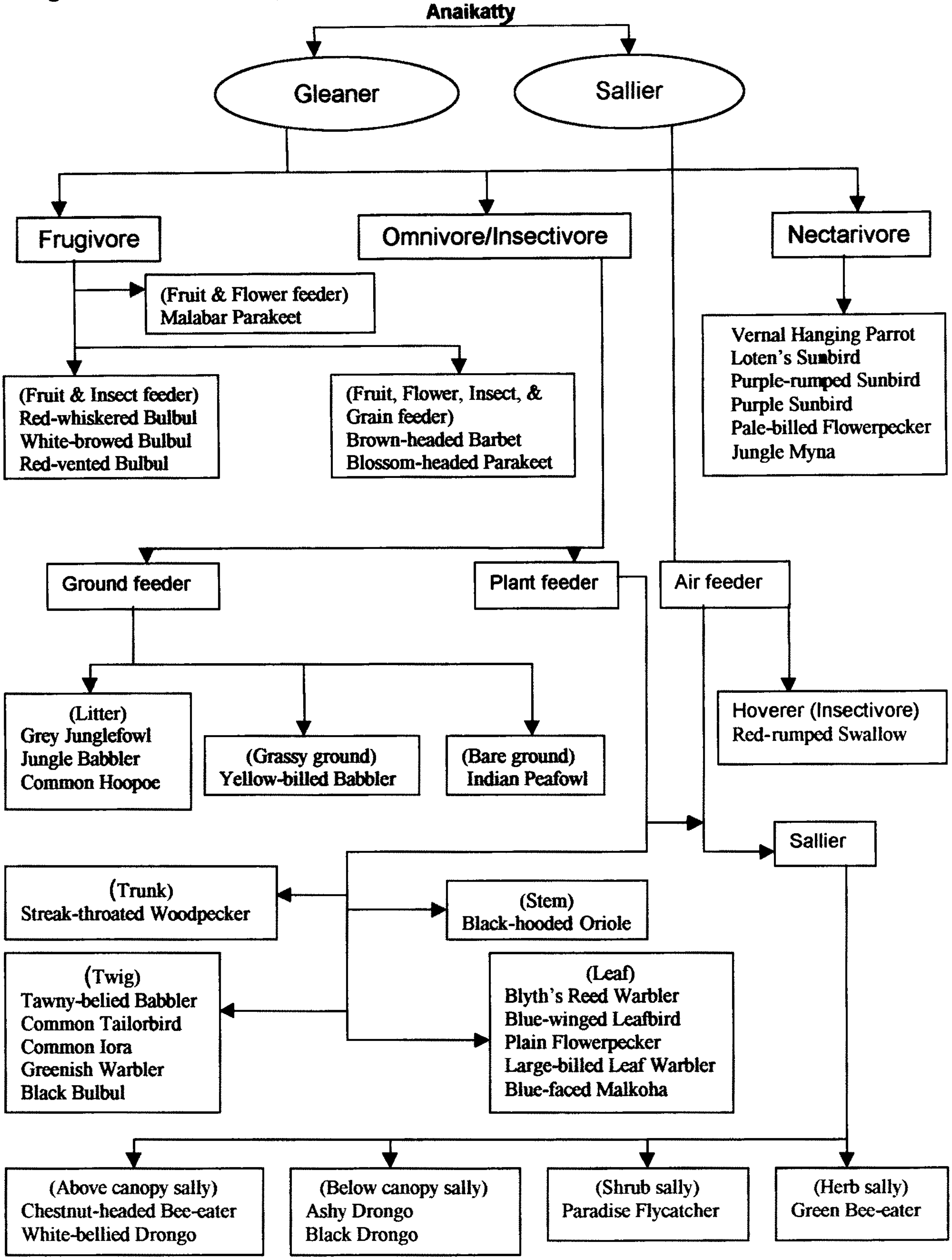
again into five groups based on the substrate: ground, twigs and leaf, main trunk and air. Based on the observational data, birds foraged in similar ways or exploited the same resources for food were grouped in a schematic representation (Figure 6.3). The schematic portrayal of the groupings relies on the foraging behavior, foraging height, and foraging substrate differences to associate species. Of the 36 species, major group was of insectivores, which comprised of 24 bird species followed by equal number of nectarivore and frugivore (6 each). Insectivores largely obtain their food from plants or from air by sally. Among the plant forms, the number of species, which obtained their food from twig and leaf, were more than the others depending on other substrates such as main trunk and secondary branches. Six bird species sallying from four different positions in the canopy were distinguished while feeding (Figure 6.3).

6.4.2. Foraging patterns of bird species in the scrub forest

6.4.2.1. Foraging height

Six height categories such as ground (0m), 0.1-1m, 1-2m, 2-3m, 3-4m and >4 were utilized by 22 bird species in the scrub forest (Table 6.10). Although most species were recorded 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 partitioned as three layers of strata; ground (0m), shrub/short trees (0.1-3), and tree layers (>3). A higher

Figure 6.3. Schematic diagram of foraging guild of birds in the mixed dry deciduous forest at Anaikatty



percentage of foraging manoeuvre were recorded in different height categories on trees. Ground supported 20% of species to forage, while 74% of the birds utilized more of the layers of shrub/short tree and only 6% used tree (>3m).

Five species foraged mainly on the ground. Among them, Laughing Dove and Yellow-billed Babbler predominantly used the ground layer while Jungle Myna showed variety in its height preference, and Common Myna and Indian Robin restricted their foraging strata from 0–1m height (Table 6.10).

The 0.1-3m-height shrub and short tree layers category was utilized by 16 species. Higher percentage of foraging manoeuvre was recorded in the shrub and short tree layer, which can be considered as lower canopy. Among these species, only the Blossom-headed Parakeet used upto 1m layer extensively. Other species such as Tawny-bellied Babbler, Common Tailorbird, Red-vented Bulbul, White-browed Bulbul, Blyth's Reed Warbler, Purple-rumped Sunbird, Baya Weaver, Chestnut-tailed Starling, Common Iora, Streak-throated Woodpecker, Indian Peafowl, Purple Sunbird, Red-whiskered Bulbul, Green Bee-eater and Yellow-eyed Babbler showed variation in their height usage.

The third layer (>3m) was used by a single bird species which foraged in air for its prey (Table 6.10). For the avian community as a whole in scrub forest, a higher percentage (73%) of foraging manoeuvre was recorded in the

Table 6.10. Height distribution of birds in the scrub forest (%)

S. code	Name of the bird species	Height in meter					
		0	0.1-1	2	3	4	>4
311	INDIAN PEAFOWL	37	63	-	-	-	-
541	LAUGHING DOVE	95	5	-	-	-	-
558	BLOSSOM-HEADED PARAKEET	-	91	7	2	-	-
750	GREEN BEE-EATER	-	38	15	3	-	44
808	STREAK-THROATED WOODPECKER	-	18	64	18	-	-
927	REDRUMPED SWALLOW	-	-	-	-	-	100
987	CHESTNUT-TAILED STARLING	-	73	27	-	-	-
1006	COMMON MYNA	66	34	-	-	-	-
1010	JUNGLE MYNA	49	10	30	5	6	1
1100	COMMON IORA	-	19	35	30	7	9
1120	RED-WHISKERED BULBUL	11	78	11	-	-	-
1128	RED-VENTED BULBUL	3	64	19	11	3	1
1138	WHITE-BROWED BULBUL	-	78	17	3	2	-
1221	TAWNY-BELLIED BABBLER	-	87	13	-	-	-
1231	YELLOW-EYED BABBLER	-	85	11	2	2	-
1267	YELLOW-BILLED BABBLER	94	6	-	-	-	-
1535	COMMON TAILORBIRD	-	84	14	3	-	-
1556	BLYTH'S REED WARBLER	-	57	39	5	-	-
1720	INDIAN ROBIN	78	22	-	-	-	-
1907	PURPLE-RUMPED SUNBIRD	3	65	11	8	11	3
1917	PURPLE SUNBIRD	-	53	44	2	-	-
1957	BAYA WEAVER	16	84	-	-	-	-

shrub/short tree layer because of the availability of more shrubs and less trees (Table 3.4).

6.4.2.2. Position in the canopy

The 10 Canopy layers were used by the bird species in scrub forest. These different canopy layers were possibly distinguished from three layers namely under canopy, middle canopy and upper canopy for 22 bird species in the scrub forest. The major canopy layers occupied were 10 (Table 6.16). Edge edge (45%), center middle (5%), center edge (5%), lower edge (5%), middle edge (9%) and ground or air (32%) were recorded from this habitat.

Six major canopy layers were possibly distinguished for 22 bird species in the scrub forest. The major canopy positions were Edge edge, center middle, center edge, lower edge, middle edge, ground and air.

Ground/Air (Under/over canopy): Bird species such as Laughing Dove, Red-rumped Swallow, Yellow-billed Babbler, Green Bee-eater, Indian Robin, Common Myna and Jungle Myna occupied this for its prey. Red-rumped Swallow depended only on air and the other bird species extended their overlap with other canopy layers (Table 6.16).

Center center (lower canopy): Bird species perched on the middle main axis of the plant canopy was Streak-throated Woodpecker. It also fed on the middle edge and center lower canopy (Table 6.16).

Table 6.16. Percent of foraging canopy preferred by bird species in the scrub forest

S. code	Name of the bird species	Ground /Air	Centre lower	Centre middle	Centre edge	Middle lower	Middle middle	Middle edge	Lower edge	Middle edge	Edge edge
311	INDIAN PEAFOWL	39	-	-	-	-	-	-	43	15	2
541	LAUGHING DOVE	97	-	-	-	-	-	-	-	3	-
558	BLOSSOM-HEADED PARAKEET	-	-	2	4	-	7	6	-	13	68
750	GREEN BEE-EATER	82	-	-	-	-	-	-	-	15	3
808	STREAK-THROATED WOODPECKER	-	7	75	-	-	-	-	-	18	-
927	REDRUMPED SWALLOW	100	-	-	-	-	-	-	-	-	-
987	CHESTNUT-TAILED STARLING	-	-	-	-	-	-	-	-	57	43
1006	COMMON MYNA	71	-	-	-	-	-	11	17	-	1
1010	JUNGLE MYNA	49	-	-	5	-	-	10	-	28	8
1100	COMMON IORA	9	-	-	7	-	17	11	6	33	17
1120	RED-WHISKERED BULBUL	25	-	-	3	-	17	6	-	3	47
1128	RED-VENTED BULBUL	7	-	1	14	-	4	19	1	17	39
1138	WHITE-BROWED BULBUL	2	-	1	11	-	3	4	3	31	44
1221	TAWNY-BELLIED BABBLER	-	11	13	2	13	9	4	4	18	27
1231	YELLOW-EYED BABBLER	-	1	9	18	-	13	8	1	19	30
1267	YELLOW-BILLED BABBLER	94	-	-	-	2	2	-	-	-	2
1535	COMMON TAILORBIRD	-	3	5	14	-	14	5	19	19	22
1556	BLYTH'S REED WARBLER	-	5	11	11	2	18	7	2	20	23
1720	INDIAN ROBIN	78	2	2	-	2	10	-	3	3	-
1907	PURPLE-RUMPED SUNBIRD	3	-	-	11	-	1	11	-	14	61
1917	PURPLE SUNBIRD	-	-	-	13	-	2	9	-	7	69
1957	BAYA WEAVER	16	-	-	22	-	3	22	-	16	22

Center edge (upper canopy): Bird species perched on the top of the main axis for feeding over the upper and middle canopy was Baya Weaver. This exploited food from the ground/ air (above canopy) also (Table 6.16).

Lower edge (lower canopy): Bird species feeding on the upper canopy was Indian Peafowl, which fed on the ground and upper canopy of herbs being on the ground.

Middle edge (upper canopy): Common Iora and Chestnut-tailed Starling were occupying the upper canopy for their prey (Table 6.16).

Edge edge (upper canopy): Blyth's Reed Warbler, White-browed Bulbul, Common Tailorbird, Yellow-eyed Babbler, Blossom-headed Parakeet, Purple-rumped Sunbird, Purple Sunbird, Tawny-bellied Babbler, Red-whiskered Bulbul, Red-vented Bulbul were feeding on the top edge position of the plant. They occupied the upper and middle canopy with four species extended to the air/ ground (Table 6.16).

6.4.2.3. Foraging substrate

Seven substrates such as ground, trunk and main branches, twigs, foliage, flower, fruit and air were recognized in the scrub forest. More number of bird species (6) used fruit (27%), whereas only a single species (5%) used trunk/main branch (Table 6.11). Birds shared equal percent of flower and twigs (14%), while air and foliage were used by two species each (Table 6.11). Ground was shared by 24% of bird species.

Table 6.11. Percent use of substrate by birds in the scrub forest

S. code	Name of the species	Ground	Trunk	Foliage	Twigs	Flower	Fruit	Air
311	INDIAN PEAFOWL	37	0	0	0	0	63	0
541	LAUGHING DOVE	97	0	0	0	0	3	0
558	BLOSSOM-HEADED PARAKEET	0	0	0	0	3	97	0
750	GREEN BEE-EATER	0	0	3	0	0	0	97
808	STREAK-THROATED WOODPECKER	0	100	0	0	0	0	0
927	REDRUMPED SWALLOW	0	0	0	0	0	0	100
987	CHESTNUT-TAILED STARLING	0	0	0	0	0	100	0
1006	COMMON MYNA	67	0	0	0	1	28	4
1010	JUNGLE MYNA	47	0	8	0	34	12	0
1100	COMMON IORA	0	2	24	65	0	0	9
1120	RED-WHISKERED BULBUL	11	0	0	0	0	75	14
1128	RED-VENTED BULBUL	3	0	1	0	3	90	4
1138	WHITE-BROWED BULBUL	0	0	0	0	1	97	2
1221	TAWNY-BELLIED BABBLER	0	0	15	85	0	0	0
1231	YELLOW-EYED BABBLER	0	0	34	65	0	1	0
1267	YELLOW-BILLED BABBLER	94	0	2	4	0	0	0
1535	COMMON TAILORBIRD	0	5	65	30	0	0	0
1556	BLYTH'S REED WARBLER	0	0	68	27	0	5	0
1720	INDIAN ROBIN	78	0	22	0	0	0	0
1907	PURPLE-RUMPED SUNBIRD	3	0	9	0	88	0	0
1917	PURPLE SUNBIRD	0	0	2	2	96	0	0
1957	BAYA WEAVER	14	0	0	0	68	19	0

Ground: The ground-foraging guild was with five species as explained under the strata (Table 6.11).

Trunk: Streak-throated Woodpecker absolutely obtained their prey from the trunk as they are able to walk along the branches searching for food.

Foliage: Two bird species such as Blyth's Reed Warbler and Common Tailorbird formed this guild and predominantly used this substrate. Twigs were the second dominant substrate used by the members of this guild.

Twigs: This guild was formed of three species namely, Tawny-bellied Babbler, Yellow-eyed Babbler and Common Iora. All these species did not use this substrate absolutely. Foliage was the second dominant substrate used by them.

Flower: This guild was also formed of three species (Table 6.11), which exploited this substrate predominantly and extended their foraging ground to other substrates also.

Fruit: Six bird species formed this guild, of which Chestnut-headed Starling was restricted to this substrate. Blossom-headed Parakeet, White-browed Bulbul and Red-vented Bulbul used this predominantly while other species such as Red-whiskered Bulbul and Indian Peafowl used this substrate along with other substrates for their prey.

Air: Two species formed this guild, Red-rumped Swallow obtained its prey absolutely from air. Green Bee-eater predominantly used air for its prey and in addition, they also used foliage to a less extent.

6.4.2.4. Foraging methods

Only three major techniques were possibly used from the five major prey attack manoeuvre, while six out of 20 minor techniques were distinguished from the major classified foraging manoeuvre for 22 bird species in the scrub forest. The major prey attack manoeuvre such as sallying, pouncing, gleaning, hovering and probing (Table 6.12). Gleaner (93%), sallier (4%), prober, pouncer (1%) and hoverer (2%) were recorded from this habitat.

Gleaning: Twenty-six species were recorded as gleaner (Table 6.12), of which 18 species used only (100%) this method.

Sallying: Green Bee-eater used absolutely this method to obtain its prey and did not use any other method.

Hovering: Red-rumped Swallow was recognized as hoverer and it absolutely used this method as a prey attacking manoeuvre (Table 6.12).

6.4.2.5. Prey attack manoeuvre by gleaner

In total, the 93% of the gleaner was classified further into seven category based on the records of foraging. The number of bird species forming the gleaning of fruit (40%) was more followed by the gleaning of ground (23%), flower (14%), twig (12%), and leaf (9%). Trunk and stem was used in insignificant number (1%).

Table 6.12. Percent prey attack manoeuvres by birds in the scrub forest

S. code	Name of the bird species	Gleaner	Hoverer	Pouncer	Prober	Sallier
255	JUNGLE BUSH QUAIL	100	-	-	-	-
311	INDIAN PEAFOWL	100	-	-	-	-
537	SPOTTED DOVE	100	-	-	-	-
541	LAUGHING DOVE	100	-	-	-	-
558	BLOSSOM-HEADED PARAKEET	100	-	-	-	-
750	GREEN BEE-EATER	-	-	-	-	100
808	STREAK-THROATED WOODPECKER	96	-	-	4	-
847	YELLOW-CROWNED WOODPECKER	100	-	-	-	-
927	REDRUMPED SWALLOW	-	100	-	-	-
987	CHESTNUT-TAILED STARLING	100	-	-	-	-
1006	COMMON MYNA	96	-	-	-	4
1010	JUNGLE MYNA	98	-	-	-	2
1100	COMMON IORA	91	-	-	-	9
1120	RED-WHISKERED BULBUL	86	-	-	-	14
1128	RED-VENTED BULBUL	96	-	-	-	4
1138	WHITE-BROWED BULBUL	98	-	-	-	2
1221	TAWNY-BELLIED BABBLER	100	-	-	-	-
1231	YELLOW-EYED BABBLER	100	-	-	-	-
1267	YELLOW-BILLED BABBLER	100	-	-	-	-
1535	COMMON TAILORBIRD	100	-	-	-	-
1556	BLYTH'S REED WARBLER	100	-	-	-	-
1720	INDIAN ROBIN	73	-	27	-	-
1891	WHITE-BROWED WAGTAIL	100	-	-	-	-
1907	PURPLE-RUMPED SUNBIRD	100	-	-	-	-
1917	PURPLE SUNBIRD	100	-	-	-	-
1938	HOUSE SPARROW	100	-	-	-	-
1957	BAYA WEAVER	100	-	-	-	-
2011	COMMON ROSEFINCH	100	-	-	-	-

Flower Gleaning: Three species exploited flowers for nectar. Purple-rumped Sunbird and Purple Sunbird used this method predominantly (Table 6.13) while the Rosefinch fed on the flower-heads.

Fruit Gleaning: Chestnut-tailed Starling used this method absolutely. Only Blossom-headed Parakeet, Red-vented Bulbul and White-browed Bulbul frequently used this method along with flower-gleaning. Red-whiskered Bulbul and Spotted Dove used this method along with other methods.

Ground Gleaning: Yellow-billed Babbler, Indian Robin, Jungle Myna, Common Myna and Laughing Dove formed this guild taking their prey from ground. The Indian Robin gleaned also from branches.

Leaf Gleaning: Blyth's Reed Warbler and Common Tailorbird used this method with twig, stem and fruit gleaning.

Trunk Gleaning: Streak-throated Woodpecker alone used this type of feeding along with stem-gleaning.

Twig Gleaning: Six species including Common Iora, Tawny-bellied Babbler, and Yellow-eyed Babbler were recognized as twig-gleaners (Table 6.13).

6.4.2.6. Specialist index

Among the four foraging dimensions (Table 6.14), specialization (J' = 0) was more in the vertical strata (height) (6) followed by substrate (3) and method (2) and position in the canopy (1) categories (Table 6.14). Bird

Table 6.13. Percent prey attack manoeuvre by gleaners in the scrub forest

S. code	Name of the bird species	Gleaner						
		Flower	Fruit	Ground	Leaf	Trunk	Stem	Twig
1957	BAYA WEAVER	68	19	14	-	-	-	-
1907	PURPLE-RUMPED SUNBIRD	88	-	3	9	-	-	-
1917	PURPLE SUNBIRD	96	-	-	2	-	-	2
2011	COMMON ROSEFINCH	100	-	-	-	-	-	-
558	BLOSSOM-HEADED PARAKEET	3	97	-	-	-	-	-
987	CHESTNUT-TAILED STARLING	-	100	-	-	-	-	-
1138	WHITE-BROWED BULBUL	1	99	-	-	-	-	-
1128	RED-VENTED BULBUL	3	94	3	1	-	-	-
1120	RED-WHISKERED BULBUL	-	87	13	-	-	-	-
311	INDIAN PEAFOWL	-	63	37	-	-	-	-
537	SPOTTED DOVE	-	62	38	-	-	-	-
1938	HOUSE SPARROW	12	46	42	-	-	-	-
255	JUNGLE BUSH QUAIL	-	-	100	-	-	-	-
1891	WHITE-BROWED WAGTAIL	-	-	100	-	-	-	-
1267	YELLOW-BILLED BABBLER	-	-	94	2	-	-	4
541	LAUGHING DOVE	-	3	97	-	-	-	-
1720	INDIAN ROBIN	-	-	72	28	-	-	-
1006	COMMON MYNA	1	29	70	-	-	-	-
1010	JUNGLE MYNA	34	12	48	6	-	-	-
1556	BLYTH'S REED WARBLER	-	5	-	68	-	-	27
1535	COMMON TAILORBIRD	-	-	-	65	-	5	30
808	STREAK-THROATED WOODPECKER	-	-	-	-	70	30	-
847	YELLOW-CROWNED WOODPECKER	-	-	-	-	50	50	-
1221	TAWNY-BELLIED BABBLER	-	-	-	15	-	-	85
1100	COMMON IORA	-	-	-	27	-	2	71
1231	YELLOW-EYED BABBLER	-	1	-	34	-	-	65

Table 6.14 Extent of specialization by birds foraging dimension (J') and diversity (H') in the scrub forest

S. code	Name of the bird species	Foraging Substrate		Foraging Canopy		Foraging Method		Foraging Height	
		H'	J'	H'	J'	H'	J'	H'	J'
311	INDIAN PEAFOWL	0.66	0.56	1.10	0.56	0.66	0.52	0.00	0.00
541	LAUGHING DOVE	0.12	0.10	0.12	0.06	0.42	0.33	0.00	0.00
558	BLOSSOM-HEADED PARAKEET	0.14	0.12	1.08	0.55	0.14	0.11	0.35	0.10
750	GREEN BEE-EATER	0.12	0.10	0.54	0.28	0.75	0.59	1.10	0.30
808	STREAK-THROATED WOODPECKER	0.00	0.00	0.71	0.36	0.00	0.00	0.90	0.25
927	REDRUMPED SWALLOW	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.08
987	CHESTNUT-TAILED STARLING	0.00	0.00	0.68	0.35	0.00	0.00	0.58	0.16
1006	COMMON MYNA	0.80	0.68	0.83	0.42	0.80	0.63	0.00	0.00
1010	JUNGLE MYNA	1.17	1.00	1.29	0.66	1.27	0.99	1.01	0.28
1100	COMMON IORA	0.92	0.79	1.78	0.91	0.92	0.72	1.50	0.41
1120	RED-WHISKERED BULBUL	0.73	0.62	1.36	0.69	1.13	0.88	0.30	0.08
1128	RED-VENTED BULBUL	0.45	0.38	1.63	0.83	0.45	0.35	0.90	0.25
1138	WHITE-BROWED BULBUL	0.14	0.12	1.45	0.74	0.28	0.22	0.70	0.19
1221	TAWNY-BELLIED BABBLER	0.42	0.36	1.96	1.00	0.42	0.33	3.63	1.00
1231	YELLOW-EYED BABBLER	0.69	0.59	1.77	0.90	1.14	0.89	0.50	0.14
1267	YELLOW-BILLED BABBLER	0.27	0.23	0.30	0.15	0.27	0.21	0.00	0.00
1535	COMMON TAILORBIRD	0.80	0.68	1.92	0.98	1.13	0.88	0.50	0.14
1556	BLYTH'S REED WARBLER	0.76	0.65	1.96	1.00	0.76	0.59	0.83	0.23
1720	INDIAN ROBIN	0.53	0.45	0.86	0.44	0.53	0.41	0.00	0.00
1907	PURPLE-RUMPED SUNBIRD	0.44	0.38	1.21	0.62	0.50	0.39	1.07	0.29
1917	PURPLE SUNBIRD	0.21	0.18	1.01	0.52	0.21	0.16	0.78	0.21
1957	BAYA WEAVER	0.85	0.73	1.68	0.86	0.85	0.66	0.00	0.00

species such as Chestnut-tailed Starling, Streak-throated Woodpecker and Red-rumped Swallow are specialists as their J' value is '0' in two or three foraging dimensions, the last one was highly specialized with '0' J values in foraging substrates, position in the canopy and foraging method.

6.4.2.7. Niche overlap

Niche overlap was calculated with foraging height (12 categories), foraging manoeuvres (18 categories), foraging canopy (10 categories) and foraging substrate (7 categories) (Table 6.15). Overlap between species was calculated for each habitat and mean overlap of each species with others was presented. The results suggested that all the bird categories in this study overlapped with others in atleast one foraging dimension (Table 6.15). Among the four dimensions (foraging height, foraging canopy, foraging method, foraging substrate), the highest mean overlap among species was found in foraging height (0.82) and the lowest in foraging method (0.15).

Height: Red-whiskered Bulbul had the highest niche overlap (0.82) while lowest (0.32) was found in the Red-rumped Swallow (Table 6.15).

Method: The mean overlap in feeding method was the highest in the Jungle Myna, Red-vented Bulbul and White-browed Bulbul (0.91) while the lowest was found in the Red-rumped Swallow (0.15).

Table 6.15. Mean niche overlap for each species in the scrub forest

S. code	Name of the Bird	Height	Substrate	Canopy	Method	Overall
311	INDIAN PEAFOWL	0.77	0.59	0.66	0.90	0.67
541	LAUGHING DOVE	0.52	0.51	0.63	0.90	0.55
558	BLOSSOM-HEADED PARAKEET	0.74	0.47	0.67	0.90	0.62
750	GREEN BEE-EATER	0.70	0.36	0.69	0.18	0.55
808	STREAK-THROATED WOODPECKER	0.68	0.39	0.54	0.90	0.53
927	REDRUMPED SWALLOW	0.32	0.40	0.61	0.15	0.45
987	CHESTNUT-TAILED STARLING	0.80	0.54	0.69	0.90	0.67
1006	COMMON MYNA	0.67	0.55	0.60	0.86	0.60
1010	JUNGLE MYNA	0.69	0.57	0.74	0.91	0.66
1100	COMMON IORA	0.67	0.49	0.78	0.90	0.64
1120	RED-WHISKERED BULBUL	0.82	0.55	0.77	0.89	0.70
1128	RED-VENTED BULBUL	0.80	0.50	0.76	0.91	0.68
1138	WHITE-BROWED BULBUL	0.77	0.46	0.73	0.91	0.65
1221	TAWNY-BELLIED BABBLER	0.78	0.44	0.71	0.90	0.63
1231	YELLOW-EYED BABBLER	0.76	0.43	0.72	0.90	0.62
1267	YELLOW-BILLED BABBLER	0.52	0.50	0.62	0.90	0.55
1535	COMMON TAILORBIRD	0.80	0.51	0.74	0.90	0.67
1556	BLYTH'S REED WARBLER	0.79	0.51	0.74	0.90	0.67
1720	INDIAN ROBIN	0.63	0.51	0.65	0.81	0.59
1907	PURPLE-RUMPED SUNBIRD	0.80	0.44	0.72	0.90	0.64
1917	PURPLE SUNBIRD	0.77	0.44	0.70	0.90	0.63
1957	BAYA WEAVER	0.79	0.57	0.78	0.90	0.70

Canopy: The highest mean overlap was found in the Baya Weaver which differed in their food (Nirmala and Rajasekaran 2001) and Common Iora (0.78) while the lowest was found in Streak-throated Woodpecker (0.54).

Substrate: The highest mean overlap was found in the Indian Peafowl (0.59) while the lowest was found in the Green Bee-eater (0.36) (Table 6.15).

Overall: All the dimensions together when combined, Red-rumped Swallow showed the lowest overlap (0.45) while the Red-whiskered Bulbul and Baya Weaver (0.70) showed the highest overlap among the 22 species in the scrub forest (Table 6.15).

6.4.2.8. Determination of foraging guilds

The guild formed in scrub forest based on the use of substrates, method and height and their relationships among the 22 bird species are summarized in the cluster diagram (Figure 6.4). Species were separated into a number of distinct groups whose members exploit food resources from similar substrates, methods, position in the canopy and vertical strata or height and considered as guilds. Two distinct major guilds were recognized from the cluster diagram (Figure 6.4) as gleaner and sallier. The salliers were only two species feeding from air on insects. The gleaner was formed of five distinct guilds based on the substrate, namely 1) fruit, 2) flower, 3) stem (trunk and twig), and 4) ground.

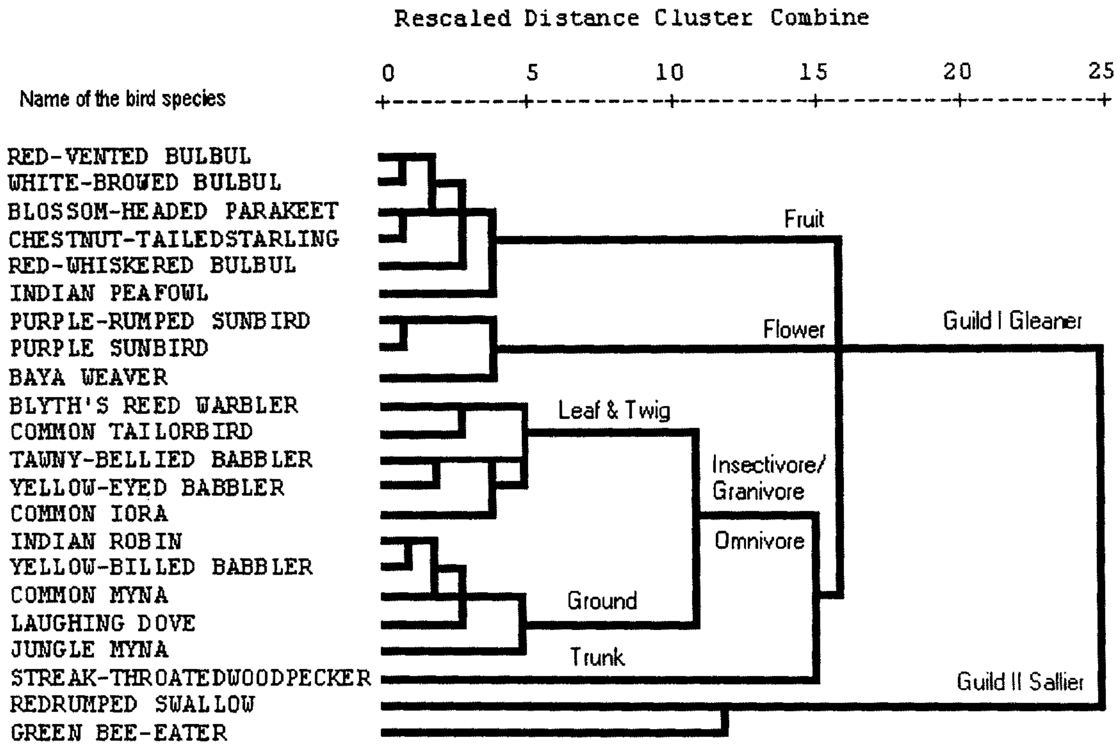


Figure 6.4. Dendrogram showing similarity among 22 bird species in the use of foraging method, substrate and height in the scrub forest

Guild I consisted of six birds that glean their prey on fruit (Figure 6.5). Guild II consisted of three birds that glean their prey from the flower, guild III consisted of 13 bird species that largely obtained their food mainly from leaf and twig, guild IV had one species feeding from the trunk of trees and guild V had five species feeding on ground.

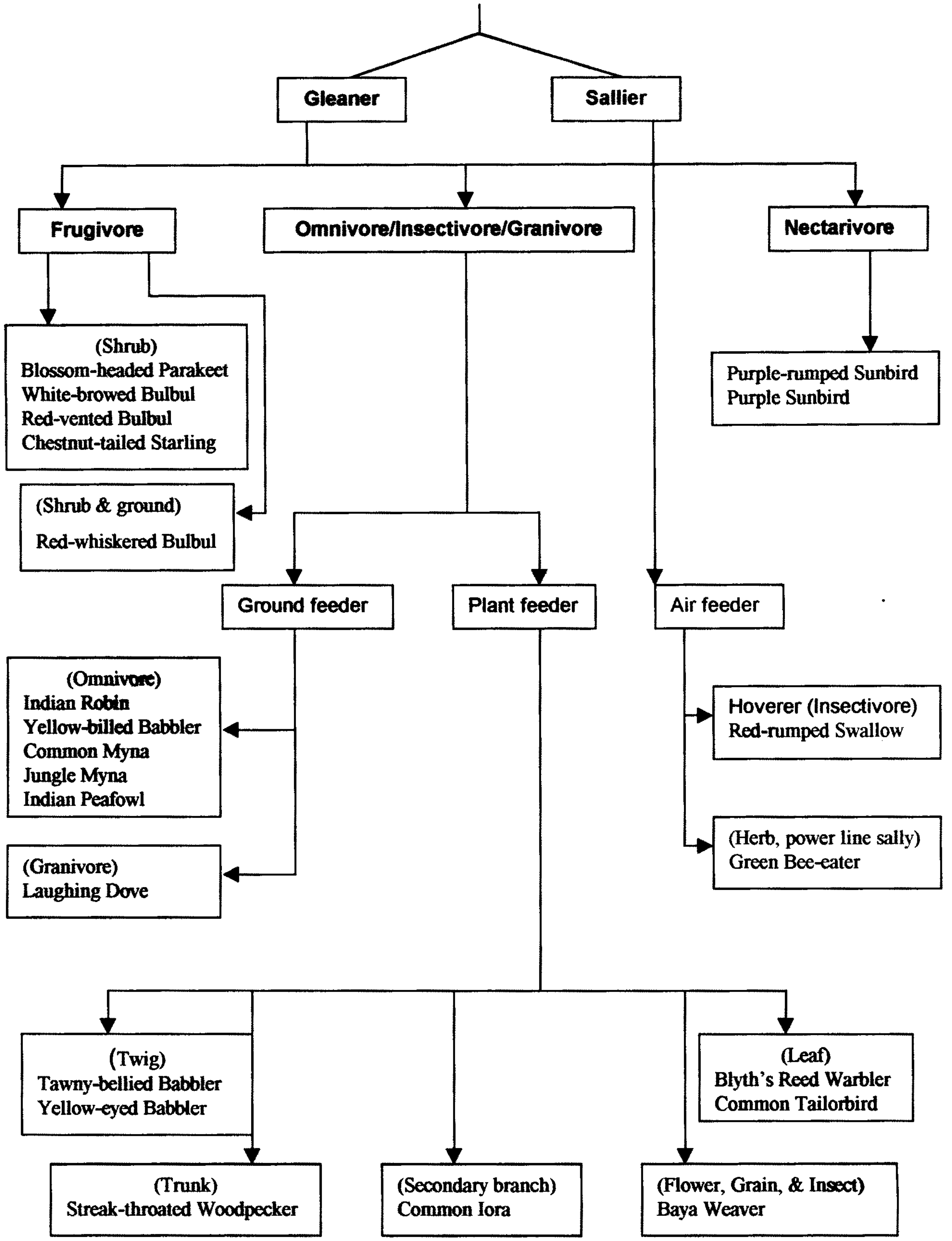
Based on the observational data, birds foraged in similar ways or exploited the same resources for food were grouped - in a schematic representation (Figure 6.5). The schematic portrayal of the groupings relied on the differences in foraging method, foraging height, and foraging substrate to associate species. Of the 22 species, major group was insectivores, which was composed of 13 bird species followed by frugivore (6) and nectarivore (3). Insectivores largely obtained their food from plant forms followed by ground and air. Among the plant forms, the number of species, which obtained their food from twig and leaf, were more than those feeding from the main trunk (1) and secondary branches. Ground feeder includes the Laughing Dove, the only representative of granivore seen in this guild (Figure 6.5).

6.4.3. Comparison of foraging patterns of birds in the mixed dry deciduous and scrub forests

6.4.3.1. Foraging height

The number of height classes used by the birds was more in the mixed dry deciduous forest (Table 6.3 and 6.10). In the mixed dry deciduous forest

Figure 6.5. Schematic diagram of foraging guild of birds in the scrub forest at Anaikatty



higher percentage of foraging were recorded in the tree layers (>3m height), whereas in the scrub forest the shrub layer accounted for more bird species (Table 6.3 and 6.10). This is because of the higher foliage strata in the mixed dry deciduous forest and more foliage cover in the upper strata.

6.4.3.2. Foraging position in the canopy

Common Tailorbird and Tawny-bellied Babbler had changed their major canopy from center layer (middle canopy) in the mixed dry deciduous forest to the edge (upper canopy) layer in the scrub forest (Tables 6.7 and 6.16).

6.4.3.3. Foraging substrate

Seven substrates were recognized in both the habitats but the number of bird species varied in using the substrates (Tables 6.4 and 6.11). In mixed dry deciduous forest five species utilized foliage and twigs while there were only two and three species each which used foliage and twigs respectively in scrub forest. Specieswise variations will be discussed later

6.4.3.4. Foraging method

Red-vented Bulbul and Red-whiskered Bulbul used sally as their secondary prey attack manoeuvre (Tables 6.5 and 6.12) along with gleaning only in the scrub forest when termites were sallied by more than 5 bird species during northeast monsoon. Common Iora (9%) and Jungle Myna (2%) sally for prey in scrub forest followed by gleaning (Tables 6.5 and 6.12) while Common Iora glean (100%) to get prey and jungle Myna adopted gleaning (96%) followed by probing (4%). All the other species showed similar method in both the habitats (Tables 6.5 and 6.12).

6.4.3.5. Niche overlap **and** *J′ index*

The mean overlap in the foraging dimensions showed highest overlap in the position in the canopy in mixed dry deciduous forest and height or vertical strata in the scrub forest (Tables 6.4 and 6.11). Specialists were found more in the method of feeding and substrate used and less in the height (Tables 6.8 and 6.14).

6.4.4. Foraging behavior of a few groups or species of birds

Although foraging ecology of most of the birds were documented in India by Ali and Ripley (1987), they described only the major foraging method such as glean, hawk, and pounce. Hence, foraging dimensions such as method, substrate, canopy and height of 16 species from 10 families were taken for species comparison between the two habitats (Table 6.2). As method is substrate-dependent, substrate is not dealt separately. Niche overlap between species in all the four dimensions, foraging height, foraging substrate, foraging canopy and foraging method together is considered for all the bird species from each habitat (Appendix 4).

6.4.4.1. Picidae

A single species namely Streak-throated Woodpecker was studied from this family. Gleaning was invariably used in both the habitats. No significant difference was found in the use of method between the habitats. The trunk and stem were largely used as substrate in both the habitats but in mixed dry deciduous forest (MDDF) alone twig-gleaning was employed as reported by Thiyagesan (1991), Yamagishi and Eguchi (1996). Here, this species used only gleaning and not excavating for prey. Excavating is an energy-consuming 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. Such a similar report was given by Santharam (1995) but differed from the result of probing (Ali and Ripley 1987, Thiyagesan 1991 and Gokula 1998). The use of height classes varied significantly between habitats; in the scrub forest (SF) it was from the ground to 3m whereas in mixed dry deciduousit was from 1-8m and the ground was not used (Table 6.17). This was because of the availability of trees here whereas in the scrub forest only smaller (shorter) trees and shrubs were there. This was the same reason for use of twig which were stronger and more in the MDDF. This species showed highest overlap with the Black-hooded Oriole (0.8) in MDDF and Common Iora in SF (0.95) (Appendix 4).

Table 6.17. Percent use of foraging method and height by Streak-throated Woodpecker in mixed dry deciduous (MDDF) and scrub forests (SF)

STREAK-THROATED WOODPECKER									
Habitat	Method			Height class					
	TRG	S G	T G	0.1-1	1-2	2-3	3-4	5-6	7-8
MDDF	65	25	10	0	7	21	57	11	4
SF	70	30	0	18	64	18	0	0	0

TRG-Trunk Glean, ST-Stem Glean, TG-Twig Glean

6.4.4.2. Psittacidae

Blossom-Headed Parakeet, Malabar Parakeet and Vernal Hanging Parrot were studied in this family. All these bird species used gleaning (Table 5and 12) to obtain their food. Vernal Hanging Parrot gleaned 100% on flowers reported by Ali and Ripley (1987) and Gokula (1998) while Malabar Parakeet gleaned on fruits as major food (98%) and 2% flowers (Table 6). Substrate used by the Vernal Hanging Parrot was flower for nectar (Table 4), while the other two birds used fruit and less of flowers (Table 4 and 11). The height at which Malabar Parakeet fed varied from 0.1 to >10 but Vernal Hanging Parrot restricted its height from 3 to 10m (Table 3 and 10). When all the dimensions combined, the Vernal Hanging Parrot had the highest overlap with the Ashy Drongo (0.69) and, Malabar Parakeet with Red-whiskered Bulbul and White-browed Bulbul (0.85) (Appendix 4). Similar result in height and method was reported by Gokula *et al.* (1999).

Blossom-headed Parakeet: This species used gleaning (Table 6.5 and 6.12) to obtain food. It gleaned predominantly fruit than flower in both the habitats (Table 6.18). Gleaning was invariably used in both the habitats which was because of the difference in the structure of the habitat as discussed earlier. It exploited food from the ground to 3m in scrub forest whereas in mixed dry deciduous the height classes were from 0 to >10m, but predominantly used 0-1m height (Table 6.18). Significant difference was found in the use of height between the habitats (r=0.989, p=0.001). Fruit was used as the major substrate (89% and 97%) and flower as a secondary substrate (11% and 3%) in the mixed dry deciduous forest and scrub forest respectively (Table 4 and 11), unlike in the study of Gokula *et al.* (1999) where it fed on flowers followed by leaves and fruits in a moist deciduous forest. This species showed highest overlap with Tawny-bellied Babbler and Yellow-eyed Babbler (0.99) in SF and Red-vented Bulbul (0.91) in MDDF and lowest (0.27) overlap with Yellow-billed Babbler in MDDF (0.27) and SF (0.28). Although the overlap in various dimensions was high for a few species they might have been feeding on an abundant resource (mainly fruits) and at different times thereby reducing actual overlap or competition. The low overlap with the Yellow-billed Babbler is because of those that differ in their resource use as discussed under strata and substrate.

Table 6.18. Percent use of foraging method and height by Blossom-headed Parakeet in mixed dry deciduous (MDDF) and scrub forests (SF)

BLOSSOM-HEADED PARAKEET							
Habitat	**Method**		**Height class**				
	Flower Glean	**Fruit Glean**	**0.1-1**	**1-2**	**2-3**	**9-10**	**>10**
MDDF	11	89	88	-	-	2	9
SF	3	97	91	7	2	-	-

6.4.4.3. Ploceidae

Baya Weaver was recorded from scrub forest alone and this is the only species studied from Ploceidae. The method of feeding used was invariably gleaning (Table 6.12) on the substrate flower (68%) and fruit (19%) from herbs and shrubs and search on ground (Table 6.13) for termites while breeding. Although it is a granivore (Ali 1979, 1980), it is an omnivores as it was obviously recorded feeding on insects, flowers, fruits and seeds during breeding season (Mathew 1976, Mathew *et al.* 1980). Its height preference was between 0 and 1m (Table 6.10). Canopy extended over the upper and middle layer and ground 16% of use (Table 6.16). It overlapped much with Indian Peafowl and Red-whiskered Bulbul (0.97) in the scrub forest.

6.4.4.4. Phasianidae

Two species were studied from this family. The Grey Junglefowl was recorded here only from the mixed dry deciduous forest (Table 6.5) largely gleaning (95%) and probing (5%) to get prey. The substrate used was predominantly ground (97%) as in Mudumalai (Gokula 1998) and less usage of foliage was observed (Table 6.4). The high percent prey attack manoeuvre was by gleaning and predominantly on ground and to a less extent on leaf and litter (Table 6.6). High overlap was observed with Yellow-billed Babbler (0.97). It was an omnivore here as viewed by Ali and Ripley (1987) and not granivore as found by Gokula (1998) in the thorn and dry deciduous forests in Mudumalai.

<u>Indian Peafowl:</u> It used gleaning and probing as its method of feeding in MDDF (Table 6.5) and only gleaning in SF (Table 6.12). Being an omnivore (Giest 1977) it fed on grains from the herbs and shrubs directly in SF and not from the litter. This may probably be because of the litter availability in MDDF, which was not noticed in SF, as it was a degraded area without much litter. It gleaned here predominantly on the ground (54%) and foliage (Table 6.19). Yasmin and Yahya (1998) commented about its feeding as, 'pecks faster' which is similar to the gleaning mentioned in this study. The percent prey attack manoeuvre was gleaning, predominantly on ground followed by fruit, litter and leaf (Table 6.6 and 6.19) in MDDF and fruit and ground in SF (Table 6.13 and 6.19). High overlap was observed with Baya Weaver (0.97) in SF and Common Hoopoe (0.92) in MDDF (Appendix 4). The feeding height was restricted mainly to the ground in MDDF but in the scrub forest it was more upto 1m above ground (Table 6.19). It fed on the seeds and fruits at the edge (Table 6.7 and 6.16) of the herbs and also from grass.

Table 6.19. Percent use of foraging method and height by Indian Peafowl in mixed dry deciduous (MDDF) and scrub forests (SF)

INDIAN PEAFOWL						
Habitats	Method				Height class	
	Fruit Glean	Ground Glean	Leaf Glean	Litter	Ground	0.1-1
MDDF	33	54	4	8	77	23
SF	63	37	0	0	37	63

6.4.4.5. Pycnonotidae

Four species of Bulbuls were studied from this family. Black Bulbul was observed only in MDDF during the non-breeding season mostly moving down locally. This species used the method of gleaning 100% for its prey (Table 6.5). It gleaned on fruit and insects from twig and stem (Table 6.6). The substrate used by it were predominantly foliage followed by twig, fruit and trunk (Table 4). The height class used was 2-10m (Table 6.3) and canopy of upper and middle layers (Table 6.7). This species highly overlapped with Common lora (0.88). Although a frugivore (Ali and Ripley 1987, Vijayan 1975), it also fed on insects and flowers (Narang *et al.* 2000).

Red-Vented, Red-Whiskered *and* White-Browed Bulbuls: These three species of Bulbuls were recorded from both the habitats. Red-whiskered Bulbul gleaned 100% while Red-vented Bulbul predominantly gleaned fruit (99%) and pounced to trap insects (1%) in MDDF (Table 6.5). In SF, Red-vented and Red-whiskered Bulbuls used gleaning predominantly and to a less extent sally (Table 6.20) to catch termites. Percent prey attack manoeuvre of White-browed Bulbul showed largely gleaning (98% and 95%) and sally to a less extent (2% and 5%) in SF and MDDF respectively (Table 6.20). Fruits and insects were exploited using five methods (Table 6.20) by these three Bulbul species in MDDF. In SF fruits were predominantly used by all the three species, followed by flower, ground and leaf-gleaning in Red-vented Bulbul. Red-whiskered Bulbul used gleaning of ground followed by fruit and White-browed Bulbul gleaning of flower (Table 6.20). Red-vented Bulbul and Red-whiskered Bulbul in SF invariably used ground but not in MDDF which used the height from 1 to >10m. White-browed Bulbul used the ground to the available height in the mixed dry deciduous forest but not in SF as it restricted its height from 1-4m (Table 6.20). Red-vented Bulbul had the highest overlap with Chestnut-Tailed Starling, Red-whiskered Bulbul with Baya Weaver and Common Tailorbird and White-browed Bulbul with Common Tailorbird, tawny-bellied Babbler and Yellow-eyed Babbler (Appendix 4). Although they are frugivores (Vijayan 1980, 1984), occasionally they also feed on insects especially during breeding as in the study of Gokula (1998) and Vijayan *et al.* (1999).

Table 6.20. Percent use of foraging method and height by Red-vented, Red-whiskered and Whitebrowed Bulbuls in the mixed dry deciduous (MDDF) and scrub forests (SF)

RED-VENTED BULBUL																	
Habitat	**Method**						**Height class**										
	FLG	**FRG**	**GG**	**LG**	**SG**	**TG**	**G**	**0.1-1**	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-8**	**8-9**	**>10**
MDDF	-	71	1	4	12	12	-	40	15	6	14	1	4	5	1	3	12
SF	3	94	3	1	-	-	3	64	19	11	3	1					

RED-WHISKERED BULBUL																
Habitat	Method					Height class										
	FRG	GG	L G	SG	T G	G	0.1-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
MDDF	70	1	1	4	24	-	14	19	24	8	12	12	7	1	1	1
SF	87	13	-	-	-	11	78	11	-	-	-					

WHITE-BROWED BULBUL															
Habitat	Method					Height class									
	FLG	FRG	GG	LG	TG	G	0.1-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
MDDF	1	81	2	1	16	2	16	30	22	17	12	1	1	1
SF	1	99	-	-	-	-	78	17	3	2	-			

LG- Leaf Glean, TG- Twig Glean, FLG-Flower Glean, GG-Ground Glean, FRG-Fruit Glean, G-Ground, TG- Twig Glean, ST-Stem Glean.

6.4.4.6. Sturnidae

Three species were studied in this family. Chestnut-Tailed Starling and Common Myna were recorded only from SF and Jungle Myna from both the habitats. They gleaned for food (Table 6.5 and 6.12). Chestnut-tailed Starling ate fruit (Table 6.13) while Common Myna shared ground as observed by Mathew *et al.* (1980) for prey along with fruit and flower (Table 6.13). The former highly overlapped (0.98) with six species while the latter with Indian (0.99) Robin (Appendix 4). As Common Myna and Indian Robin fed on insects on the ground high overlap is possible, but Common Myna being larger in size would prefer larger invertebrates and also other food material; thus reducing competition. Also it was resulting in low density further reducing competition (Pontin 1982).

Jungle Myna used gleaning on flower, fruit and ground in both the habitats while leaf gleaning was also observed in the scrub forest (Table 6.21). Height consistently varied in both the habitats from ground to 8m in MDDF but ground to 2m in SF (Table 6.21) and reasons for this have been explained earlier. It highly overlapped with Indian Peafowl in MDDF (0.81) and with Laughing Dove in SF (0.88). This bird as in the study of Mathew (1975) and Mathew *et al.* (1980) ate flower, fruit and insects.

Table 6.21. Percent use of foraging method and height by Jungle Myna in the mixed dry deciduous (MDDF) and scrub forests (SF)

JUNGLE MYNA													
Habitats	Method				Height class								
	FLG	FRG	GG	LG	G	0.1-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
MDDF	54	6	40	-	39	19	-	-	-	-	21	3	18
SF	34	12	48	6	49	10	30	5	6	1			

FLG-Flower Glean, FRG-Fruit Glean, GG-Ground Glean, LG- Leaf Glean, G-Ground

6.4.4.7. Upupidae

The only species in this family studied was **Common Hoopoe** which used gleaning and probing as its method of catching prey (Table 6.5). Ground and litter were gleaned equally followed by 1% of trunk and 1% of twig (Table 6.6). It had the highest overlap (Appendix 4) with Grey Junglefowl (0.93) occupying the same strata and gleaning for food. The method of feeding is similar to that found by Thiyagesan (1991) and Gokula (1998) but it also probes to get food according to Ali and Ripley (1987).

6.4.4.8. Capitonidae

Brown-headed Barbet: It was recorded from the mixed dry deciduous forest and adopted the method of gleaning (Table 6.5) to feed on fruit and insects from foliage and secondary branches (Table 6.6). It foraged on trees between 2 and >10m height (Table 6.3). This species had high overlap (0.93) with Red-whiskered Bulbul (Appendix 4). Although it is mainly a frugivore, it also feeds on insects (Yahya 2000) and hence considered to be omnivore

(Gokula 1998). This behavior makes the bird to glean on foliage and secondary branches. It ate mainly the fruits of figs, *Diospyros ferrea*, and *Pleurostylia wightii* in the Anaikatty hills during the present study.

6.4.4.9. Columbidae

Laughing Dove is the only species studied from this family in the scrub forest, which usually feeds in the open field. It gleaned on the ground predominantly on fruit for grains (Table 6.13). Feeding height was restricted to the ground (95%) (Table 10). Ground and middle canopy of the (fruit bearing) herbs were preferred to get the grains (Table 6.16). It showed high overlap (0.97) with Indian Robin (Appendix 4). Although it overlapped highly with Indian Robin, its food is mainly grains as documented by Mathew *et al.* (1980) destroying thousands of weed seeds. It is also likely to feed on animal food as reported by Mathew *et al.* (1980).

6.4.4.10. Cuculidae

Gleaning and probing were the two methods used by the Blue-faced Malkoha in the mixed dry deciduous forest (Table 6.5). It gleaned on twig followed by fruit, litter, leaf, secondary branches and ground (Table 6.6). It used mainly twig along with ground and foliage as substrate for foraging (Table 6.4). It exploited all available vertical (Table 6.3) as well as horizontal layers of canopy (Table 6.7). It had high overlap with Common Tailorbird

(0.83) which could not be geologically significant as the size of the two are not comparable.

6.4.4.11. Dicaeidae

Plain Flowerpecker and Pale-billed Flowerpecker were the two species studied from this family in the mixed dry deciduous forest. The former gleaned largely on leaf followed by twig and flower while the latter gleaned largely on flower followed by leaf and twig (Table 6.6). Foliage, twig and flower were the substrates used (Table 6.4). The Plain Flowerpecker mostly took prey from the foliage between 2 and 8m (Table 6.3) of the upper and middle canopies (Table 6.7) while the Pale-billed Flowerpecker used the height of 1-8m in search of flower (Table 6.3). Plain Flowerpecker overlapped highly with Blue-winged Leafbird (0.93) and the Pale-billed Flowerpecker with the Purple-rumped Sunbird (0.93).

6.4.4.12. Dicruridae

Ashy Drongo, Black Drongo and White-bellied Drongo were studied from the mixed dry deciduous forest and found them as salliers except Ashy Drongo, which also used gleaning as the secondary method (Table 6.5). Substrate usage was similar for White-bellied Drongo and Black Drongo as they use air largely (Gokula 1998) with minimal use of foliage (Cody 1974). Ashy Drongo used air (sally) to catch insects especially dipteran swarms

(Vijayan 1984) and flower for nectar (Table 6.4) from above 3m height on the upper and middle canopy along with ground (Table 6.7). White-bellied Drongo and Black Drongo used all height categories and canopy (Table 6.3 and 6.7). The former overlapped with Green Bee-eater (0.74) while the latter with Chestnut-headed Bee-eater (0.90). Ashy Drongo highly overlapped much with White-bellied Drongo (Appendix 4). White-bellied Drongo used only sallying in the present study, which is similar to that found by Vijayan (1984) and Gokula (1998). It could be confirmed that Black Drongo is feeding on grasshoppers, locusts (D'Abreu 1920) and other insects (Mathew 1975, Mathew *et al.* 1980). Although the overlap between the Ashy and White-bellied Drongos was high, they do not occur in this forest together in all the seasons because of the migration of the former, size of the food material also isolates them from competition (Vijayan 1984).

6.4.4.13. Hirundinidae

Redrumped Swallow was absolutely a hoverer (Table 6.1) recorded from both the habitats catching insects from air (Table 6.4). This species preferred the height between 2-5m and >9m in MDDF and 4-5m in SF (Table 6.22). It overlapped highly with Common Iora (0.47) in SF and with Ashy Drongo (0.6) in MDDF (Appendix 4). This species was abundant only during northeast monsoon, as insect abundance would limit the population in the other seasons as reported by Mccarty and Winkler (1999).

Table 6.22. Percent use of foraging method and height by Redrumped Swallow in mixed dry deciduous (MDDF) and scrub forests (SF)

REDRUMPED SWALLOW					
Habitats	Method	Height class			
	Hover	2-3	4-5	9-10	>10
MDDF	100	2	29	59	10
SF	100	0	100	0	0

6.4.4.14. Irenidae

Blue-Winged Leafbird and Common Iora were studied from this family. The former was recorded only from the mixed dry deciduous forest while the latter was seen in both the habitats. The Blue-Winged Leafbird obtain their prey by gleaning method (Table 6.5) and the Common Iora predominantly used gleaning (91%) and sallying (Table 6.23) in SF and absolutely gleaning in MDDF (Table 6.5). They used trees to trap their food from above ground between 0.1 and >10 in MDDF, and upto 5m in SF including ground where it sallied to trap termites (Table 6.23). Common Iora overlapped with Plain Flowerpecker (0.92) in MDDF, and in SF with Streak-throated Woodpecker (0.95) while Blue-Winged Leafbird overlapped with Plain Flowerpecker (0.95) in MDDF (Appendix 4). Common Iora, which was observed in both the habitats, used only two methods (TG and LG) in MDDF but four in SF (Table 6.23). Probably because of the presence of more number of migrants more open space and availability of termites it changed its foraging method and substrate in SF (Table 6.23). It also gleaned on fruits of *Diospyros ferrea* occasionally.

Table 6.23. Percent use of foraging method and height by Common Iora in mixed dry deciduous (MDDF) and scrub forests (SF)

COMMON IORA																
Habitat	**Method**				**Height class**											
	LG	**SG**	**TG**	**S**	**G**	**1**	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-8**	**9-10**	**>10**
MDDF	28	-	72		0	3	13	17	22	17	15	7	2	2	2
SF	24	2	65	9	8	18	32	28	6	8	0	0	0	0	0

LG- Leaf Glean, TG- Twig Glean, ST-Stem Glean, S-Sally, G-Ground

6.4.4.15. Meropidae

Of the two species, Chestnut-headed Bee-eater was observed only in MDDF (Table 6.2) and the Green Bee-eater in both the habitats. The latter was sallying above canopy (air), while the former was sallying just above the ground and the foliage along with sallying above canopy (Table 6.4 and 6.11) to obtain small beetles, ants, termites, dragonflies and cicadas (Kossenko and Fry 1998). Chestnut-headed Bee-eater overlapped much with White-bellied Drongo (0.89), while Green Bee-eater with Chestnut-headed Bee-eater (0.79) in MDDF and Chestnut-tailed Starling and Purple-rumped Sunbird in SF (Appendix 4). Although Purple-rumped Sunbird showed high overlap with Chestnut-tailed Starling, being nectarivore, the type of food varied between these two species. The height preferred by the Green Bee-eater significantly varied between the habitats (Table 6.24). It feeds on dragonflies (Mathew 1975, Mathew *et al.* 1980) and other insects including grasshoppers.

Table 6.24. Percent use of foraging method and height by Green Bee-eater in mixed dry deciduous (MDDF) and scrub forests (SF)

GREEN BEE-EATER							
Habitats	**Method**	**Height class**					
	Sally	**0.1-1**	**1-2**	**2-3**	**3-4**	**4-5**	**>10**
MDDF	100	19	0	0	52	7	21
SF	100	38	15	3	0	44	0

6.4.4.16. Oriolidae

Black-hooded Oriole in the mixed dry deciduous forest used gleaning more frequently and pouncing (17%) less frequently (Table 6.5). It showed similar percent of gleaning in both the habitats while pouncing was not observed in the dry deciduous forest as observed by Gokula (1998). Prey was taken mainly from Trunk and twigs (Table 6.4) between 3 and >10m of middle canopy predominantly (Table 6.7). High overlap (0.82) was observed with Blue-faced Malkoha (Appendix 4).

6.4.4.17. Nectariniidae:

Purple Sunbird, Purple-rumped Sunbird and Loten's Sunbird were studied of which the last one was not recorded in scrub forest (Table 6.2). Loten's Sunbird took food between 0.1 and 8m height (Table 6.3) from flower followed by twig and fruit to suck out juice (Table 6.6). The canopies it preferred were middle and upper layers (Table 6.7). Loten's Sunbird overlapped (0.97) highly with Purple-rumped Sunbird (Appendix 4).

Purple-rumped Sunbird:It followed the method gleaning (Table 6.5 and 6.12) largely on flower, followed by twigs, foliage and fruit (Table 6.4) and exploited food from all available plant height above the ground in MDDF and including ground in SF (Table 6.25). Although in SF food was taken mainly from the flower, ground was used to take termites during rainy season, when its availability was high. It overlapped (0.97) highly with Loten's Sunbird in MDDF and Common Tailorbird and Red-vented Bulbul (0.97) in SF (Appendix 4).

Table 6.25. Percent use of foraging method and height by Purple-rumped Sunbird in the mixed dry deciduous (MDDF) and scrub forests (SF)

PURPLE-RUMPED SUNBIRD																
Habitat	Method				Height class											
	FL G	G	L G	TG	G	0.1-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10
MDDF	88	-	5	7	-	22	18	9	14	16	11	6	3	1	1	1
SF	88	3	9	-	3	65	11	8	11	3						

LG- Leaf Glean, FG-Flower Glean, TG- Twig Glean.

Purple Sunbird: It followed the gleaning as the method of feeding (Table 6.5 and 6.12) largely on flower, followed by twigs, foliage, secondary branches and fruit (Table 6.4 and 6.26). It exploited food from all vegetation above the ground between 0.1 and 10m in MDDF (Table 6.3 and 6.26) and upto 3m height in SF (Table 6.26). It overlapped (0.98) highly with Chestnut-tailed Starling in SF and Purple-rumped Sunbird (0.9) in MDDF (Appendix 4). As more than one species preferred the same food, Purple-rumped Sunbird being territorial might chase Purple Sunbird which used a mobile foraging strategy as in the Hawaian Honey Creepers (Pimm and Pimm 1982) and Common Amakihi (Van Riper 1984). Loten's Sunbird visits the area only during its breeding season.

Table 6.26. Percent use of foraging method and height by Purple Sunbird in the mixed dry deciduous (MDDF) and scrub forests (SF)

PURPLE SUNBIRD												
Habitats	**Method**				**Height class**							
	FLG	**LG**	**SG**	**TG**	**0.1-1**	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**7-8**	**9-10**
MDDF	74	16	7	4	5	23	2	19	7	28	11	5
SF	96	2	-	2	53	44	2	-	-			

LG- Leaf Glean, FLG-Flower Glean, TG- Twig Glean, ST-Stem Glean, G-Ground

<u>Blyth's Reed Warbler:</u> This bird used leaf-gleaning and twig-gleaning, the leaf-gleaning being predominant in both the habitats, but in SF it also gleaned on fruit to get insects (Table 6.27). Feeding attempts were made largely upto 3-4m height class and occasionally upto 10m height, and was not feeding on the ground as in the study of Gokula (1998). Difference was found in the use of vertical strata between the habitats (Table 6.27). This is probably because of the competition among migrants in the lower strata and change in the structure of the habitats. It overlapped much with Common Tailorbird in MDDF and Chestnut-tailed Starling in SF (Appendix 4).

Table 6.27. Percent uses of foraging method and height by Blyth's Reed Warbler in the mixed dry deciduous (MDDF) and scrub forests (SF)

BLYTH'S REED WARBLER										
Habitat	**Method**			**Height class**						
	FRG	**LG**	**T G**	**0.1-1**	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**9-10**
MDDF	0	56	44	27	30	18	15	8	2	1
SF	5	68	27	57	39	5	0	0	0	0

FRG -Fruit Glean, LG-Leaf Glean, TG-Twig Glean

6.4.4.18. Muscicapidae

Ten species from this family were studied, of which four were recorded from both the habitats , namely Blyth's Reed Warbler, Yellow-billed Babbler, Tawny-bellied Babbler and Common Tailorbird. Species such as Jungle Babbler, Large-billed Leaf Warbler, Asian Paradise Flycatcher and Greenish Warbler were studied from MDDF and Indian Robin and Yellow-eyed Babbler from SF (Table 6.2).

Yellow-billed Babbler: This Babbler used gleaning as the major method of feeding in both the habitats (Table 6.5 and 6.12). Flower, ground, leaf, litter and twig were gleaned for food (Table 28). Among the five methods, ground gleaning was used chiefly in both the habitats as observed elsewhere (Rana 1970, Andrews and Naik 1970, Mathew 1975, Mathew *et al.* 1980). The other four methods were less frequently used in the mixed dry deciduous forest and litter and flower were not at all used in the scrub forest (Table 6.30).

It showed similarity in the use of feeding height class in the two habitats except 1% of feeding observation at 5-6 m height in the mixed dry deciduous forest (Table 6.28). It overlapped much with Purple Sunbird (0.97) in the scrub forest and Grey Junglefowl (0.97) in the mixed dry deciduous forest (Appendix 4). Zacharias and Mathew (1988) identified nine methods of foraging to quantify foraging behavior of the Babblers, and Gokula (1998) attempted four methods in which the higher usage of ground foraging was found similar to that in the present study.

Table 6.28. Percent use of foraging method and height by Yellow-billed Babbler in the mixed dry deciduous (MDDF) and scrub forests (SF)

YELLOW-BILLED BABBLER								
Habitats	**Method**					**Height class**		
	FLG	**GG**	**LG**	**LIG**	**TG**	**Ground**	**0.1-1**	**5-6**
MDDF	1	93	1	4	2	97	2	1
SF	0	94	2	0	4	94	6	0

LG- Leaf Glean, TG- Twig Glean, GG-Ground Glean FLG-Flower Glean, LIG-Litter Glean

Jungle Babbler: Gleaned on the substrate largely of ground followed by litter, twig and secondary branches (Table 6.6 and 6.4) to obtain prey in the mixed dry deciduous forest. The prey was taken from ground to 6m height (Table 6.3) preferring upper, lower and under (ground) canopy layers (Table 6.7). It overlapped highly with Grey Junglefowl (Appendix 4). This species was not recorded in the scrub forest hence, there is no overlap between the Yellow-billed Babbler and Jungle Babbler. Although they occur together in mixed dry deciduous forest, they occupy extensive territory with aggressive fight if they overlap even on foraging ground. No overlap existed between these two Babblers unlike in the study of Andrews and Naik (1970). They fed on grain (Rana 1970) and insects (Andrews and Naik (1970).

Tawny-bellied Babbler: This Babbler was largely twig-gleaning followed by leaf-gleaning in both the habitats, and very rarely fruit was gleaned (1%) in MDDF (Table 6.29). It showed less difference in the height used between the habitats 0.1-3m in the mixed dry deciduous and 0.1-2m-height class in SF

(Table 6.29). Upper and middle canopy layers were (Table 6.7 and 6.16) preferred to pick out the food from the substrate of twig, foliage and rarely (1%) fruit (Table 6.6 and 6.13). It overlapped much with Common Iora (0.77) in MDDF and Chestnut-tailed Starling in the scrub forest (Appendix 4).

Table 6.29. Percent use of foraging method and height by Tawny-bellied Babbler in the mixed dry deciduous (MDDF) and scrub forests (SF)

TAWNY-BELLIED BABBLER						
Habitat	Method			Height class		
	Fruit Glean	Leaf Glean	Twig Glean	0.1-1	1-2	2-3
MDDF	1	14	85	72	24	4
SF	0	15	85	87	13	0

<u>Yellow-eyed Babbler:</u> The Yellow-eyed Babbler was studied in the scrub forest, which absolutely gleaned on the substrate twig, foliage and 1% of fruit (Table 6.11). Twig-gleaning (65%) was used more than foliage-gleaning (Table 6.11). Almost all the foraging attempts were on the shrubs and short trees present in the 0.1-3m-height category. There is a morphological specialization in this species as it uses the same substrate, method, height and food in dry deciduous forest as reported by Gokula (1998). It overlapped much with Common Tailorbird, Blossom-headed Parakeet and White-browed Bulbul (0.99) in the scrub forest (Appendix 4). Largely it fed on *Chromolaena odorata* and *Lantana camara* for insects in the scrub forest (Nirmala and Vijayan 2000).

Common Tailorbird: This bird was a leaf-gleaner (Table 6.6 and 6.13) in both the habitats (Table 6.5 and 6.12). It largely used twig followed by foliage, fruit and ground in MDDF (Table 6.4), but foliage was followed by twig, trunk (Table 6.11) or stem (Table 6.30) in SF. It showed difference in the height used above the ground 0.1-5m in the mixed dry deciduous and upto 3m-height class in SF (Table 6.30) which was observed in many other species as explained earlier. This vigilant bird feeds mainly on the (center edge) upper and middle canopy layers (Table 6.7 and 6.16) and used all the canopy layers of available vegetation (Table 6.7). It overlapped much with Blyth's Reed Warbler (0.93) in MDDF and Tawny-bellied Babbler in scrub forest (Appendix 4). Similarity in substrate and method made these birds highly overlapped. Similar size and morphology of these species using the substrate might have resulted in reduced density of these birds to reduce competition (Pimm and Pimm 1982). Also the Blyth's Reed Warbler being a winter migrant is present here only during the winter, thus reducing competition during breeding.

Table 6.30. Percent use of foraging method and height by Common Tailorbird in the mixed dry deciduous (MDDF) and scrub forests (SF)

COMMON TAILORBIRD										
Habitats	Method					Height class				
	FRG	GG	LG	SG	TG	0.1-1	1-2	2-3	3-4	4-5
MDDF	5	3	35	0	58	48	30	10	8	5
SF	0	0	65	5	30	84	14	3	0	0

LG- Leaf Glean, TG- Twig Glean, SG-Stem Glean FRG-Fruit Glean, GG-Ground Glean

Large-billed Leaf Warbler: The Large-billed Leaf Warbler gleaned on the substrate largely of foliage and twig (Table 6.4) in the mixed dry deciduous forest. The percent prey attack manoeuvre by this gleaner was restricted to the foliage and twig (Table 6.6), from above the ground to 10m height (Table 6.3) preferring largely upper and middle canopy layers (Table 6.7). It overlapped highly with Blue-winged Leafbird (Appendix 4).

Greenish Warbler: The Greenish Warbler gleaned (100%) on the substrate largely twig, foliage and secondary branches (Table 6.6), recorded only in the mixed dry deciduous forest (Table 6.2). It obtained food from upper and middle canopy layers (Table 6.7) just above the ground to >10m height (Table 6.3). It overlapped highly with Common Iora (Appendix 4). The method of gleaning was the same as reported already (Price and Jamdar 1991, Gokula 1998). As Warblers are gleaners, they depend primarily on the availability of inactive (non-flying) insects that they pick up from foliage (Hutto 1981). Their activity corresponds quite well with insect activity in the bush. *Albizia amara* had lot of caterpillars, which were fed by these Warblers voraciously supporting Hutto 's (1981) view. Method of feeding was the least changed but height had greatest flexibility among Warblers since the method was related to morphology while flexible behavior in height use is least tied with morphology as suggested by Hutto (1981).

Asian Paradise Flycatcher: Sallied (Table 6.5) perching on all available canopy layers (Table 6.7), it obtains food largely from air (88%) and foliage

(Table 4) between 0.01-6m height (Table 6.3). Overlap was high with Ashy and Black Drongos (0.78) as they are salliers. Similar such finding was observed in the study at thorn forest in Mudumalai (Gokula 1998, Gokula and Vijayan 2000).

Indian Robin: The Indian Robin used gleaning (73%) and pouncing (27%) on the ground in the scrub forest as found by Gokula (1998) in thorn and dry deciduous forests in Mudumalai. Gleaning was used more frequently than pouncing (Table 6.12). The foraging attempts were made chiefly on the ground and foliage (Table 6.11) including all canopy layers (Table 6.16) between 0-1m height (Table 6.10). Although it showed high overlap with Laughing Dove (Appendix 4), the type of food varies between the two species which could reduce competition.

6.5. Discussion

Foraging method is specialized because it is depending on the morphological features, which are evolved over a long period and are mostly particular to a species. This has been documented in other studies such as Gokula (1998). However a few others such as Red-whiskered and White-browed Bulbuls had more overlap because they were frugivorous and the method was similar in other frugivores. Many species fed from different strata and positions in the canopy overlapping with others where specialists such as the Yellow-billed Babbler fed by only gleaning and that too from ground thus sharing high specialization or preference and thus having very little overlap with other species.

In the mixed dry deciduous forest higher percentage of foraging were recorded in the tree layers, whereas in the scrub forest, was in the shrub layer. This was because of the higher foliage strata and more foliage cover in the upper strata in the mixed dry deciduous forest. When food availability is high they feed on the outer part of tree canopies in this study as found by Diaz *et al.* (1998) in Tits which exploited secondary microhabitats in the periods of low food availability.

6.5.1. Foraging guilds and resource partitioning

In this study there were two major guilds, namely gleaners and salliers in MDDF and SF. There are four major groupings among the bird species based on the food eaten: insectivores, nectarivores, omnivores and frugivores. Foraging method, vertical and horizontal strata and substrate separate the aerial foragers from all other species. Therefore, three distinctive foraging environments were found in both the forests namely ground, plant forms and air. The plant (shrubs and trees) surface provides microhabitats such as trunk, twig, flower, fruit and foliage. Each one of this microhabitat is exploited by bird species that have the specialized morphology and behavior necessary for foraging over there. The proportion of foliage at different heights, which is higher in mixed dry deciduous forest, is also a function of the branching structure of the plant forms. The availability of various plant forms such as shrubs, short trees and trees in these habitats not only increases the vertical and horizontal foliage layering and complexity, but also provides many supporting substrates. In this study, closely related species used the same basic foraging method indicating the importance of phylogeny in determining the feeding patterns of birds (Robinson and Holmes 1982). However, adaptive radiation in certain groups facilitates the divergence in resource utilization by using different methods. Usually, morphologically similar group of birds formed a guild as Tawny-bellied and Yellow-eyed Babblers. Yet, species with different morphology for example, Streak-throated Woodpecker in scrub forest glean on insects as used by Common Iora in scrub forest, indicating that morphology need not necessarily predetermine the foraging behavior as it was studied elsewhere in insectivorous birds (Ricklefs and Travis 1980, Gokula and Vijayan2000).

Seven substrates such as ground, trunk, foliage, twig, flower, fruit and air were recognized. It can be further grouped into ground, plant and air of which, larger number of bird species fall under the plant-guild because plant offers a greater variety of microhabitats (trunk, secondary branches, twigs, foliage, flower and fruit) to find suitable food in these habitats. Among the four dimensions, there was more number of specialists (a species that uses a narrow range of resources) in the substrate category. Substrate largely determines the type of prey it can support which in turn was used by the bird species. Bird species evolved with specialization for a particular type of habitat or substrate or prey that resulted in a specialist for a particular habitat. Greenberg (1984a,c) investigated Warblers' response to different substrate and inferred that the species that had a diverse foraging behavior (repertoire) were conservative in their use of substrates.

Competition is yet another aspect, which was reduced by the effect of resource partitioning by decreasing the amount of overlap between the competing species (Wiens, 1989). Moreover, the incidence of overlap amongst potential competitors may be used to assess the extent of resource partitioning on the niche dimensions measured.

In this study niche overlap was looked at in four dimensions (foraging height, foraging method, position in the canopy and foraging substrate); highest mean niche overlap was found in the use of foraging height and canopy in mixed dry deciduous forest and scrub forest respectively and the least in the foraging method. Of the four, foraging methods may be constrained by morphology and thus it showed low niche overlap value. The high value in the foraging strata and position in the canopy can be attributed to the distribution of different food items (insects, fruits, flowers and seeds) particularly at certain locations where the food is in abundance or they may be utilizing different items and at different times, thus reducing competition. All the birds in these habitats overlapped with others in any one of the dimensions, in a larger or smaller extent. However, some species had higher overlap in one dimension but very little overlap in the other dimensions as in similar studies (Recher *et al.*, 1985, Gokula 2000). Thus it can be inferred that niche overlap can be attributed to the availability of food resources, morphology of species and competition as suggested by Alatalo (1982), Rolando and Robotti (1985), Szekely (1985) and Gokula and Vijayan (2000).

6.5.2. Foraging behavior of bird species between habitats

The importance of habitat structure on foraging patterns may be gained by comparing the behavior of a single species in two habitats that differ in structure (Robinson and Holmes, 1982). In the present study, foraging behavior of 16 bird species were compared between habitats. Fifteen species showed changes in their foraging heights and a single species did not show any change in height preference between habitats, which is a ground forager. This supported the view of Martin and Karr (1990) who found that birds may be more likely to change the foraging height or plant species. Moreover, the availability of foraging substrates at different heights significantly differed between these two habitats and found that the changes in the height preference took place as described by Moermond (1990) and Gokula (1998).

Of the 16 bird species, 13 species differed in their use of substrates between habitats and three species such as Green Bee-eater, Red-rumped Swallow and Blossom-headed Parakeet showed no difference. Common Iora, Jungle Myna, Red-vented Bulbul, Red-whiskered Bulbul, Brown-headed

Barbet and Common Myna in scrub forest sallied to catch termites, which is an occasional observation as noted by Yahya in the Barbets (2000). Indian Peafowl in mixed dry deciduous forest showed probing litter during a particular season but changed their method of feeding as it is an opportunistic feeder (Giest 1977). Rosenberg (1990) found that substrate type is selected nonrandomly by all species, atleast partly on the basis of the differential prey availability in each type. Maurer and Whitmore (1981) found that the American Redstart changed foraging manoeuvre between forests with different structure. Five of the 16 species showed changes in the proportions of prey attack manoeuvre used between the two habitats as in the study of Szaro and Balda (1986). They found that foraging method of a single species in bird community did not change with forest structure but 15 species changed their proportions of manoeuvre. The 11 species showed no changes due to their evolutionary and phylogenetic significance as found by Martin and Karr (1990) and Recher *et al.* (1985). Species, which were generalized in feeding, tend to vary in substrate, height, method and the type of food and food trapping techniques (Holmes and Schultz 1988, MacNally 1994a).

The changes in foraging behavior was not only because of the spatial and temporal patterns of resource abundance but also the kinds of prey and foraging substrates they used (Recher *et al.* 1985) and Recher (unpubl. Data in Brown Thornbills). The signature remains unchanged, although the proportions of particular behaviors may vary, despite changes in resource abundance and physiological requirements (Recher 1969). The vertical stratification of feeding zones has been recognized as one of the most important ways of segregation between bird species in foliage feeding and sallying insectivores (MacArthur 1958, 1969, Cody1974).

Arthropod abundance and diversity undoubtedly affect the foraging behavior of insectivorous birds (Cole 1995). The risk of predation may affect how long birds forage or which foraging sites they choose (Lima 1985). Predation of two adult birds was recorded during the study period. Also, predation of fledglings of almost all the breeding birds in both the habitats was observed. Interspecific competition also can alter foraging behavior of Warblers and Babblers (Alatalo 1981, Vijayan 1984, Carothers 1986). Thus, changes in the foraging manoeuvre may be a strategy to avoid competition. Hence, it is likely that the combination of factors such as availability of food, habitat structure and interspecific competition are responsible for the changes.

6.6. Conclusion

In four dimensions (foraging height, foraging method, position in the canopy and foraging substrate), highest mean niche overlap is found in the use of foraging height in the mixed dry deciduous forest and canopy in the scrub forest and the least in the foraging method in both the habitats.

There are two major guilds, namely gleaners and salliers in the MDDf and SF. The gleaners are grouped into four major guilds in MDDF and five in

SF as trunk gleaner is separated in the latter. There are four major groupings among the bird species based on the food eaten in both the habitats: insectivores, nectarivores, frugivores and omnivores. The plant (shrubs and trees) surface provides microhabitats such as foliage, twig, flower, fruit, secondary branches and trunk and the proportion of foliage use at different heights is higher in the mixed dry deciduous forest. Specialization of species and their niche overlap with others are analysed.

Foraging dimension of 16 species are compared between the habitats. Only five species changed the method of feeding in the two habitats while 13 species showed difference in the use of substrates and 15 species in the vertical strata. Foraging method is specialized being constrained by morphology in many species while substrates and strata are used opportuinstically depending on the environment.

CHAPTER 7

BREEDING OF BIRDS AND IMPACT OF DISTURBANCES ON THEM

7.1. Introduction

Breeding is one of the major components, which determines the species' contribution to its gene pool (Dunbar 1983) and life history attributes in an evolutionary context (Ricklefs 1983). Breeding is determined (Marshall 1949) not only by gonadal activity but also by the availability of food resources (Vijayan 1975, Shukkur 1978, Caterall *et al.* 1982, Vijayan 1984, Martin 1986, 1987, Sundaramoorthy 1991, Berryman 1996, Chakravarthy *et al.* 1997, Powelsland *et al.* 1997, Kinnaird and O'Brien 1999, Pramod and Yorn-Tov 2000), specific requirements for nesting (Martin 1993 a, b and Steele 1993) and nest site (O'connor 1984, Johnson *et al.* 1992). It is influenced by various other factors such as rainfall (Lloyd 1999) and photoperiodism (Marshall 1949, Chandola *et al.* 1990, Dawson 1998).

These factors along with nest sites act as part of the habitat suitability for the survival of the species (Chasku and Gates 1982, Alatalo *et al.* 1985) including protection from predation (Slagsvold 1982, Lundberg 1985, Thiollay 1994, Martin 1992) of eggs and nestling. Birds in responding to the above said factors select the habitat that stimulates settling at a location. Natural selection operates on the appropriateness of those selections through ecological processes that influence reproductive success of individuals (Hilden, 1965). In ecology, vegetation has been mostly studied to correlate its availability with utilization by animals. The availability of plant resources for animals in the habitat is of immense concern in recent years as forested habitats are severely exploited by man for various purposes. But in most of the studies, utilization of the plant resources by the local people is poorly documented or left incomplete (Silori and Mishra 1995). Human interference on forest not only alters the vegetation structure (Rao and Mishra 1994, Silori and Mishra 1995, Puyravaud *et al.* 1995, Reddy 1998, Vijayan and Gokula 1999) but also reduces the resources available for animals (Vijayan *et al.* 2000). Such alteration in the habitat resources leads to reduction of many animals leading to extinction (Haila and Hanski 1993) or becomes threatened or increasingly endangered (Bird Life International 2001).

Moreover, the use of biological resources should be sustainable because human existence depends upon their higher productivity (FAO 1994). Diminishing of the forest resources caused shortage of firewood and fodder (Thapa and Weber 1990). The tree species, plant density, productivity, vegetation complexity and resource exploitation patterns have a direct impact on the wildlife (Wilson 1974, Maratha and Louis 1998, Bland 1998, Chettri 2000). Substantial reduction of forest cover will be leading to serious ecological disasters such as soil erosion, landslides, loss of soil fertility and catastrophic floods (Saxena and Singh 1982b). However, a rapid depletion of forest resources has led to environmental degradation all over the Himalayas (Thapa and Weber 1990, Singh and Singh 1980) and Sikkim (Chettri 2000).

The ever increasing human and livestock population in rural areas is exerting powerful pressure on land resources to meet the requirements of food, fuel, fodder, timber and other human needs. As a result of natural and human-caused changes in the habitat, many animal species throughout the world are threatened with extinction or becoming increasingly endangered. Bird population that has a high potential growth rate may respond more rapidly to environmental changes (Pimm 1984). The effect of habitat degradation and global climatic change on the dynamics of animal populations, community and biodiversity is of worldwide concern. Bird community evaluation has become an important tool in biodiversity conservation actions in areas of high human pressure (Kremen 1992, Shafiq *et al.* 1997, Prasad *et al.* 1998, Chettri 2000). Large scale habitat changes are continued globally for fulfilling human needs that have caused habitat destruction, fragmentation and degradation, necessitating assessment of the impact of such change on birds (Whitten *et al.* 1987, Khan *et al.* 1993).

Only baseline information is available on the breeding of bird species of India as given by Baker (1934) and Ali & Ripley (1987). Although India is rich with 2060 bird species, only a few terrestrial bird species or groups in a few locations have been studied in detail (Andrews and Naik 1970, Grubh 1974, Vijayan 1975, Mathew 1975, 1996, Gaston 1978a, Shukkur and Joseph 1980, Vijayan 1984, 1990 & 2000, Price and Jamdar 1990, Sundaramoorthy 1991, Alagar Rajan 1991, Natarajan 1991, Gokula 1998, 2001, Gokula and Vijayan 2001). Gaston and Vijayan (1986) analyzed the data on the breeding seasonality of birds in different regions of the subcontinent. Vijayan *et al.* (1998) examined the impact of human disturbance on the breeding birds in Mudhumalai and also the factors determining the breeding seasons of birds at Siruvani. In order to determine the crucial factors for the breeding of birds and to identify the human-impact on breeding, with the insight to bring out the habitat requirements for successful breeding, an attempt has been made in Anaikatty hills during 1999-2001 with the following objectives: To study the

- breeding seasonality of bird species present in the mixed dry deciduous and scrub forests with the possible influencing factors
- nesting details such as nest, nest tree and nest patch characteristics of a few selected species and
- breeding biology of a few selected species in the two habitats.

7.2. Methodology

Belt-transect of 50m width and 1000m length (5ha) was used to study the breeding of birds in each habitat where bird census was done. Behavioral and opportunistic (Pettingill 1985) observations were carried-out in the Belt Transect of 5 ha area for systematic nest search. Nests were searched on foot for about 20 hours per week in all the months and 72 hours per week during the major breeding seasons. The birds were followed to locate the nests and the active nests were numbered and watched for the success of the nests. Date of presence of eggs in the nests of all the bird species was recorded to determine the breeding seasons of birds in both the habitats. Nest details such as nest variables, nest tree variables and nest patch variables were measured (Table 7.1). Observation on incubation was made as in Vijayan (1984).

7.2.1. Nest-site characteristics

The method of determining the nest-site selection was done following Hullsieg and Becker (1990). Variables were selected based on factors that were considered to have potential influence on nest-site selection and on the studies elsewhere (Titus and Mosher 1981, Warkentain and James 1988, Gokula 1998, Gokula and Vijayan 2001). The selected variables were measured to characterize the vegetation structure of and around the nests and they were studied at three levels as follows:

Table 7.1 Nest, Nest tree and Nest patch variables

S. No.	Variables
I. Nest variables	
1	Nest height (m)
2	Nest length (cm)
3	Nest width (cm)
4	Nest depth (cm)
5	Nest concealment (m)
6	Clutch size
II. Nest tree variables	
1	Nest tree species
2	Nest tree height (m)
3	Nest tree girth at breast height (cm)
4	Condition of the nest tree
III. Nest patch variables	
1	Canopy above nest (%)
2	Canopy cover (%)
3	Ground cover (%)
4	Shrub cover (%)
5	Microhabitat
6	Distance to road/path (km)

7.2.1.1. Nest

The nest variables were collected to get the information on the morphology of the nest. Nest concealment was estimated by viewing the nest at nest level from a distance of one-meter, two meter, 3 meter etc. from four cardinal directions (Martin and Roper 1988) till full concealment.

7.2.1.2. Nest tree

Nest tree variables were collected to identify the characteristics of the nest plants, which are responsible for supporting the nest of the breeding birds. Condition of the nest tree was observed to know whether the breeding species prefer live/dead/partially dead plant forms or ground.

7.2.1.3. Nest patch

Reynolds *et al.* (1982) defined "Nest patch" 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. As the study includes small sized birds, the nest patch variables were measured from 5m radius circular plot as suggested by Titus and Mosher (1981) and adopted by Gokula (1998). This is to identify the microhabitat required for nesting of bird species. Percentage of vegetation cover was recorded visually while percent canopy cover 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 estimated at identifying the physical structure of the nest site.

7.2.2. 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 site. The 10 ha plot was divided into 40 grids and numbered on an enlarged topographic map (1:25000). Using lot method, 10 grids were selected from each habitat and identified in the study area. Once the approximate grid was located, the nearest plant form was kept as the centre of random plot and nest tree and nest patch variables were measured except the nest variables from the plot. Analysis was done for the whole data together due to limited sample size. Based on the available data, eight species such as Jungle Babbler, Laughing Dove, Purple-rumped Sunbird, Tawny-bellied Babbler, Indian Robin, Red-vented Bulbul, Red-whiskered Bulbul, Yellow-billed Babbler and Yellow-eyed Babbler were selected for detailed nest-site selection study. Only Red-vented Bulbul was analyzed for its nest-site characteristics between the habitats. Plant species preference for nesting was enumerated and assessed.

7.2.3. Impact of Disturbance

Informal interviews and field records were made to assess the impact of human and livestock disturbances on plants which affect the breeding of birds in the mixed dry deciduous forest and scrub forest. To quantify the impact of human on plant resources available for birds and to assess qualitatively their perceptions of preferred firewood species, informal interviews were conducted during the study period with people collecting firewood within the study area. The size class and species were determined for stems within the collected bundle of wood.

From the neighboring eight villages 100 people were questioned for their opinion on the preferred species. Field records were maintained of the livestock entering into the forests for grazing.

7.3. Statistical analysis

All the analyses were done using the SPSS (version 6.0 for windows) software package (Norusis 1994). Multiple regression analysis was done using the number of breeding bird species and nests found in each month as dependent variables and biotic and abiotic factors as the independent variables. Kruskal-Wallis test and Spearman rank correlation were performed between the variables of environmental parameters and food abundance. Stepwise regression was done to determine the important factors influencing breeding seasonality using the number of nests and species in different months with the physical and biological parameters. Mean and standard deviation were used wherever necessary (Sokal and Rohlf 1981). Principal Component Analysis was performed on the nest site characters to determine the most important factors in delimiting the microhabitat of the breeding birds. Nest plant preference was tested using preference program by Prasad and Gupta based on Neu *et al.* (1974) and Byers *et al.* (1984). This technique consists of computing chi square statistics for significance in observed uses and then sets up confidence intervals by making use of Bonferroni normal statistics.

7.4. Results

7.4.1. Breeding bird community

Altogether, 410 nests of 32 species were observed during 1999-2001. There were 118 and 292 nests of 19 and 22 species breeding in the mixed dry deciduous and scrub forests respectively (Table 7.2). The maximum number of nests found in both the habitats was of the Red-vented Bulbul. Ten breeding species were restricted to MDDF, namely Black-hooded Oriole, Common Iora, Crow Pheasant, Indian Jungle Crow, Jungle Babbler, Long-tailed Nightjar, Green-billed Malkoha, Chestnut-headed Bee-eater, Scimitar Babbler and Spotted Dove; 13 species were breeding in SF and 9 species in both the habitats (Table 7.2).

Table 7.2 Number of nesting bird species in the mixed dry deciduous and scrub forests

Bird species	No. of nests in MDDF	% of nests in MDDF	No. of nests in SF	% of nests in SF	Total
Ashy Prinia	-		1	0	1
Baya Weaver	-		1	0	1
Black-hooded Oriole	1	1	-		1
Common Iora	3	3	-		3
Common Myna	-		2	1	2
Common Tailorbird	-		1	0	1
Crow Pheasant	1	1	-		1
Grey Junglefowl	2	2	2	1	4
Grey-breasted Prinia	-		8	3	8
Indian Jungle Crow	1	1	-		1
Indian Robin	1	1	30	10	31
Indian Silverbill	-		5	2	5
Jungle Babbler	23	20	-		23
Laughing Dove	-		20	7	20
Long-tailed Nightjar	2	2	-		2
Pied Bushchat	-		3	1	3
Plain Prinia	-		2	1	2
Purple Sunbird	-		6	2	6
Purple-rumped Sunbird	7	6	17	6	24

Bird species	No. of nests in MDDF	% of nests in MDDF	No. of nests in SF	% of nests in SF	Total
Red-vented Bulbul	43	38	84	29	127
Red-whiskered Bulbul	6	5	33	11	39
Scaly-breasted Munia	1	1	8	3	9
Spotted Dove	7	6	-		7
Spotted Babbler	-		1	0	1
Tawny-bellied Babbler	12	11	9	3	21
White-browed Bulbul	3	3	1	0	4
Yellow-billed Babbler	1	1	28	10	29
Yellow-eyed Babbler	-		28	10	28
Green-billed Malkoha	2				2
Chestnut-headed Bee-eater	1				1
Small green Bee-eater			2		2
Scimitar Babbler	1				
Grand Total	118		292		410

The number of nests showed positive correlation with the factors such as rainfall (r= 0.301, p=0.038), pitfall trapped insects (r= 0.360, p=0.016), Chilopoda (r= 0.449, p=0.001) and negative correlation with Dictyoptera (r= 0.301, p=0.038).

Breeding bird community comprised of species with six different types of nests namely platform, cavity, statant cup, pensile cup, pendulous and ground with statant-cupped nests being more in number (Figure 7.1) followed by pendulous, platform and ground in MDDF. Bird species breeding here on ground are the Grey Junglefowl and Indian Robin. The statant cup nesters were Black-hooded Oriole, Common Iora, Jungle Babbler, Red-vented Bulbul, Red-whiskered Bulbul, White-browed Bulbul, Yellow-billed Babbler and Tawny-bellied Babbler. Although Long-tailed Nightjar is described as a ground nester, here it used a platform nest. Spotted Dove and Indian Jungle Crow also used platform nest.

Figure 7.1. Percent of type of nests in the mixed dry deciduous (MDDF) (n = 292) and scrub forests (SF) (n = 118)

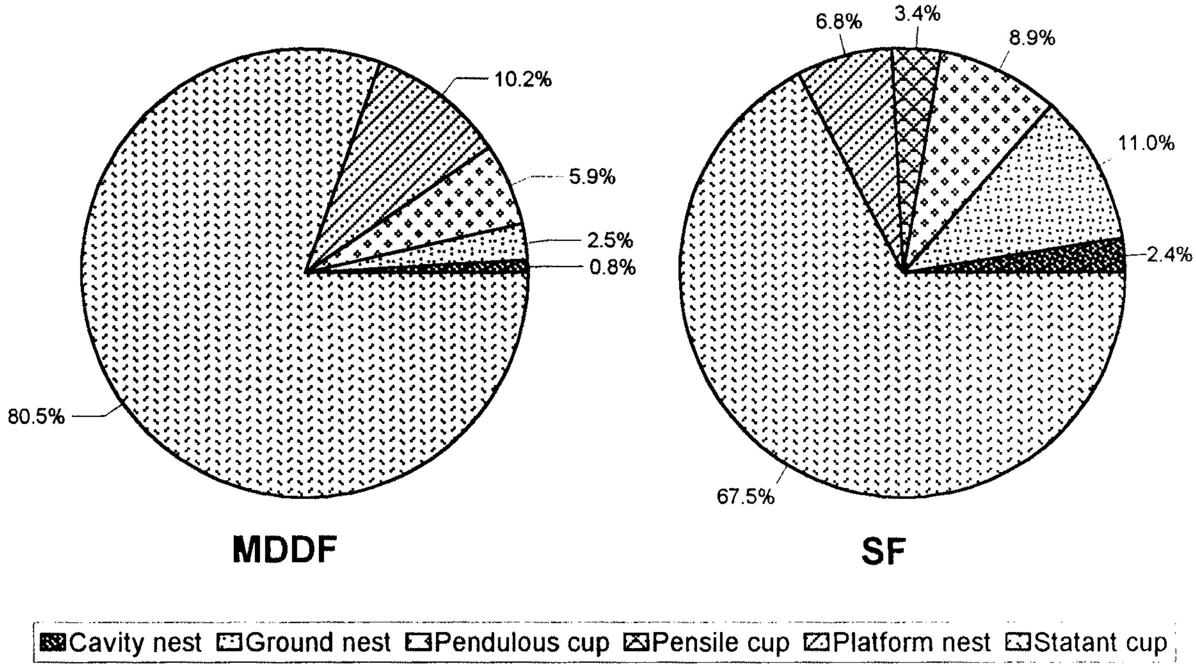
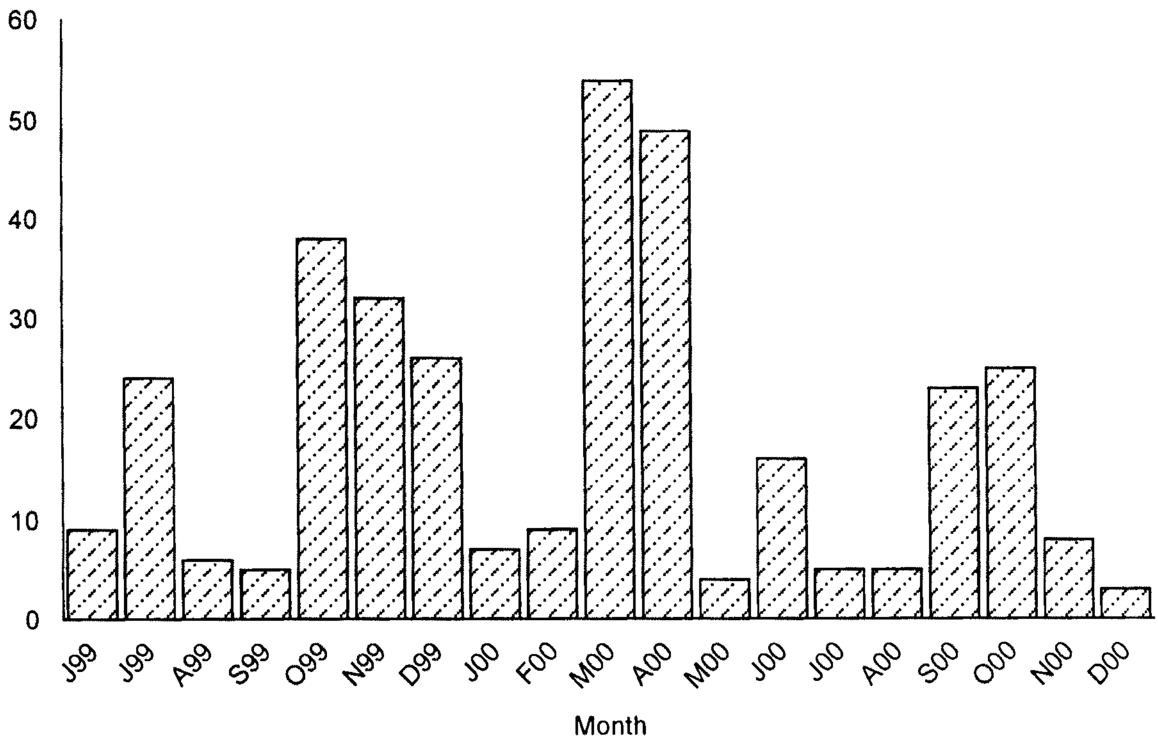


Figure 7.2. Seasonality of breeding birds in the Anaikatty Hills during 1999-2000



In the scrub forest, bird species such as Pied Bushchat used cavity nest, while Indian Robin and Grey Junglefowl used ground, Baya Weaver, Common Tailorbird, Purple Sunbird, Purple-rumped Sunbird and Ashy Prinia made pendulous nest, Plain Prinia and Grey-breasted Prinia used pensile cup while Laughing Dove used platform. Statant cup was used by Indian Silver-bill, Red-vented Bulbul, Red-whiskered Bulbul, Yellow-billed Babbler, Tawny-bellied Babbler and Yellow-eyed Babbler. Spotted Babbler and Scaly-breasted Munia had ball type with cavity. The statant-cupped and platform nests were comparatively more in MDDF than SF. This statant-cupped nest was found maximum followed by ground nests, pendulous, platform, pensile and cavity in SF (Figure 7.1).

7.4.2. Breeding seasonality

Breeding of birds extended throughout the year in Anaikatty hills with two major seasons in a year; October-December and March-April with a peak in March (Figure 7.2). In mixed dry deciduous forest, the breeding birds showed a major peak in March 2000 and a minor peak in December 1999 (Figure 7.3) corresponding to the number of species breeding (Figure 7.4), whereas in scrub forest, the major peak was in October and three minor peaks (Figure 7.3) in March, July and September (Figure 7.4).

Although the number of nests peaked during March, the number of breeding species increased from September to April with a major peak in

Figure 7.3 Temporal fluctuations of nests in the mixed dry deciduous and scrub forests during 1999-2000

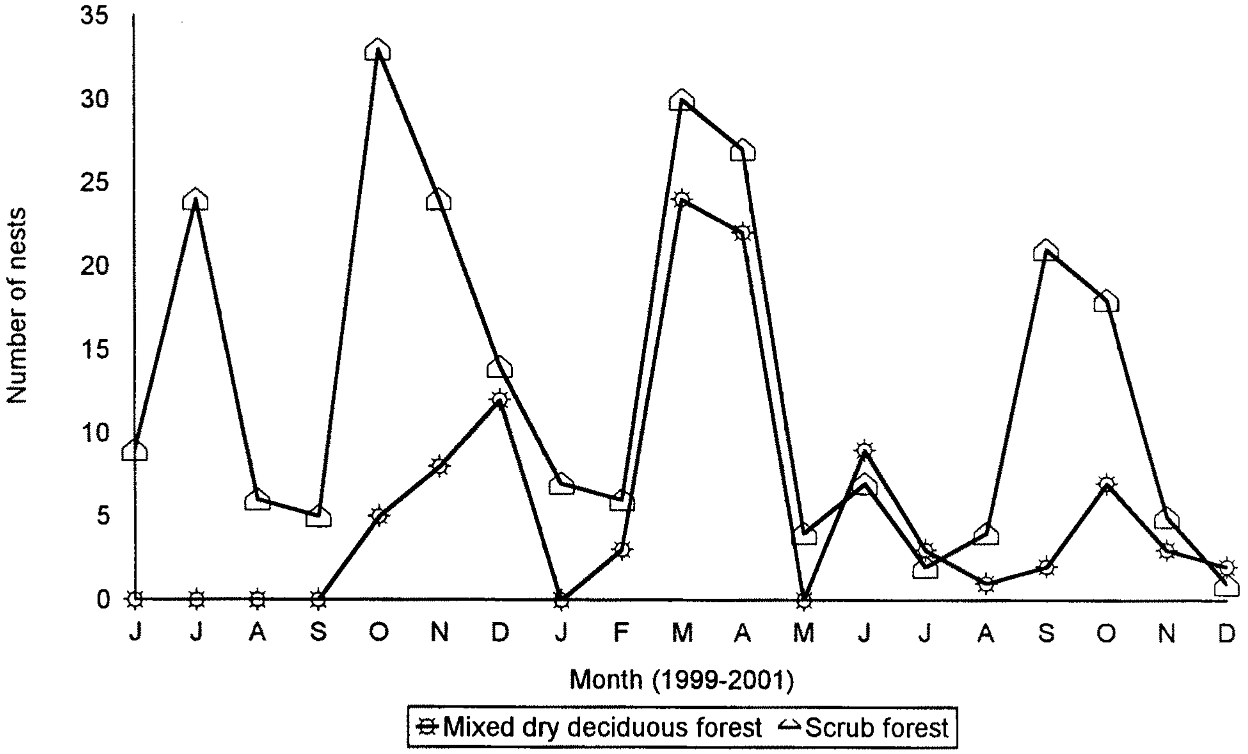
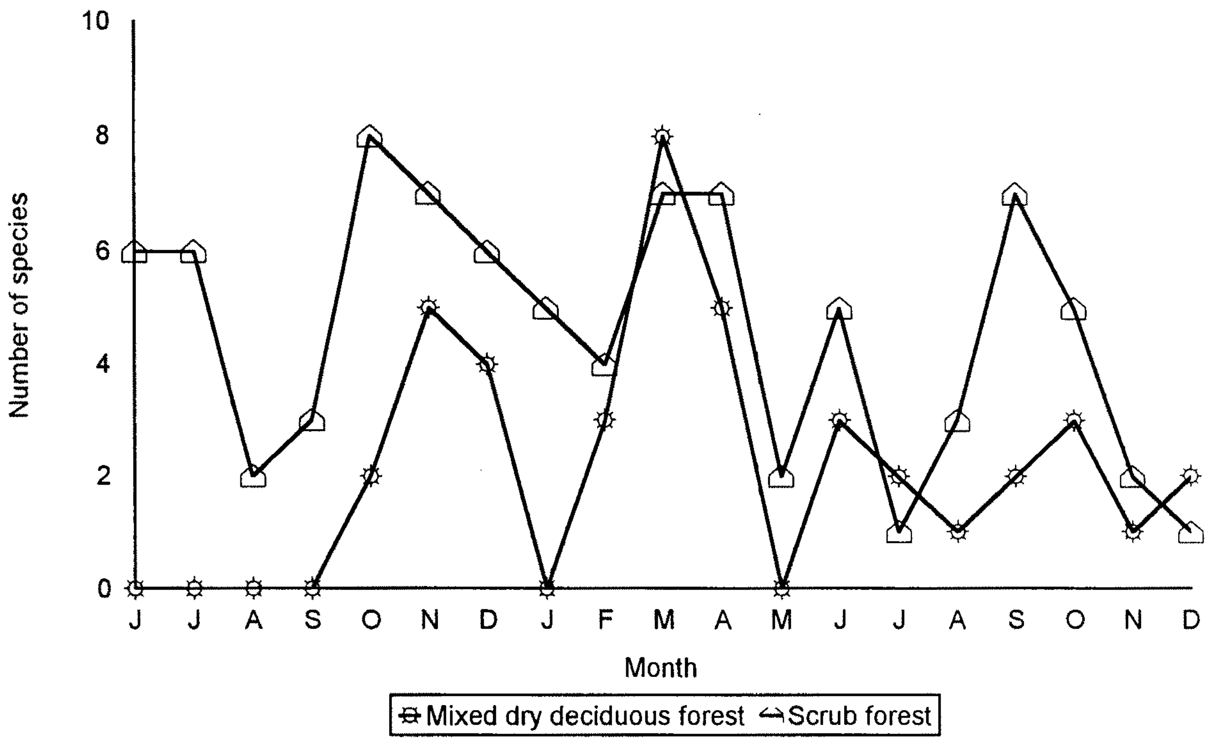


Figure 7.4. Breeding seasonality of bird species in the mixed dry deciduous and scrub forests during 1999-2000



November and another peak during March and April corresponding with the number of nests (Figure 7.8).

7.4.2.1. Breeding seasonality based on foraging guild

The breeding birds were classified into five types based on the feeding guild, namely frugivore, omnivore, insectivore, granivore and nectarivore. Although 28 species were recorded breeding in Anaikatty hills, most of them were omnivores (38%) and insectivores (25%) in MDDF, insectivores (43%) and granivores (19%) in SF (Table 7.3). There was a larger proportion of nests belonging to frugivores in both the habitats irrespective of the percentage of species according to the general bird abundance (Figure 4.5). Nectarivores were fewer in both the habitats in both numbers of nests and species. Although in MDDF omnivore species was in greater percent, the percent of nests was in less proportion than frugivore (Table 7.3). Granivore species and nests were more in SF than MDDF.

Table 7.3 Percentage of species and nests of breeding birds based on foraging guild in mixed dry deciduous (MDDF) and scrub forests (SF).

Guild	% of nests in		% of species in	
	MDDF	SF	MDDF	SF
Frugivore	46	41	19	14
Omnivore	25	11	38	14
Insectivore	16	29	25	43
Granivore	7	12	13	19
Nectarivore	6	8	6	10

Insectivore nests and nesting species were higher in SF than MDDF unlike the abundance of birds in SF.

Figure 7.7. Breeding seasonality of birds based on nest type guild in the scrub forest

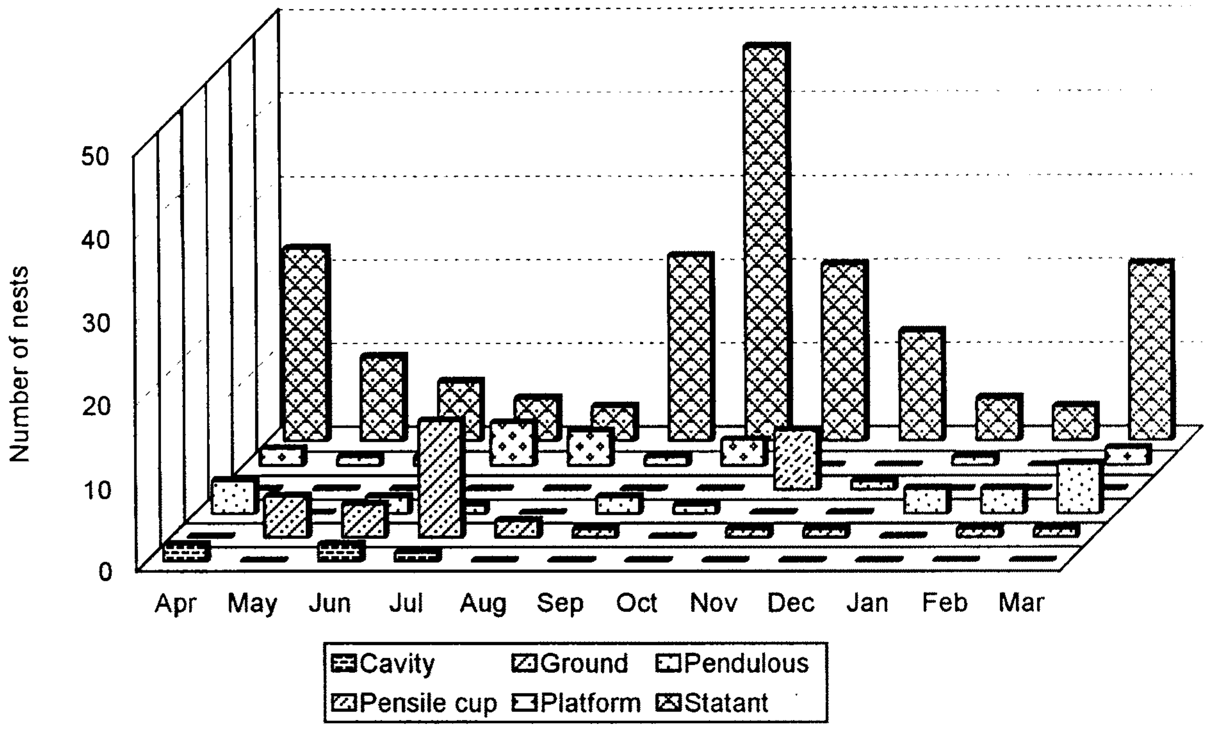
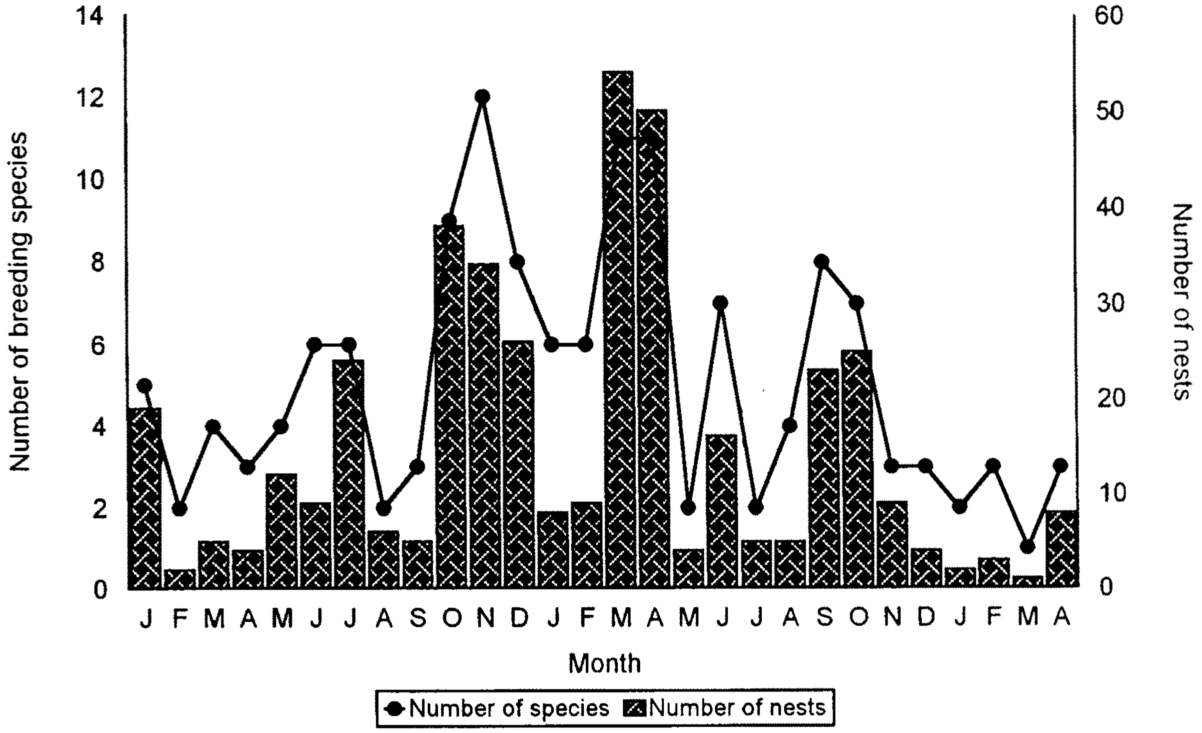


Figure 7.8. Seasonality of breeding bird species in the Anaikatty hills during 1999-2001



7.4.2.2. Breeding seasonality based on nest type guild

There were six types of nests recorded from Anaikatty hills (Figure 7.5). Statant cup nest was the dominant type, which showed peak during October. The other nest types, namely platform, pensile cup, pendulous, ground and cavity showed peak during April, November, March, July and April and June respectively (Figure 7.5).

In the mixed dry deciduous forest, statant and platform nests showed peak during April (Figure 7.6) while pendulous and ground nests peaked in March. The statant cup nesters bred continuously with a peak during October while the others were seasonal (Figure 7.7).

7.4.3. Plants harboring nests

The nest supporting plant species used by bird species in Anaikatty were 38 (Table 7.4). Of this, 12 plant species harbored 70% of nests of 50 % of species. The commonly used plants were *Pavetta indica* (16%) and *Lantana camara* (12%) which possessed closed branching architecture with the protective thorns. Six percent each of bird species preferred these two plants followed by *Chromolaena odorata,* which harbored 8% of nests of 5% species. Four species had 8 nests on three plants, namely *Chloroxylon swietenia, Randia dumetorum and Melia azadirachta* (Table 7.4). Eleven plant species were used by 3 bird species for nesting, while 9 plants by 2 bird species and 8 plants by a single species (Table 7.4). Eight substrates other than plants were also used by a few bird species.

Table 7.4 Percent of bird species and nests on nesting plant species

Nesting plant species	% of nesting bird species	% of nests
Pavetta indica	6	16.3
Lantana camara	6	12.4
Chromolaena odorata	5	8.2
Flacourtia indica	4	6.9
Albizia amara	4	5.9
Diospyros ferrea	4	4.2
Pongamia pinnata	4	3.7
Carmona retusa	4	3.2
Limonia alata	4	2.7
Chloroxylon swietenia	3	2.0
Randia dumetorum	3	2.0
Melia azadirachta	3	2.0
Cassia auriculata	2	1.7
Acalypha fruticosa	2	1.7
Opuntia dillenii	2	1.7
Parthenium hysterophorus	2	1.5
Tamarindus indicus	2	1.5
Syzygium cumini	2	1.5
Acacia polyacantha	2	1.2
Ziziphus mauritiana	2	1.2
Acacia leucophloea	2	1.2
Prosopis juliflora	2	1.0
Atalantia monophylla	1	1.0
Elaeodendron glaucum	1	1.0
Ziziphus oenoplia	1	1.0
Bauhinia racemosa	1	1.0
Acacia sp.	1	0.7
Barren ground	1	0.7
Mundulea sericea	1	0.7
Euphorbia antiquorum	1	0.7
Capparis sepiaria	1	0.5
Pteralobium hexapetalum	1	0.5
Calotropis gigantea	1	0.2
Celtis philippensis	1	0.2
Ficus benghalensis	1	0.2
Premna tomentosa	1	0.2
Scutia myrtina	1	0.2
Toddalia asiatica	1	0.2
Bitter guard	1	2.7
Grass	3	1.7

Figure 7.5. Breeding seasonality of birds based on nest type guild in the Anaikatty hills

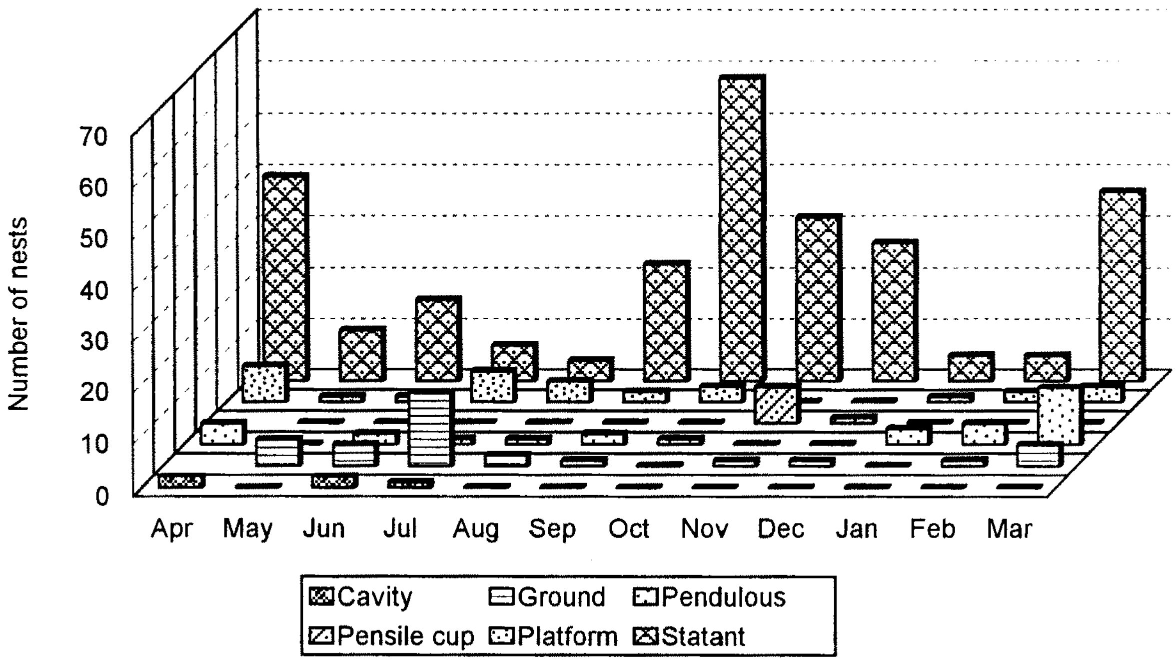
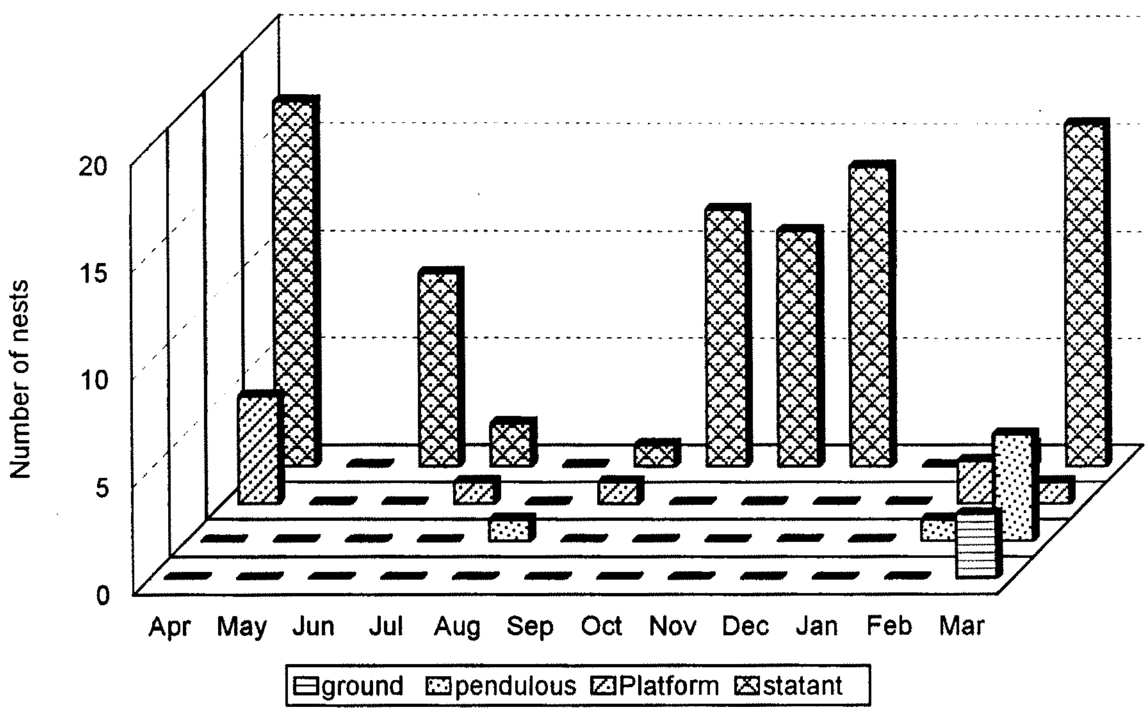


Figure 7.6. Breeding seasonality of birds based on nest type guild in the mixed dry deciduous forest



Nesting plant species	% of nesting bird species	% of nests
Ground	2	0.5
Hut	1	0.5
Pit	1	0.5
Pillar	1	0.2
Brick	1	0.2
Sack	1	0.2
Total number (N)	32	410

Twenty-seven plant species harbored nests of 118 bird species in mixed dry deciduous forest. The commonly used plants were *Limonia alata* followed by *Carmona retusa* (Table 7.5). Most of the nests were on tree species in MDDF unlike scrub forest where 57 % of nests were on shrubs such as *Pavetta indica* followed by *Lantana camara, Chromolaena odorata* and *Carmona retusa* (Table 7.5). Indian Robin nesting in holes used a variety of substrates in this area.

Table 7.5 Plant species preferred for nesting in mixed dry deciduous and scrub forests.

Mixed dry deciduous forest		Scrub forest	
Nesting plant	**No. of nests**	**Nesting plant**	**No. of nests**
L.alata	13	*P.indica*	19.7
C.retusa	9	*L.camara*	14.1
L.camara	8	*C.odorata*	9.7
P.indica	7	*C.retusa*	7.9
A.monophylla	6	ground	7.6
A.fruticosa	5	grass	4.1
F.indica	5	*F.indica*	3.1
P.pinnata	5	*C.auriculata*	2.8
A.amara	4	*D.ferrea*	2.8
B.racemosa	4	*E.glaucum*	2.4
Z..oenoplia	4	*A.amara*	2.1
A.polyacantha	4	*C.swietenia*	2.1
Acacia sp.	4	*O.dillenii*	1.7
B.ground	3	*P.hysterophorus*	1.7
D.ferrea	3	*R.dumetorum*	1.7
C.sepiaria	2	*S.cumini*	1.7
O.dillenii	2	*T.indicus*	1.7
Z.mauritiana	2	*M.azadirachta*	1.4

Mixed dry deciduous forest		Scrub forest	
Nesting plant	No. of nests	Nesting plant	No. of nests
ground	2	*M.sericea*	1.0
A.leucophloea	1	*P.juliflora*	1.0
C.philippensis	1	pit	1.0
C.swietenia	1	*A.leucophloea*	0.7
E.glaucum	1	*E.antiquorum*	0.7
F.benghalensis	1	*L.alata*	0.7
P.hexapetalum	1	*Z.mauritiana*	0.7
P.hysterophorus	1	pillar	0.7
T.asiatica	1	hut	0.7
T.indicus	1	*A.fruticosa*	0.3
grass	1	*A.monophylla*	0.3
		C.gigantea	0.3
		Ipomea splendida	0.3
		P.hexapetalum	0.3
		P.pinnata	0.3
		P.tomentosa	0.3
		S.myrtina	0.3
		Z..oenoplia	0.3
		sack	0.3
		B.ground	0.3
		bitterguard	0.3
		brick	0.3
Total number (N)	118	Total number (N)	292

7.4.4. Impact of disturbance on breeding birds

In the eight villages surveyed, namely Dhomanur, Chembukkarai, Gudanoor, Jambugundy, Panappalli, KondanoorPudhur, Kondanoor, Kootupulikadu (Alamaramedu+Moongilpallam), forest produces were used mostly by scheduled tribes (Table 7.6). They collected Bamboo for selling and their house maintenance, which was also higher in percentage while comparing with the population size (Table 7.6).

Table 7.6 Percent of population of Anaikatty villages and their forest use

Caste	% of population in 8 villages	% of Firewood collectors(n=75)	% of Bamboo pole collectors (n=15)
Scheduled caste	3	12	13
Scheduled tribes	71	73	87
Other castes	26	15	0

Recorded livestock revealed that scrub forest was disturbed by cattle and sheep of Moongilpallam and Alamaramedu (Table 7.7). Mixed dry deciduous forest received cattle from Kondanoor, Alamaramedu, KondanoorPudhur, Jambugundy and Horticulture, sheep from Jambugundy and Horticulture farm and goat from Dhomanur and Chembukarai (Table 7.7).

Table 7.7 Number of livestock grazing in mixed dry deciduous (MDDF) and scrub forests (SF)

Village name	Livestock category			Area of visit
	No. of cattle	No. of Goat	No. of Sheep	Transect name
Kondanoor	28			SAT-MDDF
Alamaramedu & Kondanoor Pudhur	25			AT-MDDF
Horticulture & Jambugundy	19	28		MT-MDDF
Moongilpallam, Alamaramedu	50		55	SAC-SF
Dhomanur & Chembukarai			65	MT-MDDF

The plant species collected by local communities were largely used as firewood and exploitation varied between habitats depending on the availability of plant species (Table 7.8). In total, people collected 22 plant species, of this seven were used for leaves as fodder. Bamboo poles were collected largely from mixed dry deciduous forest and part of this forest around SACON is otherwise called as Moongilpallam where Bamboo is abundant which was preferred by elephants.

People used it for building and maintaining their houses and also for selling to the people from other areas. *Atalantia monophylla* and *Acacia leucophloea* were collected for fuel use and selling to brick factories. People depend on this largely followed by other plant species such as *Albizia amara* and *Bauhinia racemosa* (Table 7.8). In scrub forest, Cassia *auriculata* was collected for selling as medicinal plant. Firewood collectors preferred *Chromolaena odorata* followed by *Lantana camara* from scrub forest for their use since they are common and dry fast to use as firewood (Table 7.8).

Table 7.8 List of plant species collected for various purposes by the people

Plant species	% of usage by people		Usage
	Mixed dry deciduous forest	Scrub forest	
Acacia polyacantha	1.1	0.0	Firewood
Acacia leucophloea	10.3	0.0	Firewood
Albizia amara	5.7	4.3	Leaves for livestock
Atalantia monophylla	11.5	0.0	Firewood
Bauhinia racemosa	4.6	0.0	Firewood & leaves for livestock
Canthium dicoccum	2.3	0.0	Firewood & leaves for livestock
Chromolaena odorata	5.7	15.2	Firewood
Celtis philippensis	2.3	0.0	Firewood & leaves for livestock
Chloroxylon swietenia	2.3	2.2	Firewood & leaves for livestock
Diospyros ferrea	8.0	0.0	Firewood & leaves for livestock
Flacourtia sp.	1.1	0.0	Firewood
Lantana camara	2.3	13.0	Firewood
Limonia alata	3.4	0.0	Firewood
Pongamia pinnata	2.3	0.0	Firewood
Tamarindus indica	2.3	0.0	Firewood
Ziziphus mauritiana	1.1	0.0	Firewood & leaves for livestock
Ziziphus oenoplea	1.1	0.0	Firewood
Grass	5.7	0.0	Broomstick making for sales
Prosopis juliflora	2.3	0.0	Poles for house construction/sales
Bambusa sp.	13.8	0.0	Poles

Plant species	% of usage by people		Usage
	Mixed dry deciduous forest	Scrub forest	
Cassia auriculata	9.2	60.9	Leaves & flowers
Cassia fistula	1.1	4.3	Leaves & flowers
Total	n = 87	n = 46	

7.5. Breeding biology of a few select species

7.5.1. Laughing Dove *Streptopelia senegalensis*

Methodology for breeding biology was as described earlier (Page 156).

7.5.1.1. Nest and nest-site characteristics

Laughing Dove is the only species studied from the family Columbidae in the scrub forest during 1999-2001, and no detailed study was conducted earlier on this species (Ali & Ripley 1987, Grimmett *et al.* 1998).

7.5.1.2. Nesting plant

The plant species preferred for nesting were mostly *Pavetta indica* (Figure 7.9) followed by *Opuntia dillenii, Randia dumetorum* and *Carmona retusa*. Although it had more nests on *Pavetta indica*, it did not show any specific preference for this plant as the availability was high. Species such as Lantana camara, Cassia auriculata were avoided inspite of their abundance (Appendix 5). *Acacia leucophloea, Limonia alata, Melia azadirachta* and *Prosopis juliflora* were utilized in proportion to its availability (Appendix 5).

Apart from plant species, hut and ground were also used for nesting. The nest in a hut showed very little disturbance, which resulted in 100% success.

Prosopis juliflora with 15% canopy of a single tree was used for a nest, which also yielded a successful nest. *Prosopis* sp. is a thorny tree with very close crotches. Such a networking of thorny branches gave more protection from predators. The nest concealment distance was 2 m for the successful nest.

Nest-site variables were measured for 20 nests. The nest was platform type (Pettingill 1985). It used 7-9 dry sticks kept on the plant among the twigs, under the crown. Mostly it built nests on the branches, which bifurcate into three twigs. Roots of grass and leaves of *Pavetta indica* was used for the inner lining of the nests (Plate 4). The nest tree height was 2.1 ± 0.8m with a mean girth at breast height of 14.13cm. (Table 7.9). The nests were placed at the mean height of 1.3m (Table 7.9). Nests were concealed upto 1.5m.

Table 7.9 Nest-site characteristics of Laughing Dove

Variables	Mean ± SD
Nest-tree height (m)	2.1 ± 0.8
Canopy above the nest (%)	23.7 ± 28.2
Nest-tree GBH (cm)	14.13 ± 8
Nest height (m)	1.3 ± 0.6
Clutch size	1.7 ± 0.6
Nest depth	1.67 ± 1.7
Nest diameter (cm)	7 ± 2.1
Distance to the road/path (m)	26.4 ± 23.4
Distance from nearest tree (m)	2.5 ± 2.7
Nest concealment (m)	1.5 ± 0.6
Ground canopy (%)	40 ± 17.8
Plant canopy (%)	7.5 ± 5
Shrub cover (%)	26.3 ± 6.3

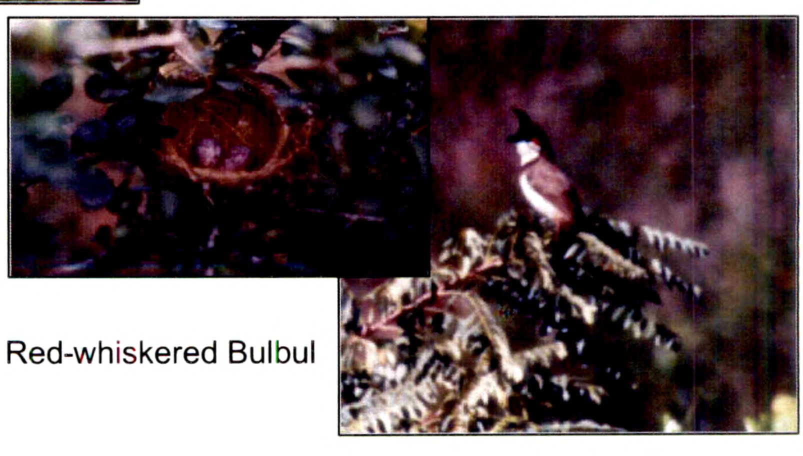
Anova showed the following variables having significant variance to prefer for nesting; tree height, tree GBH, distance from the nearest tree, ground canopy,

PLATE 4. A FEW BREEDING BIRDS AND NESTS IN ANAIKATTY HILLS

Laughing (Little Brown) Dove

Tawny-bellied (White-throated) Babbler

Yellow-eyed Babbler



Red-whiskered Bulbul

Photo by Sr. T. Nirmalaa

plant canopy and shrub canopy (Table 7.10). Distance to the road or path was not significant. Linear regression (stepwise) analysis showed tree height ($t = 15.29$, $p = 0.004$) as a significant factor in selecting the nest site.

Table 7.10 Comparison of Nest-site variables of the Laughing Dove with random sites

Parameters	Nest site (n = 20)	Random site (n = 20)	Significance P
Tree height (m)	2.1 ± 0.8	5.1 ± 1.7	0.000
Tree GBH (cm)	14.13 ± 8	29 ± 18	0.001
Distance to the road/path (m)	26.4 ± 23.4	16 ± 19	0.167
Distance from nearest tree (m)	2.5 ± 2.7	3.3 ± 2.2	0.07
Ground canopy (%)	40 ± 17.8	47 ± 22	0.005
Plant canopy (%)	7.5 ± 5	16 ± 9	0.001
Shrub cover (%)	26.3 ± 6.3	24 ± 11	0.013

The first two principal components were selected which accounted for 60% of the total variance. The first component was highly associated with nest concealment, distance to the nearest tree, ground cover, plant canopy and shrub cover (Table 7.11). The second component was associated with the nest characteristics such as nest tree height, nest height and nest diameter. The factors highly correlated with these three components were those that directly related to the microhabitat and indicate the characteristics of concealment in nest-site selection.

Table 7.11. Factor loading of the nest site characteristics with the first two principal components in the Laughing Dove

Variables	PC I	PC II
Shade over nest	0.17	0.28
Nest concealment	0.93	-0.25
Distance to nearest tree	0.92	0.07
Distance to road	-0.22	0.13
Nest tree GBH	0.60	0.49

Variables	PC I	PC II
Ground cover	0.96	-0.23
Nest depth	0.03	-0.17
Nest diameter	-0.03	0.70
Nest height	0.46	0.80
Plant canopy	0.95	-0.19
Shrub cover	0.94	-0.27
Nest tree height	0.14	0.86
Total	5.10	2.66
% of Variance	39.23	20.46
Cumulative %	39.23	59.70

7.5.1.3. Breeding season

Twenty nests were recorded during the study period. Although it breeds throughout the year (Grimmett *et al.* 1998), breeding pairs increased during July to October, with a major peak in July and minor peaks in October and March (Figure 7.10). As seeds which formed its major food and dry sticks used for the nest were available mostly during the dry season or summer, the maximum breeding was before monsoon. However, there was no significant correlation with any of the environmental factors.

7.5.1.4. Breeding biology

Altogether 20 nests were recorded from the scrub forest. Mostly one and rarely three eggs were laid. Incubation period varied from 11 to13 (n = 4) and nestling period 15 days (n = 3). Kumar and Ramachandran (1990) and Javed and Yahya (1991) found incubation period in a single nest to be 14 days. The total number of eggs laid by 20 pairs were 34, of which only 24% hatched. In total, 18% of nestlings fledged successfully. Thus the nesting success was 18%.

Figure 7.9. Percent of nests of the Laughing Dove on plant species (n = 20)

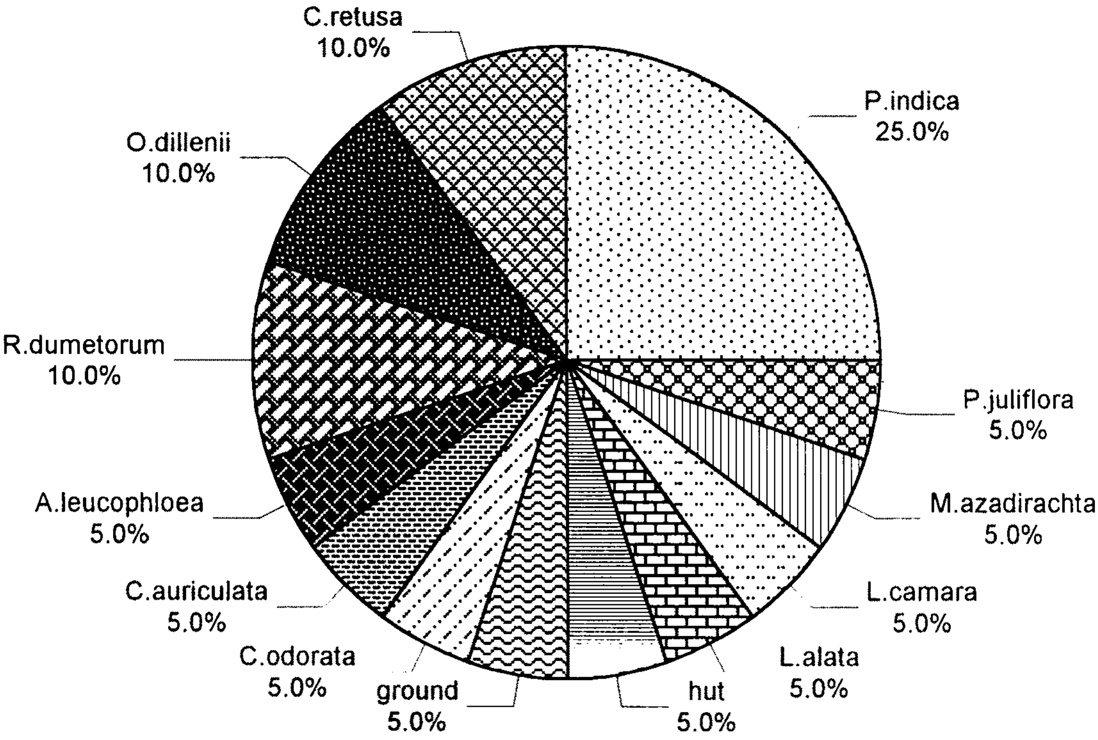
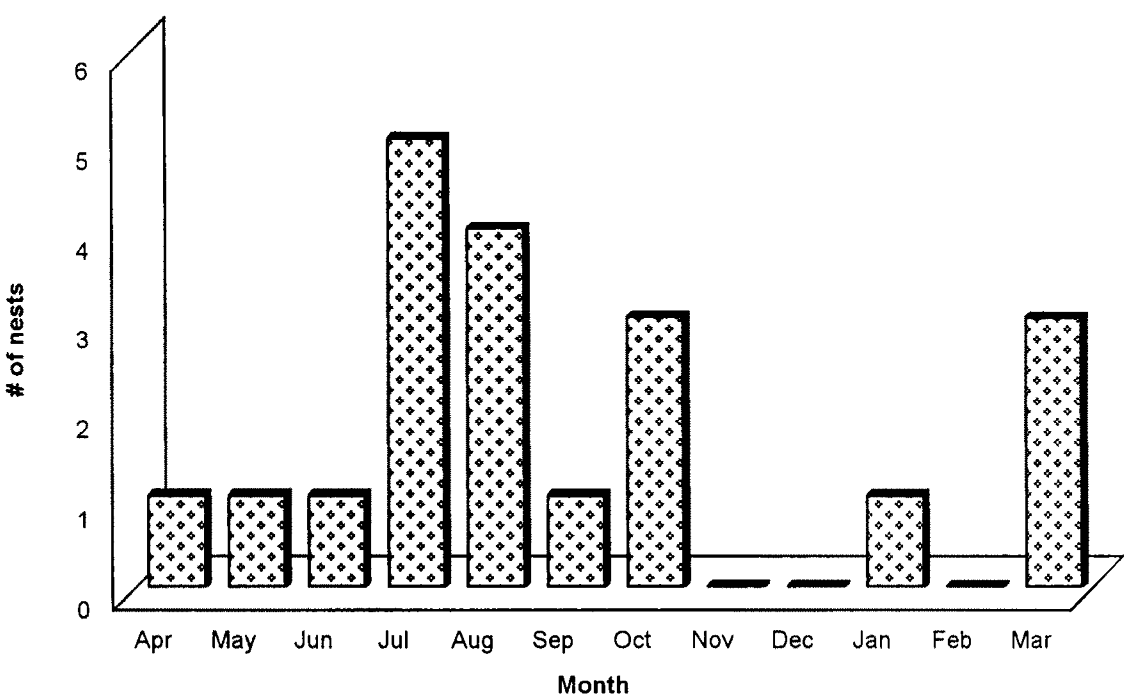


Figure 7.10. Breeding season of the Laughing Dove during 2000-2001



Only three nests (15%) showed success in bringing out fledgling. If the eggs were touched or any disturbances occurred near the nest, this bird abandoned the nest even with eggs and selected some other site for nesting.

7.5.2. Jungle Babbler *Turdoides striatus*

7.5.2.1. Nest and nest-site characteristics

The Jungle Babbler nests were found only in the MDDF and not in the SF. Twenty-three nests were recorded during the study (1999-2001). The nest was a statant cup (Pettingill 1985) built only on the branches of living trees (100%) and not in dead or partially dead plants. Forked twigs were used as supporting base for constructing nest which is formed of twigs, roots and leaves. Nests were made up of sticks kept on the plant among the twigs, under the crown. Roots of grass and leaves of *Pavetta indica* and *Limonium alata* were used for the inner lining of the nests.

7.5.2.2. Nesting plants

Limonium alata was highly preferred for nesting (Figure 2) followed by *Bauhinia racemosa* (17%), *Albizia amara* (13%), *Pavetta indica* (9%) and three other species (Figure 7.11). *Limonium alata* is the most common tree (Table 3.2) recorded in mixed dry deciduous forest, which was used by this species for nesting.

Although it had more nests on *Limonia alata*, it does not prefer this plant, as it was more abundant. However, it avoided some species such as *Bauhinia* *racemosa, Pongemia pinnata* and *Ziziphus mauritiana* were utilized in proportion to its availability (Appendix 5).

Nest-site variables were measured for 23 nests. Nest was placed in trees at the mean height of 3.3 ± 1.2m. The nest tree height showed 5.1 ± 1.7m (Table 7.12) with a mean girth at breast height of 29cm. Nests were concealed upto 3.5 ± 2.5m.

Table 7.12 Nest-site characteristics of Jungle Babbler

Variables	Mean ± SD
Nest-tree height (m)	5.1 ± 1.7
Canopy above the nest (%)	33 ± 27
Nest-tree GBH (cm)	29 ± 18
Nest height (m)	3.3 ± 1.2
Clutch size	3.6 ± 0.9
Nest depth	5.6 ± 1.1
Nest diameter (cm)	9.8 ± 2.8
Distance to the road/path (m)	16 ± 19
Distance from nearest tree (m)	3.3 ± 2.2
Nest concealment (m)	3.5 ± 2.5
Ground canopy (%)	47 ± 22
Plant canopy (%)	16 ± 9
Shrub cover (%)	24 ± 11

Table 7.13 Comparison of Nest-site variables of the Jungle Babbler with random site

Parameter	Nest site (n = 23)	Random site (n = 23)	Significance P
Tree height (m)	5.1 ± 1.7	2.6 ± 0.76	0.000
Tree GBH (cm)	29 ± 18	26.97 ± 40.1	0.062
Distance to the road/path (m)	16 ± 19	25.6 ± 23.9	0.042
Distance from nearest tree (m)	3.3 ± 2.2	4.01 ± 3.9	0.760
Ground cover(%)	47 ± 22	47.3 ± 15.6	0.860
Plant canopy (%)	16 ± 9	5.18 ± 1.8	0.015
Shrub cover (%)	24 ± 11	32.73 ± 14.4	0.150

Anova between nest site and random site showed tree height, plant canopy and distance to the road or path, as significant factors to select a nesting site (Table 7.13); other variables such as ground cover and distance from the nearest tree were not significant.

The first three principal components were selected which accounted for 62% of the total variance. The first component was highly associated with nest tree height, nest height, plant canopy and distance to road (Table 7.14). The second component was associated with the shrub cover, distance to nearest tree and nest concealment. The third component was associated with shade over nest. The factors highly correlated with these three components were those that directly related to the nest tree mainly shade over the nest leading to nestconcealment which was responsible for better success of the nest.

Table 7.14. Factor loading of the nest site characteristics with the first three principal components in the Jungle Babbler.

Variables	PC I	PC II	PC III
Nest tree height	0.84	-0.18	-0.15
Shade over nest	0.57	0.25	0.53
Nest concealment	0.09	0.65	-0.66
Nest diameter	0.30	-0.66	0.19
Distance to road	0.67	-0.22	-0.30
Nest tree GBH	-0.35	-0.08	0.37
Ground cover	0.84	0.09	0.17
Distance to nearest tree	0.39	0.72	0.14
Nest depth	0.34	0.40	-0.09
Nest height	0.76	0.11	0.40
Plant canopy	0.69	-0.22	-0.39
Shrub cover	-0.22	0.76	0.19
Total	3.75	2.32	1.40
% of Variance	31.21	19.36	11.68
Cumulative %	31.21	50.57	62.26

7.5.2.3. Breeding season

Breeding season was between October and July with the peak during January followed by March and April (Figure 7.12). The number of nests showed positive relation with biotic factors namely Anoplura ($r = 0.623$, $p = 0.013$), Arachnida ($r = 0.606$, $p = 0.017$), Hemiptera ($r = 0.601$, $p = 0.018$), Neuroptera ($r = 0.694$, $p = 0.004$) and the abundance of insects ($r = 0.588$, $p = 0.021$). Abiotic factors namely rainy days also showed positive correlation with the nests ($r = 0.599$, $p = 0.018$).

7.5.2.4. Breeding biology

The period between beginning of nest building and laying of first egg was 10 days. Rarely one and mostly four to five eggs were laid. Clutch size varied between 3 and 5. Colour of the egg is copper sulphate blue as given in Ali and Ripley (1987). Incubation period varied from 12 to13 ($n = 14$) and nestling period was 13-14 days ($n = 12$). Although 23 nests were recorded from the mixed dry deciduous forest, 12 (52%) nests showed success in bringing out fledgling. The total number of eggs laid was 83; of this hatching success was only 53%. In total, 45% of nestlings fledged successfully.

7.5.3. Purple-rumped Sunbird *Nectarinia zeylonica*

7.5.3.1. Nest and nest-site characteristics

Altogether 24 nests were observed. The nest was pendulous type,being placed on tertiary branches (Pettingill 1985) as given by Ali & Ripley (1987). Nest-site variables were measured for 24 nests.

Figure 7.11. Percent of nests of the Jungle Babbler on plant species (n = 23)

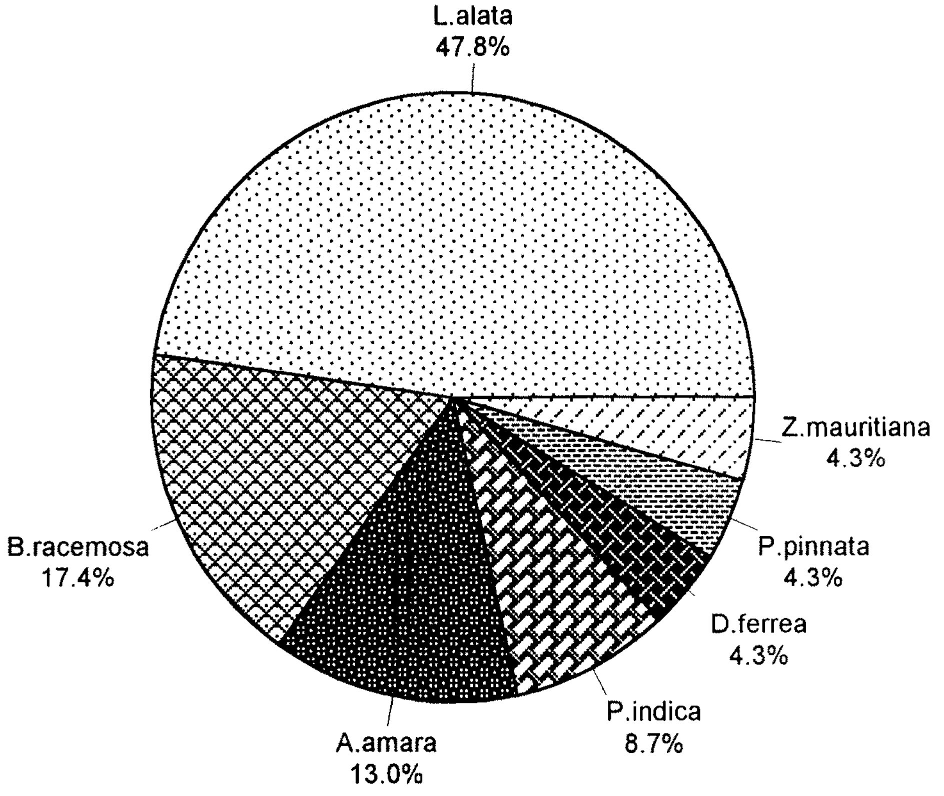
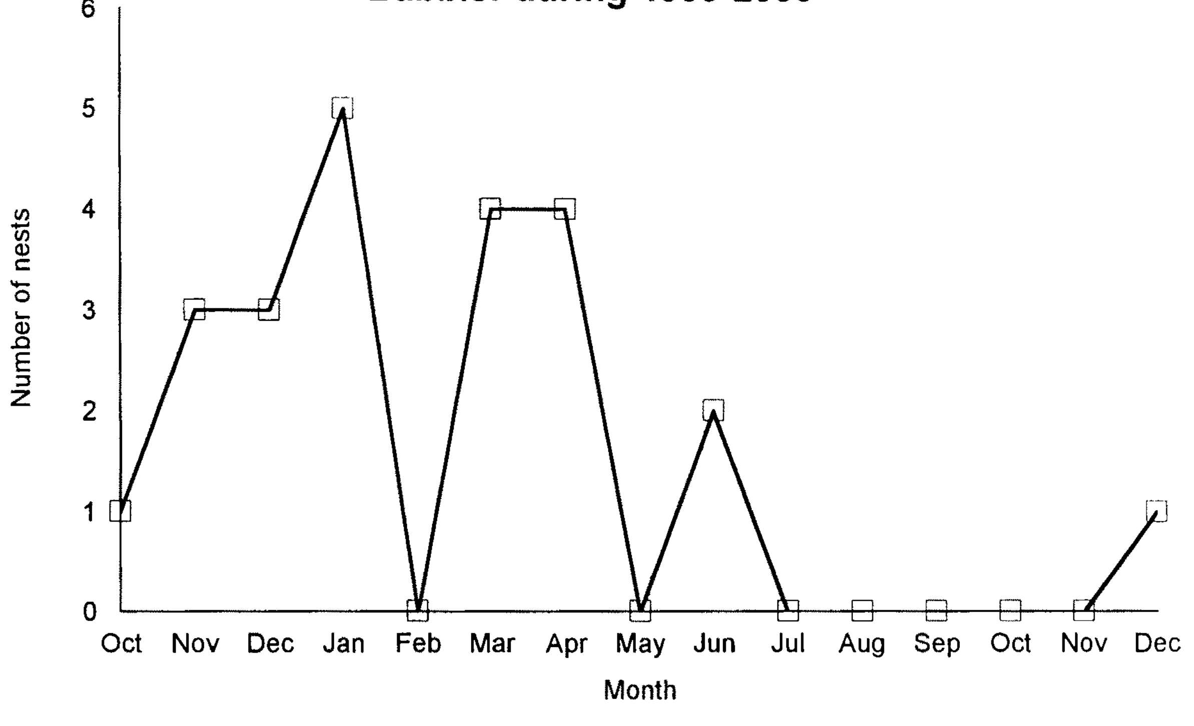


Figure 7.12. Breeding season of the Jungle Babbler during 1999-2000



7.5.3.2. Nest plant selection

The plant species used for nesting were mostly shrubs and a few tree species such *as L. camara. C. odorata, P. hexapetalum, T. indicus, A. fruticosa, Acacia* sp.,*C. philippensis, C. swietenia, M. azadirachta, P. juliflora, P. pinnata, S. cumini, T. asiatica and Z. mauritiana.* Major plants used were *Lantana camara* followed by *Chromolaena odorata, Pteralobium hexapetalum* and *Tamarindus indicus* harboring 59% of nests (Figure 7.13). Apart from these plant species, 10 species were used <5% for nesting. Nests were positioned mainly on tertiary branches which helps in hanging the nest. Nests on *Lantana camara* and *Chromolaena odorata* were on secondary branches.

Although it had more nests on *Lantana camara* and *Chromolaena odorata*, it did not show any special preference to these plants as these were more abundant. Other plants were utilized in proportion to its availability (Appendix 5) while a few species such as ***Acacia* sp,** , *Acalipha fruticosa* were avoided.

The nests were placed at the mean height of 1.7m (Table 7.15) with girth at breast height of 7.8 ± 8.3cm. The nest tree height showed 2.8 ± 1.6m. Nests were concealed upto 2m (Table 7.15).

Table 7.15 Nest-site characteristics of the Purple-rumped Sunbird

Variables	Mean ± SD
Nest-tree height (m)	2.8 ± 1.6
Canopy above the nest (%)	23 ± 27
Nest-tree GBH (cm)	7.8 ± 8.3
Nest height (m)	1.7 ± 0.9
Clutch size	2 ± 0.6
Nest depth	7.2 ± 2.2
Nest diameter (cm)	3.5 ± 0.5

Figure 7.13. Percent of nests of the Purple-rumped Sunbird on plant species (n = 24)

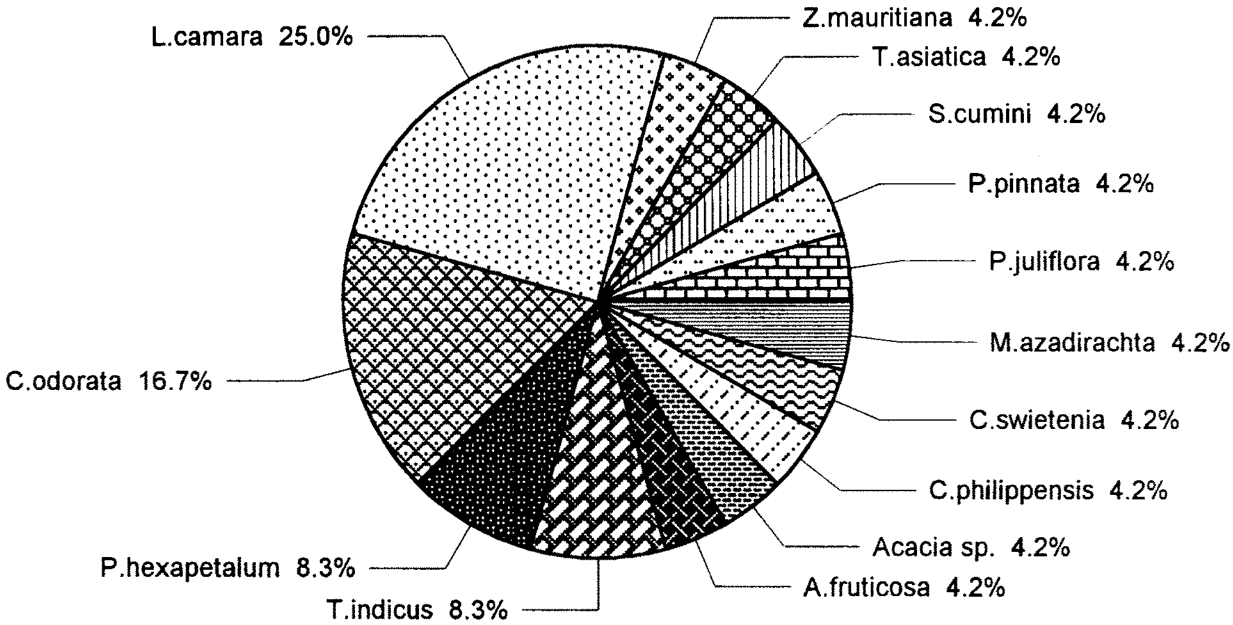
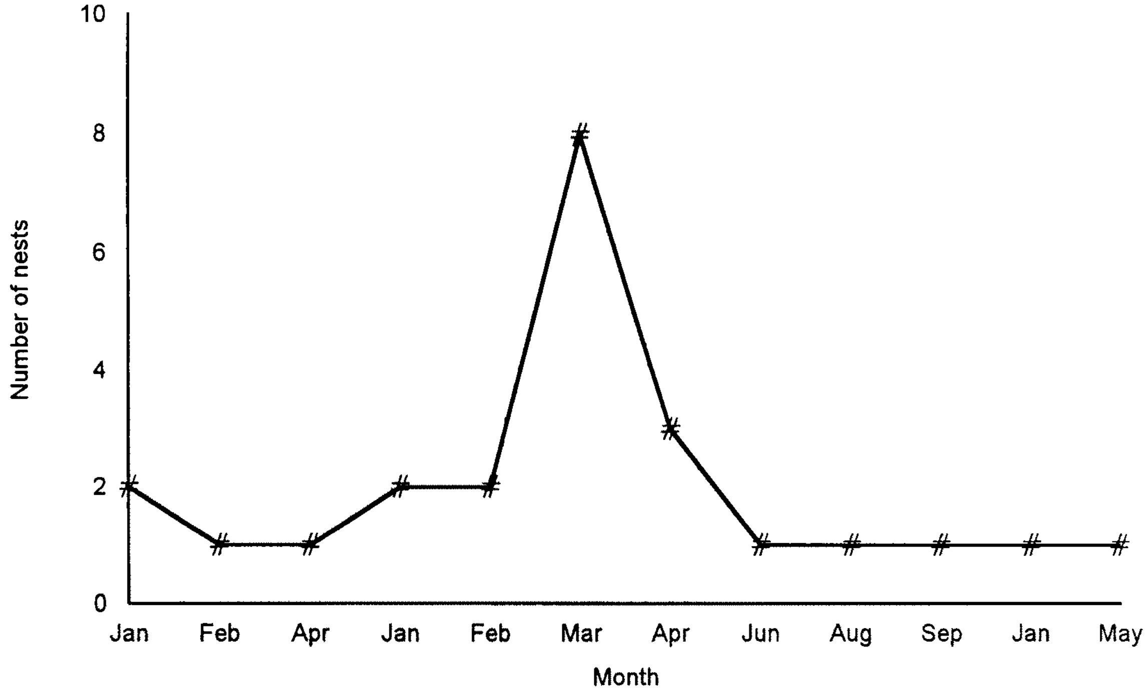


Figure 7.14. Breeding season of the Purple-rumped Sunbird during 1999-2001



Variables	Mean ± SD
Distance to the road/path (m)	8.8 ± 11
Distance from nearest tree (m)	6.1 ± 5.6
Nest concealment (m)	2 ± 1.4
Ground cover (%)	38 ± 18
Plant canopy (%)	6.4 ± 7.2
Shrub cover (%)	22 ± 16

Tree height and shrub cover showed significant variance (Anova) between the nesting site and the random sites (Table 7.16). The other variables such as tree GBH, distance to the road/path, distance from nearest tree, ground canopy and plant canopy were insignificantly different.

Table 7.16 Comparison of Nest-site variables of the Purple-rumped Sunbird with random sites

Parameters	Nest site (n = 24)	Random site (n = 20)	Significance p
Tree height (m)	2.8 ± 1.6	0.94 ± 0.62	0.000
Tree GBH (cm)	7.8 ± 8.3	6.47 ± 6.33	1.230
Distance to the road/path (m)	8.8 ± 11	7.9 ± 16.7	0.823
Distance from nearest tree (m)	6.1 ± 5.6	6.03 ± 6.62	0.967
Ground cover (%)	38 ± 18	43.6 ± 16.2	0.437
Plant canopy (%)	6.4 ± 7.2	5.83 ± 8.86	0.640
Shrub cover (%)	22 ± 16	34.7 ± 6.96	0.001

The first three principal components were selected which accounted for 60% of the total variance. The first component was highly associated with nest tree height, nest depth, nest diameter, nest height and plant canopy (Table 7.17). The second component was associated with the nest concealment, ground cover and plant canopy. The third component was associated with nest tree GBH. The factors highly correlated with these three components were directly related to the nest tree showing preference for a particular size of the nesting plant with dense canopy cover to conceal the nest.

Table 7.17. Factor loading of the nest site characteristics with the first three principal components in the Purple-rumped Sunbird

Variables	PC I	PC II	PC III
Nest tree height	0.85	0.29	-0.05
Shade over nest	0.26	-0.54	0.58
Nest concealment	-0.29	0.75	0.09
Nest diameter	0.53	-0.23	0.03
Distance to nearest tree	0.31	-0.02	-0.39
Distance to road	-0.14	0.23	-0.41
Nest tree GBH	0.11	-0.31	0.70
Ground cover	-0.35	0.54	0.59
Nest depth	0.74	-0.15	0.08
Nest height	0.85	0.42	-0.08
Plant canopy	0.74	0.52	0.19
Shrub cover	-0.67	0.33	0.35
Total	3.85	2.04	1.86
% of Variance	29.59	15.71	14.32
Cumulative %	29.59	45.30	59.62

7.5.3.3. Breeding season

Although it breeds throughout the year (Grimmett *et al.* 1998), breeding pairs increased during January to April (2000), with a peak in March (Figure 7.14). Flower abundance was increasing from May onwards, (3.7 & 3.8) which provides food for its young ones. Nesting material such as dry root, grass blades and inner lining materials such as white inner layer of the seed cover and leaves are available during this dry season. The nest also looked like a bunch of dry leaves and sticks suspended from a branch. The vigilant bird (Red-whiskered Bulbul) also bred during the same time and shared association ($r = 0.864$, $p = 0.012$) which gives signal to protect it from predators.

7.5.3.4. Breeding biology

Nests were recorded from both mixed dry deciduous (17) and scrub forests (7) during 1999-2001. Although 24 nests were recorded, only five nests (21%) showed success in bringing out fledgling. The total number of eggs laid was 47. Clutch size varied between 2 and 3, mostly two. Eggs were laid in the consecutive days. Only female incubated the eggs while male fed the female and nestling and guarded the nest. Incubation period varied from 9 to10 (n = 9) and nestling period was 10 days (n = 5). Hatching success was only 34% of eggs. In total, 21% of nestling successfully fledged off. Nestling was preyed mostly by carnivores as they were more and open area was high as the leaves withered and gave easy access to the nest. Number of successful nests was only 5 and nestlings 10 (21%).

7.5.4. Red-vented Bulbul *Pycnonotus cafer*

7.5.4.1. Nest and nest-site characteristics

Altogether 127 nests were observed in the MDDF and SF. This frugivore species built statant cup nest (Pettingill 1985) as given in Ali & Ripley (1987) and Vijayan (1980).

7.5.4.2. Nest plant selection

The number of plant species preferred for nesting was 18 in the mixed dry deciduous forest. The plant species preferred were mostly shrubs and a very few tree species such as *Carmona retusa, Lantana Camara, Atalantia monophylla, Ziziphus oenoplia, Acacia sp., Capparis sepiaria, Pavetta indica* and so on. Major plants used were *Carmona retusa* followed by *Lantana Camara* and *Atalantia monophylla* (Figure 7.15).

The number of plant species preferred for nesting was 21 in the scrub forest. The plant species preferred were shrub and tree species such *as Lantana Camara* followed by *Pavetta indica, Carmona retusa, Chromolaena odorata, Cassia auriculata* and so on (Figure 7.16). Major plants used were shrubs such as *Lantana Camara* followed by *Pavetta indica* and *Carmona retusa*.

Although it had more nests on *Lantana camara followed by Flacourtia indica* these plant species were not significantly preferred, but they were utilized in proportion to its availability (Appendix 5).Nest-site variables were measured for 127 nests. The nests were placed at the mean height of 1m (Table 7.18) with girth at breast height of 8 ± 6cm. The nest tree height showed 2 ± 1m. Nests were concealed at 1 ± 1m (Table 7.18). It preferred more open space (Ground cover % = 46 ± 17).

Table 7.18 Nest site characteristics of the Red-vented Bulbul

Variables	Mean ± SD
Nest-tree height (m)	2 ± 1
Canopy above the nest (%)	32 ± 28
Nest-tree GBH (cm)	8 ± 6
Nest height (m)	1 ± 1
Clutch size	3 ± 1
Nest depth	4 ± 1
Nest diameter (cm)	6 ± 1
Distance to the road/path (m)	15 ± 23
Distance from nearest tree (m)	7 ± 8
Nest concealment (m)	1 ± 1
Ground cover (%)	46 ± 17
Plant canopy (%)	5 ± 4
Shrub cover (%)	37 ± 15

Figure 7.15. Percent of nests of the Red-vented Bulbul on plant species in the mixed dry deciduous forest (n = 43)

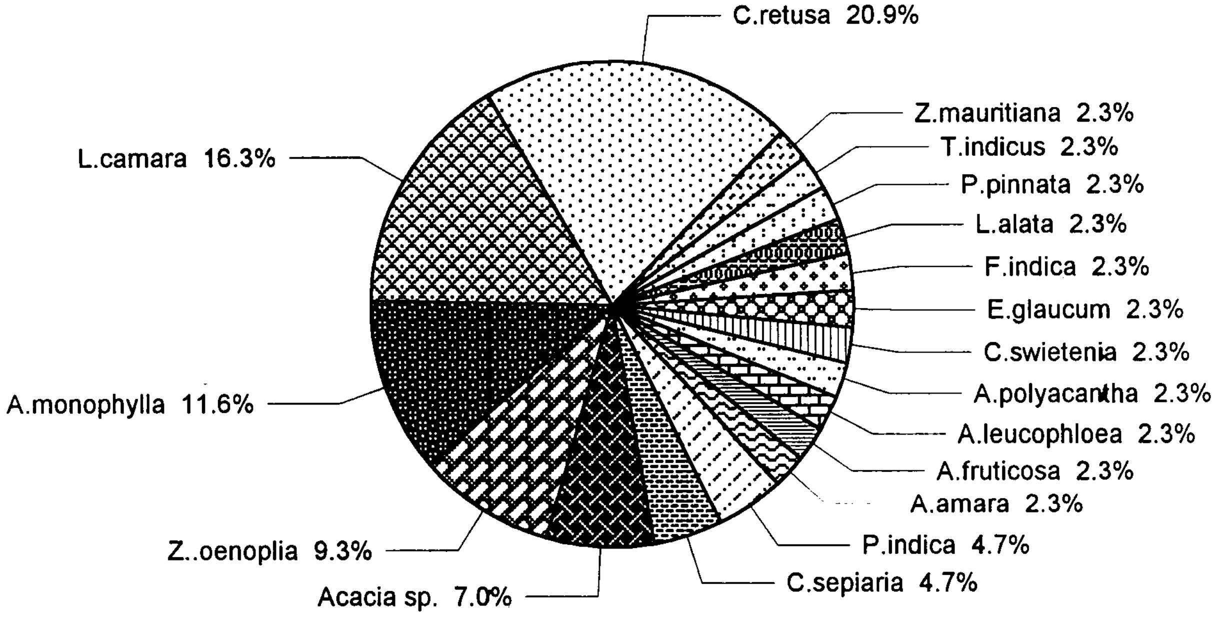
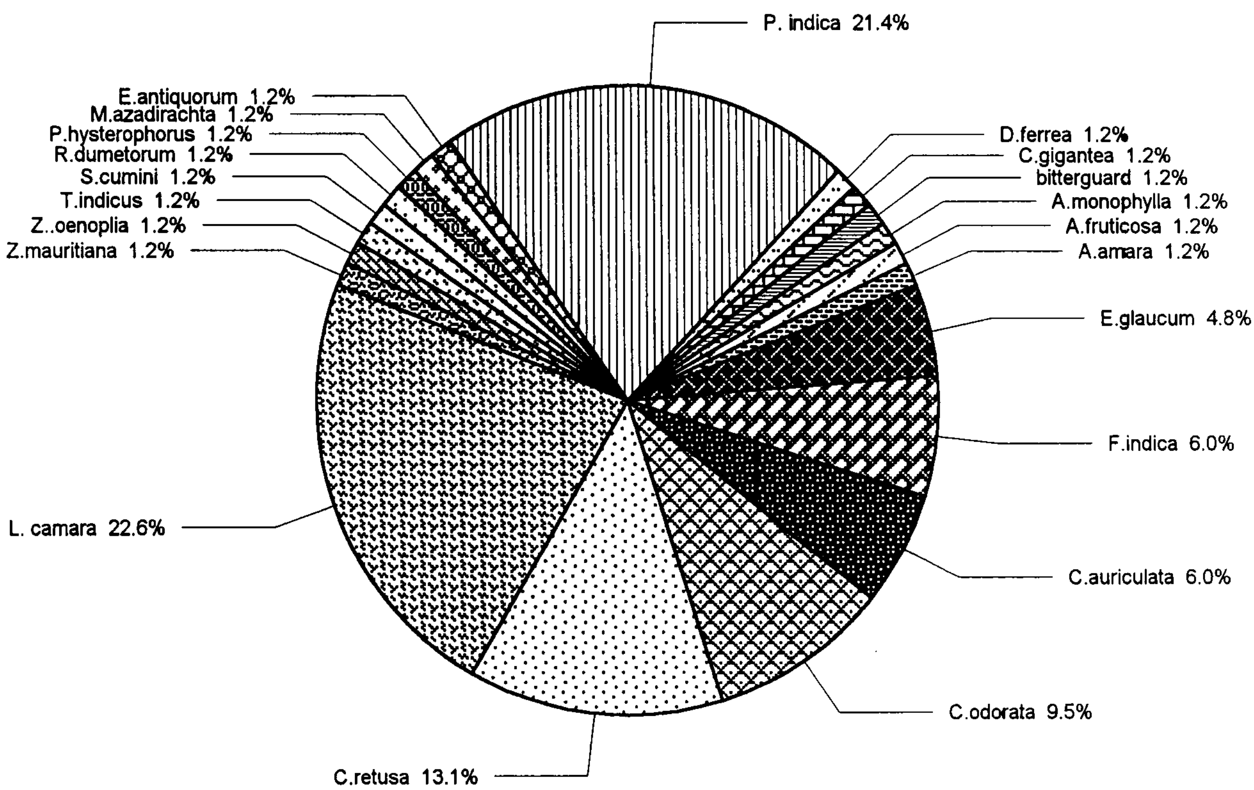


Figure 7.16. Percent of nests of the Red-vented Bulbul on plant species in the scrub forest (n = 84)



Tree height and tree GBH were significant factors in the selection of nesting plants preferring shrubs (Table 7.19). The distance from nearest tree and the other variables such as distance to the road/path, ground cover, shrub cover and plant canopy did not show significant variation between the nest-site and random sites.

Table 7.19 Comparison of Nest-site variables of the Red-vented Bulbul with random sites

Parameters	**Nest site (n = 127)**	**Random site (n = 20)**	**Significance p**
Tree height (m)	2 ± 1	5.1 ± 1.7	0.000
Tree GBH (cm)	8 ± 6	29 ± 18	0.000
Distance to the road/path (m)	15 ± 23	16 ± 19	0.962
Distance from nearest tree (m)	7 ± 8	3.3 ± 2.2	0.056
Ground cover (%)	46 ± 17	47 ± 22	0.963
Plant canopy (%)	5 ± 4	16 ± 9	0.159
Shrub cover (%)	37 ± 15	24 ± 11	0.712

The first three principal components were selected which accounted for only 54% of the total variance. The first component was highly associated with plant canopy, shrub cover, ground cover, and nest concealment (Table 7.20). The second component was associated with the nest tree height and nest height. The third component was associated with nest depth and shade over nest. The factors highly correlated with these three components were directly related to the nest tree bringing out the importance of the nest tree and cover for the nest as found in most of the birds for their success.

Table 7.20. Factor loading of the nest site characteristics with the first three principal components in the Red-vented Bulbul

Variables	PC I	PC II	PC III
Shade over nest	-0.46	0.02	0.57
Nest concealment	0.83	0.03	-0.03
Distance to road	-0.09	-0.15	0.03
Distance to nearest tree	-0.41	-0.09	0.06
Nest tree GBH	0.15	0.41	-0.24
Ground cover	0.90	-0.14	0.16
Nest depth	0.13	0.09	0.62
Nest diameter	-0.05	0.26	0.76
Nest height	-0.03	0.92	-0.15
Plant canopy	0.77	0.22	0.31
Shrub cover	0.88	-0.17	-0.07
Nest tree height	-0.06	0.94	-0.06
Total	3.37	2.16	1.51
% of Variance	25.96	16.61	11.65
Cumulative %	25.96	42.57	54.22

7.5.4.3. Breeding season

Although the data were recorded throughout the study period, search was intensified during September 1999 to January 2001 for three breeding seasons. Moreover it bred throughout the year in both the habitats (Figure 7. 17). There was a major peak in October and a minor peak in April in the scrub forest whereas in the mixed dry deciduous forest, peak was during December and July (Figure 7. 17). Rainfall was the significant factor, which showed positive relation with the number of nests ($r = 0.581$, $p = 0.018$).

7.5.4.4. Breeding biology

In total, 127 nests were recorded from the Anaikatty hills, 43 and 84 from the mixed dry deciduous and the scrub forests respectively. Clutch size varied between 2 and 4, mostly three and rarely two and four. Eggs were laid in the consecutive days. Incubation period varied from 11 to14 (n = 25) and nestling period was 11-12 days (n = 25). Six (14%) and 19 (23%) nests showed success in bringing out fledgling in the MDDF and SF respectively. Together for both the habitats, 25 nests showed success (20%). The total number of eggs laid by 127 breeding pairs was 322; of this hatching success was only 26%. In total, 16% of nestling fledged successfully.

7.5.5. Red-whiskered Bulbul *Pycnonotus jocosus*

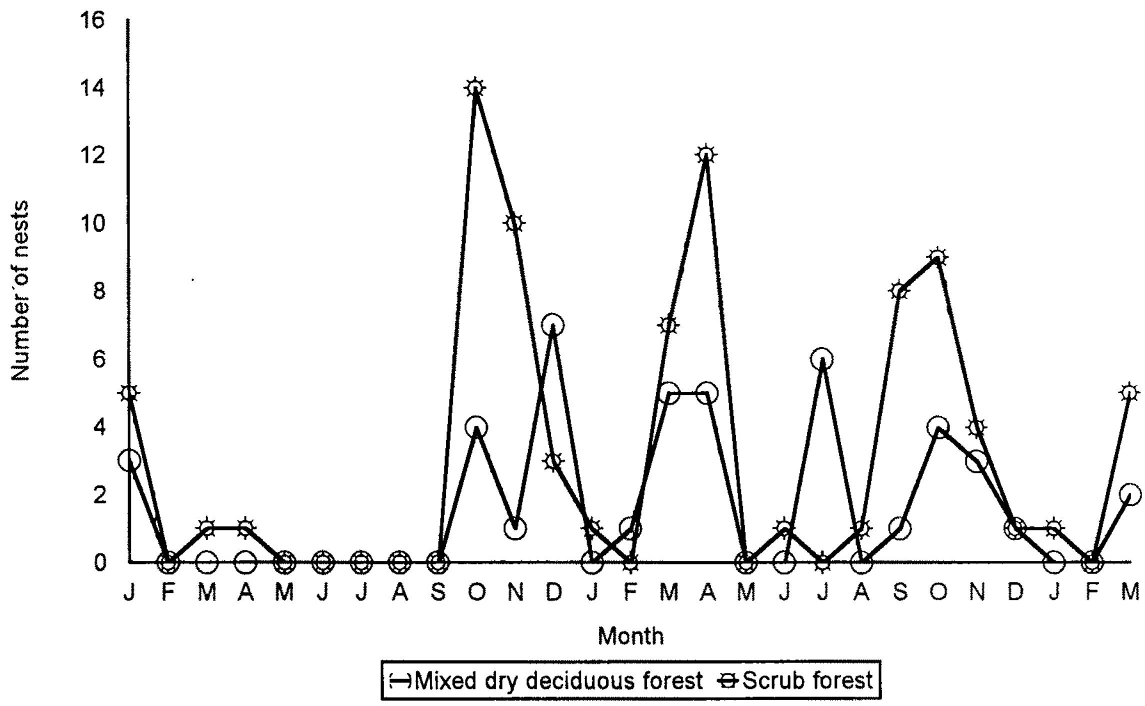
7.5.5.1. Nest and nest-site characteristics

In total, 39 nests were recorded from both mixed dry deciduous (6) and scrub forests (33) during 1999-2001. The nest (Plate 4) was made up of twigs and dead leaves bound with cobweb with the inner lining of roots, leaves and flower petals as given in Ali & Ripley (1987). This frugivore species built statant cup nest (Pettingill 1985). Nest-site variables were measured for 39 nests.

7.4.5.2. Nest plant selection

The plant species preferred for nesting were 15, mostly shrubs (10 species) and a few tree species (5). *Pavetta indica* was preferred largely (26%) followed by *Carmona retusa, Diospyros ferrea* and *Flacourtia indica.* Another four species showed 5% of preference while seven species showed least preference (2.6%) for nesting (Figure 7.18).

Figure 7.17. Breeding seasonality of the Red-vented Bulbul in the mixed dry deciduous and scrub forests during 1999-2001



Although it had more nests on *Pavetta indica*, it does not prefer this plant. Other plant species were utilized in proportion to its availability (Appendix 5). It showed preference of *Flacourtia indica* in MDDF.

The nests were placed at the mean height of 1.49m (Table 7.21) with girth at breast height of 9.87 ± 8cm. The nest tree height showed 2.2 ± 1m. Nest concealment was not high ie. 4.05 ± 11m (Table 7.21).

Table 7.21 Nest-site characteristics of the Red-whiskered Bulbul

Variables	Mean ± SD
Nest-tree height (m)	2.2 ± 1
Canopy above the nest (%)	35.9 ± 31
Nest-tree GBH (cm)	9.87 ± 8
Nest height (m)	1.49 ± 1
Clutch size	2.26 ± 1
Nest depth	4.67 ± 1
Nest diameter (cm)	6.36 ± 1
Distance to the road/path (m)	20.4 ± 33
Distance from nearest tree (m)	6.14 ± 6
Nest concealment (m)	4.05 ± 11
Ground cover (%)	48.6 ± 19
Plant canopy (%)	5.69 ± 3
Shrub cover (%)	27.8 ± 14

Tree GBH, shrub cover, plant canopy and distance from nearest tree significantly differed from the random site in the selection of nesting plants (Table 7.22). The other variables such as tree height, distance to the road/path and ground cover did not influence in the nest-site selection.

Table 7.22 Comparison of Nest-site variables of the Red- whiskered Bulbul with random sites

Parameters	**Nest site (n = 39)**	**Random site (n = 29)**	**Significance p**
Tree height (m)	2.2 ± 1	1.9 ± 0.6	0.102
Tree GBH (cm)	9.87 ± 8	4.56 ± 2.06	0.012
Distance to the road/path (m)	20.4 ± 33	19.4 ± 23.2	0.852
Distance from nearest tree (m)	6.14 ± 6	9.74 ± 7.58	0.030
Ground cover (%)	48.6 ± 19	52.3 ± 16	0.380
Plant canopy (%)	5.69 ± 3	4.3 ± 1.3	0.008
Shrub cover (%)	27.8 ± 14	37.4 ± 10	0.004

The first three principal components were selected which accounted for 62% of the total variance. The first component was highly associated with nest tree height and nest tree GBH (Table 7.23). The second component was associated with the shrub cover and nest concealment. The third component was associated with distance from road. The factors highly correlated with these three components were directly related to the nest tree and indicate significance of the tree preferring shrub with dense canopy as found in Siruvani (Vijayan *et al.* 2000).

Table 7.23. Factor loading of the nest site characteristics with the first three principal components in the Red-whiskered Bulbul

Variables	**PC I**	**PC II**	**PC III**
Shade over nest	0.41	-0.14	-0.09
Nest concealment	0.10	0.10	-0.59
Distance to road	-0.32	-0.45	0.44
Distance to nearest tree	0.27	0.21	0.51
Nest tree GBH	0.85	0.04	0.19
Ground cover	0.03	0.79	0.00
Nest depth	0.25	-0.19	-0.51
Nest diameter	0.46	-0.36	-0.43
Nest height	0.71	-0.09	0.39
Plant canopy	0.50	0.25	0.18
Shrub cover	0.09	0.81	-0.12

Variables	PC I	PC II	PC III
Nest tree height	0.69	-0.23	0.00
Total	2.66	1.85	1.63
% of Variance	20.50	14.23	12.51
Cumulative %	20.50	34.73	47.24

7.5.5.3. Breeding season

This frugivore species bred throughout the year (Figure 7.19). Moreover the number of nests increased from December to April; there was a peak in March 2000. This breeding season may provide enough food for their fledglings to survive better in the forth coming months where the fruit abundance increased from May onwards in both the habitats (Figure 3.7 & 3.8). Although it is a frugivore, it fed on insects and nectar during breeding season as given in Ali & Ripley (1987). Breeding season had relation with the abundance of insects such as Anoplura ($r = 0.613$, $p = 0.009$), Arachnida ($r = 0.644$, $p = 0.005$), Hemiptera ($r = 0.551$, $p = 0.022$), Neuroptera ($r = 0.691$, $p = 0.002$) and Orthoptera ($r = 0.669$, $p = 0.003$). Also positively related with the abiotic factors such as Relative humidity ($r = 0.675$, $p = 0.003$) and sunshine hours ($r = 0.552$, $p = 0.022$).

7.5.5.4. Breeding biology

Altogether 39 nests were recorded. Clutch size varied between 2 and 3, mostly two and rarely three. Eggs were laid in the consecutive days. Incubation period varied from 13-14 ($n = 5$) and nestling period was 10-11 days ($n = 5$). The total number of eggs laid were 88; of this hatching success was only 22% of eggs. In total, 15% of nestlings successfully fledged off. Nestling was preyed

Figure 7.18. Percent of nests of the Red-whiskered Bulbul on plant species (n = 39)

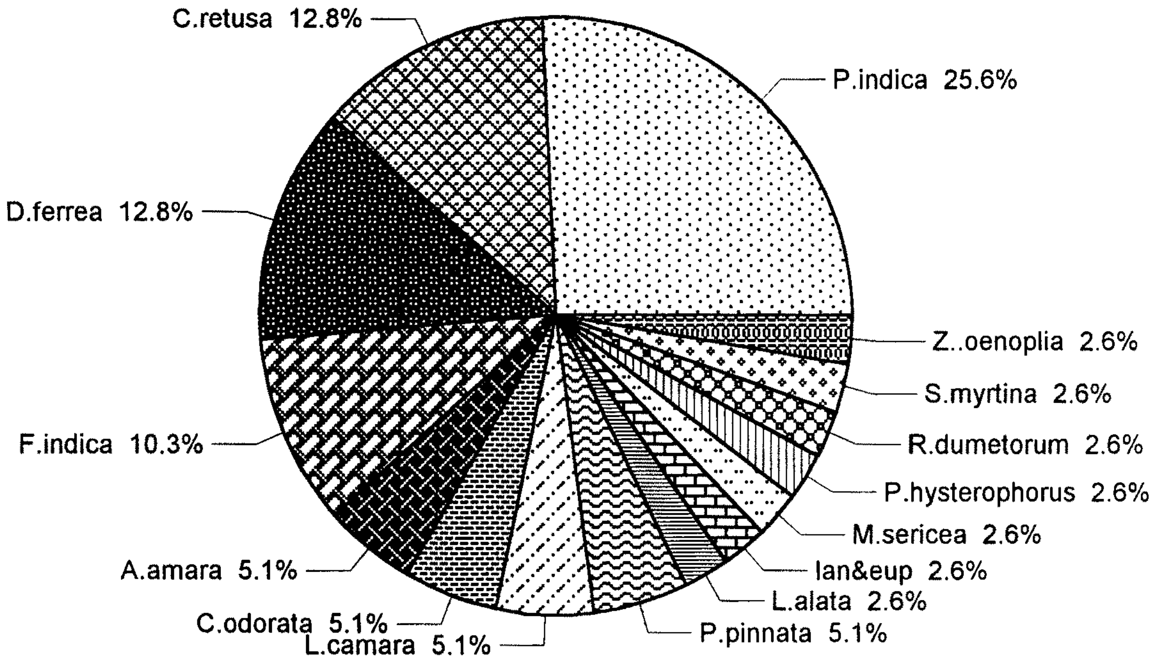
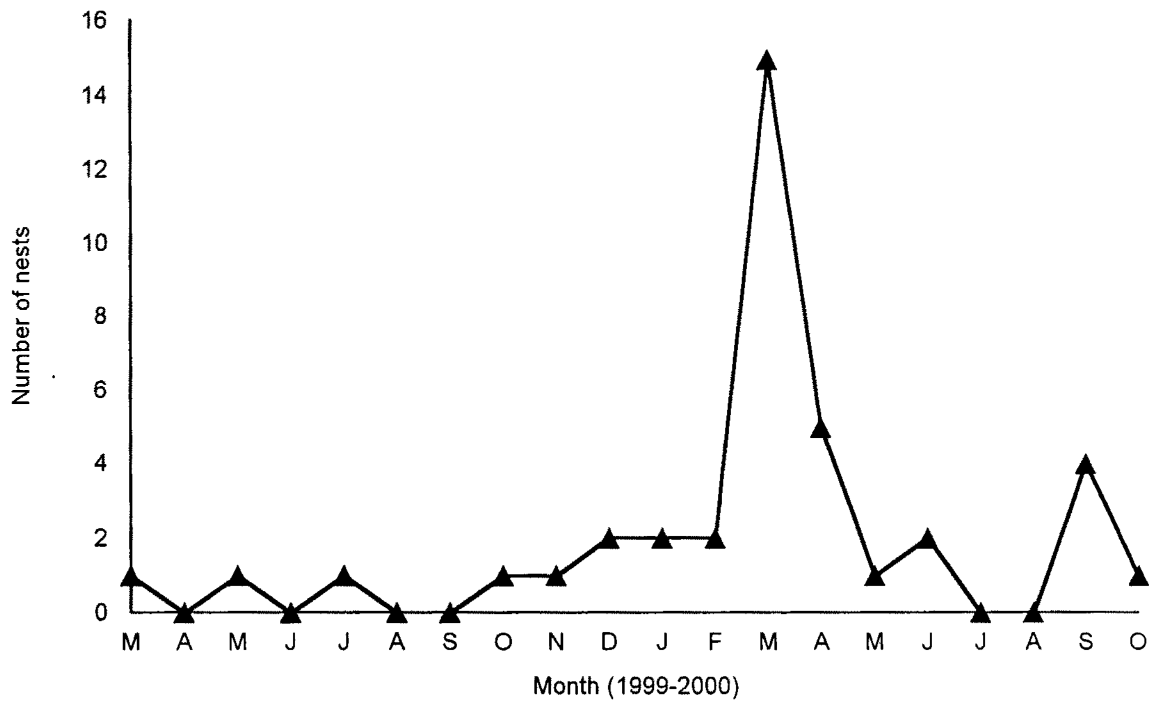


Figure 7.19. Breeding season of the Red-whiskered Bulbul in the Anaikatty hills



mostly by carnivores. Number of successful nests was only 5 (13%) and nestling 10 (21%).

7.5.6. Tawnybellied (Rufousbellied) Babbler *Dumetia hyperythra*

7.5.6.1. Nest and nest-site characteristics

This insectivore species built a ball type nest (Ali and Ripley 1987) of coarse grass blade lined with softer grass and rootlets with entrance hole at the side and placed in a bush >1m (Plate 4).

7.5.6.2. Nest plant selection

The plant species preferred for nesting were only six, mostly shrubs and a herb. Major species preferred for nesting were *Acalypha fruticosa, Pavetta indica, Opuntia dillenii* and *Parthenium hysterophorus* followed by grass (14%) and *Mundulea sericea* (Figure 7.20).

Although it had equal number of nests on four plant species, it does not prefer these plants (Appendix 5); plants in MDDF and SF were utilized in proportion to their availability (Appendix 5).

Nest site variables were measured from 21 nests. The nests were placed at the mean height of 0.23m (Table 7.24) with girth at breast height of 6.47 ± 6.33cm. The nest tree height showed 0.94 ± 0.62m. Nest concealment was low ie. 6.36 ± 15.9m (Table 7.24).

Table 7.24 Nest-site characteristics of the Tawny-bellied Babbler

Variables	Mean ± SD
Nest-tree height (m)	0.94 ± 0.62
Canopy above the nest (%)	35 ± 30.4
Nest-tree GBH (cm)	6.47 ± 6.33
Nest height (m)	0.23 ± 0.14
Clutch size	2.33 ± 0.73
Nest depth	8.86 ± 1.35
Nest diameter (cm)	4.67 ± 0.91
Distance to the road/path (m)	7.9 ± 16.7
Distance from nearest tree (m)	6.03 ± 6.62
Nest concealment (m)	6.36 ± 15.9
Ground cover (%)	43.6 ± 16.2
Plant canopy (%)	5.83 ± 8.86
Shrub cover (%)	34.7 ± 6.96

Tree height (F=40.95) and tree GBH (F=5.55) significantly differed from the random site in the selection of nesting plants (Table 7.25). The other variables such as tree GBH, distance from nearest tree, ground cover, plant canopy, shrub cover and distance to the road/path were not significantly different between the nest site and random sites.

Table 7.25 Comparison of Nest-site variables of the Tawny-bellied Babbler with random sites

Parameters	Nest site (n = 21)	Random site (n = 21)	Significance p
Tree height (m)	0.94 ± 0.62	2.1 ± 0.6	0.000
Tree GBH (cm)	6.47 ± 6.33	11.81 ± 7.8	0.024
Distance to the road/path (m)	7.9 ± 16.7	9.9 ± 16.7	0.707
Distance from nearest tree (m)	6.03 ± 6.62	7.9 ± 12.4	0.543
Ground cover (%)	43.6 ± 16.2	45± 17	0.214
Plant canopy (%)	5.83 ± 8.86	5.95 ± 4.4	0.648
Shrub cover (%)	34.7 ± 6.96	34.8 ± 11.9	0.219

The first three principal components were selected which accounted for 62% of the total variance. The first component was highly associated with nest characteristics such as shade over the nest, nest depth, nest height, nest diameter and distance to road (Table 7.26). The second component was associated with the nest height and nest concealment. The third component was associated with nest tree height, nest tree GBH and nest diameter. The factors highly correlated with these three components were those that directly related to the nest characteristics and the nesting location and plant mainly shorter shrubs and herbs.

Table 7.26. Factor loading of the nest site characteristics with the first three principal components in the Tawny-bellied Babbler

Variables	PC I	PC II	PC III
Shade over nest	0.74	0.16	-0.13
Nest concealment	-0.47	0.45	0.00
Distance to nearest tree	-0.09	0.13	-0.36
Distance to road	0.63	0.41	-0.41
Nest tree GBH	0.07	-0.26	0.93
Ground cover	-0.50	-0.37	-0.12
Nest depth	0.82	-0.27	0.04
Nest diameter	0.79	-0.23	0.47
Nest height	0.43	0.62	0.13
Plant canopy	0.08	-0.71	-0.02
Shrub cover	-0.95	0.03	0.14
Nest tree height	-0.20	0.57	0.64
Total	3.86	2.56	1.88
% of Variance	29.66	19.72	14.44
Cumulative %	29.66	49.38	63.82

7.5.6.3. Breeding season

This species bred from November to July (Figure 7.21). Moreover the number of nests increased from March to June, with a peak in April 2000, highly

Figure 7.20. Percent of nests of the Tawny-bellied Babbler on plant species

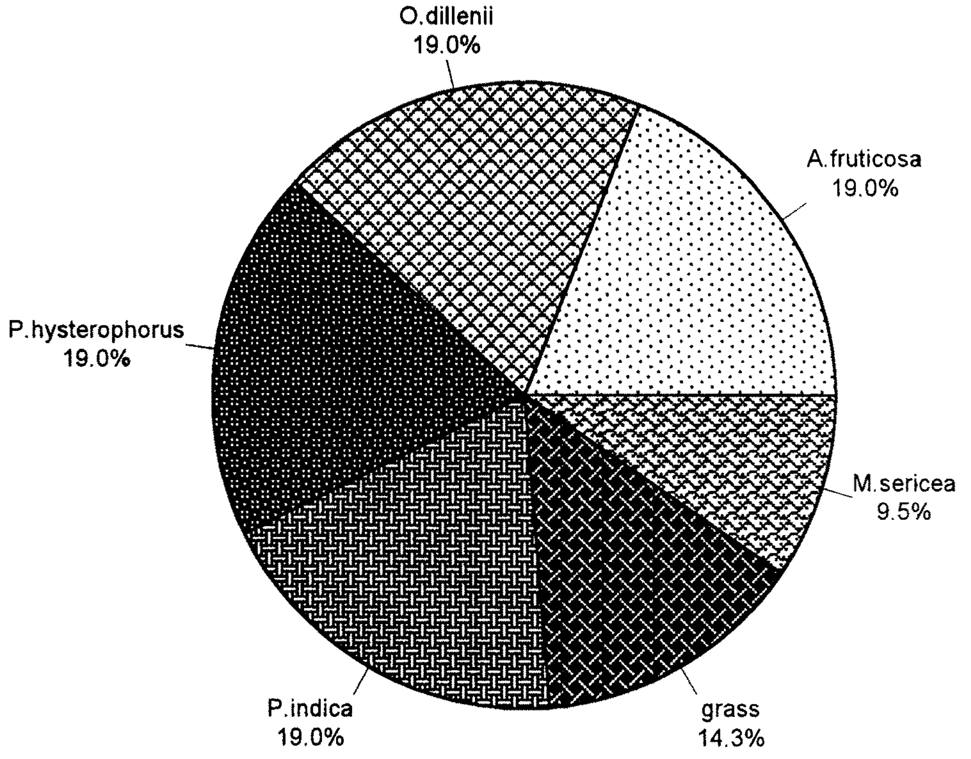
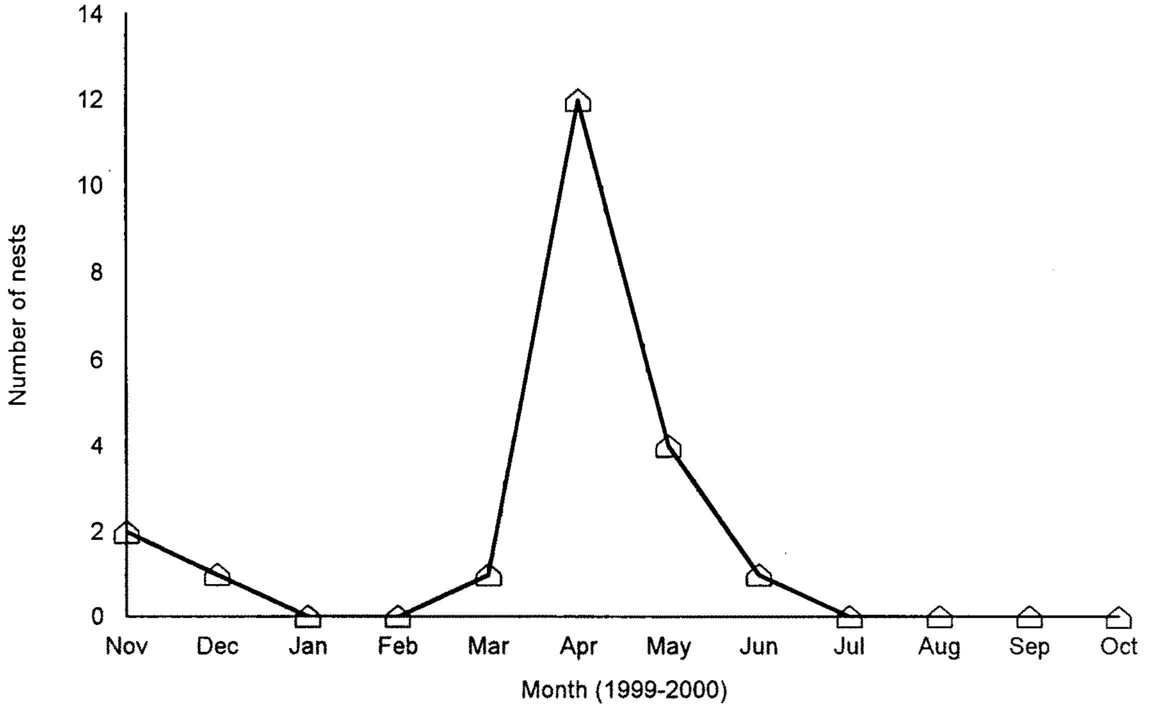


Figure 7.21. Breeding season of the Tawny-bellied Babbler in Anaikatty hills (n = 21)



correlating with the maximum temperature (r = 0.583, p = 0.047) and Mallophaga (r = 0.938, p = 0.000).

7.5.6.4. Breeding biology

Twenty-one nests were recorded from the Anaikatty hills during 1999-2001. Eggs were laid in the consecutive days. Clutch size was between 1 and 3, mostly 3. Both the parents participated in all the nesting activities. Incubation period was about 13 (n = 5) days. The young ones left the nest 13-15 (n = 4) days after hatching. Although 21 nests were recorded, only four nests (19%) showed success in bringing out nestling. The total number of eggs laid was 49, of this hatching success was only 18% of eggs. In total, only 10% of nestlings successfully fledged off. Nestlings were preyed mostly by carnivores. High predation occurred due to the feeding of eggs by snake and Crow-Pheasant, along with the disturbance by elephant and cattle grazing which trampled the nesting plant and the nest.

7.5.7. Yellow-billed (White-headed) Babbler *Turdoides affinis*

7.5.7.1. Nest and nest-site characteristics

Altogether 29 nests were studied. The nest was statant cup type (Pettingill 1985). Forked twigs were used as supporting base for constructing nest which is formed of twigs, roots and leaves. Nests were made up of sticks and roots kept on the plant among the twigs always under the canopy. Mostly it built nests on the branches. Roots of grass and leaves of *Bauhinia racemosa* were used for the inner lining of the nests.

7.5.7.2. Nesting plants

Nesting plant species were mostly shrubs (60%) and trees (40%). This statant cup nest was built on the living trees (93%) and partially dead plants (7%). *Pavetta indica* was used maximum for nesting (Figure 7.22) followed by *Carmona retusa* (17%), *Elaeodendron glaucum* and *Lantana Camara* (10% each). Four plants had 7% each of nests and two plants 3% each (Figure 7.22).

Although it had more nests on *Pavetta indica*, it does not prefer this plant. A few plant species were either avoided or utilized in proportion to its availability (Appendix 5).

Nest-site variables were measured for 29 nests. Nest was placed at the mean height of 1.9m. The nest tree height showed 2.6 ± 0.76m (Table 7.27) with a mean girth at breast height 17cm. Nests were concealed upto 1.95 ± 1.84m.

Table 7.27 Nest -site characteristics of the Yellow-billed Babbler

Variables	Mean ± SD
Nest-tree height (m)	2.6 ± 0.76
Canopy above the nest (%)	37.24 ± 30.8
Nest-tree GBH (cm)	16.97 ± 40.1
Nest height (m)	1.9 ± 0.6
Clutch size	3.48 ± 1.02
Nest depth	5.36 ± 1.3
Nest diameter (cm)	8.8 ± 1.3
Distance to the road/path (m)	25.6 ± 23.9
Distance from nearest tree (m)	4.01 ± 3.9
Nest concealment (m)	1.95 ± 1.84
Ground cover (%)	47.3 ± 15.6
Plant canopy (%)	5.18 ± 1.8
Shrub cover (%)	32.73 ± 14.4

Anova showed tree height, tree GBH, distance from the nearest tree and plant canopy as significant factors to prefer nesting site (Table 7.28). Other variables such as distance to the road or path, ground cover and shrub cover were not significant.

Table 7.28 Comparison of nest-site variables of the Yellow-billed Babbler with random sites

Parameters	Nest site (n = 20)	Random site (n = 20)	Significance p
Tree height (m)	2.6 ± 0.76	2.1 ± 0.6	0.000
Tree GBH (cm)	16.97 ± 40.1	11.81 ± 7.8	0.016
Distance to the road/path (m)	25.6 ± 23.9	19.9 ± 16.7	0.493
Distance from nearest tree (m)	4.01 ± 3.9	7.9 ± 12.4	0.022
Ground cover (%)	47.3 ± 15.6	45 ± 17	0.614
Plant canopy (%)	5.18 ± 1.8	5.95 ± 4.4	0.002
Shrub cover (%)	32.73 ± 14.4	34.8 ± 11.9	0.069

The first three principal components were selected which accounted for 62% of the total variance. The first component was highly associated with nest tree concealment, nest tree GBH, ground cover and plant canopy (Table 7.29). The second component was associated with the nest tree height and nest height. The third component was associated with nest depth. The factors highly correlated with these three components in nest-site selection were directly related to the nest tree and their microhabitat especially canopy and ground cover.

Table 7.29. Factor loading of the nest site characteristics with the first three principal components in the Yellow-billed Babbler.

Variables	PC I	PC II	PC III
Nest tree height	-0.51	0.73	-0.16
Shade over nest	-0.40	0.21	0.37
Nest concealment	0.60	0.45	0.05
Nest diameter	-0.37	0.33	-0.26

Variables	PC I	PC II	PC III
Distance to road	-0.01	-0.63	-0.07
Nest tree GBH	-0.54	0.45	0.42
Ground cover	0.89	0.37	0.05
Distance to nearest tree	-0.25	-0.28	-0.51
Nest depth	-0.06	-0.06	0.81
Nest height	-0.50	0.68	-0.30
Plant canopy	0.72	0.23	-0.23
Shrub cover	0.84	0.38	0.06
Total	3.56	2.37	1.48
% of Variance	29.70	19.73	12.34
Cumulative %	29.70	49.43	61.77

7.5.7.3. Breeding season

It bred throughout the year with a major peak during March or May and minor peak during October (Figure 7.23) as the invertebrate abundance also increased (Figure 5.10) which formed the major food for this species. It also showed positive correlation with the abundance of Isoptera ($r = 0.510$, $p = 0.036$) and Anoplura ($r = 0.482$, $p = 0.050$) which were used to feed their young ones.

7.5.7.4. Breeding biology

Twenty-nine nests were recorded from Anaikatty hills, of this 28 were from the scrub forest and one from the mixed dry deciduous forest. Clutch size varied between 3 and 6 ($n = 13$). Colour of the egg was as in Ali and Ripley (1987). Eggs were laid on the consecutive days. Incubation period varied from 11 to 12 days ($n = 12$) and nestling period 13 to 14 days ($n = 5$). Only 5 (17%) nests showed success in bringing out fledglings. The total number of eggs laid was 101; of this hatching success was only 32%. In total, 16% of nestling fledged successfully. Rarely one, two and six which were predated as they laid.

Figure 7. 22. Percent of nests of the Yellow-billed Babbler on plant species (n = 29)

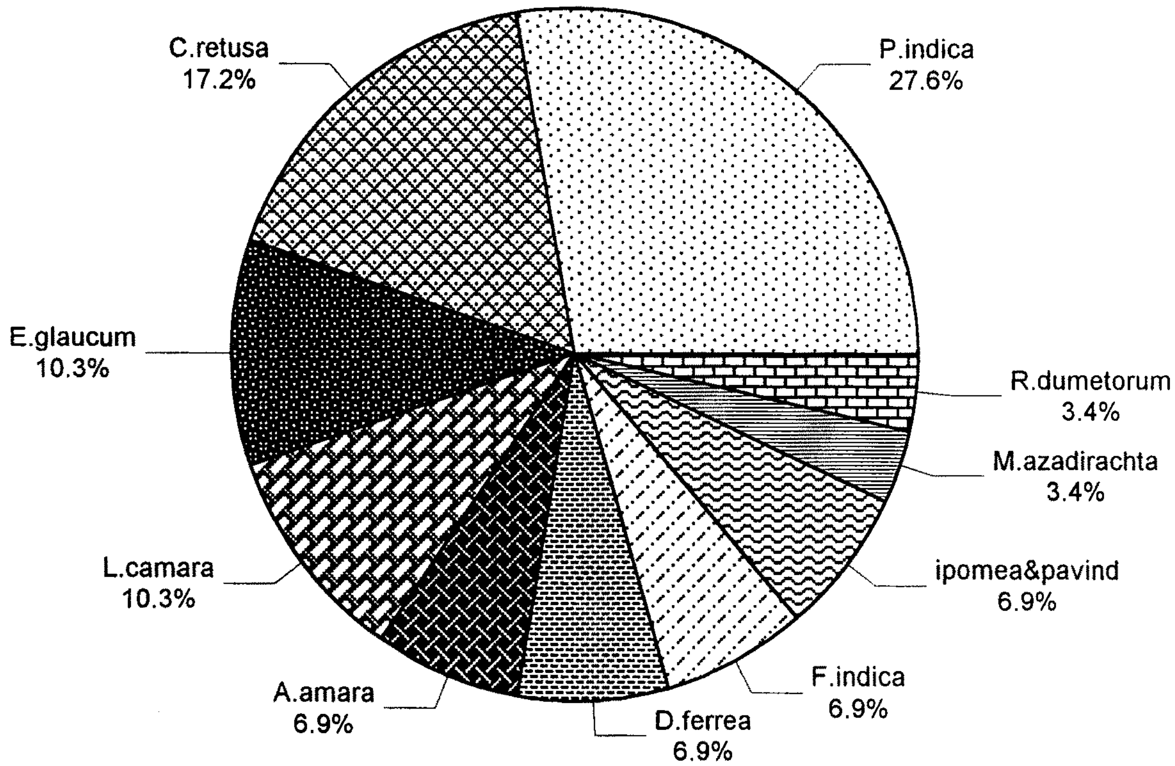
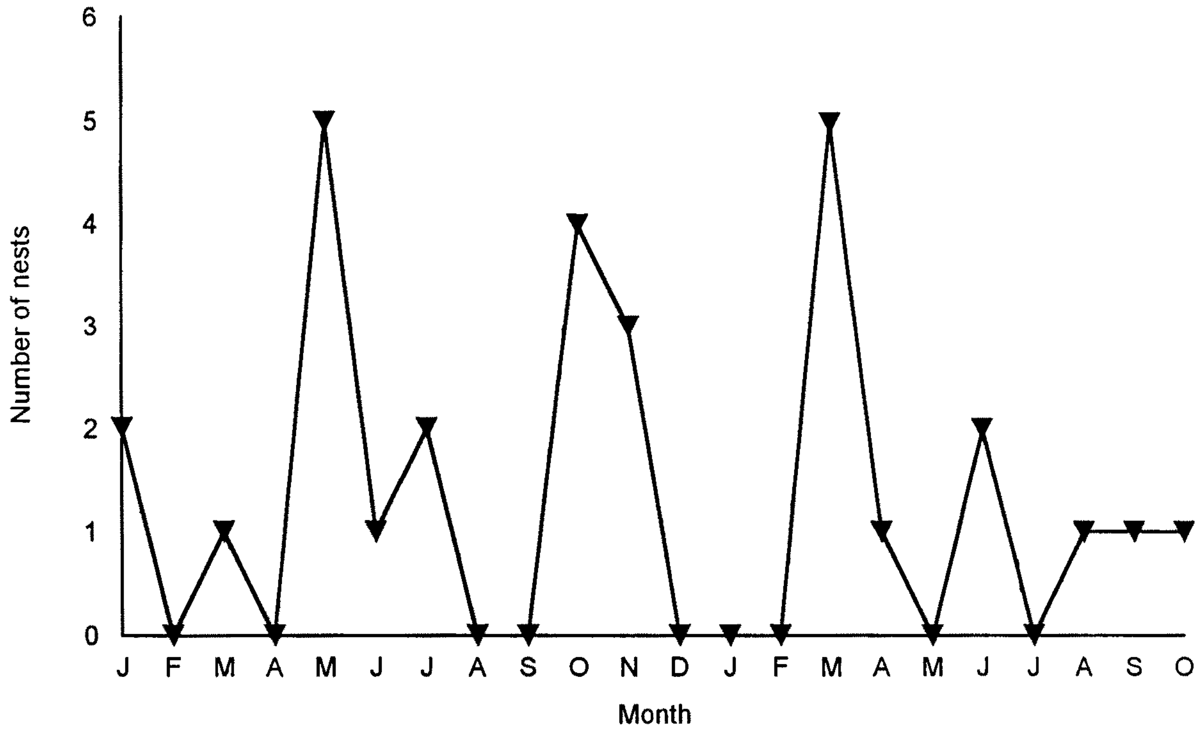


Figure 7. 23. Breeding season of the Yellow-billed Babbler in the scrub forest during 1999-2000



7.5.8. Yellow-eyed Babbler (*Chrysomma sinense*)

7.5.8.1. Nest and nest-site characteristics

Altogether 28 nests of the Yellow-eyed Babbler (YEB) were observed in the scrub forest. Even-though dense thorny forest (MDDF) is adjuvant to the SF in the study area, there was not even a single nest in MDDF. This shows that Yellow-eyed Babbler is habitat specific to breed in the open scrub forest. Partridge (1974) experimentally proved that the habitat preference was 'genetically determined' and could be taken to imply that the development of the mechanisms controlling the behavior could have been evolved with the environmental factors. The presence of these individuals of species is an indicator of environmental quality (Kiester and Slatkin 1974). YEB placed the nest at the junction of the main bifurcated branches so as to get a firm support at the bottom. The nests are easily distinguished with a definite deep statant cup, and were built with grass, rootlet and fully lined by cobweb outside, which gives the appearance of cemented outer layer. Leaves softened the inner base. Apparently the nest has been located more towards the center of the plant and confined itself to the interior of the bush. The three sides of the rim of the nest are attached to the adjoining branches. The possible adaptive significance of Yellow-eyed Babbler nesting in the main axis of the plant is because of i. the clutch size is three to four, which needs stronger support for the nest. ii. To feed three or four chicks, the visits of the parents are frequent and a nest in the center of a bush is more suitable for avoiding detection by the predator.

7.5.8.2. Nesting plants

The most favored plant for nesting was *Pavetta indica* followed by *Chromolaena odorata, Lantana camera and Carmona retusa* (Figure 7.24). These plants were preferred in combination with *Lantana camera* invariably for all the nests. The availability of extensive branching system, suitable for placing the cup nests gives more security as found by Vijayan (1984) in the Drongos.

Although it had more nests on *Pavetta indica* and *Chromolaena odorata*, it did not prefer this plant as well as other two plants but showed avoidance of a few species in preference test (Appendix 5).

Nest-site variables were measured for 28 nests. The nest was statant cup. Nest was placed at the height of 1.09 ± 0.24m. The nest tree height showed 1.94 ± 0.55m (Table 7.30) with a mean girth at breast height of 4.5cm. Nests were concealed upto 1.13 ± 0.35m.

Table 7.30 Nest-site characteristics of the Yellow-eyed Babbler

Variables	**Mean ± SD**
Nest-tree height (m)	1.94 ± 0.55
Canopy above the nest (%)	38.9 ± 29.6
Nest-tree GBH (cm)	4.5 ± 2.05
Nest height (m)	1.09 ± 0.24
Clutch size	3.04 ± 0.92
Nest depth	5.39 ± 1.03
Nest diameter (cm)	5.43 ± 1
Distance to the road/path (m)	19.4 ± 23.2
Distance from nearest tree (m)	9.74 ± 7.18
Nest concealment (m)	1.13 ± 0.35
Ground cover (%)	52.3 ± 15.5
Plant canopy (%)	4.27 ± 1.28
Shrub cover (%)	37.3 ± 9.98

Tree height and tree GBH showed significant variance (Anova) to prefer the nesting sites. Other variables such as distance from the nearest tree, plant canopy, distance to the road or path, ground cover and shrub cover were not significantly different between the nest-site and random sites (Table 7.31).

Table 7.31 Comparison of Nest-site variables of the Yellow-eyed Babbler with random sites

Parameters	**Nest site (n = 25)**	**Random site (n = 25)**	**Significance p**
Tree height (m)	1.94 ± 0.55	2.1 ± 0.6	0.032
Tree GBH (cm)	4.5 ± 2.05	11.81 ± 7.8	0.000
Distance to the road/path (m)	19.4 ± 23.2	9.9 ± 16.7	0.165
Distance from nearest tree (m)	9.74 ± 7.18	7.9 ± 12.4	0.167
Ground cover (%)	52.3 ± 15.5	45 ± 17	0.610
Plant canopy (%)	4.27 ± 1.28	5.95 ± 4.4	0.106
Shrub cover (%)	37.3 ± 9.98	34.8 ± 11.9	0.659

The first three principal components were selected which accounted for 62% of the total variance. The first component was highly associated with nest diameter, nest depth and shade over nest (Table 7.32). The second component was associated with the nest height. The third component was also associated with nest height. The factors highly correlated with these three components were directly related to the position of the nest on tree including cover in nest-site selection.

Table 7.32. Factor loading of the nest site characteristics with the first three principal components in the Yellow-eyed Babbler.

Variables	**PC I**	**PC II**	**PC III**
Nest tree height	0.28	0.40	0.30
Shade over nest	0.59	-0.39	-0.19
Nest concealment	0.20	0.35	-0.55
Nest diameter	0.81	-0.31	0.21
Distance to road	0.68	-0.40	0.37
Nest tree GBH	0.41	0.34	0.48
Ground cover	0.45	0.07	-0.59

Variables	PC I	PC II	PC III
Distance to nearest tree	-0.07	-0.69	-0.06
Nest depth	0.59	0.12	0.25
Nest height	-0.24	0.67	0.56
Plant canopy	0.25	0.67	-0.28
Shrub cover	-0.51	-0.55	0.31
Total	2.66	2.51	1.75
% of Variance	22.19	20.89	14.54
Cumulative %	22.19	43.08	57.62

7.5.8.3. Breeding season

There were two breeding seasons, August to January and May-June as the area had little shower during these months (Figure 7.25) and abundance of insects were also high (Figure 5.10). Altogether, 28 nests were observed only from the scrub forest. Although it was recorded in census in both the forests, it did not breed in the mixed dry deciduous forest. The breeding season showed positive correlation with the abundance of insects ($r = 0.601$, $p = 0.030$), Coleoptera ($r = 0.482$, $p = 0.050$), Neuroptera ($r = 0.568$, $p = 0.043$) and Odonata ($r = 0.573$, $p = 0.041$) which were used to feed their young ones.

7.5.8.4. Breeding biology

Altogether 28 nests were recorded from the scrub forest. Mostly three (n = 14) and four (n = 9) eggs were laid. Clutch size varied between 3 and 4. Colour of the egg is pinkish white, thickly marked all over with chestnut red as in Ali and Ripley (1987). Eggs were laid on the consecutive days. Incubation period was 12-13 (n = 14) and nestling period 12-13 (n = 7) days as recorded by Nirmala and Vijayan (2000). Both parents participated in all the nesting activities. The total number of eggs laid were 85, of this hatching success was only 44%; rarely

Figure 7.24. Percent of nests of the Yellow-eyed Babbler on plant species (n = 28)

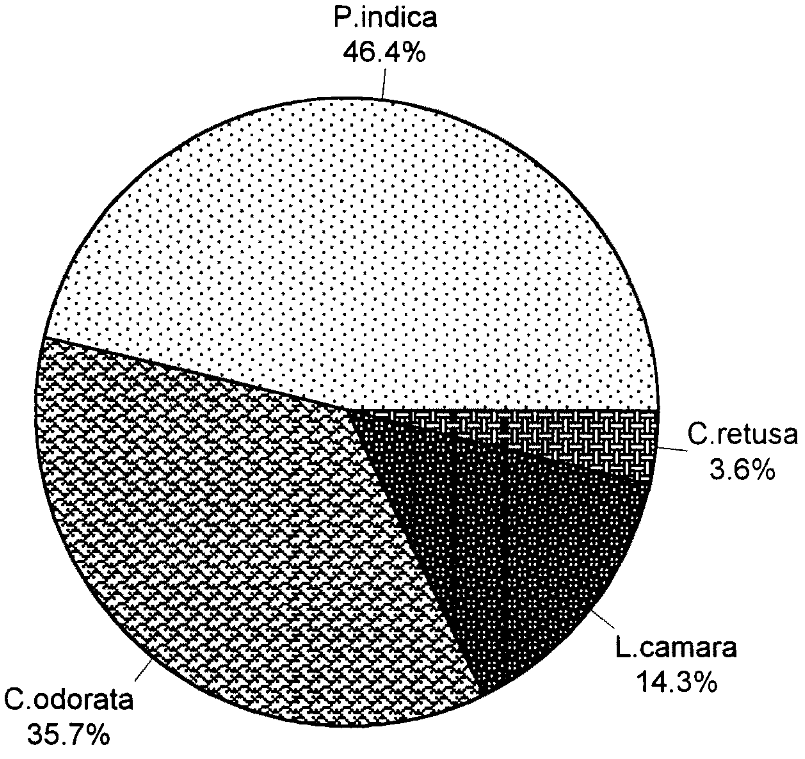
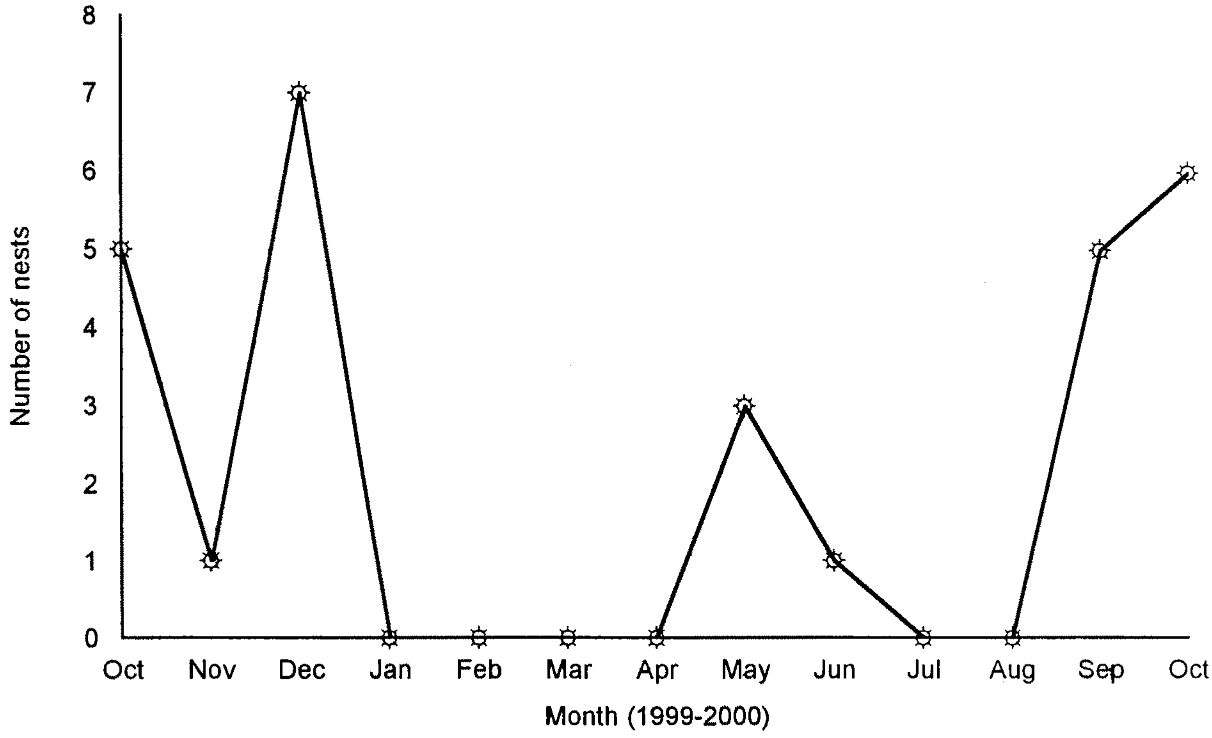


Figure 7.25. Breeding season of the Yellow-eyed Babbler in the scrub forest



one and two eggs, as they lay, were predated. In total, 24% of nestling fledged successfully. Only 7 (25%) nests showed success in bringing out fledglings. Rarely one and two eggs as they lay eggs were predated.

7.5.9. Indian Robin (*Saxicoloides fulicata*)

7.5.9.1. Nest and nest-site characteristics

Thirty nests from scrub forest and one from mixed dry deciduous forest, totally 31 nests of the Indian Robin were recorded. Of this, 19 nests were seen on the ground where there was grass or herbs, 2 nests on barren ground near shrub, 2 nests on the pillar, one on the brick piles, another one on a sack of gravel and yet another on the roof of a hut. Five nests occupied the old used nests of Bulbul, which is unusual. The nests were in cup shape built with fine root and grass blades as given in Ali & Ripley (1987). The inner side was lined with a few leaves. Both sexes shared the nesting activities. Although this insectivore species constructed nest in such a way that the mouth of the cup was facing all the directions, the nest facing towards West showed 100% success (Table 7.33). However this needs further investigations as the number of nests in this case was fewer.

Table 7.33 Opening of the nests in the four cardinal directions in the Indian Robin

Direction	No. of nests	No. of Successful nest	% of success
South	7	3	43
North	11	2	18
East	10	3	30
West	3	3	100

The nests were placed mostly on the ground, at a mean height of 0.41 ± 0.7 when it is on plants. The mean diameter and depth of the nests were 4.49 cm and 2.83 cm respectively (Table 7.34). Nest concealment was high (nest will be seen only in the close vicinity of <1m distance which probably resulted in high success of the nest.

7.5.9.2. Nesting plant or substrate selection

Nests were found on 8 different substrates, of which ground (61%) was the most preferred site for nesting followed by the unusual preference of *Lantana camara, Pavetta indica* and *Carmona retusa* (Figure 7.26). They used barren ground during March and April, one nest was successful while the other one was failure by predation. A nest of Red-vented Bulbul on *Carmona retusa* was used by Robin in the same season in 1999 and the success of the fledgling was 100%. Anova between nest site and random site showed tree height, distance from the nearest tree, plant canopy, ground cover, shrub cover and tree GBH as significant factors to prefer the nesting site. Other variable such as distance to the road or path was not significantly different between the nesting site and random sites (Table 7.35).

Table 7.34 Nest-site characteristics of the Indian Robin

Variables	**Mean ± SD**
Nest-tree height (m)	0.55 ± 1
Canopy above the nest (%)	45.58 ± 30
Nest-tree GBH (cm)	0.5 ± 0
Nest height (m)	0.41 ± 0.7
Clutch size	2.52 ± 0.5
Nest depth	2.83 ± 0.9

Variables	Mean ± SD
Nest diameter (cm)	4.3 ± 1.6
Distance to the road/path (m)	26.67 ± 32
Distance from nearest tree (m)	10.44 ± 19
Nest concealment (m)	1 ± 0
Ground cover (%)	21.67 ± 5.8
Plant canopy (%)	2 ± 0
Shrub cover (%)	28.33 ± 5.8

Table 7.35 Comparison of Nest-site variables of the Indian Robin with random sites

Parameters	Nest site (n = 30)	Random site (n = 30)	Significance p
Tree height (m)	0.55 ± 1	1.94 ± 0.55	0.000
Tree GBH (cm)	0.5 ± 0.1	4.5 ± 2.05	0.000
Distance to the road/path (m)	26.67 ± 32	19.4 ± 23.2	0.291
Distance from nearest tree (m)	10.44± 19	9.74 ± 7.18	0.036
Ground cover (%)	21.67 ± 5.8	52.3 ± 15.5	0.000
Plant canopy (%)	2 ± 0.14	4.27 ± 1.28	0.000
Shrub cover (%)	28.33 ± 5.8	37.3 ± 9.98	0.000

The first three principal components were selected which accounted for 62% of the total variance. The first component was highly associated with nest concealment, nest tree GBH, ground cover, plant canopy, shrub cover and distance to road (Table 7.36). The second component was associated with the nest diameter. The third component was associated with nest height when they used plants. The factors highly correlated with these three components were directly related to the nest concealment in nest-site selection.

Table 7.36. Factor loading of the nest site characteristics with the first three principal components in the Indian Robin

Variables	PC I	PC II	PC III
Nest tree height	-0.30	0.54	0.59
Nest concealment	0.86	-0.29	0.27
Nest diameter	0.42	0.64	-0.02
Distance to nearest tree	0.16	0.16	-0.64
Nest tree GBH	0.85	0.30	-0.04

Variables	PC I	PC II	PC III
Nest depth	0.54	0.45	-0.07
Shrub cover	0.82	-0.33	0.29
Ground cover	0.90	-0.22	0.24
Plant canopy	0.85	0.30	-0.04
Shade over nest	-0.47	0.40	-0.04
Nest height	-0.29	0.64	0.59
Distance to road	0.77	0.38	-0.36
Total	5.25	2.12	1.73
% of Variance	40.42	16.29	13.30
Cumulative %	40.42	56.71	70.01

7.5.9.3. Breeding seasonality

Breeding extended throughout the year with major peak in July (Figure 7.27) and a minor peak in May. Although this bird bred through out the year, only single nest was recorded for 10ha area except March, May June and July. Breeding did not show any correlation with the major environmental factors.

7.5.9.4. Breeding biology

The clutch size varied from 2 to 3 eggs. The eggs were white in color with brown spots gradient starts from animal pole as described by Ali and Ripley (1987). The mean incubation period was 7.75 ± 0.77 (n=31). Nestling period falls between 11 and 13. Although the total number of eggs was (79) less than in many other species, it showed high (55%) percent of successful nests (n = 17) in bringing out fledglings. Hatching success was 65% while nesting success was only 44%.

Figure 7.26. Nesting substrate of the Indian Robin (n = 31)

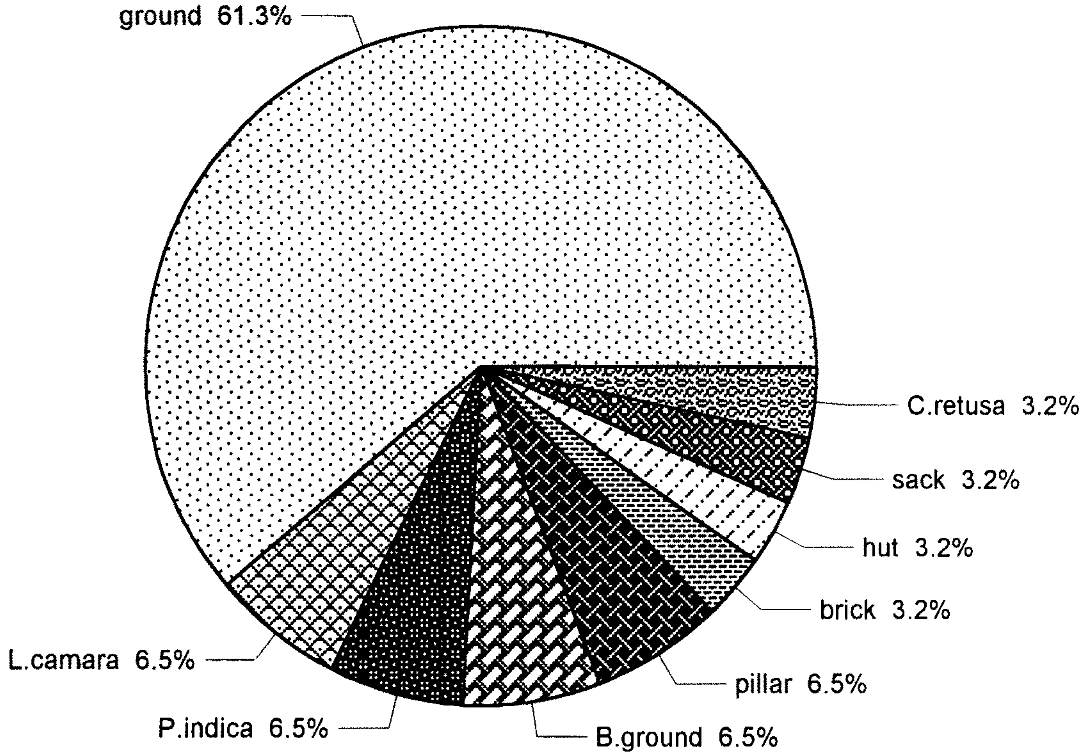
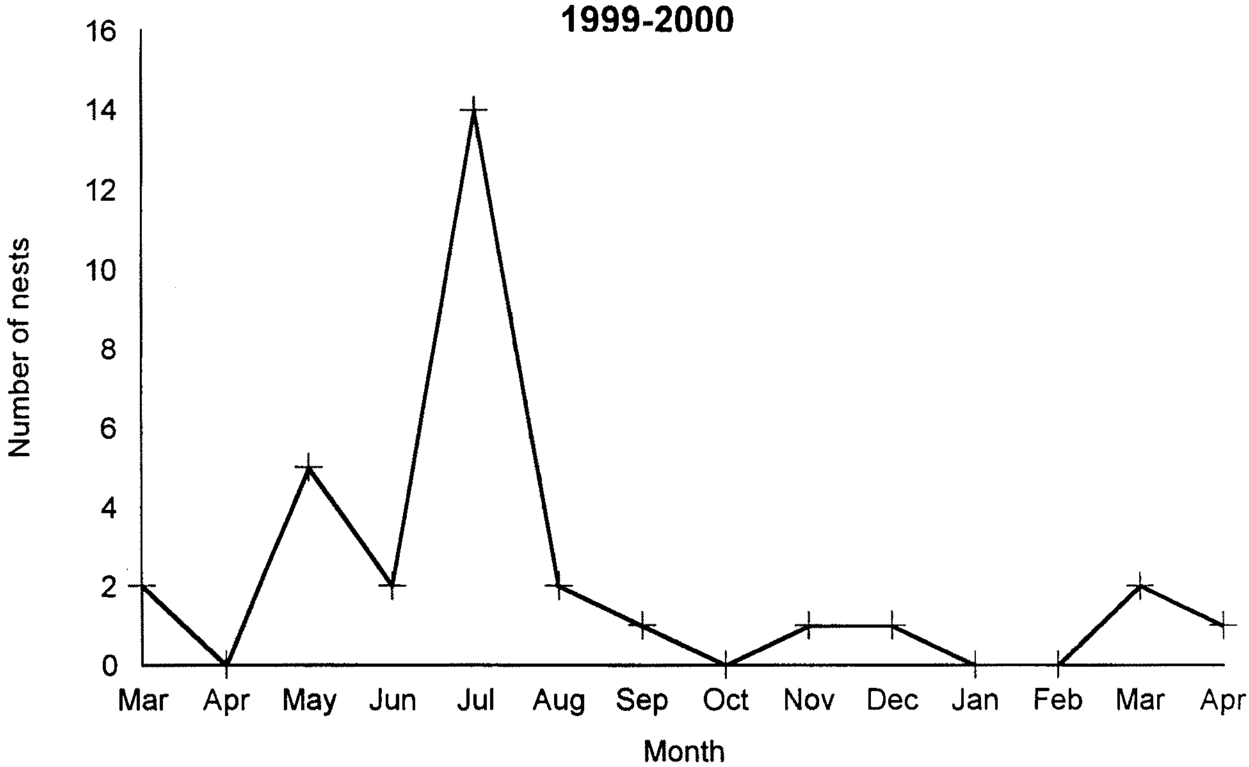


Figure 7.27. Breeding season of the Indian Robin during 1999-2000



7.6. Discussion

Breeding bird community: Although insectivores are higher as in the case of many of the disturbed forests, they are mostly highly territorial demanding larger territories for feeding during breeding unlike the omnivore and frugivore. Low number of nests in MDDF in this study area might be because of various factors such as nesting site specificity and scarcity of nesting site, less availability of foraging habitat and disturbance in the undergrowth where they prefer to nest. Granivore species and nests were more in SF than MDDF as in the study of bird communities in a disturbed forest inMundanthurai (Johnsingh and Joshua 1994) and in Mudumalai (Gokula 1998).

Breeding season: Bird species breed at the time of the high food abundance so that it can raise its young ones more successfully (Lack 1968, Immelman 1971, Perrins and Birkhead 1983, Perrins 1996). Egg laying was intensified after heavy rain as found by Natarajan (1997). Hence breeding peak mostly coincided with the peak insect abundance. The availability of insects was greater during the rainy season as in the study of Murali and Sukumar (1993) which enhanced more breeding species. Birds bred during heavy rain in disturbed forest as found by Johnsingh and Joshua (1994) in Mundanthurai, South India. Factors governing the breeding season of birds in Anaikatty hills were (1) food abundance as reported by Immelmann (1971), Martin (1987) and (2) availability of nesting material (Collias and Collias 1984). As most of the nests were made of stem or root of grasses and some species used to line the inner region of the nest with grass blades and leaves as they are available during rainy season (Sivaganesan 1991). Both food and nesting materials are available during rainy season and so the peak of breeding took place corresponding with the abundance of nest material as documented by Lack (1968).

The nest-types and the number of nests and species analysed showed larger number of cup nests in MDDF mainly because of the species. The type of the nest is probably genetically determined, being evolved over a very long time as explained for morphology by Hutto (1981), and Rolando and Robotti (1985). The habitat specific species in MDDF were mostly cup or platform-nesters and the proportion of ground-nesters were more in SF as these ground-nesters were in SF because of the availability of more open areas with ground cover. Gokula (1998) also found similar result of cup nest being dominant in thorn and dry deciduous forests. The availability of thorny species with extensive and dense branching system with more open area secures suitability for placing cup nests as noted by Vijayan *et al.* (2000), Gokula and Vijayan (2000), Gokula (2001).

In the mixed dry deciduous forest, statant and platform nests showed peak during April while pendulous and ground nests peaked in March. The peak season was the same as found in Siruvani hills by Vijayan *et al.* (2000). The statant cup nesters bred continuously with a peak during October while the others were seasonal (Figure 7.7). Cup nesters preferred monsoon periods unlike in the study of Yahya (1988), Venkatraman and Vijayan (1997), Gokula (1998), Vijayan *et al.* (2000) but cavity nesters avoided monsoon as in their observations.

Nesting plants: Although 38 nest supporting plant species were in Anaikatty hills, the plants commonly used were *Pavetta indica* and *Lantana camara* which were abundant and possessed closed branching architecture with the protective thorns in the latter supporting the finding of Collias and Collias (1984), whereas the former also had thick foliage in the canopy giving more concealment for the nest providing protection from predators and also harsh environment (Vijayan 1980, Petersen 1990, Gokula 1998, Flaspohler *et al.* 2000). The plant species, which were selected for nesting, were common and abundant in Anaikatty hills. This probably helped to avoid predation as in the study of Martin and Roper (1988) and Gokula (1998, 2001). *Pavetta indica, Lantana camara, Chromolaena odorata* etc. showed suitable size and geometrical fork of branches, which provided suitable location for nest as reported by Titus and Mosher (1987) and Martinsen and Whitham (1994). Kozma and Mathews (1997) documented that the physical complexity such as dense foliage (eg. *Pavetta indica, L. alata* and *A. monophylla.*), spinescent stems (*L.camara*), stiff branches (*C.retusa*) and greater height as in *Acacia polyacantha* were the reasons for the selection of these plants while many other species were avoided.

Impact of disturbance: Firewood collection and grazing were the major activities observed disturbing these forests as found in many other studies in the Western Ghats (Silori and Mishra 1995, Desai and Bhaskaran 1996, Ramakrishnan and Sivaganesan 1997, Vijayan *et al.* 1998, 1999, Sartorius *et al.* 1999, Gokula 1998, 2001). The existing level of anthropogenic pressures on plant affects the bird communities (Restrepo *et al.* 1999, Nirmala and Vijayan

2001) largely by nest plant reduction and alteration of the foliage strata as reported by Vijayan *et al.* (1999). Forest produces became the primary source for the local communities of this area as found by Silori and Mishra (1995) in Mudumalai. High extraction attributed to greater annual demand of firewood in the study area. Some of the highly used firewood and bamboo species show poor regeneration and may affect the future condition of the forest and availability of fuel resource for future. In the scrub forest in this study (SACON campus) care has been taken to improve its plant taxa and protect from anthropogenic pressure in future. Although afforestation was done in mixed dry deciduous forest, until there is an alternative to firewood, this will not enhance the restoration of natural forest.

7.6.1. Laughing Dove

No detailed study was conducted on this species except brief note by Ali and Ripley (1987) and breeding period was the same as given in Grimmett *et al.* (1998). It bred in the scrub forest making use of the available plants and did not breed in mixed dry deciduous forest eventhough it is abutting on the scrub forest which indicates the site fidelity. It preferred to nest on shrubs or short trees. Breeding season was similar as given by Ali and Ripley (1987). Also they reported 2 eggs as observed invariably, but in this study 3 eggs were recorded. Nest concealment was the major factor in nest-site selection. Mudge and Talbot (1993) found nest failure was due to desertion of nest. Any disturbance by humans also becomes a cause of desertion. This is true in this species. The number of nest was correlated positively with the windspeed in the Laughing Dove. This factor was probably the reason for it's failure of nest, as a few nests were predated, quite a few eggs were observed falling on the ground and broken due to heavy wind (Kumar 1995).

7.6.2. Purple-rumped Sunbird

This species showed similar type of nest as explained by Ali and Ripley (1987). Incubation and Nestling periods differed from Ali's observation where these were 14-15 and 16-17 days respectively, but in this study 9-10 and 10 days respectively; this may be due to the environmental factors and topographic differences. Peak breeding season was in February to April as flower abundance was also high as found by Khacher (2000). The Purple-rumped Sunbird has no well-defined season (Khacher 2000) but a definite peak. It selects the plants, which has a branch that is able to support the nest.

7.6.3. Red-vented Bulbul

Nest construction and the material used were as given by Ali and Ripley (1987). It preferred mostly shrubs in both the habitats, and nests were found among dense vegetation as found by Hsu and Lin (1997). The structure of the supporting branches, nest accessibility were the dominant factors as documented by Hsu and Lin (1997). Nestling success was low due to predation as it is nesting on the bushes where there are more open areas. High predation of nestlings is attributed to the thinness of cover as found by Newton (1964) in the Chaffinch, Vijayan (1980) in the Red-vented Bulbul. It locates its nest with high canopy, shrub and ground cover mainly for nest-concealment which was the major factor in deciding the nesting site.

7.6.4. Red-whiskered Bulbul

There is a peak during March which coincides with the flower and insect abundance as in other studies where food is a limiting factor. Nest-site selection was based on nest tree height. Nest construction and the material used were as given by Ali and Ripley (1987). It preferred mostly shrubs in both the habitats, and nests were found among dense vegetation as found by Hsu and Lin (1997) in the Chinese Bulbul. Incubation period was as found by Ali and Ripley (1987), but the nestling period was 11-12 days. They prefer nesting near human habitation to escape from predators as documented by Vijayan *et al.* (1998). Smaller clutch size is considered to be an adaptation to reduce the chance of predation.

7.6.5. Jungle Babbler

This bird was recorded only from the mixed dry deciduous forest, which shows its preference of dense trees, and nest construction was as found by Andrews and Naik (1966). Gupta and Meenu (1995) studied the same species in Haryana and found difference in incubation period which might be because of the geographical change in location. Cluth size was the same as found by Ali and Ripley (1987) and Andrews and Naik (1970). The plant species preference depends on its availability and it showed no preference but the height. Tendency to choose patches with more common trees reflects the choice of patches with large potential for nest-sites and this may reduce the predator efficiency since it will be forced to search more sites for a successful prey as found by Martin and Roper (1988).

7.6.6. Tawny-bellied Babbler

It is difficult to distinguish its nest from the nesting place as it is made of green nesting material which makes it camoflaged and might act insecticidal and anti-pathogenic agents as found by Clark and Mason (1985). Their nests were mostly predated since the concealment was low which is a pre-requisite for success as found by Vijayan (1980), Flaspohler and Temple (2000). They showed well defined season from March to June and another in November and December unlike that reported by Ali and Ripley (1987) which might be because of the geographical variation. It selected its nest-site where the nest characteristics are well suited. Clutch size is three and incubation period is 13 days as found by Nirmala and Vijayan (2000) in White-throated Babbler.

7.6.7. Yellow-billed Babbler

The type of nest and construction were as given by Ali and Ripley (1987) and Zacharias and Mathew (1988). This species was observed only in the scrub forest, as they prefer plant species mostly shrubs such as *Pavetta indica, Carmona retusa* and the most important factor in nest-site selection (PCA) was the nest tree height. Low nestling success was due to predation as the concealment is low which is the key factor for nest success as reported by Flaspohler *et al.* (2000).

7.6.8. Yellow-eyed Babbler

The nest is cemented outside with cobweb as given by Ali and Ripley (1987). It placed its nest in the centre of the axis of the plant which provides good concealment to the nest and success was high as found by Nirmala and Vijayan (2000) and its first principal component is associated with the shade over nest. It used *Pavetta indica* and *Chromolaena odorata* as its successful nesting plant because of their branching system and canopy cover to provide better concealment of the nest as recorded in some other species such as Indian Robin, Red-vented Bulbul.

7.6.9. Indian Robin

This ground nester had high nesting success. The clutch size was small and smaller clutch size is considered to be an adaptation to reduce the chance of predation as found by Vijayan (1980) when compared to the other breeding birds in this study area. The principal component analysis of the nest-site characteristics also indicated the importance of nest concealment to this bird as it is the key factor for nest success as reported by Flaspohler *et al.* (2000).

The Indian Robin is a hole-nester (Ali and Ripley 1987). George (1963) documented breeding of this bird only on the ground using various substrates..

Most of the nest locations are similar to the hole-nest except that recorded by Field (1902) and Saxena (1995). Indian Robin nesting in holes used a variety of substrates in this area. which may be a strategy to counteract predators' search tactics for a particular type as suggested by Furrer (1975). In our observations five nests were found as unusual using the old nests of the Red-vented Bulbul. These cup-nests of the Red-vented Bulbul were covered with foliage, almost fully concealed, having a similar environment as of a hole. Probably, this was one of the major reasons for selecting this site and had better success. Cup nests although reported to have less success usually than hole nests (Skutch 1976, Thiollay 1994) these cup nests had better success because of better concealment as found in Bulbuls elsewhere (Vijayan 1980, Bhatt and Kumar 1996, Hsu and Lin 1997). Hence, these adaptations exhibited by Robin were mainly to overcome predation of their progeny which was a strategy in selecting the breeding season in the Grey-headed Robin in the Paluma Range (Frith and Frith 2000).

REFERENCES

Aigner, P. A. (1996). Effect of firewood harvesting on avian abundance and guild structure in California oak-pine woodland. *Ph. D. Thesis*, Northern Arizona University, Flagstaff, Arizona, USA.

Aigner, P. A., W. M. Block and M. L. Morrison (1998). Effect of firewood harvesting on avian abundance and guild structure in California oak-pine woodland. *Journal of Wildlife Management*. **62:** 485-496.

Alagarrajan, S (1989). The impact of forest degradation on the avifauna. **In**: Ecology of Point Calimere Sanctuary (An endangered ecosystem). *Annual report* 1988-90, pp. 42-48.

Alagarrajan, S. (1991). The ecology of the Indian Ring Dove *Streptopelia decaocto decaocto* (Frivaldzsky) and the Indian Spotted Dove *Streptopelia chinensis suratensis* (Gamelin) at Point Calimere Wildlife Sanctuary, Tamil Nadu. *M. Sc. Dissertation*, University of Bombay.

Alatalo, R. V. (1981). Interspecific competition in tits *Parus* spp.and the Goldcrest *Regulus regulus*: foraging shifts in multispecific flocks. *Oikos*. **37:** 335-344.

Alatalo, R. V. (1982). Multidimensional foraging niche organization of foliage gleaning birds in northern Finland. *Ornis Scandinavica*. **13:** 56-71.

Alatalo, R. V., A. Lundberg and S. Ulfstrand (1985). Habitat selection in the Pied Flycatcher *Ficedula hypoleuca*. **In**: Habitat selection in birds. (Ed. M. L. Cody) Academic Press, New York. pp. 59-85.

Ali, S. (1979). The book of indian birds, Bombay Natural History Society, Mumbai.

Ali, S. (1980). C V Raman memorial lecture 1979: Some aspects of modern field ornithology. Pinsa. **46 B(3):** 243-249.

Ali, S. and S. D. Ripley. (1987). Handbook of the birds of India and Pakistan. Compact edition, Oxford University Press, New Delhi. Oxford Univ. Press, New Delhi.

Ali, S. and V. S. Vijayan (1986.) Keoladeo National Park Ecology study Summary report1980-1985. *J. Bombay. nat. Hist. Soc.* pp. 186.

Anderson, A. (1972). Notes on the raptorial birds of India Part 2. *Proc. Zool. Soc.* London. pp. 68-81.

Andrews, M. I. and R. M. Naik (1970). The biology of the Jungle Babbler. *Pavo* **8(1):** 1-34.

Arun, P. R. (2000). Seasonal variations in the abundance of insect groups in a natural moist deciduous forest of Western Ghats. *Ph. D. Thesis*, Bharathiar University, Coimbatore.

Assad, Y. O. H., B. Torto, A. Hassanali, P.G.N. Njagi, N.H.H Bashir, and H. Mahamat (1997). Seasonal variation in the essential oil composition of *Commiphora quadricincta* and its effect on the maturation of immature adults of the desert locust, *Schistocerca gregaria*. *Phytochemistry*, **44(5):** 833-841.

Baker, E. C. S. (1934). The game birds of the Indian empire, part 21. *J. Bombay nat. Hist. Soc.* **37(2):** 245-254.

Balasubramanian, P. (1990). Plant-animal interrelations in Point Calimere Wildlife Sanctuary *Ph. D. Thesis*, university of Bombay.

Balasubramanian, P. (1996). Interactions between fruit-eating birds and bird-dispersed plants in the tropical dry evergreen forest of Point Calimere, South India. *J. Bombay. nat. Hist. Soc.* **93(3):** 428-441.

Balasubramanian, P. and P. V. Bole (1993). Fruiting phenology and seasonality in the tropical dry evergreen forest of Point Calimere Wildlife Sanctuary.. *J. Bombay. nat. Hist. Soc.* **90(2):** 163-177.

Balasubramanian, P., M. P. Mahendramani and K. P. Priya (2001). Comparison of plant biodiversity patterns of variously disturbed habitats of Moongilpallam area in the Western Ghats. *Miscellaneous report* of Salim Ali Centre for Ornithology and Natural History and Tamil Nadu Forest Department. pp. 46.

Balasubramanian, P., S. N. Prasad and K. Kandavel (1998). Role of birds in seed dispersal and natural regeneration of forest plants in Tamil Nadu. *Technical report* of SalimAli Centre for Ornithology and Natural History and Tamil Nadu Forest Department (Research wing). pp. 44.

Balda, R. P. (1969). Foliage use by birds of the oak-juniper woodland and ponderosa pine forest in southeastern Arizona. *Condor.* **71:** 399-412.

Basset. Y (1991). The seasonality of arboreal arthropods foraging within an Australian rainforest tree. *Ecological Entomology.* **16(3):** 265-278.

Beals, E. W. (1970). Birds of a Euphorbia-Acacia woodland in Ethiopia: Habitat and seasonal changes. *J. Anim. Ecol.* **39:** 277-297.

Becking, J. H. (1981). Notes on the breeding of Indian Cockoos . J. Bombay nat. Hist. Soc. **78(2):** 201-231.

Beehler, B., K. S. R. K. Raju and S. Ali (1987). Avian use of man disturbed forest habitats in the Eastern Ghats, India. *Ibis.* **129:** 197-211.

Bell, G. P. , G. A. Bartholomew and K. A. Nagy (1986). The roles of energetics, water economy, foraging behavior, and geothermal refugia in the distribution of the bat, *Macrotus californicus. J. Comp. Psych. B.* **156:** 441-450.

Berryman, A. A. (1996). What causes population cycles of forest lepidoptera? *Trends in ecology. and evolution*. **11:** 28-32.

Bhupathy, S. (1991). Population and resource utilization of waterfowl in Keoladeo National Park, Bharatpur *Ph. D. Thesis*, Rajasthan University.

Bibby, C. J., N. D. Burgess and D. A. Hill (1993). Bird census techniques. British Trust for Ornithology and the Royal Society for the Protection of Birds. Academic Press, London. pp. 66-84.

Blake, J. G. and B. A. Loiselle (1991). Variation in resource abundance affects capture rates of birds in three lowland habitats in Costa Rica. *Auk*. **108:** 114-130.

Bland, J. D. (1998). Indigenous forest use as an agent of change in plant and animal communities of temperate broad-leaved forest, northern Nepal. *Ph. D. Thesis*, University of California, Los Angeles.

Block, W. M. (1989). Spatial and temporal pattern of resource use by birds in California oak woodlands. *Ph. D. Thesis*, University of Calofornia, Berkeley, Calofornia, USA.

Borchert, R. (1998). Responses of tropical trees to rainfall and its long term changes. *Climate change*. **39:** 381-393

Brown, K. S. (1991). Conservation of Neotropical Environment insects as indicators. The conservation of insects and their habitats.(Ed.by T.C.whitemore and G.T.Prance). pp. 255-308

Burnham, K. P., D. R. Anderson and J. L. Laake (1980). Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* pp. 72.

Byers, C. R., R. Steinhorst and P. R. Krausman (1984). Clarification of a technique of analysis of utilization availability data. *J. Wildl. Mgmt.* **48(3):** 1050-1053.

Carey, B. S. (1983). The Great Crested Grebe in Burma. *J. Bombay nat. Hist. Soc.* **13(1):** 186.

Carothers, J. H. (1986). Behavioral and ecological correlates of interference competition among some Hawaiian drepanidinae. *Auk.* **103** : 564 – 574

Caterall, C. P., W. S. Wyatt and L. J. Henderson (1982). Food resources, density and reproductive success of an island Silvereye population *Zosterops lateralis*. *Ibis.* **124:** 405-421.

Chakravarthy, A. K., D. Rajagopal and R. Jagannatha (1997). Insects as bio indicators of conservation in the tropics. *Zoosprint.* **12:** 21-25.

Champion, H. G. and S. K. Seth (1968). A revised survey of the forest types of India. Government of India publications. New Delhi, India.

Chandola, A. S., K. K. Sharma, M. S. Bisht and P. Lakhera (1990). Ecophysiology of seasonal reproduction in the tropics: the Baya Weaver Japan Sci. Soc. Press. pp. 207-224

Chapman, F. M. (1933). Autobiography of a bird lover. D. Appleton and Company, New York.

Chasku, G. G. and J. E. Gates (1982). Avian habitat suitability along a transmission line corridor in an Oak-hickory forest region. *Wildlife Monogr.* **82:** 1-42.

Chettri, N. (2000). Impact of habitat disturbances on bird and butterfly communities along the Yuksam-Dzolgri Trail in Khanchendzonga Biosphere Reserve *Ph. D. thesis*, University of North Bengal.

Clark, L. and J. R. Mason (1985). Use of nest material as insecticidal and anti pathogenic agents by the European starling. *Oecologia* (Berlin). **67:** 169-176.

Cody, M. L. (1968). Interspecific territoriality among hummingbird species. *Condor.* **70(3):** 270-271.

Cody, M. L. (1970). Chilean bird distribution. *Ecology.* **51:** 445-464.

Cody, M. L. (1974). Competition and the structure of bird communities. Princeton Monogr. **In.** Population Biology 7, Princeton Univ. Press, Princeton, New Jersey.

Cody, M. L. (1975). Towards a theory of continental species diversity bird distributions over Mediterranean habitat gradients. Ecology and Evolution of communities (Eds.)M. L. Cody and J. M. Diamond.Harvard University Press, Cambridge, USA.

Cody, M. L. (1978). Habitat selection and interspecific territoriality among the sylviid warblers of England and Sweden. *Ecol. Monogr.* **48(4):** 351-396.

Cole, D. N. (1995). Experimental trampling of vegetation. II. Predictors of resistance and resilience. *Journal of Applied Ecology.* **32:** 215-224.

Collias, N. E. and Collias, E. C. (1984). Nest building and bird behaviour. Princeton University Press, Princeton, New Jersey.

Crawford, H. S., R. G. Hooper and R. W. Titterington (1991). Songbird population response to silvicultural practices in central Applachian hardwoods. *J. Wildl. Manage.* **45:** 680-692.

Crome, F. H. J. (1978). Foraging ecology of an assemblage of birds in lowland rainforest in Northern Queensland. *Aust. J. Ecol.* **3:** 195-212.

Cronk, Q. (1988). Biodiversity, the key role of plants IUCN and WWF, England.

Croxall, J. P. (1977). Foraging behaviour and ecology of New Guinea rainforest insectivorous passerines. *Ibis*. **119(2):** 113-146

D'Abreu, E. A. (1920). On the ecology of the niltavas. *J. Bombay nat. Hist. Soc.* **27:** 405-406.

Daniels, R. R. J. (1985). On the subspecies concept. *Newsletter for Bird watchers.* **25(7-8):** 3-5.

Daniels, R. J. R. (1989). A conservation strategy for the birds of the uttara Kannada District. *Ph. D. Thesis.* Indian Institute of Science, Bangalore, India.

Daniels, R. J. R. (1996). Landscape ecology and conservation of birds in the Western Ghats, South India. *Ibis.* **138:** 64-69.

Daniels, R. J. R. (1997). A field guide to the birds of Southwestern India Oxford University Press, New Delhi. pp. 217.

Danilevskii, A. S. (1966). Photoperiodism and seasonal development of insects. Fotoperiodism from sezonnoe razvitie nasekomyh. Izdatel'stvo leningradskogo Universiteta, leningrad (Transl.by J. Johnston and N.Waloff). pp. 283.

Davies, N. B. (1978a). Ecological questions about territorial behaviour. In Behavioural ecology- an evolutionary approach. (Eds.) Krebs, J. R. and N. B. Davies. Blackwell scientific publications. Oxford, London Edinburgh and Melbourne. pp. 317-350.

Dawson, A. (1998). Photoperiodic control of the termination of breeding and the induction of moult in House Sparrows *Passer domesticus*. *Ibis*. **140:** 35-40.

Diamond, J.M. (1978). Niche shifts and rediscovery of inter specific computers. American scientist. **66:** 322.

Diaz, M., J. C. Illera and J.C.. Atienza (1998). Food resource matching by foraging tits parus spp. during spring – summer in a mediterranean mixed forest ; evidence for an ideal free distribution. *Ibis*. **140 :** 654 – 660.

Dingle, H. and C. P. M. Khamala (1972). Seasonal changes in insect abundance and biomass in East African Grassland with reference to breeding and migration in birds. *Ardea*. **59:** 216-221.

Dolman, P. and W. Sutherland (1991). Historical clues to conservation. *New Scientist*. **17:** 49, 22-25.

Dunbar, R. I. M. (1983). Life history tactics and alternative strategies of reproduction. In: Mate choice. (Ed. P. Bateson), Cambridge University Press. pp. 423-433.

Erdelen, M., (1984). Bird communities and vegetation structure : 1. Correlation and comparison of sample and diversity indices. *Oecologia*. pp. 277 – 284.

FAO (1994). Forest Development and Policy Dilemmas. Rome, Italy.

Feeny, P. (1970). Seasonal changes in Oak leaf tannins and nutrients as a cause of spring feeding by winter moth caterpillars. *Ecology*. **50(4):** 565-581.

Feinsinger, P. (1978). Ecological interactions between plants and hummingbirds in a successional tropical community. *Ecological Monographs*. **48:** 269-287.

Field, F. (1902). Robin laying in babbler's nest. *J. Bombay nat. Hist. Soc.* **14(3):** 610-611.

Fitzpatrick, J. W. (1980). Foraging behaviour of Neotropical tyrant flycatchers. *Condor*. **82:** 810-821.

Flaspohler, D. J., S. A. Temple and R. N. Rosenfield (2000). Relationship between nest success and concealment in two ground – nesting passerines. *J. Field Ornithology.* **71 (4):** 736 – 747.

Fogden, M. P. L. (1972). The seasonality and population dynamics of equatorial forest birds in Sarawak. *Ibis.* **114:** 307-343.

Ford, H. A. and D. C. Paton (1985). Habitat selection in Australian Honeyeaters, with special reference to nectar productivity.In: Habitat selection in birds. (Ed.) M. L. Cody, Academic Press, New York. pp. 368-388.

Fox, J. (1979). Intermediate-disturbance hypothesis. *Science.* **204:** 1344-1345.

Francis, W. (1906). Madras district gazetteers: The Nilgiris. Government Press, Madras pp. 394.

Francis, W. (1908). Madras district gazetteers: The Nilgiris. Government press, Madras. pp. 394.

Frith, D. W. and C. B. Frith (2000). The nesting biology of the Grey-headed Robin *Heteromyias albispecularis* (Petroicidae) in Australian Upland Tropical Rainforest. *Emu.* **100:** 81-94.

Furrer, R. K. (1975). Breeding success and nest site stereotypy in a population of Brewer's Blackbirds (*Euphagus cyanocephalus*). *Oecologia.* **20:** 339-350.

Gadagkar, R., K. Chandrashekara and P. Nair (1990). Insects species diversity in the tropics : sampling methods and a case study. *J. Bombay nat. Hist. Soc.* **87 (3) :** 337-353.

Gandhi, T. (1986). A comparative study of birds in monoculture plantations and natural scrub near Madras. *M. Sc. Dissertation*, University of Bombay.

Gaston, A. J. (1972). Black Bulbuls *Hypsipetes madagascariensis* (P.L.S. Müller) in Delhi. *J. Bombay nat. Hist. Soc.* **69(3):** 651-652.

Gaston, A. J. (1978a). Seasonal occurrence of birds on New Delhi ridge. *J. Bombay. nat. Hist. Soc.* **75:** 115-128.

Gaston, A. J. (1978b). Demography of the Jungle Babbler. *J. Animal Ecology.* **47:** 845-870.

Gaston, A. J. (1978c). Distribution of birds in relation to vegetation in the New Delhi ridge. *J. Bombay nat. Hist. Soc.* **75 (2)** : 257 – 265.

Gaston, A. J. (1981). Seasonal breeding, moulting and weight changes among birds of dry deciduous forest in North India. *J. Zool., London.* **194(2):** 219-243.

Gaston, A. J. (1983). The effect of grazing on the abundance and diversity of birds in scrub vegetation at Nathwara, Rajasthan. *J. Bombay. nat. Hist. Soc.* **83:** 214-217.

Gaston, A. J. and V. S. Vijayan (1986). Breeding seasonality of the birds in the Indian sub-continent. Paper presented at the 19th International Ornithological Congress, Ottawa, Canada.

George, J. C. (1963). Some observations on the breeding behaviour of the Indian Robin, Saxicoloides fulicata (Linnaeus). Pavo. **1(2):** 71-78.

Giest, V. (1977). A comparison of social adaptations in relation to ecology in gallinaceous birds and ungulate societies. *Ann. Rev. Ecol.Systematics* **8:** 193-207.

Gilbert, L. E. (1984). The biology of butterfly coomunities. The biology of Butterflies (Eds. Vane-Wright, R. I. & Ackrey, P. R.). Symposium of the Royal Entomological Society of London, Academic Press.

Gill, A. J., W. J. Sutherland and A. R. Watkinson (1996). A method of quantifying the effects of human disturbance on animal populations. *Journal of Applied Ecology.* **33:** 786-792.

Gokula, V. (1998). Bird communities of the thorn and dry deciduous forests in Mudumalai Wildlife Sanctuary, South India. *Ph. D. Thesis*, Bharathiar University, Coimbatore.

Gokula, V. (2000). Foraging and nesting behaviour of Bay-backed Shrike (*Lanius vittatus*) in Southern India. *J. South Asian Natural History.* **5:** 97 –100.

Gokula, V. and L. Vijayan (1996). Birds of Mudumalai Wildlife Sanctuary. *Forktail.* **12:** 107-117.

Gokula, V. and L. Vijayan (2000). Foraging pattern of birds during the breeding season in thorn forest of Mudumalai Wildlife Sanctuary, Tamil Nadu, South India. *Tropical ecology.* **41(2)** : 195 – 208.

Gokula, V. and L. Vijayan (2001). Nest-site characteristics of Spotted Munia (*Lonchura punctata*) in Mudumalai Wildlife Sanctuary, Southern India. *J. South Asian Nat. Hist.* **5(2):** 187-190

Gokula, V. and L. Vijayan (2001). Foraging patterns of birds in the thorn forest of Mudumalai Wildlife Sanctuary, Southern India. *J. South Asian Nat. Hist.* **5 (2)** : 143 – 152.

Gokula, V., C. Venkataraman, S. Saravanan and S. Swaminathan (1999). Inter and intraspecific variation in the resource use of blossomheaded and bluewinged parakeets in Siruvani, Tamil Nadu, India. *J. Bombay nat. Hist. Soc.* **96(2):** 225 – 231.

Grassle, J. F. G. P. Patil, W. Smith and C. Taillie (1979). Ecological diversity in theory and practice. International Co-operative Publishing House, Maryland, U. S. A.

Greenberg, R. (1981). The abundance and seasonality of forest canopy birds on Barro Colorado Island, Panama. *Biotropica.* **13:** 241-251.

Greenberg, R. (1984a). The Winter exploitation systems of Bay-breasted and Chestnut-sided warblers in Panama. University of California. *Publ. Zool.* **116:** 1-107.

Greenberg, R. (1984c). Neophobia in the foraging site selection of a neotropical migrant bird: an experimental study. *Proc. Nat. Acad. Sci.* **81:** 3778-3780.

Greenberg, R. (1995). Insectivorous migratory birds in tropical Eco systems : the breeding currency hypothesis. *Journal of Avian biology.* **26 (3):** 260 – 264.

Grimmett, R., C. Inskipp and T. Inskipp 1998). Birds of the Indian Subcontinent Oxford University Press, Delhi. pp. 888.

Grubh, R. B. (1974). The ecology and behaviour of vultures in Gir forest. *Ph. D. Thesis.* University of Bombay.

Gunnersson, B. (1996). Bird predation and vegetation structure affecting spruce living Arthropods in a temperate forest. *Journal of Animal Ecology.* **65(3):** 389-397.

Gupta, R. C. and M. Meenu (1995). Breeding biology of Jungle Babbler *Turdoides striatus* (Dumont). *Zoosprint.* **10(5):** 1-7.

Hagan, J. M., P. S. McKinley, A. L. Meehan and S. L. Grove (1997). Diversity and abundance in land birds in a northeastern industrial forest. *Journal of Wildlife and Management.* **61:** 718-735.

Haila, Y. and I. K. Hanski (1993). Birds breeding on small British islands and extinction risks. *American Naturalist.* **142:** 1025-1029.

Hannah, L., J. L. Carr and A. Lakerani (1995). Human disturbances and natural habitat: A biome level analysis of a global dataset. *Biodiversity and conservation.* **4:** 128-155.

Harrison, C. (1981). Recovery of lowland grassland and heathland in southern England from disturbance by seasonal trampling. *Biological Conservation.* **19:** 189-190.

Helle, P (1986). Forest bird communities: Habitat utilization in mature and successional phases. Acta XIX Congressus nternationalis Ornithologici, Vol. 1. Ottawa, Canada. **1:** 22:-29.

Hilden, O. (1965). Habitat selection in birds: a review. *Ann. Zool. Fenn.* 2: 53-75.

Hilty, S. L. (1980). Flowering and fruiting periodicity in a premontane rain forest in Pacific Colombia. *Biotropica.* **12:** 292-306.

Hobbs, R. J. and L. F. Huenneke (1992). Disturbance, diversity an invasion: implication for conservation. *Conservation Biology.* **6:** 325-337.

Hobson, K. A. and J. Schieck (1999). Changes in boreal mixwood forest: horvest and wildfire effects over thirty years. *Ecological applications.* **9(3):** 849-863.

Holloway, J. D. (1987). Macro lepidopteran diversity in the Indoaustralian tropics; Geographic, biotopic and taxonomic variations. *Biological journal of Linnaean Society.* **30:** 325-341.

Holmes, R. T. (1986). Community structure, population fluctuations, and resource dynamics of birds in temperate deciduous forests Acta XIX Congressus Internationalis Ornithologici, Ottawa, Canada. **1:** 22 – 29.

Holmes, R. T. and J. C. Schultz (1988). Food availability for forest birds: effects of prey distribution and abundance on bird foraging. *Can. J. Zool.* **66:** 720-728.

Holmes, R. T., R. E. Jr. Bonney and S. W. Dalala. (1979). Guild structure of the Hubbard Brook bird community: a multivariate approach. *Ecology.* **60:** 512-520.

Homes, R. T. and S. K. Robinson (1981). Tree species preferences of foraging insectivorous birds in a northern hardwoods forest. *Oecologia*. pp. 31 – 35.

Horn, H. S. (1966). The measurement of 'overlap' in comparative ecological studies. *Am. Nat.* **100:** 419-424.

Howel, T. R. (1971). An ecological study of the birds of lowland pine savanna and the adjacent rain forest in Northeast Nicaragua. *The Living Bird*. **10:** 185-242.

Hsu, M. J. and Y. S. Lin (1997). Breeding ecology of Styan's Bulbul *Pycnonotus taivanus* in Taiwan. *Ibis*. **139:** 518-522.

Hullsieg, C. and D. M. Becker (1990). Nest site habitat selected by Merlins in southeastern Montana. *Condor*. **92:** 688-694.

Hussain, S. A. (1984). Some aspects of the biology and ecology of Narcondam Hornbill (*Rhyticeros Narcondami*). *J. Bombay nat. Hist. Soc.* **81(1):** 1-18.

Hutchinson, G. E. (1978). An introduction to population ecology NewHaven, Connectiant: Yale University Press.

Hutto, R. L. (1981). Seasonal variation in the foraging behaviour of some migratory Western Wood Warblers. *Auk*. **98** : 765 – 777.

Immelmann, K (1971). Ecological aspects of periodic reproduction. In: Avian biology Vol I. (D. S. Farner and J. R. King, eds.). Academic Press, New York. pp. 341-389.

Infield, M. (1988). Attitudes of a rural community towards conservation and a local conservation area in Natal, South Africa. *Biol. Conserv.* 45: 21-46.

Innes, G. J. (1989). Feeding ecology of fruit pigeons in subtropical rainforests of Southeastern Queensland. *Aust. Wildl. Res.* **16:** 365-394.

Inskipp, T., N. Lindsey, and W. Duckworth (1996). An annotated checklist of the birds of the Oriental region. Oriental Bird Club. Sandy.

Ishii, M. (1993). Transect count of butterflies. In Decline and conservation of butterflies in Japan **11:** 91-101.

Islam, M. A. (1994). Breeding habits of the Nilgiri Laughing Thrush *Garrulax cachinnans* (Jerdon). *J. Bombay nat. Hist. Soc.* **91:**16-28.

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

Jansen, D. H. and T. W. Schoener (1968). Differences in insect abundance and diversity between wetter and drier sites during a tropical dry season. *Ecology.* **49:** 96-110.

Javed, S. (1996). Study on bird community structures of Terai forest in Dudwa National Park *Ph. D. Thesis*, Aligarh Muslim University, India.

Javed, S. and H. S. A. Yahya (1991). Abnormal nesting behavior of Little Brown Dove *Streptopelia senegalensis cambayensis* (Gmelin.). *J. Bombay. nat. Hist. Soc.* **88(3):** 453.

Jayson, E. A. and D. N. Mathew (2000). Diversity and Species-abundance distribution of birds in the tropical forests of Silent Valley, Kerala *J. Bombay nat. Hist. Soc.* **97(3):** 390-399.

Jayson, E. A., and D. N. Mathew (2000). Seasonal changes of tropical forest birds in the southern western ghats *J. Bombay nat. Hist. Soc.* **97 (1):** 52 – 61.

Jerdon, T. C. (1862-64). Birds of India, Calcutta. 2: (part 3).

Jha, K. K. and J. S. Singh (1999). Temporal patterns of bole volume and biomass of young teak plantations raised in moist deciduous forest region, India. *International journal of ecology and environmental sciences.* **25:** 177-184.

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

Johnsingh, A. J. T. and S. Murali (1980). The ecology and behaviour of the Indian Peafowl (*Pavo cristatus*) Linn. of INIAR. *J. Bombay nat. Hist. Soc.* **75(1):** 1069-1079.

Johnsingh, A. J. T., K. Paramanandham., and S. Murali (1982). Foraging behaviour and interactions of white headed babblers *Turdoides affinis* with other species. *J. Bombay nat. Hist. Soc.* **79:** 503 – 515.

Johnsingh, A. J. T., N. H. Martin., J. Balasingh., and V. Chelladurai. (1987). Vegetation and avifauna in a thorn scrub habitat in South India. *Tropical Ecology.* **28:** 22-34.

Johnson, D. H., Nichols, J. D and M. D. Schwartz (1992). Population dynamics of breeding waterfowl. In Ecology and Mangement of Breeding Waterfowl. (Eds. Bhat, B. D., A> D. Afton, M. G.. Anderson, C. D. Ankney, D. H. Johnson, and G. L. Krapu) Minneapolis: University of Minnesota Press.

Joshua, J. and A. J. T. Johnsingh (1988). Observations on birds of Mundanthurai Plateau. Tamil Nadu. *J. Bombay nat. Hist. Soc.* **85:** 565-577.

Karr, J. R. (1968). Habitat and Avian diversity on strip-mined land in east-central Illinois. *Condor.* **70:** 348-357.

Karr, J. R. (1971). Structure of avian communities in selected Panama and Illinois habitats. *Ecol. Monogr.* **41:** 207-233.

Karr, J. R. (1976b). Seasonality, resource availability and community diversity in tropical bird communities. *American Naturalist.* **110:** 973 – 994.

Karr, J. R. S. K. Robinson, J. G. Blake and R. O. Berregard Jr. (1990). The bird communities of four neotropical forest. Yale University Press, New Haven, CT. pp. 237-269.

Karr, J. R. and R. R. Roth (1971). Vegetation structure and avian diversity in several New World areas. *American Naturalist.* **105:** 423 – 435.

Karr, J. R., D. W. Schemske and N. V. L. Brokaw (1982). Temporal variation in the understory bird coomunity of a tropical forest In: the ecology of a tropical forest-seasonal rhythms and longterm changes. (Eds. Leigh, E. G., Rand, A. S. & Windsor, D. M.). Smithsonian institution press, Washington DC.

Karr, J. R., M. Dionne and I. J. Schlosser (1992). Bottom-up versus top-down regulation of Vertebrate populations: Lessons from birds and fish. **In.** Effects of resource distribution on animal plant interactions. Academic press Inc. pp. 243-286.

Karr, J. R., S. K Robinson, J. G. Blake and R. O Bierregaard (1990). Birds of four neotropical forests Four Neotropical rain forests. pp. 237 – 269.

Katti, M. and J. Price (1996). Effects of climate on palaearctic warblers over-wintering in India. *J. Bombay nat. Hist. Soc.* **93(1):** 411-427.

Katti, M. V. (1989). Bird communities of Lower Dachigam Valley, Kashmir. *M. sc. Dissertation*, Sowrashtra university, Rajkot.

Kendeigh, T. (1934). The role of environment in the life of birds. *Ecological monograph.* **4:** 229 – 417.

Khacher, L. (1998). Range extension of the Purple-rumped Sunbird *Nectarinia zeylonica. J. Bombay. nat. Hist. Soc.* **97(1):** 146-147.

Khadka, R. B., L. Shrestha and A. S. Tamraker (1984). Ecology of Gadawari. Nepal Nature Paradise (Ed. T. C. Majupuria). White Lotus Company, Bangkok.

Khan, J. A., D. N. Khan and A. Ahmed (1993). Preliminary investigations of bird community structure at Aligarh, India. *Tropical Ecology.* **34(2):** 217-225.

Khan, M. A. R. (1980). A comparative account of the avifauna of the sholas and neighboring plantations in the Nilgiris. *J. Bombay. nat. Hist. Soc.* **75:** 1028-1035.

Kharboulti, M. S. and T. P. Mack (1993). Comparison of three methods for sampling Arthropod pests and their natural enemies in peanut fields. *Journal of Economic Entomology.* **86(6):** 1802-1810.

Kiester, A. R. and M. Slatkin (1974). A strategy of movement and resource utilization. *Theoret. Pop. Biol.* **6:** 1-20

Kinnaird, M. F. and T. G. O'Brien (1999). Breeding ecology of the Sulawesi Red-knobbed Hornbill *Aceros cassidix. Ibis.* **141:** 60-69.

Koen, J. H. (1988a). Stratal distribution and resource partioning of birds in the Knysna forest, South Africa. *Afr. J. Ecol.* **26:** 229-238.

Koen, J. H. (1992). Medium – term fluctuations of birds and their potential food resources in the Knysna forest. *Ostrich.* **63:** 21 – 30.

Koen, J. H and H. T. M. Crowe (1987). Animal-habitat relationships in the Knysna forest, South Africa: discrimination between forest types by birds and invertebrates. *Oecologia* (Berlin). **72:** 414-422.

Kossenko, S. M. and C. H. Fry (1998). Competition and coexistence of the european bee – eater merops apiaster and the blue – cheeked bee – eater merops persicus in asia. *Ibis.* **140:** 2 – 13.

Kozma, J. M. and N. E. Mathews (1997). Breeding bird communities and nest plant selection in Chihuahuan desert habitats in south-central New Mexico. *Wilson Bull.* **109(3):** 424-436.

Kremen, C. (1992). Assessing the indicator properties of the species assemblages for natural areas monitoring. *Ecological applications*. **2:** 203-217.

Kremen, C. (1994). Biological inventory using target taxa: A case study of butterflies of Madagascar. *Ecological applications*. **4:** 407-422.

Kricher, J. C. (1975). Diversity in two wintering bird communities: Possible weather effects. *Auk*. **92(4):** 766-777.

Kumar, A., D. Bhatt, and V.D Joshi (1999). Breeding ecology of Purple Sunbird *Nectarinia asiatica* with special reference to song behaviour. Ann. For. **7 (2):** 192 – 198.

Kumar, C. R. A. and N. K. Ramachandran (1990). Incubation period of Indian Little Brown Dove *Streptopelia senegalensis* (Linn.). *J. Bombay. nat. Hist. Soc.* **87(2):** 299-300.

Kumar, S. (1995). Ground nesting in the Little Brown Dove *Streptopelia senegalensis* (Linn.). *J. Bombay. nat. Hist. Soc.* **92(2):** 265-266.

Kwok, H. K. and R. T. Corlett (1999). Seasonality of a bird community in Hongkong, South China. *Ibis*. **141:** 70-79.

Lack, D. (1933). Habitat selection in birds. *Journal of animal ecology*. **2:** 239 – 262.

Lack, D. (1968). Ecological adaptations of reproduction in birds. Methuen, London.

Lale, N. E. S., P. Dudu and S. N. Okiwelu (1996). The effects of temperature and humidity on oviposition and developmental period of *Oryzaephilus mercator* (Fauvel) *Post harvest biology and technology*. **8(1):** 75-79.

Langbein, J., Hutchings M.R., Harris S., Stoate C., S. C. Tapper and S. Wray (1999). Techniques for assessing the abundance of Brown hares *Lepus europaeus*. *Mammal Rev.* **29 (2):** 93-116.

Legendre, L. and P. Legendre (1983). Numerical ecology. Developments in environmental modelling, 3. Elsevier Sci. Publ. Co., Amsterdem.

Levey, D. J. (1988). Spatial and temporal variation in Costa Rican fruit and fruit-eating bird abundance. *Ecol. Monogr.* **58:** 251-269.

Levings, S. C. and D. M. Windsor (1985). Litter Arthropod populations in a tropical deciduous forest: Relationships between years and Arthropod groups. *J. Anim. Ecol.* **54:** 61-69.

Levins, R. (1969). Evolution in changing environments. Princeton Univ. Press, Princeton and New Jersey.

Lima, S. L. (1985). Sampling behaviour of Starlings foraging in simple patchy environments. *Behav. Ecol. Sociobiol.* **16:** 135-142.

Lloyd, P. (1999). Rainfall as a breeding stimulus and clutch size determinant in south African arid-zone birds. *Ibis*. **141:** 637-643.

Loiselle, B. A. (1988). Bird abundance and seasonality in Costa Rican lowland forest canppy. *Condor.* **90:** 716-722.

Loman, J. (1982). A model of clutch size determination in birds. *Oecologia*. **52:** 253-257.

Lovejoy, T. E. (1975). Bird diversity and abundance in Amazon forest communities. *Living bird.* **13:** 127-191.

Ludwig, J. A. and J. F. Reynolds. (1988). Statistical ecology and Computing. Wiley, New York.

Lundberg, S. (1985). The importance of egg hatchability and nest predation in clutch size evolution in altricial birds. *Oikos*. **45:** 110-117.

MacArthur, R. H. (1957). On the relative abundance of species. *Proc. Natl. Acad. of Sci.* U. S. A. **43:**293-295.

MacArthur, R. H. (1958). Population ecology of some warblers of Northeastern coniferous forests. *Ecology*. **39:** 599-619.

MacArthur, R. H. (1964). Environmental factors affecting bird species diversity. *American Naturalist*. **903:** 387-397.

MacArthur, R. H. (1965). Patterns of species diversity. *Biological Reviews*. **40:** 510-533.

MacArthur, R. H. (1968). The theory of niche. **In**. population biology and evolution (R.C.Lewontin. Ed.) Syracuse University Press. Syracuse. pp. 159-176.

MacArthur, R. H. (1969). Patterns of communities in tropics. *Biol. J. Linn. Soci.* **1:**19-30.

MacArthur, R. H. (1971). Patterns of terrestrial bird communities in avian biology. (Eds. D.S.Farner and J.R.King.). Academic Press, New York.

MacArthur, R. H. and H. S. Horn (1969). Foliage profile by vertical measurements. *Ecology*. **50:** 802-804.

MacArthur, R (1972). Geographical ecology. Harper and Row, New York.

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

MacArthur, R. H., H. Recher and M. L. Cody (1966). On the relation between habitat selection and species diversity. *American Naturalist.* **100:** 319-332.

MacArthur, R. H., J. W. MacArthur and J. Preer (1962). On bird species diversity II Prediction of bird census from habitat measurements *American Naturalist.* **96:** 167-174.

MacNally, R. (1994). Habitat specific guild structure of forest birds in southeastern Australia: a regional scales perspective. *J. Anim. Ecol.* **63:** 988-1001.

MacNally, R. C. (1994a). On characterizing foraging versatalization illustrated by using birds. *Oikos.* **69:** 95-106.

MacNally, R. C. (1994b). Habitat specific guild structure of forest birds in South Eastern Australia: a regional scale perspective. *J. of Anim. Ecol.* **63:** 988-1001.

Mahat, T. B. S., D. M. Griffin and K. R. Sheperd (1987). Human impact of some forest of middle hills of Nepal part 4. A detail study in southeast Sindhu Palchok and northeast Kabre Palanchok. *Mountain Research and Development.* **7:** 111-134.

Manoharan, V. (1988). Studies on the diversity of avifauna in relation to vegetation at Mudumalai Wildlife Sanctuary, Tamil Nadu. *M.sc. dissertation*, Bharathidasan University.

Manual, D. A. and A. B Carey (1991). Wildlife – habitat relationships : sampling procedures for Pacific Northwest Vertebrates. Methods for measuring populations of small, diurnal forest birds. pp. 1 – 23.

Maratha, C. and B. B. Louis (1988). Bird abundance and species richness in roadsides adjacent to Iowa rowcrop fields. *Wildlife Society Bulletin.* **21:** 315-325.

Marshall, A. J. (1949). Weather factors and spermatogenesis in birds. *Proc. Zool. Soc. Lond.* **119:** 143-144.

Martin, T. E (1986). Competition in breeding birds: on the importance of considering processes at the level of the individual. *Curr. Ornithol.* **4:** 181-210.

Martin, T. E (1987). Food as a limit on breeding birds: a life-history perspective. *Ann. Rev. Ecol. Syst.* **18:** 453-487.

Martin, T. E (1992). Breeding season productivity considerations: what is the appropriate habitat features for management? **In.** ecology and conservation of neotropical migrant landbirds (j. M. Hagan and D. W. Johnston, eds.). Smithsonian Institution Press, Washington D.C. pp. 445-473.

Martin, T. E (1993a). Nest predation and nest sites: new perspective and old patterns. *BioScience*. **43:** 523-532.

Martin, T. E (1993b). Nest predation among vegetation layers and habitat types: revising the dogmas. *Am. Nat.* **141(6):** 897-913.

Martin, T. E. and J. A. Karr (1990). Behavioural plasticity of foraging maneuvers of migratory warblers: multiple selection period for niches. *Stud. Avian Biol.* **13:** 353-359

Martin, T. E. and J. J. Roper. (1988). Nest predation and nest-site selection of a western population of the Hermit Thrush. *Condor.* **90:** 51-57.

Martinsen, G. D. and T. G. Whitham (1994). More birds nest in hybrid cottonwood trees. *Wilson Bull.* **106(3):** 474-481.

Mathew, D.N (1975). Ecology of the Weaver Bird. *J. Bombay. nat. Hist. Soc.* **73:** 250-260.

Mathew, D.N., T.C Narendran and V. J. Zacharias (1980). A comparative study of the feeding habits of certain species of Indian birds affecting agriculture *J. Bombay nat. Hist. Soc.* **75** : 1178 – 1211.

Mathew, G. (1990). Studies on the Lepidoptera fauna. **In**. Ecological studies and long-term monitoring of the biological processes in the Silent Valley National Park. Report submitted to Ministry of Environment, Govt. of India, Kerala forest Research Institute. pp. 239.

Mathew, G. (1996). Insect diversity in the Nilgiri Biosphere Reserve-An overview *Zoosprint.* **11(7):** 11-13.

Maurer, B. A. and R. C. Whitmore (1981). Foraging of five bird species in two forests with different vegetation structure. *Wilson Bull.* **93:** 478-490.

Maya, V. M (2000). A study of the select species of weeds in different vegetation types of Nilgiri Biosphere reserve. *Ph. D. Thesis*, Bharathiar University, Coimbatore.

McCarty, J. P. and D. W. Winkler (1999). Relative importance of environmental variables in determining the growth of nestling Tree Swallows *Tachycine bicolor. Ibis.* **141:** 286 – 296.

Mittermeir, R. (1988). Primate density and type, tropical forest. Case studies from Brazil and Madagascar and the importance of mega diversity countries. Biodiversity (Eds. By E.O. Wilson and F. M. Peter) National Academic press, Washington DC. pp. 145-154.

Mittermeir, R., N. Myers, J. B. Thomson, G. A. B. Da Fonseca and S. Olivieri (1998). Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Cons. Biol.* **12:** 516-520.

Moermond, T. C. (1990). A functional approach to foraging: morphology, behaviour, and the capacity to exploit. In, Avian foraging: theory, methodology, and applications (Eds. M. L. Morrison, C. J. Ralph, J. Verner, and J. R. Jehl Jr.). *Stud. Avian Biol.* **13:** 427-430.

Morrison, M. L. (1984). Influence of sample size and sampling design on analysis of avian foraging behaviour. *Condor.* **86:** 146-150.

Morrison, M. L. (1986). Bird populations as indicators of environmental change. (Ed. R. F. Johnston, Plenum press, New York). *Current Ornithology.* **3:** 429-451.

Morrison, M. L., A. Kimberly and I. C. Timossi (1980). The structure of a forest bird community during winter and summer. *Willson Bull.* **98(2):** 214-230.

Mudappa, D. (2000). Breeding biology of the Malabar Grey Hornbill in Southern Western Ghat, India. *J. Bombay nat. Hist. Soc.* **97:** 15-24.

Mudappa, D. C. and R. Kannan (1997). Nest-site characteristics and nesting success of the Malabar Gray Hornbill in Southern Westem Ghats, India. *Wilson Bull*, **109 (1):** 102-111.

Mudge, G. P. and T. R. Talbot (1993). The breeding biology and causes of nest failure of Scottish Black-throated divers *Gavia arctica*. *Ibis*. **135:** 113-120.

Murali, K. S. and R. Sukumar (1993). Leaf flushing phenology and herbivori in a tropical dry deciduous forest, Southern India. *Oecologia*. **94:** 114-119.

Nagarajan, R. P. Neelanarayana and R. Kanakasabai (1993). Tips for the identification of Common Barn Owl nests. *Newsletter for Birdwatchers.* **33(5):** 93.

Narang M. L., Rana R.S., and M. Prabhakar (2000). Avian species involved in pollination and seed dispersal of some forestry species in Himachal Pradesh. *J. Bombay nat. Hist. Soc.* **97 (2):** 215 – 223.

Natarajan, V. (1991). The ecology of the Southern Crow-Pheasant Centropus sinensis parroti stresemann at Point Calimere Wildlife Sanctuary, Tamil Nadu. *Ph. D. Thesis*, University of Bombay.

Natarajan, V. (1997). Breeding biology of the Southern Crow-Pheasant *Centropus sinensis parroti* Stresemann (Aves: Cuculidae) at Point Calimere, Tamil Nadu. *J. Bombay nat. Hist. Soc.* **94:** 56-63.

Natuhara, Y., C. Imai, M. Ishii, Y. Sakuratani and S. Tanaka (1996). Reliability of transect count method for monitoring butterfly communities;1. Repeated counts in an urban park. *Japaneese Journal of Environmental Entomology and Zoology*. **8(1):** 13-22.

Nestel, D., F. Dicksschen and A. Altieri (1994). Seasonal and spatial population loads of a tropical insect: The case of the coffee leaf miner in Mexico. *Ecological Entomology*. **19(2):** 159-167.

Neu, C. W., C. R. Byers and J. M. Peek (1974). A technique for analysis of utilization – availability data. White G. R. and R. A. Garrdt 1990. Analysis of Radio Tracking data. Academic Press, New York. *Jour. Wildl. Mgmt.* **38(3):** 541-545.

Newmark, W. D. and N. L. Leonard (1991). The attitudes of local people toward Kilimanjaro National Park and forest reserve. In The Conservation of Mount Kilimanjaro (Ed.) W. D. Newmark, IUCN, Gland. pp. 87-96.

Newmark,W. D., N. L. Leonard H. I. Sariko and D. M. Gamassa (1993). Conservation attitudes of local people living adjacent to five protected areas in Tanzania. *Biol. Conserv.* **63:** 177-183.

Nirmala, T. and A. Rajasekaran (2001). Rose Finch – Weed destroyer or disperser? *Newsletter for Bird watchers*: **41(1):** 13.

Nirmala, T. and L. Vijayan (2000). Avifauna of SACON campus. *Sacon News* (special edition). **3 (1):** 18.

Nirmala, T. and L. Vijayan (2000). Ecology of the Yellow-eyed Babbler. Proc. of Second Pan Asian Ornithological Congress. **27:** 2.

Nirmala, T. and L. Vijayan (2000). Feeding and breeding behaviour of White-throated Babbler Proc. of 26th Ethological Society of India, pp. 18.

Nirmala, T. and L. Vijayan (2001). Impact of habitat degradation on the forest birds at Anaikatty, Coimbatore. Proc. of Environmental issues. pp. 16.

Norusis, M. J. (1994). SPSS Inc. SPSS release 6.0 for Unisys 6000, Chicago, Illinois, USA.

O'Connor, R. J. (1984). The growth and development of birds. Chichester. John Wiley and sons. pp. 315.

Odum, E. P. (1950). Bird population of highlands (North caroline) : pattern and relation to plant succession and avian invation. *Ecology* **31:** 587 – 605

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

Partridge, L. (1974). Habitat selection in titmice. *Nature, Lond.* **247:** 573-4.

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

Pearson, D. L. (1982). Historical factors and bird species richness. In: Biological Diversification in the Tropics. (Ed. G. T. Prance). Columbia University Press, New York. pp. 441-452.

Pekelharing, C.J., C. M. Frampton and P. A. Suisted (1998). Seasonal variation in the impacts of Brush Tailed Possums (Trichosurus bulpecula) on five palatable plant species in the New Zealand beech (Nothofagus) forest. New Zealand. *Journal of Ecology*. **22(2):** 141-148.

Perrins, C.M. (1996). Eggs, egg formation and the timing of breeding. *Ibis*. **138:** 2-15.

Perrins, C.M. and T.R. Birkhead. (1983). Avian ecology. Blackie, New York. pp. 221.

Pettingill, O. S. R. (1985). Ornithology in laboratory and field. University of Minnesota, Museum of Natural History. pp. 523.

Pianka, E. R. (1981). Competition and niche theory. **In**. Theoretical Ecology: Principles and applications (Ed. May, R. M.) Sunderland, Massachussettes: Sinauer Associates. pp. 167-196.

Picket, S. T. A. and P. S. White (1985). Natural disturbance and patch dynamics: an introduction. The ecology of natural disturbances and patch dynamics. (Eds. S. T. A. Picket and P. S. White). Academic Press, Orlando, Florida. pp. 3-13.

Pielou, E. C. (1975). Ecological diversity. Wiley, New York.

Pimm, S. L. (1984). Food chains and return times. **In**. Ecological; communities. Conceptual issues and the evidence. (Eds. D. R. Jr. Strong, D. Simberloff, L. G. Abele and A. B.Thistle). Princeton University Press. pp. 397-412.

Pimm, S. L. and J. W. Pimm (1982). Resource use, competition and resource availability in Hawaiian honeycreepers. *Ecology*. **63:** 1468-1480.

Pollard, E. (1977). A method for assessing changes in the abundance of butterflies. *Biological conservation*. **12:** 115-131.

Pollard, E. (1988). Temperature, rainfall and butterfly numbers. *Journal of applied Ecology*. **25:** 819-828.

Pollard, E. and D. Moss (1995). Historical records of the occurrence of butterflies in Britain: examples showing the associations between annual number of records and weather. *Global change biology.* **1(2):** 107-113.

Pollard, E. and T. J. Yates (1993). Monitoring butterflies for Ecology and Conservation. Chaman and Hall, London. pp. 274.

Posonby, D. J. and M. J. W. Copland (1996). Effect of temperature on development and immature survival in the scale insect predator, *Chilocorus nigritus* (F) (Coleoptera: Coccinellidae). *Bio-control science and technology.* **6(1):** 101-109.

Poulin, B. and G. lefebvre (1997). Estimation of arthropods available to birds : effect of trapping technique, prey distribution, and bird diet. *J. Field Ornithology.* **68 (3):** 426 – 442.

Poulin, B., G. Lefebvre and R. McNeil (1994). Characteristics of feeding guilds and variation in diets of birds species of three adjacent tropical sites. *Biotropica.* **26:** 187-197.

Powlesland, R. G., P. J. Dilks, I. A. Flux, A. D. Grant and C. J. Tisdall (1997). Impact of food abundance, diet and food quality on the breeding of the fruit pigeon, *Parea hemiphaga novaeseelandiae* chathamensis, on Chatham Island, New Zealand. *Ibis.* **139:** 353-365.

Prabhakar, R. and M. Gadgill (1994). Nilgiri Biosphere reserve: Biodiversity and population growth. **In**. Anon., eds., Survey of the Environment, The Hindu. pp. 33-37.

Pramod, P. (1995). Ecological studies of Bird communities of Silent Valley and neighbouring forests. *Ph. D. Thesis* submitted to the university of Calicut, Kerala.

Pramod, P. (1999). Bird Community Structure in the three different vegetation types of silent valley and adjacent forest area Silent. Valley – Whispers of reason. pp. 325 – 329.

Pramod, P. and Y. Yorn-Tov (2000). Breeding season and clutch size of Indian Passerines. *Ibis*. **142:** 75-81.

Prasad, S. N., Balachandran S., Vijayan .L, Ramachandran V. S., and C. P. A. Varghese (1998). Conservation planning for the Western Ghats of Kerala : 1 A GIS approach for location of biodiversity hotspots. *Current Science*. **75 (3):** 211 – 219.

Price, P. W. , I. R. Diniz, H. C. Moraise and E. S. A. Marques (1995). The abundance of insect herbivore species in the tropics: the high richness of rare species. *Biotropica*. **27(4):** 468-478.

Price, T. D (1979). The seasonality and occurrence of birds in the Eastern Ghats of Andhra Pradesh. *J. Bombay nat. Hist. Soc.* **76 (3):** 379 – 422.

Price, T. D. and N. Jamdar (1990). The breeding birds of Overa Wildlife Sanctuary, Kashmir. *J. Bombay. nat. Hist. Soc.* **87:**1-15

Price, T. D. and N. Jamdar (1991). Breeding biology of the Yellowbrowed Leaf warbler *Phylloscopus inornatus* in Kashmir. *J. Bombay nat. Hist. Soc.* **88(1):** 1-17.

Puyravaud, J. P., D. Shridhar, A. Gaulier, S. Aravajy and S. Ramalingam (1995). Impact of fire on a dry deciduous forest in the Bandipur National Park, southern India: Preliminary assessment and implications for management. *Current Science*. **68(7):** 745-751.

Pyke, G. H. (1984). Seasonal patterns of abundance of insectivorous birds and flying insects. *Emu*. **85(1):** 34-39.

Pyke, G. H. (1985). Seasonal patterns of abundance of insectivorous birds and flying insects. *Emu.* **85:** 34-39.

Ramakrishnan, B., and N. Sivaganesan (1997). Human interference and its impact on elephant corridors in South India, Gajah. *Indian Journal of Forestry.* **18:** 1-20.

Ramakrishnan, P. (1983). Environmental studies on the birds of Malabar forests *Ph. D. Thesis*, University of Calicu, Kerala.

Raman, T. R. S. (1999). Flocking and altitudinal movements of the Black Bulbul *Hypsipetes madagascariensis* in the southern western ghats, india *J. Bombay nat. Hist. Soc.* **96 (2):** 320 – 321.

Raman, T. R. S. (2001). Community ecology and conservation of tropical rain forest birds in the Southern Western Ghats, India. *Ph. D. Thesis.* Indian Institute of Science, Bangalore.

Ramsen, J. V. and S. K. Robinson (1990). A classification scheme for foraging behaviour of birds in terrestrial habitats. *Studies in Avian Biology* **123:** 144-160.

Rana, B. D. (1970). Winter food of the Common Babbler (*Turdoides caudatus*) in Rajasthan. *Indian Forester.* **96(2):** 153-155.

Rao, S. V. S. and R. M. Mishra (1994). Phytosociological analysis of two tropical deciduous forests of central India. *J. of Tropical Forestry.* **10(iv):** 278-296.

Rathinasabapathy, B. (1988). Study of the diversity of avifauna in the North Eastern Ghats of Andhra Pradesh during February to july 1988. *M. Phil dissertation.* Bharathidasan University.

Rawat, Y. S., Y. D. Bhatta, P. Pande and S. P. Singh (1994). Production and Nutrient cycling in *Arundinaria falcata* and *Lantana camara*: the two converted Ecosystems in Central Himalaya. *Tropical Ecology.* **35:** 53-67.

Recher, H. F. (1969). Bird species density and habitat diversity in Australia and North America. *American Naturalist.* **103:** 75-80.

Recher, H. F., D. Lunny and I. Dunn (1986). A natural ligacy Ecology in Australia, 2nd edn. Sydney, Pergamon Press.

Recher, H. F., R. T. Holmes, M. schulz J. .Shields and R. Kavanagh (1985) Foraging patterns of breeding birds in eucalyptus forest and woodland of Southern Australia. *Aust. J. Ecol.* **10:** 399-419.

Reddy, K. B. (1998). Effect of long-term disturbance on herbaceous plant community: A case study. *Intl. J. Ecol & Env. Sciences.* **24(1):** 131-139.

Restrepo, C., N. Gomez and S. Heredia (1999). Anthropogenic edges, tree fall caps, and fruit-frugivore interactions in a Neotropical montane forest. *Ecology.* **80(2):** 668-685.

Reynolds, R. T., E. C. Meslow, and H. M. Wight (1982). Nesting habitat of coexisting Accipiter in Oregon. *J. Wildl. Manage.* **46:** 124-138.

Rice, J. B., B. W. Anderson and R. D. Ohmart (1984). Comparison of the importance of different habitat attributes to avian community organisation. *J. Wildl. Management..* **48:** 895-911.

Richards, O. W. and R. G. Davies (1977). Imm's General Text Book of Entomology, 10th edition; vol 2,Classification and Biology. Chapman and Hall, London pp. 933.

Ricklefs, R. E. (1975). Competition and structure of bird communities (Review) *Evolution.* **29:** 581-585.

Ricklefs, R. E. (1983). Avian post-natal development Avian Biol. VII, Academic Press, New York. pp. 1-83.

Ricklefs, R. E. and J. Travis (1980). A morphological approach to the study of avian community organization. *Auk*. 97**:** 321-338.

Ripley, S. D. (1978). Changes in the bird fauna of a forest area: Simlipal hills, Mayurbhanj district and Dhankanal district, Orissa. *J. Bombay. nat. Hist. Soc.* **75:** 570-574.

Robinson, S. K. and R.T. Holmes (1982). Foraging behaviour of forest birds: the relationships among search tactics, diet, and habitat structure. *Ecology*. **63:** 1918-1931.

Robinson, S. K. and R.T. Holmes (1984). Effects of plant species and foliage structure on the foraging behaviour of forest birds. *Auk*. **101:** 672-684.

Robinson, S. K., J. Terborgh and J.W. Fitzpatrick (1988). Habitat selection and relative abundance of migrants in southeastern Peru. Proceedings of XIX Ornithological Congress. pp. 2298-2301.

Robinson, S. K., J. Terborgh and C. H. Munn (1990). Low land tropical forest bird communities of a site in Western Amazonia. **In**. Biogeography and ecology of bird communities. S. P. B. academic publishing, The Hague, The Netherlands. pp. 229-258.

Rodriguez, J. P., D.L. Pearson and R.R. Barrera (1998). A test for the adequacy of the bioindicators taxa: are tiger beetles (Coleoptera: Cicindelidae) appropriate indicator for monitoring the degradation of tropical forest in Venezuela. *Biological conservation* **83:** 69-76.

Rohlf, F. L. (1987). Numerical Taxonomy and Multivariate Analysis System. Exeter publishing, Setauket, New York.

Rolando, A. and C. A. Robotti (1985). Foraging niches of tits and associated species in north-western Italy. *Boll. Zool.* **52:** 281-297.

Root, R. B. (1967). The niche exploitation pattern of the Blue-gray Gnatcatcher *Ecol. Monogr.* **37:** 317-350.

Rosenberg, K. V. (1990). Dead-leaf foraging specializations in tropical forest birds: measuring resource availability and use. *Stud. Avian Biology.* **13:** 360-368.

Saab, V. (1999). Importance of spatial scale to habitat use by breeding birds in Riparian forest: A hierarchical analysis. *Ecological applications.* **9(1):** 135-151.

Santharam, V. (1995). A note on the preliminary findings on the distribution of the Great Black Woodpecker in the Western Ghats. *Newsletter for Birdwatchers.* **35(4):** 68-69.

Sartorius, S. S. L. J. Vitt and G. R. Colli (1999). Use of naturally and anthropogenically distributed habitats in Amazonian rain forest by the teiid lizard *Ameiva ameiva. Biological conservation.* **90(2):** 99-101.

Saulich, A. H., T. A. Volkovich and H. Numata (1994). Control of seasonal development by photoperiod and temperature in the linden bug, *Pyrrhocoris apterus* in Belgorod, Russia. *Zool. Sci.* **11(6):** 883-887.

Saxena, A. K. and J. S. Singh (1982a). A phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya. *Vegetatio.* **50:** 3-22.

Saxena, A. K. and J. S. Singh (1982b). Quantitative profile structure of certain forests in the Kumaun Himalaya. *Proceeding of Indian National Science Academy.* **91:** 529-549.

Saxena, R. (1995) Alternate use of nest by Little Brown Dove and Indian Robin (*Streptopelia senegalensis, Saxicoloides fulicata*, Madhya Pradesh). *Newsletter for Birdwatchers.* **35(1):** 16.

Schemske, D. W. and N. Brokaw (1981). Treefalls and the distribution of understory birds in a tropical forest. *Ecology*. **62:** 938-945.

Schieck, J., K. S. Smith and M. Nortan (2000). Bird communities are affected by amount and dispersion of vegetation retained in mixwood boreal forest harvest areas. *Forest ecology and management*. **162:** 239-254.

Schowalter, T. D. and L. M. Ganio (1998). Vertical and seasonal variation in canopy Arthropod communities in an old growth conifer forest in South Western Washington, U SA. *Bulletin of Entomological Research*. **88:** 633-640.

Shafiq, T., S. Javed and J. A. Khan (1997). Bird community structure of middle altitude oak forest in Kumaon Himalayas, India: A preliminary investigation. International. *Journal of Ecology and Environmental Sciences*. **23:** 389-400.

Shannon, C. E. and W. Weaver (1963). The mathematical theory of communication. University of Illinois Press, Urbana.

Sherry, T.W. and R.T. Holmes (1996). Winter habitat quality, population limitation, and conservation of Neotropical Neoarctic migrant birds. *Ecology*. **77:** 36-48.

Shukkur, E. A. A (1978) Biology, ecology and behaviour of the Black drongo, Dicrurus adsimilis. Ph. D. Thesis, University of Calicut, Kerala.

Shukkur, E. A. A. and K . J. Joseph (1980). Breeding biology of the Black Drongo. *J. Bombay nat. Hist. Soc.* **75:** 1212-1226.

Silori, C. S. and B. K. Mishra (1995). Pressure and resource dependency of Masinangudi group of villages on the surrounding elephant habitat. **In** A week with elephants., (Eds.Daniel J.C. and H. Datye). Pro. Intrn. Semi. Asian Elephant, Bombay Natural History Society, Bombay. pp. 270-278.

Simandal, J. (1993). Canopy arthropods on Scots pine: influence of season and stand age on community structure and position of sawflies (Diprionidae) in the community. *Forest Ecology and Management*. **62(1-4):** 85-98.

Singh, S. R. and A. Singh (1980). A brief report of birding in Nainital during Feb-March. *Newsletter for Birdwatchers*. **20(8):** 4-6.

Sivaganesan, N (1991). Ecology of Asian Elephants *Elephas maximus* with special reference to habitat utilization in Mudumalai Wildlife Sanctuary. *Ph. D. Thesis*, Bharathidasan University, Thiruchirapalli, Tamil Nadu, India.

Skutch, A. F. (1976). Parent birds and their young. University of Texas Press, Austin, Texas.

Slagsvold, T. (1982). Clutch size variation in passerine birds: the nest predation hypothesis. *Oecologia*. **54:** 159-169.

Slobotkin, L. B. (1986). On susceptibility of different species to extinction: Elementary instructions for owners of a world. The Preservation of species (Ed. By B. G. Norton). Princeton University, Princeton, NJ. pp. 226-242.

Smith, P. G. (1986). Chaos or order-organization. **In** Community ecology: Pattern and process. (Eds. J. Kikkawa and D. J. Anderson). Blackwell scientific publications. pp. 17-29.

Sokal,. R. R. and F. J. Rohlf (1981). Biometry, 2nd eds, W. H. Freeman & company. New York.

Sorensen, A. E. (1981). Interactions between birds and fruits in a temperate woodland. *Oecologia*. **50:** 242-249.

Soundarapandian, P. (1992). Working plan of the Forest Department of Tamil Nadu for the years 1982-1992, Coimbatore Forest Division.

Southwood, T. R. E. (1971). Ecological methods with particular reference to insect populations. English Language Book Society. pp. 524.

Sparks, T. H. and T. Parish (1995). Factors affecting the abundance of butterflies in the field boundaries in Swaresey fens. Cambridge, U. K. *Biological conservation.* **73(3):** 221.

Stattersfield, A. J., M. J. Crosby, A. J. Long and D. C. Wege (1998). Endemic bird areas of the world: priorities for biodiversity conservation. Birdlife International, cambridge.

Steele, B. B. (1993). Selection of foraging and nesting sites by Black-throated Blue-warblers: their relative influence on habitat choice. *Condor.* **95:** 568-579.

Stiles, F. G. (1978). Ecological and evolutionary implications of bird pollination. *Am. Zool.* **18:** 715-727.

Subramanyam, D. and B. W. Hagstrum (1993). Predicting development times of six stored food product moth species (Lepidoptera: Pyralidae) in relation to temperature, relative humidity and diet. *European Journal of Entomology.* **90(1):** 51-64.

Sultana, A. and J. A. Khan (1999). Avian community in the Kumaon Himalaya, India-a preliminary study. *International Journal of Ecology and Environmental Sciences.* **25:** 171-176.

Sultana, A. and J. A. Khan (2000). Birds of oak forests in the Kumaon Himalaya, Uttar Pradesh, India. *Forktail.* **16:** 131-146.

Sun, C., B. A. Kaplin, K. A. Kristensen, V. Munyaligoga, J. Mvuklyumwami, K. K. Kajondo and T. C. Moermond (1996). Tree phenology in a tropical montane forest in Rwanda. *Biotriopica.* **28(4b):** 668-681.

Sundaramoorthy, T. (1991). Ecology of terrestrial birds in Keoladeo National Park, Bharatpur *Ph. D. Thesis*, University of Bombay.

Sundriyal, R. C. and E. Sharma (1996). Anthropogenic pressure on tree structure and biomass in the temperate forest on mamlay Watershed in Sikkim. *Forest Ecology and Management*. **81:** 113-134.

Sundriyal, R. C., E. Sharma, L. K. Rai and S. C. Rai (1994). Tree structure, regeneration and woody biomass removal in a sub-tropical forest of Mamlay watershed in the Sikkim Himalaya. *Vegetatio*. **113:** 53-63.

Szaro, R. C. and R. P. Balda (1986). Relationships among weather, habitat structure, and Ponderosa pine forest birds. *J. Wildl. Manage*. **50:** 253-260.

Szekely, T. (1985). Foraging structure of the foliage-gleaning and bark-foraging guild in winter and spring. *Proc.Fifth Nordic Ornithological Congress*: pp. 140-146.

Terborgh, J. (1971). Distribution on environmental gradient theory and a preliminary interpretation of distributional patterns in the avifauna of the Cordillera Vilacamba, Peru. *Ecology*. **52:** 23-40.

Terborgh, J. (1977). Bird species diversity on an Andean elevational gradient. *Ecology*. **58:** 1007-1019.

Terborgh, J. (1980a). Causes of tropical species diversity. In Acta XVII Congress Internationalis Ornithologici ed. Nohring. R, pp. 955-961.

Terborgh, J. (1980b). The conservation status of neotropical migrants: present and future: **In**. migrant birds in the neotropics. Ecology behaviour, distribution and conservation. Smithsonian Institution Press, Washington DC. pp. 21-30.

Terborgh, J. (1985a). The role of ecotones in the distribution of Andean birds. *Ecology*. **66:** 1237-1246.

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

Terborgh, J. (1986). Keystone plant resources in the tropical forest. In M. E. Soule (Ed.). Conservation biology. Sinauer Assoc., Sunderland, MA. pp. 330-344.

Terborgh, J. (1990). Structure and organization of an Amazonian forest bird community. *Ecol. Monogr.* **60:** 213-238.

Thapa, G. B. and K. E. Weber (1990). Actors and factors of deforestation in "Tropical Asia". *Environmental Conservation.* **17:** 19-27.

Theberge, J. B. (1976). Bird populations in the Kluane Mountains, Southwest Yukon with special reference to vegetation and fire. *Can. J. Zool.* **54:** 1346-1356.

Thiollay, J. D. (1994). Structure, density and rarity in an Amazonian rain forest community. *J. Trop. Ecol.* **10:** 449-481.

Thiyagesan, K. (1991). Ecology of cavity nesting birds in and around Mayiladuthurai, Tamil Nadu, South India. *Ph. D. thesis*, Bharathidasan University, Trichirapalli.

Titus, K. and J. A. Mosher (1981). Nest site habitat selected by woodland Hawks in the Central Appalachians. *Auk.* **98:** 270-281.

Titus, K. and J. A. Mosher (1987). Selection of nest tree species by Red-shouldered and Broad-winged Hawks in two temperate forest regions. *J. Field Ornithol.* **58:** 274-283.

Trematerra, P., F. fontana and M. Mancani (1996). Effects of dead and alive insects in trap on the capture of Tribolium castaneum (Herbst) Anzeiger fur Schadlingksunde Pflanzenschutz Umweltschuz. **63:** 3-9.

Trezcinsky, M. K., L. Fahrig and G. Merriam (1999). Independent effect of forest cover and fragmentation on distribution of forest breeding birds. *Ecological applications* **9(2):** 586-593.

Turner, A. M. and J. P. Maccarty (1998). Resource availability, breeding site selection and reproductive success of Red-winged blackbirds. *Oecologia.* **113(1):** 140-146.

Van Riper, C. III. (1984). The influence of nectar resources on nesting success and movement patterns of the Common Amakihi (Hemignathus virens). *Auk.* **101:** 38-46.

VanderWerf, E. A. (1994). Intraspecific variation in foraging behavior in Hawaiian forests of different structure. *Auk.* **11(4):** 917-932.

Venkatraman, C. and L. Vijayan (1997). Breeding record of Greateared Nightjar (Eurostopodus macrotis) at Siruvani Hills, Tamil Nadu. *J. Bombay nat. Hist. Soc.* **94:** 407-408.

Verner, J. (1985). Assessment of counting techniques (Ed. R. F. Johnston). Plenum Press, New York. *Current Ornithology.* **2:** 247-302.

Verner, J. and T. A. Larson (1989). Richness of breeding bird species in mixed conifer forest of the Sierra Nevada, California. *Auk.* **106:** 447-463.

Vijayan, L. (1984). Comparative biology of Drongos (Family: Dicruridae, Class: Aves) with special reference to ecological Isolation. *Ph. D. Thesis,* Bombay University, Bombay.

Vijayan, L. (1990). Feeding behaviour of the Malabar Woodshrike *Trephrodornis virgatus sylvicola* Jerdon at Thekkady, Kerala. *J. Bombay nat. Hist. Soc.* **86:** 396-399.

Vijayan, L. and V. Gokula (1999). Impact of human interference on some of the rare endemic birds of the Upper Nilgiris, Tamil Nadu. **In**. Proc. of the

National Seminar on the endemic and endangered plants and animals of the eastern and western Ghats. Forest Department of Tamil Nadu. pp. 127-134.

Vijayan, L., C. Venkatraman, P. R. Arun and V. S. Vijayan. (1998). Breeding strategies of birds in a moist deciduous forest at Siruvani in the Nilgiri Biosphere Reserve. **In.** Maikhuri, (Eds. R. K., Rao, K. S. and Rai, R. K). Biosphere Reserves and Management in India. pp. 179-185.

Vijayan, L., S. N. Prasad, P. Balasubramanian V. Gokula, N.K. Ramachandran, D. Stephen and M. V. Mahajan (1999) Impact of human interference on the plant and bird communities in the Nilgiri Biosphere Reserve. Final report, SACON.

Vijayan, L., V. Gokula and S. N. Prasad (2000). A study of the Population and habitat of the Rufous-breasted Laughing Thrush *Garrulax cachinnans*. Project report, SACON. pp. 26.

Vijayan, V. S (1980). Breeding biology of bulbuls, *Pycnonotus cafer* and *Pycnonotus luteolus* (Class : Aves, family : Pycnonotidae) with special reference to their ecological isolation). *J. Bombay nat. Hist. Soc.* **75 :** 1090 – 1117,

Vijayan, V. S. (1975). Ecological isolation of bulbuls with special reference to *Pycnonotus cafer cafer* (Linnaeus) and P. luteolus in Point Calimere, Tamil Nadu. *Ph. D. Thesis*, University of Bombay. Bombay.

Vijayan, V. S. (1990). Keoladeo National Park Ecology Study (1980-1990) - an Overview. Bombay Natural History Society, Bombay.

Vijayan, V. S. (1991). Keoladeo National Park ecology study; Final report. *J. Bombay nat. Hist. Soc.* pp. 337.

Warkentain, I. G. and P. C. James (1988). Nest site selection by urban Merlins. *Condor.* **90:** 734-738.

Wheeler, A. G. and M. C. Calver (1996). Resource partitioning in an Island community of insectivores birds during winter. *Emu*. **96:** 23-31.

Wheelwright, N. T. (1986b). The diet of American Robins: an analysis of U.S. Biological Survey records. *Auk*. **103:** 710-725.

Whittaker, R .H (1975). Communities and eco system Macmillan press, New York.

Whitten, A. J., K. D. Bishop, S. V. Nash and L. Clayton (1987). One or more extinction from Sulawesi, Indonesia. *Conservation Biology*. **1:** 42-48.

Wiens, J. A. (1973). Pattern and process in grassland bird communities. *Ecol. Monogr.* **43:** 237-270.

Wiens, J. A. (1974). Climatic instability and ecological saturation of bird communities in North American grasslands. Condor. **76:** 385-400.

Wiens, J. A. (1983). Avian community ecology: an iconoclastic view. In Perspective in Ornithology (eds. A. H. Brush and G. A. Clark). Cambridge university Press, Cambridge.

Wiens, J. A. (1989). Ecology of bird communities. Cambridge University Press, Cambridge Vol 1 & 2.

Wiens, J. A. and J. T. Rotenberry (1981). Censusing and habitat evaluation of avian habitat occupancy. *Studies in Avian Biology*. **6:** 522-532.

Wiens, J. A. and J. T. Rotenberry (1985). Response of breeding passerine birds to rangeland alteration in a North American shrubsteppe locality. *Journal of Applied Ecology*. **22:** 655-668.

Willson, F. M. (1974). Avian community organization and habitat structure. *Ecology*. **55:** 1017-1029.

Wilson, M. F., C. Sabag and J. J. Armesto (1994). Avian communities of fragmented south-temperate Rain forests in Chile. *Conservation Biology.* **8:** 508-520.

Winternitz, B. L. (1976) Temporal change and habitat difference of some mountane breeding birds. *Condor.* **78:** 383-393.

Woinarski J. C. Z. and J. M. Cullen (1984). Distribution of invertebrates on foliage in forests of south-eastern, Australia. *Aust. J. Ecol.* **9:** 207-232.

Wolda, H. (1978a). Fluctuations in abundance of tropical insects. *American Naturalist.* **112:** 1017-1045.

Wolf, L. L. (1975). Energy intake and expenditures in a nectar feeding Sunbird. *Ecology* . **56:** 92-104.

Wright, J. S. (1970). Competition between insectivorous lizards and birds in Central Panama. *Amer. Zool.* **19:** 1145-1156.

Yahya, H. S. A (1988). Breeding biology of barbets, megalaima spp. (Capitonidae : ticiformes) at Periyar Tiger Reserve, Kerala. *J. Bombay nat. Hist. Soc.* **85 (3):** 493 – 511.

Yahya, H. S. A (1989). Habitat preference of birds in the Periyar Tiger Reserve, Kerala. *Indian Journal of forestry.* **12(4) :** 288 – 295.

Yahya, H. S. A. (2000). Food and feeding habits of Indian Barbets, *Megalaima* spp. *J. Bombay nat. Hist. Soc.* **97 (1):** 103 – 116.

Yamagishi, S. and K. Eguchi (1996). Comparative foraging ecology of madagascar vangids (vangidae). *Ibis.* **138:** 283 – 290.

Yasmin. S. and H.S.A. Yahya (1998). Group size and vigilance in Indian Peafowl *Pavo cristatus* (LINN.), family : phasianidae. *J. Bombay nat. Hist. Soc.* 95: 103-105.

Yoshio, M. and M. Ishii (1994). Photoperiodic determination of seasonal morphs associated with reproductive diapause in Melanitis phedima oitensis (Lepidoptera: Satyridae). *Japanese Journal of Entomology*. **62(1):** 40-49.

Young, E. C. (1977). Egg-laying in relation to latitude in southern hemisphere skuas. *Ibis* **119:** 191-195.

Zacharias, V. J. and A. J. Gaston (1999). The recent distribution of endemic, disjunct and globally uncommon birds in the forests of Kerala State, Southwest India. *Bird Cons. Intern.* **9:** 191-225.

Zacharias, V. J. and D. N. Mathew (1988). Ecology of Babblers. *J. Bombay nat. Hist. Soc.* **85:** 50-64.

Appendix 1. Avifauna in the Anaikatty Hills, Coimbatore.

s. code	Ali's Nomenclature	Scientific Name	Inskipp's name	Guild	Status
5	Little Grebe	*Podiceps ruficollis*	LITTLE GREBE	O	R
21	Spottedbilled Pelican	*Pelecanus philippensis*	SPOT-BILLED PELICAN	P	RM
26	Large Cormorant	*Phalacrocorax carbo*	GREAT CORMORANT	P	RM
28	Little Cormorant	*Phalacrocorax niger*	LITTLE CORMORANT	P	R
36	Grey Heron	*Ardea cinerea*	GREY HERON	C	RM
37	Purple Heron	*Ardea purpurea*	PURPLE HERON	C	R
42	Indian Pond Heron	*Ardeola grayii*	INDIAN POND HERON	P I	LM
44	Cattle Egret	*Bubulcus ibis*	CATTLE EGRET	I	R
46	Large Egret	*Ardea alba*	INTERMEDIATE EGRET	C	R
49	Little Egret	*Egretta garzetta*	LITTLE EGRET	O	R
61	Openbill Stork	*Anastomus oscitans*	ASIAN OPENBILL	C	R
97	Spotbill Duck	*Anas poecilorhyncha*	SPOT-BILLED DUCK	L	R
124	Blackwinged Kite	*Elanus caeruleus*	BLACK-SHOULDERED KITE	C	LM
133	Pariah Kite	*Milvus migrans*	BLACK KITE	O	LM
135	Brahminy Kite	*Haliastur indus*	BRAHMINY KITE	C	R
139	Indian Shikra	*Accipiter badius*	SHIKRA	C	LM
161	Indian Crested Hawk-Eagle	*Spizaetus cirrhatus*	CHANGEABLE HAWK-EAGLE	C	R
168	Tawny Eagle	*Aquila rapax vindhiana*	TAWNY EAGLE	C	LM
172	Black Eagle	*Ictinaetus malayensis*	BLACK EAGLE	C	LM
185	Indian White-backed Vulture	*Gyps bengalensis*	INDIAN WHITE-BACKED VULTURE		
190	Pale Harrier	*Circus macrourus*	PALLID HARRIER	C	R
197	Peninsular Crested Serpent Eagle	*Spilornis cheela*	CRESTED SERPENT EAGLE	C	LM
246	South Indian Grey Partridge	*Francolinus pondicerianus*	GREY FRANCOLIN	G I	R
255	Jungle Bush Quail	*Perdicula asiatica*	JUNGLE BUSH QUAIL	C	LM
260	Rock Bush Quail	*Perdicula argoondah*	ROCK BUSH QUAIL	G I	LM
275	Red Spur Fowl	*Galloperdix spadicea*	RED SPURFOWL	O	LM
301	Grey Junglefowl	*Gallus sonneratii*	GREY JUNGLEFOWL	O	R
311	Indian Peafowl	*Pavo cristatus*	INDIAN PEAFOWL	O	R
318	Indian Bustard Quail	*Tumix suscitator*	BARRED BUTONQUAIL	O	LM
344	Indian Whitebreasted Waterhen	*Amauromis phoenicurus*	WHITE-BREASTED WATERHEN	O	R
366	Red-wattled Lapwing	*Vanellus indicus*	RED-WATTLED LAPWING	C	RM
496	Greyfronted Greenpigeon	*Treron pompadora*	POMPADOUR GREEN PIGEON	F	R
504	Common Green Pigeon	*Treron phoenicoptera*	YELLOW-FOOTED GREEN PIGEON	F	LM
511	Maroonbacked Imperial Pigeon	*Ducula badia*	MOUNTAIN IMPERIAL PIGEON	F	R
517	Indian Blue Rock Pigeon	*Columba livia*	ROCK PIGEON	G	R
533	Rufous Turtle Dove	*Streptopelia orientalis*	ORIENTAL TURTLE DOVE	G	RM

s. code	Ali's Nomenclature	Scientific Name	Inskipp's name	Guild	Status
534	Indian Ring Dove	*Streptopelia decaocto*	EURASIAN COLLARED DOVE	G	LM
537	Indian Spotted Dove	*Streptopelia chinensis*	SPOTTED DOVE	G	R
541	Indian Little Brown Dove	*Streptopelia senegalensis*	LAUGHING DOVE	G	R
542	Indian Emerald Dove	*Chalcophaps indica*	EMERALD DOVE	G I	LM
550	Roseringed Parakeet	*Psittacula krameri*	ROSE-RINGED PARAKEET	F	LM
558	Southern Blossom-headed Parakeet	*Psittacula cyanocephala*	BLOSSOM-HEADED PARAKEET	F	R
564	Bluewinged Parakeet	*Psittacula columboides*	MALABAR PARAKEET	G F	R
566	Indian Lorikeet	*Loriculus vernalis*	VERNAL HANGING PARROT	N	LM
570	Pied Crested Cuckoo	*Clamator coromandus*	PIED CUCKOO	I	R
573	Brainfever Bird	*Cuculus varius*	COMMON HAWKCUCKOO	I	LM
578	Cuckoo	*Cuculus canorus*	EURASIAN CUCKOO	I	RM
582	Indian Baybanded Cuckoo	*Cacomantis sonneratii*	BANDED BAY CUCKOO	I	R
590	Indian Koel	*Eudynamys scolopacea*	ASIAN KOEL	F	R
595	Small Greenbilled Malkoha	*Rhopodytes viridirostris*	BLUE-FACED MALKOHA	O	R
598	Southern Sirkeer Cuckoo	*Taccocua leschenaultii*	SIRKEER MALKOHA	O	R
602	Southern Crow-Pheasant	*Centropus sinensis*	GREATER COUCAL	O	R
617	Scops Owl	*Otus scops*	ORIENTAL SCOPS OWL	C	RM
627	Indian Great Horned Owl	*Bubo bubo*	EURASIAN EAGLE OWL		
631	Brown Fish Owl	*Bubo zeylonensis*	BROWN FISH OWL	C	LM
652	Southern Spotted Owlet	*Athene brama*	SPOTTED OWLET	O	RM
676	Longtailed Nightjar	*Caprimulgus macrurus*	LARGE-TAILED NIGHTJAR	I	RM
680	Common Indian Nightjar	*Caprimulgus asiaticus*	INDIAN NIGHTJAR	I	LM
694	Alpine Swift	*Apus melba*	ALPINE SWIFT	I	LM
703	House Swift	*Apus affinis*	HOUSE SWIFT	I	LM
707	Palm Swift	*Cypsiurus parvus*	ASIAN PALM SWIFT	I	R
709	Creasted Swift	*Hemiprocne longipennis*	CREASTED TREESWIFT	I	LM
720	Pied Kingfisher	*Ceryle rudis*	PIED KINGFISHER	C	R
724	Small Blue Kingfisher	*Alcido atthis*	COMMON KINGFISHER	P	R
736	Indian Whitebreasted Kingfisher	*Halcyon smyrnensis*	WHITE-THROATED KINGFISHER	P I	LM
739	Blackcapped Kingfisher	*Halcyon pileata*	BLACK-CAPPED KINGFISHER	P	R
744	Chestnutheaded Bee-eater	*Merops leschenaulti*	CHESTNUT-HEADED BEE-EATER	I	LM
750	Small Green Bee-eater	*Merops orientalis*	GREEN BEE-EATER	I	LM
753	Bluebearded Bee-eater	*Nyctyornis athertoni*	BLUE-BEARDED BEE-EATER	G I	LM
756	Indian Roller	*Coracias benghalensis*	INDIAN ROLLER	C	LM

s. code	Ali's Nomenclature	Scientific Name	Inskipp's name	Guild	Status
765	Hoopoe	*Upupa epops*	COMMON HOOPOE	I	R
767	Common Grey Hornbill	*Tockus birostris*	INDIAN GREY HORNBILL	O	R
785	Small Green Barbet	*Megalaima viridis*	WHITE-CHEEKED BARBET	F	R
790	Crimsonthroated Barbet	*Megalaima rubricapilla*	CRIMSON-FRONTED BARBET	F	LM
792	Crimson-breasted Barbet or Coppersmith	*Megalaima haemacephala*	COPPERSMITH BARBET	F	R
796	Wryneck	*Jynx torquilla*	EURASIAN WRYNECK	I	M
804	Rufous Woodpecker	*Micropternus brachyurus*	RUFOUS WOODPECKER	I	RM
808	Little Scalybellied Green Woodpecker	*Picus myrmecophoneus*	STREAK-THROATED WOODPECKER	I	R
816	Small Yellownaped Woodpecker	*Picus chlorolophus*	LESSER YELLOWNAPE WOODPECKER	I	R
820	Lesser Goldenbacked woodpecker	*Dinopium benghalense*	BLACK-RUMPED WOODPECKER	I	R
825	Indian Goldenbacked Threetoed Woodpecker	*Dinopium javanense*	COMMON FLAMEBACK	I	LM
847	Yellowfronted Pied Woodpecker	*Picoides mahrattensis*	YELLOW-CROWNED WOODPECKER	I	R
853	Pigmy Woodpecker	*Picoides nanus*	BROWN-CAPPEDPIGMY WOODPECKER	I	LM
858	Blackbacked Woodpecker	*Chrysocolaptes festivus*	WHITE-NAPED WOODPECKER	I	RM
867	Indian Pitta	*Pitta brachyura*	INDIAN PITTA	I	RM
872	Singing Bush Lark	*Mirafra javanica*	SINGING BUSHLARK	I	R
874	Bush Lark	*Mirafra assamica*	RUFOUS-WINGED BUSH LARK	I	R
877	Redwinged Bush Lark	*Mirafra erythroptera*	INDIAN BUSHLARK	I	LM
878	Ashy Crowned or Blackbellied Finch-Lark	*Eremopterix grisea*	ASHY-CROWNEDSPARROW LARK	I	R
882	Indian Rufoustailed Finch-lark	*Ammomanes phoenicurus*	RUFOUS-TAILED LARK	I	M
917	Eastern Swallow	*Hirundo rustica*	BARN SWALLOW	I	LM
919	Nilgiri House Swallow	*Hirundo tahitica*	PACIFIC SWALLOW	I	R
921	Indian Wiretailed Swallow	*Hirundi smithii*	WIRE-TAILED SWALLOW	I	R
927	Redrumped Swallow	*Hirundo daurica*	REDRUMPED SWALLOW	I	RM
930	House Martin	*Delichon urbica*	NORTHERN HOUSE MARTIN	I	RM
933	Grey Shrike	*Lanius excubitor*	GREAT GREY SHRIKE	C	RM
940	Indian Baybacked shrike	*Lanius vittatus*	BAY-BACKED SHRIKE	I	LM
946	Rufous Backed Shrike	*Lanius schach*	LONG-TAILED SHRIKE	I	LM
949	Brown Shrike	*Lanius cristatus*	BROWN SHRIKE	I	M
953	Indian Golden Oriole	*Oriolus oriolus*	EURASIAN GOLDEN ORIOLE	O	RM
954	Eastern Blacknaped Oriole	*Oriolus chinensis*	BLACK-NAPED ORIOLE	O	R
959	South Indian Blackheaded Oriole	*Oriolus xanthornus*	BLACK-HOODED ORIOLE	O	R
963	South Indian Black Drongo	*Dicrurus adsimilis*	BLACK DRONGO	I	R

s. code	Ali's Nomenclature	Scientific Name	Inskipp's name	Guild	Status
965	Indian Grey Drongo	*Dicrurus leucophaeus*	ASHY DRONGO	I	LM
967	Indian Whitebellied Drongo	*Dicrurus caerulescens*	WHITE-BELLIED DRONGO	I	RM
971	Bronzed Drongo	*Dicrurus aeneus*	BRONZED DRONGO	I	LM
977	Racket-tailed Drongo	*Dicrurus paradiseus*	GREATER RACKET-TAILED DRONGO	I	R
982	Ashy Swallow-shrike	*Artamus fuscus*	ASHY WOODSWALLOW	I	RM
987	Greyheaded Myna	*Sturnus malabaricus*	CHESTNUT-TAILED STARLING	F	LM
994	Blackheaded or Brahminy Myna	*Sturnus pagodarum*	BRAHMINY STARLING	F	LM
996	Rosy Paster or Rosecoloured Starling	*Sturnus roseus*	ROSY STARLING	I	R
1006	Indian Myna	*Acridotheres tristis*	COMMON MYNA	O	R
1010	Southern Jungle Myna	*Acridotheres fuscus*	JUNGLE MYNA	F	R
1034	Treepie	*Dendrocitta vagabunda*	RUFOUS TREEPIE	O	R
1049	Indian House Crow	*Corvus splendens*	HOUSE CROW	O	R
1057	Indian Jungle Crow	*Corvus macrorhynchos*	LARGE-BILLED CROW	O	R
1070	Indian Wood Shrike	*Tephrodornis pondicerianus*	COMMON WOODSHRIKE	I	R
1079	Peninsular Blackheaded Cuckoo-shrike	*Coracina melanoptera*	BLACK-HEADED CUCKOOSHRIKE	I	RM
1081	Scarlet Minivet	*Pericrocotus flammeus*	SCARLET MINIVET	I	RM
1089	Rosy Minivet	*Pericrocotus roseus*	ROSY MINIVET	I	R
1093	Southern Small Minivet	*Pericrocotus cinnamomeus*	SMALL MINIVET	I	LM
1096	Whitebellied Minivet	*Pericrocotus erythropygius*	WHITE-BELLIED MINIVET	I S	R
1100	Common Iora	*Aegithina tiphia*	COMMON IORA	I	R
1104	Southern Goldfronted Chloropsis	*Chloropsis aurifrons*	GOLDEN-FRONTED LEAFBIRD	N I	R
1108	Goldmantled Chloropsis	*Chloropsis cochinchinensis*	BLUE-WINGED LEAFBIRD	N I	R
1114	Greyheaded Bulbul	*Pycnonotus priocephalus*	GREY-HEADED BULBUL	F I	LM
1120	Redwhiskered Bulbul	*Pycnonotus jocosus*	RED-WHISKERED BULBUL	F	R
1128	Redvented Bulbul	*Pycnonotus cafer*	RED-VENTED BULBUL	F	R
1138	White-browed Bulbul	*Pycnonotus luteolus*	WHITE-BROWED BULBUL	F	R
1149	Southindian Black Bulbul	*Hypsipetes madagascariensis*	BLACK BULBUL	F	LM
1154	Peninsular Spotted Babbler	*Pellorneum ruficeps*	PUFF-THROATED BABBLER	I	RM
1175	Slaty Headed Scimitar Babbler	*Pomatorhinus schisticeps*	INDIAN SCIMITAR BABBLER	O	R
1221	Whitethroated Babbler	*Dumetia hyperythra*	TAWNY-BELLIED BABBLER	I	R
1231	Yelloweyed Babbler	*Chrysomma sinense*	YELLOW-EYED BABBLER	I	R

s. code	Ali's Nomenclature	Scientific Name	Inskipp's name	Guild	Status
1254	Common Babbler	*Turdoides caudatus*	COMMON BABBLER	I F	R
1259	Rufous Babbler	*Turdoides subrufus*	RUFOUS BABBLER	F	LM
1262	Peninsular Jungle Babbler	*Turdoides striatus*	JUNGLE BABBLER	O	R
1267	White-headed Babbler	*Turdoides affinis*	YELLOW-BILLED BABBLER	O	R
1390	Nilgiri Quaker Babbler	*Alcippe poioicephala*	BROWN-CHEEKED FULVETTA	I	RM
1407	Brown Flycatcher	*Muscicapa latirostris*	ASIAN BROWN FLYCATCHER	I	R
1440	Blue-throated Flycatcher	*Muscicapa rubeculoides*	BLUE-THROATED FLYCATCHER	I	LM
1442	Tickell's Blue Flycatcher	*Muscicapa tickelliae*	TICKELL'S BLUE FLYCATCHER	I	LM
1446	Nilgiri Verditer Flycatcher	*Muscicapa albicaudata*	VERDITER FLYCATCHER	I	LM
1449	Greyheaded Flycatcher	*Culicicapa ceylonensis*	GREY-HEADED CANARY FLYCATCHER	I	R
1452	Whitebrowed Fantail Flycatcher	*Rhipidura aureola*	WHITE-BROWED FANTAIL	I	LM
1461	Peninsular Indian Paradise Flycatcher	*Terpsiphone paradisi*	ASIAN PARADISE FLYCATCHER	I	R
1504	Franklin's Ashy-grey Wren-Warbler	*Prinia hodgsonii*	GREY-BREASTED PRINIA	I	RM
1513	Plain Wren-Warbler	*Prinia subflava*	PLAIN PRINIA	I	R
1517	Southern Ashy Wren-Warbler	*Prinia socialis*	ASHY PRINIA	I	LM
1521	Peninsular Jungle Wren Warbler	*Prinia sylvatica*	JUNGLE PRINIA	I	LM
1535	Indian Tailor Bird	*Orthotomus sutorius*	COMMON TAILORBIRD	I	R
1550	Indian Great Reed Warbler	*Acrocephalus stentoreus*	CLAMOROUS REED WARBLER	I	LM
1556	Blyth's Reed Warbler	*Acrocephalus dumetorum*	BLYTH'S REED WARBLER	I	RM
1557	Indian Paddyfield Warbler	*Acrocephalus agricola*	PADDYFIELD WARBLER	I	R
1563	Indian Booted Tree Warbler	*Hippolais caligata*	BOOTED WARBLER	I	LM
1568	Lesser Whitethroat	*Sylvia curruca*	LESSER WHITETHROAT	I	M
1578	Tytler's Leaf Warbler	*Phylloscopus tytleri*	TYTLER'S LEAF WARBLER	I	M
1579	Tickell's Leaf Warbler	*Phylloscopus affinis*	TICKELL'S LEAF WARBLER	I	M
1601	Largebilled Leaf Warbler	*Phylloscopus magnirostris*	LARGE-BILLED LEAF WARBLER	I	M
1602	Dullgreen Leaf Warbler	*Phylloscopus trochiloides*	GREENISH WARBLER	I	M
1661	Indian Magpie-Robin	*Copsychus saularis*	ORIENTAL MAGPIE ROBIN	I	R
1702	Nilgiri Pied Bush Chat	*Saxicola caprata*	PIED BUSHCHAT	I	LM
1720	South Indian Blackbacked Robin	*Saxicoloides fulicata*	INDIAN ROBIN	I	R
1728	Malabar Whistling Thrush	*Myiophonus horsfieldii*	MALABAR WHISTLING THRUSH	I	LM
1731	Pied Ground Thrush	*Zoothera wardii*	PIED THRUSH		
1794	Grey Tit	*Parus major*	GREAT TIT	I	LM
1860	Paddyfield Pipit	*Anthus novaeseelandiae*	PADDYFIELD PIPIT	I	LM

s. code	Ali's Nomenclature	Scientific Name	Inskipp's name	Guild	Status
1868	Rufous Rock Pipit	*Anthus similis*	LONG-BILLED PIPIT	I	RM
1874	Forest Wagtail	*Mottacilla indica*	FOREST WAGTAIL	I	RM
1875	Yellow Wagtail	*Motacilla flava*	YELLOW WAGTAIL	I	RM
1884	Grey Wagtail	*Motacilla caspica*	GREY WAGTAIL	I	R
1891	Large Green Barbet	*Megalaima zeylanica*	BROWN-HEADED BARBET	F	R
1891	Large Pied Wagtail	*Motacilla maderaspatensis*	WHITE-BROWED WAGTAIL	I	LM
1892	Thickbilled Flowerpecker	*Dicaeum agile*	THICK-BILLED FLOWERPECKER	FL F	RM
1899	Tickell's Flowerpecker	*Dicaeum erythrorhynchos*	PALE-BILLED FLOWERPECKER	FL F	RM
1902	Plaincoloured Flowerpecker	*Dicaeum concolor*	PLAIN FLOWERPECKER	N FL	LM
1907	Indian Purplerumped Sunbird	*Nectarinia zeylonica*	PURPLE-RUMPED SUNBIRD	N	R
1909	Small Sunbird	*Nectarinia minima*	CRIMSON-BACKED SUNBIRD	N	R
1911	Maroonbreasted or Loten's Sunbird	*Nectarinia lotenia*	LOTEN'S SUNBIRD	N	R
1917	Indian Purple Sunbird	*Nectarinia asiatica*	PURPLE SUNBIRD	N	RM
1933	Indian White-eye	*Zosterops palpebrosa*	ORIENTAL WHITE-EYE	N	RM
1938	Indian House Sparrow	*Passer domesticus*	HOUSE SPARROW	G	LM
1957	Indian Baya Weaver bird	*Ploceus philippinus*	BAYA WEAVER	G	LM
1966	Whitethroated Munia	*Lonchura malabarica*	INDIAN SILVERBILL	G	LM
1974	Indian Spotted Munia	*Lonchura punctulata*	SCALY-BREASTED MUNIA	G	RM
1978	Blackheaded Munia	*Lonchura malacca*	BLACK-HEADED MUNIA	G	R
2011	Indian Rosefinch	*Carpodacus erythrinus*	COMMON ROSEFINCH	G	M

C - Carnivore, F - Frugivore, G. Granivore, I - Insectivore,
O - Omnivore, P - Piscivore, LM - Local migrant,
R - Resident, M. Migrant, RM - Resident migrant.

Appendix 2. List of plants observed in the study sites in the Anaikatty hills.

Name of the plant	Family	Growth forms
Abutilon indicum	Malvaceae	S+
Acacia leucophloea	Mimosaceae	T+
Acacia polyacantha	Mimosaceae	T
Acacia sp.	Mimosaceae	S
Acalypha fruticosa	Euphorbiaceae	S+
Ailanthus excelsa	Simaroubaceae	T+
Albizia amara	Mimosaceae	T+
Albizia lebbeck	Mimosaceae	T
Alphonsea sclerocarpa	Annonaceae	T
Andrographis sp.	Acanthaceae	H
Argyreia pomacea	Convolvulaceae	S
Atalantia monophylla	Rutaceae	T
Bambusa sp.	Gramineae	T
Barleria sp.	Acanthaceae	S
Bauhinia racemosa	Caesalpiniaceae	T+
Borreria ocymoides	Rubiaceae	H+
Breynia rhamnoides	Euphorbiaceae	S+
Calotropis gigantea	Asclepiadaceae	S+
Cansjera rheedii	Opiliaceae	ST+
Canthium dicoccum	Rubiaceae	T+
Capparis grandiflora	Capparaceae	S+
Capparis grandis	Capparaceae	T+
Capparis roxburghii	Capparaceae	ST+
Capparis sepiaria	Capparaceae	ST+
Caralluma sp.	Asclepiadaceae	H
Cardiospermum canescens	Sapindaceae	H+
Cardiospermum halicacabum	Sapindaceae	S+
Carissa spinarum	Apocynaceae	S+
Carmona retusa	Cordiaceae	S+
Cassia auriculata	Caesalpiniaceae	S+
Cassia fistula	Caesalpiniaceae	T
Celtis philippensis	Ulmaceae	T
Chloroxylon swietenia	Rutaceae	T+
Chromolaena odorata	Compositae	S+
Cissus quadrangularis	Vitaceae	S+
Clausena heptaphylla	Rutaceae	T+
Commiphora caudata	Burseraceae	T
Cordia monoica	Cordiaceae	S
Croton bonplandianum	Euphorbiaceae	S+
Dalbergia paniculata	Papilionaceae	T+
Dendrophthoe falcata	Loranthaceae	S
Dichrostachys cinerea	Mimosaceae	T
Diospyros ferrea	Ebenaceae	T
Dodonaea viscosa	Sapindaceae	S+
Ehretia ovalifolia	Cordiaceae	T

Name of the plant	Family	Growth forms
Elaeodendron glaucum	Celastraceae	T+
Eragrostis pomila	Poaceae	H
Erythrina indica	Paplionaceae	T+
Erythroxylum monogynum	Erythroxylaceae	S+
Euphorbia antiquorum	Euphorbiaceae	T
Ficus benghalensis	Moraceae	T+
Ficus infectoria	Moraceae	T
Ficus microcarpa	Moraceae	T
Ficus racemosa	Moraceae	T+
Ficus virens	Moraceae	T
Flacourtia indica	Flacourtiaceae	T+
Fluggea leucopyros	Euphorbiaceae	S
Fluggea virosa	Euphorbiaceae	S
Gardenia species	Rubiaceae	S
Glycosmis pentaphylla	Rutaceae	T+
Gmelina asiatica	Verbenaceae	S
Grewia hirsuta	Tiliaceae	S
Grewia rhamnifolia	Tiliaceae	S
Gymnema sylvestre	Asclepiadaceae	ST+
Gyrocarpus americanus	Hernandiaceae	S
Hibiscus sp.	Malvaceae	S+
Hyptis sp.	Laminaceae	H+
Ipomoea splendida	Convolvulaceae	S
Ixora pavetta	Rubiaceae	T
Jasminum rotterianum	Oleaceae	S
Jasminum sp.	Oleaceae	ST
Justicia betonica	Acanthaceae	S
Kleinia grandiflora	Asteraceae	S
Lantana camara	Verbenaceae	S
Lantana wightiana	Verbenaceae	S+
Leucas aspera	Laminaceae	H+
Limonia alata	Rutaceae	T
Loranthus sp	Loranthaceae	S
Malvastrum sp.	Malvaceae	S
Manilkara sp.	Sapotaceae	T
Maytenus emarginata	Celastraceae	S
Melia azadirachta	Meliaceae	T+
Mimosa pudica	Mimosaceae	H
Mundulea sericea	Paplionaceae	S+
Murraya exotica	Rutaceae	T+
Ocimum sp.	Laminaceae	H
Opilia amantacea	Opiliaceae	ST
Opuntia dillenii	Cactaceae	S
Panicum sp.	Poaceae	H
Parthenium hysterophorus	Asteraceae	H
Passiflora edulis	Passifloraceae	H
Pavetta indica	Rubiaceae	S

Name of the plant	Family	Growth forms
Phyllanthus emblica	Euphorbiaceae	T+
Phyllanthus reticulata	Euphorbiaceae	T
Pithecellobium dulce	Mimosaceae	T
Pleurostylia wightii	Celastraceae	T
Pongamia pinnata	Fabaceae	T+
Premna tomentosa	Verbenaceae	T
Prosopis juliflora	Mimosaceae	T
Pterolobium hexapetalum	Caesalpiniaceae	ST
Randia dumetorum	Rubiaceae	S+
Ruellia sp.	Acanthaceae	H
Santalum album	Santalaceae	T+
Sapindus laurifolius	Sapindaceae	T
Sarcostemma acidum	Asclepiadaceae	T+
Scutia myrtina	Rhamnaceae	S
Secamone emetica	Asclepiadaceae	ST
Securinega leucopyrus	Euphorbiaceae	S+
Sida acuta	Malvaceae	H
Sida spinosa	Malvaceae	H
Solanum melongena	Solanaceae	S
Solanum surratense	Solanaceae	S+
Syzygium cumini	Myrtaceae	T+
Tamarindus indica	Caesalpiniaceae	T
Tephrosia villosa	Papilionaceae	S
Toddalia asiatica	Rutaceae	ST+
Ziziphus mauritiana	Rhamnaceae	T
Ziziphus oenoplia	Rhamnaceae	T+
T-Tree, S-Shrub, H-Herb, ST-Straggler and + Medicinal plant		

Appendix 3. Relation between bird species and insect groups

Insect group	Name of the bird species	R value	Significance p
Mixed dry deciduous forest			
Lepidoptera	ASIAN PARADISE FLYCATCHER	0.725**	0.000
	COMMON IORA	0.595**	0.002
	WHITE-BROWED FANTAIL	0.496*	0.014
	VERDITER FLYCATCHER	0.450*	0.027
	RUFOUS WOODPECKER	0.469*	0.021
	COMMON HAWKCUCKOO	0.523**	0.009
	FOREST WAGTAIL	0.653**	0.001
	BLUE-THROATED FLYCATCHER	0.696**	0.000
	BROWN SHRIKE	0.614**	0.001
	BLACK DRONGO	0.407*	0.048
Orthoptera	COMMON IORA	0-443*	0.023
	BAY-BACKED SHRIKE	0.595**	0.002
	BLACK-HEADED CUCKOOSHRIKE	0.506*	0.012
	BLYTH'S REED WARBLER	0.622**	0.001
	BRONZED DRONGO	0.521**	0.009
	GREAT TIT	0.595**	0.002
	LARGE-BILLED LEAF WARBLER	0.898**	0.000
	LONG-TAILED SHRIKE	0.59**	0.002
	ORIENTAL MAGPIE ROBIN	0.713**	0.000
	SCARLET MINIVET	0.488*	0.016
Odonata	WHITE-NAPED WOODPECKER	0.649*	0.001
	EURASIAN WRYNECK	0.991*	0.000
	CREASTED TREESWIFT	0.991*	0.000
	BROWN SHRIKE	0.728*	0.000
Hymenoptera	COMMON FLAMEBACK	0.436*	0.033
	LARGE-BILLED LEAF WARBLER	0.512*	0.011
	ORIENTAL MAGPIE ROBIN	0.473*	0.019
	REDRUMPED SWALLOW	0.416*	0.043
Coleoptera	BLACK-RUMPED WOODPECKER	0.543**	0.006
	BARN SWALLOW	0.812**	0.000
	SMALL MINIVET	0.787**	0.000
	WHITE-BROWED WAGTAIL	0.634**	0.001
Hemiptera	BLACK-HEADED CUCKOOSHRIKE	0.69**	0.000
	BLYTH'S REED WARBLER	0.535**	0.001
	CHESTNUT-HEADED BEE-EATER	0.674**	0.000
	EURASIAN CUCKOO	0.436*	0.033
	LARGE-BILLED LEAF WARBLER	0.715**	0.000
	ORIENTAL MAGPIE ROBIN	0.608**	0.002
Diptera	BLYTH'S REED WARBLER	0.835*	0.000
	BROWN SHRIKE	0.627*	0.001
	COMMON FLAMEBACK	0.679*	0.000
	GREENISH WARBLER	0.541*	0.006
	LARGE-BILLED LEAF WARBLER	0.788*	0.000
	LESSER WHITETHROAT	0.656*	0.001

Insect group	Name of the bird species	R value	Significance p
	NORTHERN HOUSE MARTIN	0.734*	0.000
	ASIAN PARADISE FLYCATCHER	0.546*	0.006
	PLAIN PRINIA	0.734*	0.000
	REDRUMPED SWALLOW	0.660*	0.000
	YELLOW-EYED BABBLER	0.536*	0.007
Acarina	BLYTH'S REED WARBLER	0.756**	0.000
	LARGE-BILLED LEAF WARBLER	0.858**	0.000
	NORTHERN HOUSE MARTIN	0.484*	0.016
	ASIAN PARADISE FLYCATCHER	0.465	0.002
	REDRUMPED SWALLOW	0.436*	0.033
Isoptera	CHESTNUT-HEADED BEE-EATER	0.482*	0.017
	COMMON HAWKCUCKOO	0.689**	0.000
	COMMON HOOPOE	0.778**	0.000
Insect abundance	BLYTH'S REED WARBLER	0.914**	0.000
	BROWN SHRIKE	0.544**	0.006
	COMMON FLAMEBACK	0.482*	0.017
	GREENISH WARBLER	0.527**	0.008
	LARGE-BILLED LEAF WARBLER	0.877**	0.000
	LESSER WHITETHROAT	0.477*	0.019
	NORTHERN HOUSE MARTIN	0.534**	0.007
	ASIAN PARADISE FLYCATCHER	0.547**	0.006
	PLAIN PRINIA	0.534**	0.007
	REDRUMPED SWALLOW	0.535**	0.007
	ABUNDANCE OF BIRDS	0.851**	0.000
Arachnida	CHESTNUT-HEADED BEE-EATER	0.702**	0.000
	COMMON HAWKCUCKOO	0.501*	0.013
	COMMON HOOPOE	0.639**	0.001
	REDRUMPED SWALLOW	0.445*	0.040
	PLAIN PRINIA	0.492*	0.015
	NORTHERN HOUSE MARTIN	0.492*	0.015
	GREAT TIT	0.498*	0.013
	BLYTH'S REED WARBLER	0.598**	0.002
	BLACK-HEADED CUCKOOSHRIKE	0.565**	0.004
	BAY-BACKED SHRIKE	0.498**	0.013
Scrub forest			
Insect abundance	ASIAN PARADISE FLYCATCHER	0.553**	0.005
	ASHY DRONGO	0.553**	0.005
	BLYTH'S REED WARBLER	0.639**	0.001
	COMMON IORA	0.504*	0.012
	LARGE-BILLED LEAF WARBLER	0.490*	0.015
	PIED BUSHCHAT	0.553**	0.005
Isoptera	BROWN SHRIKE	0.852**	0.000
	BARN SWALLOW	0.428*	0.037
	COMMON HAWKCUCKOO	0.769**	0.000
	CLAMOROUS REED WARBLER	0.486*	0.016
	LESSER WHITETHROAT	0.659**	0.000

Insect group	Name of the bird species	R value	Significance p
	REDRUMPED SWALLOW	0.702**	0.000
	RUFOUS-WINGED BUSH LARK	0.420*	0.041
	WHITE-BELLIED DRONGO	0.405*	0.050
	YELLOW-CROWNED WOODPECKER	0.549**	0.005
Lepidoptera	YELLOW-EYED BABBLER	0.488*	0.016
	WHITE-BROWED WAGTAIL	0.739**	0.000
	CLAMOROUS REED WARBLER	0.508*	0.011
	BLYTH'S REED WARBLER	0.766**	0.000
Orthoptera	INDIAN BUSHLARK	0.799**	0.000
	PLAIN PRINIA	0.544**	0.006
	INDIAN ROBIN	0.634**	0.001
Odonata	WHITE-BELLIED DRONGO	0.738**	0.000
	WHITE-BROWED WAGTAIL	0.710**	0.000
	CLAMOROUS REED WARBLER	0.927**	0.000
	BLACK DRONGO	0.547**	0.006
Hymenoptera	ASIAN PALM SWIFT	0.841**	0.000
	BARN SWALLOW	0.678**	0.000
	CREASTED TREESWIFT	0.841**	0.000
	GREEN BEE-EATER	0.633**	0.001
	RUFOUS-WINGED BUSH LARK	0.614**	0.001
	HOUSE SWIFT	0.494*	0.014
	TAWNY-BELLIED BABBLER	0.797**	0.000
Hemiptera	ALPINE SWIFT	0.469*	0.021
	BLACK-HEADED CUCKOOSHRIKE	0.469*	0.021
	WHITE-NAPED WOODPECKER	0.453*	0.026
Diptera	PIED BUSHCHAT	0.926**	0.000
	PUFF-THROATED BABBLER	0.591**	0.002
	LARGE-BILLED LEAF WARBLER	0.874**	0.000
	COMMON IORA	0.696**	0.000
	BLYTH'S REED WARBLER	0.715**	0.000
	ASHY DRONGO	0.926**	0.000
	ASIAN PARADISE FLYCATCHER	0.926**	0.000
Acarina	ASIAN PARADISE FLYCATCHER	0.948*	0.000
	ASHY DRONGO	0.948*	0.000
	BLYTH'S REED WARBLER	0.747*	0.000
	COMMON IORA	0.777*	0.000
	LARGE-BILLED LEAF WARBLER	0.889*	0.000
	PUFF-THROATED BABBLER	0.681*	0.000
	PIED BUSHCHAT	0.948*	0.000
Lepidoptera	ABUNDANCE OF BIRDS	0.542**	0.007

* Significance at 0.05 ; ** Significance at 0.01

Appendix 4. Niche overlap calculated for the bird species in the mixed dry deciduous forest for the foraging dimensions namely method, height, canopy and substrate

S#	Name of the Bird species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	ASHY DRONGO	1.00																																			
2	BLACK BULBUL	0.66	1.00																																		
3	BLACK DRONGO	0.89	0.60	1.00																																	
4	BLACK-HOODED ORIOLE	0.68	0.65	0.60	1.00																																
5	BLOSSOM-HEADED PARAKEET	0.59	0.56	0.58	0.49	1.00																															
6	BLYTH'S REED WARBLER	0.58	0.78	0.55	0.62	0.61	1.00																														
7	MALABAR PARAKEET	0.62	0.58	0.59	0.58	0.79	0.55	1.00																													
8	BLUE-FACED MALKOHA	0.69	0.72	0.63	0.82	0.66	0.75	0.65	1.00																												
9	GREY JUNGLEFOWL	0.41	0.28	0.39	0.32	0.29	0.24	0.19	0.57	1.00																											
10	BLUE-WINGED LEAFBIRD	0.70	0.75	0.59	0.64	0.56	0.78	0.71	0.71	0.25	1.00																										
11	COMMON HOOPOE	0.59	0.44	0.57	0.49	0.42	0.39	0.34	0.74	0.93	0.40	1.00																									
12	COMMON IORA	0.64	0.88	0.59	0.69	0.51	0.91	0.62	0.75	0.20	0.84	0.37	1.00																								
13	JUNGLE BABBLER	0.46	0.39	0.41	0.47	0.34	0.42	0.23	0.70	0.94	0.31	0.89	0.36	1.00																							
14	JUNGLE MYNA	0.70	0.50	0.64	0.50	0.58	0.49	0.49	0.69	0.69	0.57	0.78	0.48	0.69	1.00																						
15	LARGE-BILLED LEAF WARBLER	0.66	0.80	0.61	0.65	0.48	0.86	0.62	0.71	0.24	0.92	0.39	0.89	0.33	0.50	1.00																					
16	BROWN-HEADED BARBET	0.74	0.77	0.72	0.69	0.79	0.68	0.86	0.80	0.36	0.74	0.54	0.72	0.43	0.64	0.72	1.00																				
17	VERNAL HANGING PARROT	0.69	0.57	0.62	0.48	0.59	0.49	0.59	0.50	0.28	0.60	0.42	0.51	0.27	0.68	0.51	0.64	1.00																			
18	LOTEN'S SUNBIRD	0.69	0.61	0.59	0.58	0.73	0.68	0.66	0.64	0.24	0.73	0.41	0.65	0.34	0.70	0.62	0.68	0.78	1.00																		
19	STREAK-THROATED WOODPECKER	0.61	0.55	0.60	0.80	0.46	0.61	0.55	0.74	0.35	0.57	0.53	0.62	0.47	0.51	0.60	0.69	0.49	0.53	1.00																	
20	PLAIN FLOWERPECKER	0.70	0.82	0.63	0.72	0.55	0.88	0.69	0.77	0.29	0.93	0.45	0.92	0.41	0.57	0.91	0.75	0.63	0.76	0.64	1.00																
21	INDIAN PEAFOWL	0.61	0.46	0.60	0.50	0.62	0.47	0.46	0.77	0.84	0.45	0.92	0.40	0.81	0.81	0.42	0.63	0.45	0.49	0.52	0.47	1.00															
22	ASIAN PARADISE FLYCATCHER	0.78	0.53	0.78	0.55	0.56	0.69	0.48	0.63	0.32	0.52	0.49	0.60	0.42	0.52	0.58	0.68	0.46	0.59	0.63	0.62	0.55	1.00														
23	GREENISH WARBLER	0.68	0.83	0.65	0.80	0.49	0.83	0.63	0.78	0.24	0.85	0.40	0.94	0.39	0.52	0.87	0.74	0.56	0.61	0.66	0.91	0.42	0.55	1.00													
24	PURPLE-RUMPED SUNBIRD	0.66	0.68	0.57	0.56	0.66	0.74	0.65	0.62	0.19	0.77	0.34	0.71	0.28	0.64	0.69	0.69	0.78	0.97	0.54	0.82	0.42	0.59	0.67	1.00												
25	PURPLE SUNBIRD	0.77	0.69	0.68	0.67	0.60	0.74	0.66	0.70	0.31	0.80	0.48	0.74	0.40	0.75	0.76	0.76	0.82	0.88	0.68	0.84	0.52	0.64	0.75	0.90	1.00											
26	TAWNY-BELLIED BABBLER	0.49	0.66	0.48	0.61	0.65	0.86	0.43	0.70	0.22	0.56	0.36	0.77	0.43	0.46	0.59	0.57	0.43	0.65	0.58	0.70	0.46	0.60	0.70	0.64	0.61	1.00										
27	REDRUMPED SWALLOW	0.60	0.39	0.48	0.49	0.38	0.34	0.37	0.54	0.52	0.38	0.60	0.36	0.50	0.49	0.37	0.46	0.47	0.37	0.44	0.42	0.58	0.43	0.39	0.32	0.42	0.28	1.00									
28	RED-VENTED BULBUL	0.61	0.68	0.62	0.63	0.91	0.73	0.84	0.76	0.28	0.64	0.44	0.67	0.38	0.56	0.61	0.88	0.56	0.72	0.61	0.69	0.59	0.61	0.65	0.71	0.70	0.70	0.37	1.00								
29	RED-WHISKERED BULBUL	0.66	0.75	0.64	0.68	0.82	0.78	0.85	0.81	0.29	0.72	0.47	0.77	0.42	0.57	0.71	0.93	0.57	0.72	0.65	0.77	0.59	0.69	0.74	0.73	0.73	0.70	0.41	0.92	1.00							
30	GREEN BEE-EATER	0.77	0.44	0.76	0.55	0.57	0.52	0.53	0.67	0.50	0.52	0.61	0.50	0.52	0.56	0.49	0.58	0.45	0.54	0.59	0.54	0.66	0.75	0.51	0.50	0.56	0.44	0.60	0.60	0.55	1.00						
31	COMMON TAILORBIRD	0.63	0.77	0.61	0.69	0.69	0.93	0.58	0.83	0.37	0.70	0.53	0.84	0.54	0.59	0.75	0.74	0.55	0.72	0.69	0.83	0.62	0.72	0.78	0.76	0.76	0.90	0.44	0.81	0.83	0.59	1.00					
32	PALE-BILLED FLOWERPECKER	0.74	0.77	0.63	0.66	0.60	0.79	0.69	0.72	0.25	0.88	0.42	0.83	0.36	0.66	0.81	0.75	0.79	0.89	0.63	0.90	0.46	0.59	0.81	0.93	0.93	0.63	0.39	0.69	0.76	0.56	0.76	1.00				
33	WHITE-BROWED BULBUL	0.59	0.64	0.56	0.59	0.81	0.77	0.85	0.76	0.25	0.67	0.42	0.72	0.37	0.52	0.63	0.85	0.48	0.68	0.59	0.73	0.54	0.69	0.65	0.68	0.66	0.69	0.33	0.89	0.93	0.57	0.79	0.69	1.00			
34	WHITE-BELLIED DRONGO	0.90	0.59	0.89	0.63	0.53	0.56	0.62	0.66	0.35	0.67	0.53	0.63	0.38	0.61	0.67	0.71	0.60	0.60	0.57	0.67	0.55	0.76	0.69	0.58	0.67	0.43	0.50	0.57	0.64	0.74	0.58	0.67	0.58	1.00		
35	YELLOW-BILLED BABBLER	0.36	0.24	0.34	0.30	0.27	0.22	0.16	0.51	0.97	0.20	0.84	0.17	0.92	0.66	0.20	0.31	0.24	0.22	0.32	0.25	0.79	0.28	0.20	0.16	0.27	0.22	0.47	0.25	0.27	0.46	0.35	0.22	0.22	0.30	1.00	
36	CHESTNUT-HEADED BEE-EATER	0.88	0.58	0.90	0.60	0.54	0.54	0.57	0.65	0.43	0.57	0.61	0.59	0.44	0.66	0.59	0.71	0.58	0.59	0.56	0.62	0.61	0.79	0.63	0.58	0.67	0.45	0.57	0.62	0.63	0.79	0.64	0.61	0.58	0.89	0.38	1.00

Appendix 4. Contd. Niche overlap calculated for the bird species in the scrub forest for the foraging dimensions namely method, height, canopy and substrate

S#	Name of the bird species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	BAYA WEAVER	1.00																					
2	BLOSSOM-HEADED PARAKEET	0.91	1.00																				
3	BLYTH'S REED WARBLER	0.81	0.88	1.00																			
4	CHESTNUT-TAILED STARLING	0.87	0.94	0.98	1.00																		
5	COMMON IORA	0.58	0.61	0.85	0.77	1.00																	
6	JUNGLE MYNA	0.66	0.47	0.73	0.68	0.74	1.00																
7	LAUGHING DOVE	0.58	0.27	0.35	0.36	0.35	0.88	1.00															
8	STREAK-THROATED WOODPECKER	0.55	0.63	0.90	0.81	0.95	0.82	0.37	1.00														
9	INDIAN PEAFOWL	0.97	0.79	0.73	0.79	0.53	0.76	0.76	0.52	1.00													
10	PURPLE-RUMPED SUNBIRD	0.91	0.91	0.92	0.94	0.82	0.67	0.42	0.77	0.82	1.00												
11	PURPLE SUNBIRD	0.78	0.86	1.00	0.98	0.83	0.74	0.35	0.90	0.71	0.89	1.00											
12	TAWNY-BELLIED BABBLER	0.92	0.99	0.93	0.98	0.67	0.57	0.32	0.68	0.82	0.94	0.91	1.00										
13	INDIAN ROBIN	0.75	0.46	0.50	0.54	0.41	0.86	0.97	0.42	0.89	0.57	0.49	0.52	1.00									
14	REDRUMPED SWALLOW	0.27	0.19	0.28	0.28	0.47	0.26	0.26	0.32	0.26	0.34	0.27	0.24	0.24	1.00								
15	RED-VENTED BULBUL	0.90	0.94	0.97	0.98	0.83	0.66	0.39	0.86	0.81	0.97	0.95	0.96	0.53	0.25	1.00							
16	RED-WHISKERED BULBUL	0.97	0.94	0.91	0.96	0.70	0.71	0.54	0.70	0.93	0.95	0.90	0.96	0.70	0.29	0.95	1.00						
17	GREEN BEE-EATER	0.72	0.70	0.80	0.81	0.80	0.59	0.37	0.73	0.65	0.81	0.79	0.76	0.48	0.77	0.76	0.79	1.00					
18	COMMON TAILORBIRD	0.92	0.98	0.95	0.98	0.74	0.63	0.37	0.74	0.83	0.97	0.93	0.99	0.56	0.28	0.98	0.97	0.80	1.00				
19	WHITE-BROWED BULBUL	0.88	0.98	0.95	0.98	0.73	0.56	0.28	0.77	0.77	0.94	0.94	0.99	0.45	0.21	0.98	0.94	0.73	0.99	1.00			
20	YELLOW-BILLED BABBLER	0.58	0.28	0.35	0.37	0.34	0.87	1.00	0.36	0.76	0.41	0.35	0.33	0.97	0.24	0.38	0.54	0.37	0.37	0.28	1.00		
21	YELLOW-EYED BABBLER	0.91	0.99	0.92	0.97	0.67	0.53	0.29	0.69	0.79	0.94	0.90	1.00	0.48	0.21	0.96	0.95	0.73	0.99	0.99	0.30	1.00	
22	COMMON MYNA	0.84	0.58	0.57	0.63	0.40	0.81	0.92	0.41	0.94	0.64	0.55	0.63	0.99	0.21	0.60	0.78	0.51	0.66	0.56	0.93	0.59	1.00

Appendix 5. Nest tree preference by nine bird species in the Anaikatty hills

Plant species	Observed usage	Expected usage	Upper confidence limit
Laughing Dove in the scrub forest			
P. indica	5	18.54	0.577*
C. retusa	2	24.66	0.321*
O. dillenii	2	9.54	0.321*
R. dumetorum	2	7.74	0.321*
A. leucophloea	1	0.36	0.208U
C. auriculata	1	30.06	0.208*
C. odorata	1	82.8	0.208*
L. alata	1	0.54	0.208U
L. camara	1	86.4	0.208*
M. azadirachta	1	1.26	0.208U
P. juliflora	1	0.18	0.208U
Jungle Babbler in the mixed dry deciduous forest			
A. amara	3	19.78	0.319*
B. racemosa	4	4.6	0.387U
D. ferrea	1	40.02	0.158*
L. alata	11	77.51	0.758*
P. indica	2	25.53	0.245*
P. pinnata	1	0.23	0.158U
Z. mauritiana	1	0.69	0.158U
Red-vented Bulbul in the mixed dry deciduous forest			
A. amara	1	36.98	0.092*
A. fruticosa	1	94.17	0.092*
A. leucophloea	1	5.59	0.092*
A. monophylla	5	47.73	0.262*
A. polyacantha	1	4.73	0.092*
Acacia sp.	3	27.09	0.186*
C. retusa	9	58.48	0.394*
C. sepiaria	2	9.89	0.142*
C. swietenia	1	18.49	0.092*
E. glaucum	1	1.29	0.092U
F. indica	1	8.6	0.092*
L. alata	1	144.91	0.092*
L. camara	7	142.33	0.331*
P. indica	2	47.73	0.142*
P. pinnata	1	0.43	0.092U
T. indicus	1	1.29	0.092U
Z. oenoplia	4	8.17	0.225U
Z. mauritiana	1	6.02	0.092*
Red-vented Bulbul in the scrub forest			
A. amara	1	16.8	0.048*
A. fruticosa	1	10.92	0.048*
A. monophylla	1	10.08	0.048*
Bitterguard	1	0	0.048U
C. auriculata	5	140.28	0.138*

Plant species	Observed usage	Expected usage	Upper confidence limit
C. gigantea	1	14.28	0.048*
C. odorata	8	386.4	0.192*
C. retusa	11	115.08	0.242*
D. ferrea	1	16.8	0.048*
E. antiquorum	1	5.88	0.048*
E. glaucum	4	5.88	0.118U
F. indica	5	64.68	0.138*
L. camara	19	403.2	0.365*
M. azadirachta	1	5.88	0.048*
P. hysterophorus	1	1.68	0.048U
P. indica	18	86.52	0.35*
R. dumetorum	1	36.12	0.048*
S. cumini	1	0.84	0.048U
T. indicus	1	0.84	0.048U
Z. oenoplia	1	2.52	0.048U
Z. mauritiana	1	16.8	0.048*
Red-whiskered Bulbul in the mixed dry deciduous forest			
C. retusa	1	8.16	0.559*
D. ferrea	1	10.44	0.559*
P. pinnata	1	0.06	0.559U
Z. oenoplia	1	1.14	0.559U
F. indica	2	1.2	0.83U
Red-whiskered Bulbul in the scrub forest			
L. alata	1	0.99	0.116U
M. sericea	1	2.31	0.116U
P. hysterophorus	1	0.66	0.116U
P. pinnata	1	0.33	0.116U
R. dumetorum	1	14.19	0.116*
S. myrtina	1	7.59	0.116*
A. amara	2	6.6	0.18*
F. indica	2	25.41	0.18*
L. camara	2	158.4	0.18*
C. odorata	3	151.8	0.235*
C. retusa	4	45.21	0.285*
D. ferrea	4	6.6	0.285U
P. indica	10	33.99	0.533*
Purple-rumped Sunbird in the mixed dry deciduous forest			
A. fruticosa	1	15.33	0.499*
Acacia sp.	1	4.41	0.499*
C. philippensis	1	1.61	0.499U
L. camara	1	23.17	0.499*
P. hexapetalum	1	0.07	0.499U
P. pinnata	1	0.07	0.499U
T. asiatica	1	2.03	0.499U
Purple-rumped Sunbird in the scrub forest			
C. odorata	4	78.2	0.52*
C. swietenia	1	4.59	0.217*

Plant species	Observed usage	Expected usage	Upper confidence limit
L. camara	5	81.6	0.6*
M. azadirachta	1	1.19	0.217U
P. hexapetalum	1	0.34	0.217U
P. juliflora	1	0.17	0.217U
S. cumini	1	0.17	0.217U
T. indicus	2	0.17	0.334U
Z. mauritiana	1	3.4	0.217U
Yellow-billed Babbler in the scrub forest			
C. retusa	5	36.99	0.392*
D. ferrea	2	5.4	0.214U
E. glaucum	3	1.89	0.279U
F. indica	2	20.79	0.214*
I. splendida	1	1.89	0.138U
L. camara	3	129.6	0.279*
M. azadirachta	1	1.89	0.138U
P. indica	9	27.81	0.585*
R. dumetorum	1	11.61	0.138*
Tawny-bellied Babbler in the mixed dry deciduous forest			
Grass	1	3.24	0.289U
P. hysterophorus	1	0.24	0.289U
O. dillenii	2	9.72	0.444*
A. fruticosa	4	26.28	0.684*
P. indica	4	13.32	0.684*
Tawny-bellied Babbler in the scrub forest			
Grass	2	2.7	0.569U
M. sericea	2	0.63	0.569U
O. dillenii	2	4.77	0.569U
P. hysterophorus	3	0.18	0.726U
Yellow-eyed Babbler in the scrub forest			
C. odorata	10	128.8	0.584*
C. retusa	1	38.36	0.123*
L. camara	4	134.4	0.308*
P. indica	13	28.84	0.7*
Indian Robin in the mixed dry deciduous forest			
Barren ground	1	62	1*
Indian Robin in the scrub forest			
Barren ground	1	3	0.124U
Brick	1	90	0.124*
C. retusa	1	41.1	0.124*
Ground	19	13.8	0.877U
Hut	1	30	0.124*
L. camara	2	144	0.193*
P. indica	2	30.9	0.193*
Pillar	2	180	0.193*
Sack	1	150	0.124*
* - Avoidance, U - Utilization in proportion to availability.			