Bird community structure along the altitudinal gradient in Silent Valley National Park, Western Ghats, India

K.S. Anoop Das

A thesis submitted to the Bharathiar University
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IN

ZOOLOGY

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THIS THESIS IS DEDICATED TO ....

Karumampoyil Padmanabhan
Ayyappan Vaidyar
Sakthidas
Savithri
Neenadas
Hariharan &
Dr. Sajeev

CERTIFICATE

This is to certify that the thesis, entitled '**Bird community structure along the altitudinal gradient in Silent Valley National Park, Western Ghats, India**'. submitted to the Bharathiar University, in partial fulfilment of the requirements for the award of the Degree of **Doctor of Philosophy** in **Zoology** is a record of original work done by **Mr. K.S. Anoop Das** during the period August 2003 - March 2008 of his study in the Department of Conservation Ecology at Sálim Ali Centre for Ornithology and Natural History, under my supervision and guidance and the thesis has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title to any candidate of any University.

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DECLARATION

I, **Anoop Das** hereby declare that the thesis, entitled **'Bird community structure along the altitudinal gradient in Silent Valley National Park, Western Ghats, India'** submitted to the Bharathiar University, in partial fulfilment of the requirements 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 August 2003 - March 2008 under the supervision and guidance of Dr. Lalitha Vijayan, Senior Principal Scientist, Department of Conservation Ecology, Sálim Ali Centre for Ornithology and Natural History, Coimbatore and it has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title to any candidate in any University.

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Acknowledgments

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CHAPTER I

GENERAL INTRODUCTION

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1.1 Background

The simplest definition of a community is a group of species populations occurring together in space and time (Cody 1974). Community ecology is considered as one of the challenging fields in biology, owing to the complexity and diversity of interactions between and among species in a changing environment. Community ecology is studied on a wide range of temporal and spatial scales, from millimetres to kilometres and from days to centuries (Gauch 1982). Community ecology field data are noisy because, although numerous species abundances are controlled by a relatively small number of environmental and historical factors, each species of individual and each site and environmental factor is, to some degree, unique (Barbra 2004). A major goal of community ecology is to find whether ecological communities are structured in space and time and to reveal the underlying processes and mechanisms (MacArthur and Wilson 1967; Cody 1974; Wiens 1989; Rosenzweig 1995; Whittaker 1998; Drake *et al.* 2002). An understanding of how communities function has innumerable practical implications and is a prerequisite to formulate conservation planning for a particular area. With diminishing opportunities to protect large tracts of native habitat, efforts to preserve biodiversity in fragmented landscapes and to understand ecological processes in these systems are becoming increasingly important (Gaston *et al.* 1999).

Tropical forests encompass a high proportion of the biodiversity (Myers *et al.* 2000), whereas much of its biodiversity and dynamics is still unknown. The tropical forest biome must be the realm which has got immense attention and motivated much enthusiasm among the biologists due to the diversity and richness impregnated in it. Twenty of the 34 biodiversity hotspots identified by Mittermeir *et al.* (2005) lie in tropical countries, dejectedly which for the most part, face the gravest threats to their natural resources and have the least resources for conservation (Jha *et al.* 2000; Das *et al.* 2006). Efforts to document and understand tropical rainforest diversity have gained greater momentum in recent decades by the recognition that the degree of destruction of the rainforest is in its higher end across much of the tropics (Gaston 2000). Nearly all tropical forests lie within developing countries where there are limited resources and opportunities for local researcher to work in the natural habitat, and most of such works are carried out by Western ecologists (Molleman 2006). It has been alerted and discussed in detail in recent studies that, habitats around the world, and especially those in the tropics, are being fragmented at a rapid rate, causing a tremendous loss of biodiversity (Sekercioglu 2002; Raman 2003; Kumar *et al.* 2004). Dejectedly 12% of the approximately 10,000 extant bird species are threatened with extinction in the next 10 to 100 years, and another 8% are Near-Threatened (Stattersfield and Capper 2000; Birdlife International 2001). Although patterns of biodiversity loss have been explored extensively, their ecological implications have become the subject of very few studies. Though 1.3% of bird species have gone extinct since 1500 (Stattersfield and Capper 2000) the global number of individual birds is estimated to have experienced a reduction of 20-25% during the same period, indicating that avian populations and dependent ecosystem services are declining faster than species extinctions would indicate (Sekercioglu 2004). Restricted range species are consequently under serious threats by loss and fragmentation of the forests (Balmford 1994). It is logical that a large area will support more individual organisms than a small area of equivalent habitat. As the number of individuals increases, the probability of the inclusion of new taxa increases thereby increasing species richness. Published reports on this subject dates back to 1855 (*see review by* McGuinness 1984) and species-area curves, where the number of species observed increases as a function of area, were fitted to plant community data as early as 1859 (Rosenzweig 1995).

Efforts to survey and catalog biological diversity has identified Western Ghats as a hotspot for species endemism (Myers *et al.* 2000). Management of any protected area needs a baseline data on the fauna and flora it supports and monitoring of the major components of the ecosystem. Although several research attempts have been made on the avifauna of the Western Ghats (Vijayan *et al.* 1999; Raman 2001) basic life history information is lacking for most of the native and endemic species except a few. This lack of information hampers the development and implementation of conservation measures. The success of forest protection as well as biodiversity conservation in the tropical world depends greatly on the actions of local community.

1.2 Rationale for selecting birds

Birds are sufficiently documented, fairly easy to monitor (Bibby *et al.* 1992, 2000), and have increasingly been used by conservation planners to prioritize habitat conservation efforts throughout the world (Bibby *et al.* 1992; Collar *et al.* 1994; Prasad *et al.* 1998). Birds are also used to monitor the condition of tropical forests (Johns 1992; Canterbury *et al.* 2000). Like most endangered species, threatened and near-threatened bird species of Western Ghats, have suffered habitat loss due to deforestation (Collar *et al.* 1994; BirdLife International 2001). Birds, as indicator species are helpful in alarming when forest loss is threatening particular ecosystem. In tropical forests, the diversity of birds is particularly high and are readily identifiable due to their colouration. They have been identified as sensitive to ecosystem changes in general (Raman 2004) for e.g. the natural treefalls (Wunderle *et al.* 2005) and specifically to floral and vegetation structure, structural components of the habitat (Blake and Loiselle 2000) and climate change (Crick 2004). It has also been commented that the reliability of biodiversity indicator taxa is questionable (Prendergast *et al.* 1993; Dobson *et al.* 1997) because of the reason that species rich areas do not always coincide for different taxa. Lawton *et al.* (1999) have commented that not even flagship taxa like the birds and butterflies are significantly correlated in a gradient of tropical forest degradation.

Birds are widely regarded as powerful monitoring tools in environmental management because of their great abundance, diversity and functional importance, their sensitivity to perturbation and the ease with which they can be sampled (Bibby 1999). Birds are highly habitat specific and often endemic and they are closely linked to the diversity and health of their habitats through the dependence on the plants for nesting and foraging in addition to the role of the adults as pollinators and seed dispersers (Balasubramanian 1990; Balasubramanian and Maheswaran 2003). They also respond rapidly to forest disturbance, and thus can be useful indicators of the effects of tropical forest disturbance (Sekercioglu 2002). Further to this, they are relatively large, conspicuous in comparison to some other vertebrates, mostly diurnal, their taxonomy is relatively well known, and there are some data on their geographic distributions and for some species on their life history (Collar *et al.* 1994). Consequently, as a result of the close links between bird diversity and health of their habitats, birds also have been suggested as potential bioindicators of ecological changes in the tropical regions (Bibby 1999). Furthermore, response of bird communities to temperature, humidity and light levels is most rapid and conspicuous, making birds as useful indicator of habitat quality.

1.3 Relevant research to date on the topic

The studies on bird community ecology has attained its charisma after the pioneering works of MacArthur and MacArthur (1961), which was followed by reviews by Cody (1974) and Wiens (1989). A detailed study on bird community of a large area had been accomplished by Terborgh *et al.* (1990) at Amazonian Peru and they predicted that many of the birds are vulnerable to forest fragmentation and disturbances. Loiselle and Blake (1991) have studied the effect of temporal fluctuations in the fruit production by plants on populations of understorey fruit-eating birds at different elevations and suggested that some species have seasonal altitudinal movements which imply that preservation of many species and of the biotic integrity of entire systems may require conservation planning at a landscape level. Although the climate variability, change in land cover and land use pattern play a key role in the dynamics of populations and communities, there is not much work in this line except a long-term study from Puerto Rico (Faaborg *et al.* 1984) which had listed out the effects of drought (Faaborg 1982) and rainfall on total populations, foraging guilds and on status of winter residents. Gaston and Lawton (1990) reported wintering migrants to be more abundant in lowland forests of India and Malaysia. Wiens (1989) prepared a review on bird community ecology, in which all the debates have been discussed thoroughly.

Several ornithologists have looked into specific ecological questions and commented about the underlying principles and patterns of the avian distributions (Pearson 1971). Holmes and Sherry (2001) presented an analysis of 30 years of data on breeding bird abundance and demography in a temperate forest and found a drastic reduction of total number of individuals by nearly 66%. Woltmann (2003) documented the bird community characteristics of the subtropical humid forest in Bolivia and inferred that differences in the bird community structure between disturbed and intact forests were primarily due to the addition of widespread species with less narrow habitat requirements and changes in the distribution of different food types. Wunderle *et al.* (2005) studied the influence of gaps on birds and concluded that gaps supported a higher diversity of birds in terms of species evenness but closed-canopy sites contained species with more restricted geographical distributions. They added that there was little similarity between bird communities in gaps and forests and, dispersal rates also varied between the two. They warn that the habitat modification that opens up the canopy is likely to result in an increase in the widespread species and a decline in understorey species with restricted distributions.

1.4 Indian context

India is a home for about 1300 species of birds. In India, the studies on birds are largely attributed to attempts made by Ali and Ripley (1987). But recently, ornithological research has been rapidly accelerated with its main focus on the ecological requirements, in part due to an increased need to assess ecosystem condition when making regulatory decisions (Vijayan and Balakrishnan 2005).

The evergreen forests of the Western Ghats are some of the most threatened ecosystems in the world. The Western Ghats, one of the 34 global hotspots of biodiversity (Mittermeir *et al.* 2005), harbours 16 restricted range species, and occupies a unique position with 218 endemic bird areas of the world (Stattersfield *et al.* 1998). Tropical forests of Western Ghats hold a global priority for conservation of biodiversity, especially bird populations (Vijayan *et al.* 2000) and many locations are also ranked by international conservation organizations as important bird areas (Islam and Rahmani 2004). While the general ranges of endangered and endemic birds are known for Western Ghats, little is known about specific seasonal movements, seasonal habitat requirements, or the basic ecology of most of these birds (Vijayan and Balakrishnan 2005). In Western Ghats, many studies have been conducted on birds addressing their ecological requirements (Ramakrishnan 1983; Daniels *et al.* 1992; Jayson 1994; Pramod 1995; Vijayan *et al.* 1999; Devy and Davidar 2001; Raman 2001). Pramod *et al.* (1997) assessed the hospitability of the Western Ghats for birds and commented that no systematic survey on distribution and status of species has been done so far.

In birds, a negative correlation of species richness was found with composite environmental indices of heterogeneity and woody plant diversity (Daniels 1989; Daniels *et al.* 1992). The bird community structure at a middle altitude forest has been examined by Sultana *et al.* (2007) and they have brought out the bird habitat relationship in the Himalayan region. Beehler *et al.* (1981) scrutinized the avian preferences of man disturbed forest habitats in the Eastern Ghats. Gokula (1998) studied the bird community in detail in Mudumalai Wildlife Sanctuary. Prasad *et al.* (1998) examined the bird and plant communities in Kerala, a part of Western Ghats and used this information along with mammal abundance to prioritize the area for biodiversity conservation. Vijayan *et al.* (1998, 1999) documented the bird communities in different habitats in the Nilgiri Biosphere Reserve. Raman (2001) studied the bird communities of different rainforest fragments in Valparai. Vijayan and Gokula (2006) assessed the impact of disturbance on the bird communities in five major forest types in the Western Ghats. Gaston and Vijayan (1986) compared the data on the breeding seasonality of the birds in different regions of India. Bird community at Terai forest in Dudwa

National Park has been examined by Javed (1996). However, a large number of studies concentrated on foraging and nesting aspects by selecting individual birds or groups of birds. (Vijayan 1975; Khan 1977, 1978; Zacharias 1979; Vijayan 1980;1984; Zacharias and Mathew 1988; Thiyagesan 1991; Kannan 1994; Nagarajan 2000; Vijayan *et al.* 2001; Robin and Sukumar 2002; Nirmala 2002; Maheswaran 2002; Vijayan *et al.* 2005; Vijayan 2002, 2004; Somasundaram 2006; Vinod 2007; Balakrishnan 2007).

1.5 Ornithological research in Silent Valley National Park

The SVNP is famous for being one of the largest continuous tracts of pristine wet evergreen forests in the Western Ghats. The Government of India recognized the uniqueness of this region and an area of 89.52 sq km was declared as a National Park in 1984. This National Park is recently identified as one of the Important Bird Areas of the country supporting most of the rare and endemic birds of the region (Islam and Rahmani 2004). The area is ideal for field investigations because of its biological importance, diversity of habitats available and the proximity of large blocks of protected and relatively undisturbed forests.

The avifauna of SVNP had been studied extensively over the last 30 years. However, thorough knowledge of forest birds and their habitat requirements is far from complete. Limited studies have been published on the bird species of the SVNP (Jayson and Mathew 2000a, 2000b, 2002, 2003) and others were either limited in terms of duration or in ecological and geographical scope. Species inventory work is of great importance: however, such spatially non-specific studies provide limited information for applied conservation recommendations within a multiple stakeholder environment.

The first checklist of birds from the Valley with a total of 99 species was prepared by Vijayan and Balakrishnan (1977). Later, Ramakrishnan (1983) conducted a study considering the correlation between structure of vegetation and avian community. Basheer and Nameer (1990) during their short survey examined bird community along 14 transects of one kilometer length covering all major areas and came up with a list of 156 species of birds and recorded breeding of 29 species. Later Vijayan *et al.* (1992)

recorded 189 species in the area including Mukkali and Attappady ranges. Jayson (1994) compared the bird community structure at Mukkali and Silent Valley and reported 99 species of birds at SVNP. Pramod (1995) studied the bird community structure of SVNP and adjacent areas and provided a list of 127 species. Sugathan (1999) compiled a bird list of 211 bird species. A rapid survey done by Vijayan *et al.* (2000) covering different areas in summer reported a total of 107 species of birds. Vijayan *et al.* (1999), and Vijayan and Gokula (2006) studied the impact of the disturbance on the avian community comparing a forest patch inside SVNP with another patch situated outside the park which was exposed to disturbances. Although detailed bird community studies have already been done in SVNP by several researchers (Ramakrishnan 1983; Jayson 1994; Pramod 1995), all of them have focused on the bird community structure of the fringe areas of the park rather than approaching different habitats and elevations with in its political boundary. Taking into consideration of all these facts, this study was undertaken with the objectives as given below:

(1) To examine patterns of bird community structure in different habitats along the altitudinal gradient
(2) To understand the spatial and temporal variation of breeding bird species in different habitats of SVNP

1.6 Thesis structure

This thesis comprises of six chapters. In the first chapter I present the rationale and overview of the study. In Chapter 2, I describe physio-geographical attributes, faunal and floral characteristics and ecological history of the study area in detail. In Chapter 3, I examine and present differences in vegetation community structure along the altitudinal gradient. Abundance occupancy relationships are plotted for each of the six transects to examine distribution patterns across the area. Chapter 4 deals with dynamics of bird community along the altitudinal-habitat gradient and the bird-habitat relationship at SVNP. In Chapter 5, I discuss habitat associations and seasonality of breeding birds in different habitats and altitudes. In this

Chapter, the nest-site selection of a few species and their resource partitioning are also discussed. In Chapter 6, I interpret relationships shown by various habitats and bird habitat attributes with respect to different altitudes. The references and appendices are given in the last section.

CHAPTER II

STUDY AREA

2.1 THE WESTERN GHATS

- 2.1.1 Ecological history
- 2.1.2 Climate

2.2 STUDY AREA: SILENT VALLEY NATIONAL PARK

- 2.2.1 History
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2.3 LOCATIONS OF THE INTENSIVE STUDY

CHAPTER II
STUDY AREA

2.1 THE WESTERN GHATS

This study was conducted in the Western Ghats hill ranges, which has gained attention due to its status as a unique and discrete bio-geographic region of India (Mani 1974; Rodgers and Panwar 1988). The Western Ghats is internationally recognized as an important ecoregion (Oslon and Dinerstein 1998). Because of rich floral and faunal diversity, it has been recognised as one among the 34 biodiversity hotspots of the world (Mittermeier *et al.* 2005) and also the most thickly populated hotspot of all. This mountain chain, perhaps the most remarkable geological feature in the peninsular India, is spread over 0.14 million sq km across the five southern states, and anchors an estimated population of over 35 million.

The Western Ghats mountain ranges and plains running along the western coastline from the southern tip of India (8° N) up to the River Tapti in the north (21° N) cover an extremely diverse range of biotic provinces and biomes and comprise 5.8% of the country's landmass. This, being one of the Gondwanaland breakup landmasses, is spread across a distance of 1600 km and covers a variety of habitats. This sequence of hills is interrupted by the 30 km wide Palakkad Gap at around 11° N, and a few other minor gaps along its length (Figure 2.1). In width, the hill chain averages 100 km; its highest peak is around 1,500 m in the north and 2,600 m in the south. The extensive devastation of vast stretches of rainforests of the Western Ghats has occurred for various purposes as an offshoot of development (Chattopadhyay 1985; Kumar *et al.* 2004). It has been estimated that more than 60% of the remaining rainforests occur as small patches occupying an area from a few hectares up to 20 sq km (Kumar *et al.* 2004).

2.1.1 Ecological History

The Western Ghats were uplifted in two phases; one post-Miocene and the other Pleistocene (Legris and Meher-Homji 1977). It extended 1600 km along the western cost of peninsular India with an average elevation of 1200 m. The continuity of the hills is lost, at Palakkad gap which is supposed to be an outcome of the formation of a valley of a pre-Pleistocene river (Pearson and Ghorpade 1989). This unique biogeographic Malabar province of the Oriental realm (Mani 1974; Rodgers and Panwar 1988) with undulating elevational gradients has an important role in the distribution of plants and animals (Raman 2001). The extraction of Stone Age tools from the Western Ghats provides substantial evidence to the influx of the human intervention during the Palaeolithic or old stone age, over 12,000 years BP (Chandran 1997). Several theories are prevailing regarding the formation of the vegetation types of these tracts such as climatic change theory which proposes the expansion of the C_4 grasslands in the montane Nilgiris, during the 4^{th} millennium BP where during a similar arid spell 20,000 years BP such grasslands had existed (Chandran 1997). Whilst Pascal (1988) is of an opinion that savannas in the Western Ghats are a byproduct of the fire, in contrary to the views of Gadgil and Meher-Homji (1986) who presume it to be the consequence of the human interventions in the woodland ecosystem.

The constant exposure of the land mass for a long period of time with a close proximity to the equator, since its past position in the Gondwanaland and present position also might have contributed a great deal of the rich genetic diversity of the tracts (Nair 1991). The peculiarity and uniqueness in the rock types prevailing in the tracks which is largely attributed to the soil characteristics, topography in particular and its combating effect from the entry and human interventions, local micro and meso-climatic conditions etc., might also be the underlying principle of the biological wealth of the Ghats. The Southern Western Ghats has the best preserved and most extensive climax vegetation in peninsular India. Some of the tropical moist forest areas of the three states, are best known areas of the Indo - Malayan rain forest formations. These tracts are basically the western edge of the Indian peninsular plateau, which is a stable mass of Archaean and Pre-

Cambrian formations, where the mountain building had ceased in the Pre-Cambrian times.

2.1.2 Climate

The area is benefited from a tropical climate which exhibits a clear cut variation along the north - south as well as east- west, and along altitudinal realms. The mean annual temperature is 29°C at the sea level and around 15°C in high altitudes. The average annual rainfall in the evergreen forests ranges from 1,800 to 7,500 mm depending on the locality (Pascal 1988; Daniels 1992).

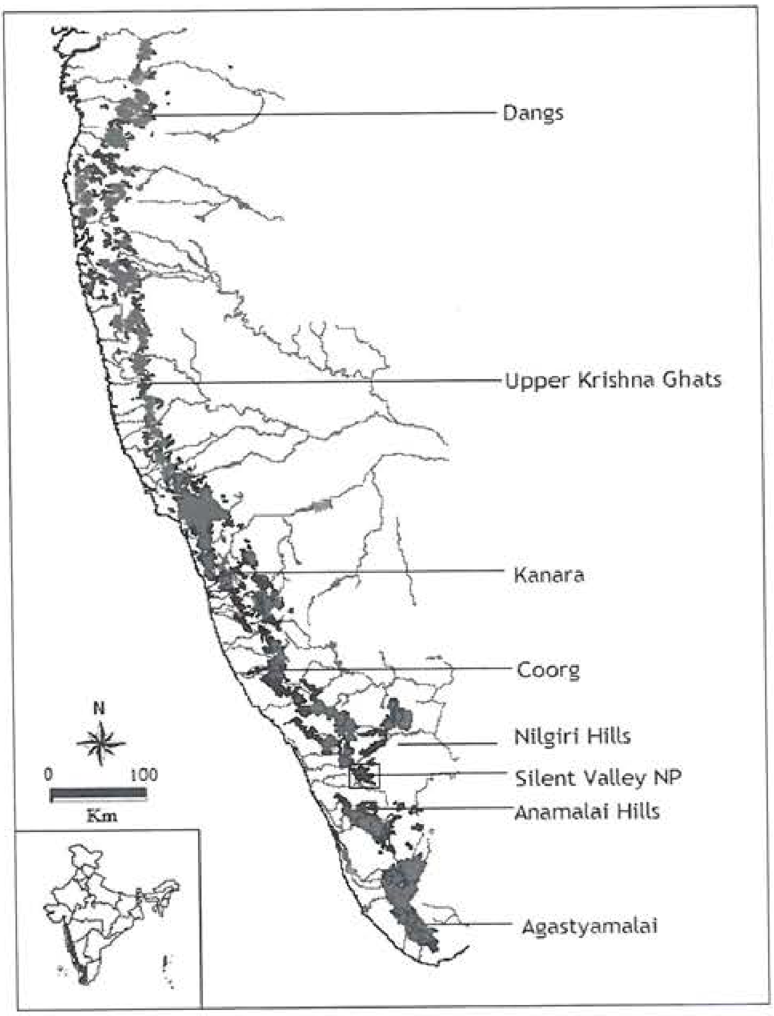


Figure 2.1 The Western Ghats indicating the approximate location of the study area.

2.2 SILENT VALLEY NATIONAL PARK

2.2.1 History

The history of Silent Valley National Park (SVNP) had been somewhat overshadowed by that of its popularity by its candidature as making an environmental consciousness among people. There have been no human settlements in the area since prehistoric times. It had been examined as early as 1847, and was found that there was no private right whatsoever and the whole extent of watershed was at the disposal of the Government during 1847 and 1873. Government decided to give 400 ha in the middle of Silent Valley for lease to the coffee planters at Walakkad. It was a fruitless attempt to cultivate coffee that was abandoned by 1889. During 1901-02, there were human interferences for timber collection, principally *Dysoxylum malabaricum* was being extracted under selection felling system. Government then had approved to extract only merchantable species such as *Mesua ferrea, Palaquium ellipticum, Hopea parvifolia* and *Acrocarpus fraxinifolius* mainly for railway sleepers (Unnikrishnan 1991). Thus over these decades, a total of 48,000 cubic meter of timber is estimated to have been extracted from the Silent Valley largely from the southern part (Figure 2.2) (Manoharan *et al.* 1999).

The present administrative boundary (Figure 2.3) which has been notified as a reserve forest in 1914 encloses 89.52 sq km. Later in 2007, a buffer zone, with an extent of 148 sq km, was added to the SVNP (Figure 2.2). The proposal for Silent Valley hydro-electric project originated during 1921; later on Mr. E.A. Dawson, conducted the preliminary survey on the feasibility of the project and by 1973, the proposal of dam across River Kunthi got approval from the planning commission and, Kerala State Electricity Board commenced preliminary works of the project. This ensnared much public attention, which led to an environmental sensibility in public and bagged international attention. After a much pronounced dispute over the decision on dam the area was declared as a National Park on 15 November 1984. Encroachments, forest alienation, conversion of forests to plantations and fire have practically wiped out the buffer available in many parts outside the Park. This had happened in spite of the nationalization of of private forests in 1971, the Forest Conservancy Act 1980, the notification of the SVNP in 1984, the notification of the Nilgiri Biosphere Reserve in 1986 and greater environmental consciousness. The SVNP has not yet recovered from the threats and the pressures from the developmental programmes.

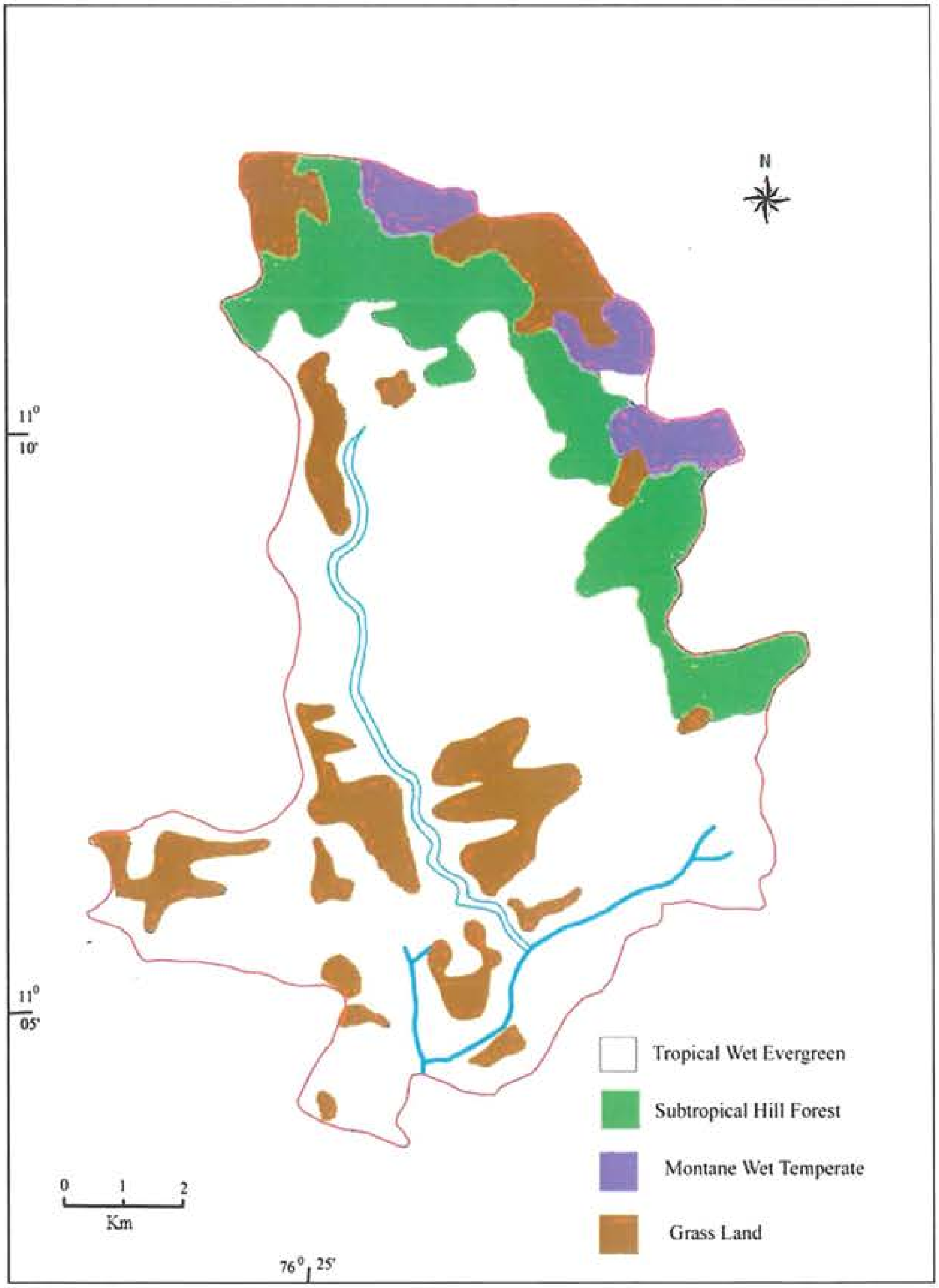


Figure 2.2 Vegetation map of Silent Valley National Park (Source: Premkumar 2002).

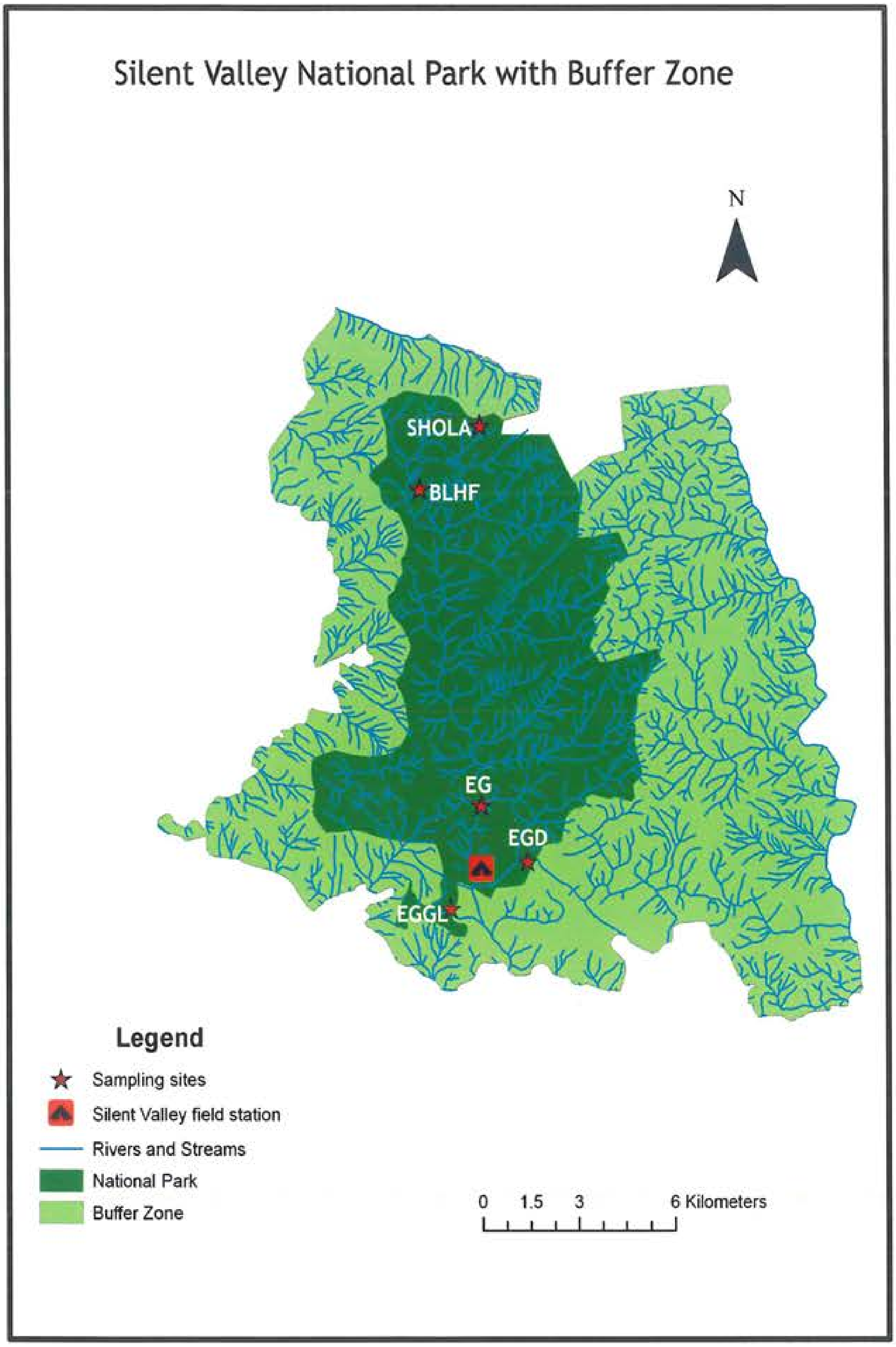


Figure 2.3 Map of Silent Valley National Park, including buffer zone.

2.2.2 Physical features

SVNP is an approximately rectangular portion located at the south-west corner of the Nilgiris. The park is closed on all sides with high and continuous ridges along the entire north, north-east and east with steep escarpments along the western and southern borders. The River Kunthi flows through the area and has numerous perennial tributaries joining at different elevations. Along the narrow east-west axis, the Silent Valley plateau is 7-8 km broad (aerial distance) and along the longer north-south axis it is about 12 km long. The river valley bottom is approximately 900 msl. Along the west and south, the edge of the plateau rises up to 1,200 m with a few peaks higher than 1300 m. The north-western edge rapidly rises to 1900 m and the National Park boundary corresponding with the watershed line swings east and merges with the Nilgiri crestline. The eastern boundary of the Silent Valley plateau is higher and a very steep ridge of more than 1,600 m elevation separates the Kunthi Valley from the immediately adjacent east draining Bhavani Valley. At its northern end in the Nilgiris it is more than 2,300 m in elevation. Along the mid southern border of the Silent Valley plateau Kunthi descends from the 1,000 m elevation within the park to less than 100m elevation through a very narrow gorge approximately shaped like a 'Z'. The old Silent Valley dam site was at the apex (northern end) of the 'Z' while the recent proposal for dam at Pathrakkadavu is at the lowest (southern) end.

The SVNP is divided in to two halves by the River Kunthi that lies along approximately 23 km. The river has eroded a deep gorge, bound by cliffs and steep rocky slopes in excess of 35 degrees. Tributary streams such as Onnampuzha and Kummatomthodu are also bordered by banded rock buttresses, which are virtually impenetrable to humans on foot. Past deposition of river silt, sand and gravel has created small, discontinuous terraces near most stream confluences with river, although many of these are now the present river-bed, occurring at the Parathode and Poonchola.

Forest structure in the study area is heterogeneous due to rugged and rocky terrain with varying degree of steepness and frequently cut channels of perennial streams, and is characterized by uneven canopy heights, treefall gaps and presence of lianas. Some of the rocky areas which lie mostly along the forest fringes and besides stream are dominated by cane or bamboo vegetation. Around 35% of the forest in SVNP has undergone selective logging in early 1900s.

2.2.3 Location

The SVNP (11° 3' to 11° 13' N and 76° 22' to 76° 30' E) is in the Palakkad district of Kerala State. The SVNP is situated at the south- western corner of Nilgiri hills, in the Kundah hills of the Western Ghats. The Park is bounded by Attappady reserved forest to the east and Mannarghat Forest Division to the south. Nilambur South Forest Division defines the western boundary. The rest of northern boundary is contiguous with the Nilgiri Forests in Tamil Nadu including the Mukurthi National Park.

2.2.4 Altitude

The Silent Valley represents a very well preserved example of undulating terrain with most part at mid-elevations (685 to 1500 m). The highest peak at Anginda (2383 m) is anchored at the north-eastern part of the park, and lowest elevation is at the Pathrakkadavu region (685 m) where the River Kunthi descends out of the boundary, squirting through the sharp rocks.

2.2.5 Climate

SVNP experiences heavy rainfall, with a mean annual variation ranging from 3,500 mm to 6,500 mm (Figure 2.4). These areas are exposed to both the south-west and north-east monsoons with heavy downpour during June to August (Figure 2.5). December to March is comparatively drier. The average annual rainfall varies in different regions and increases along the elevational gradient, 3200 mm at Sairandhri to 4500 mm at Neelikkal. The northern portion receives the maximum rainfall of about 7500 mm variations in different years were evident with the maximum in 2004 (Figure 2.6) (Source: Kerala Forest Department). The mean minimum temperature during 2002-2005 varied from 11 to 23° C and the maximum from 23 to 29° C. The highest temperature was recorded in March and the lowest in January (Figure 2.7).

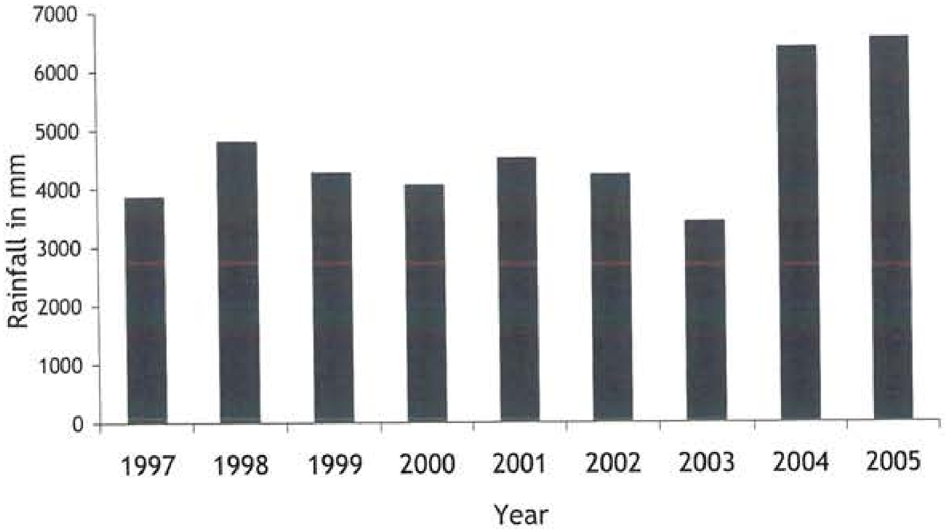


Figure 2.4 Total rainfall in SVNP over nine years 1997 to 2005.

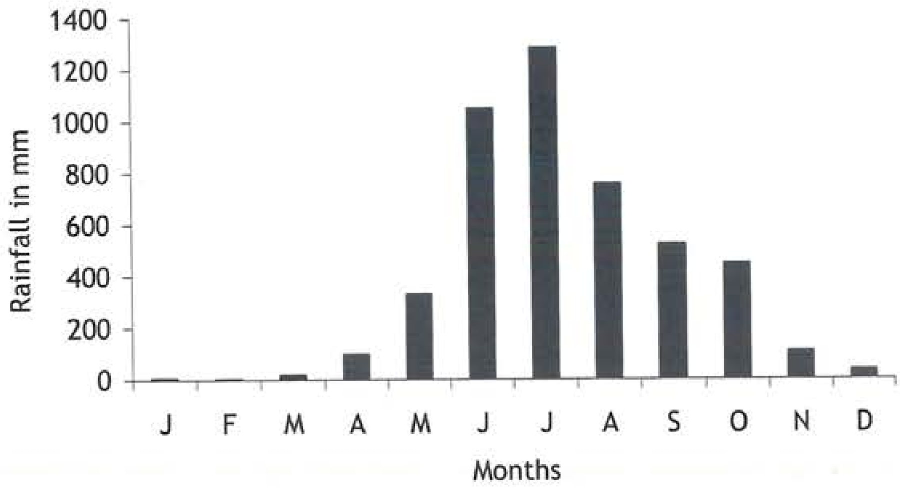


Figure 2.5 Average monthly rainfall in SVNP over nine years

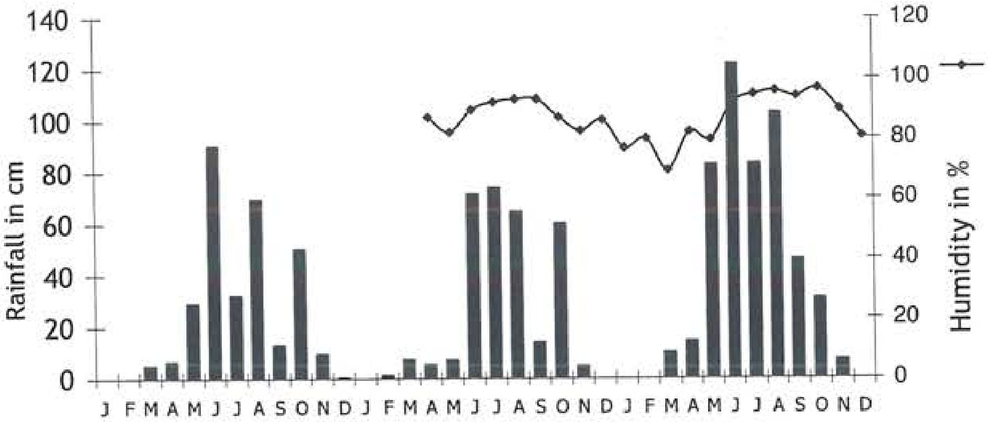


Figure 2.6 Average monthly rainfall and relative humidity in SVNP during 2002-2004

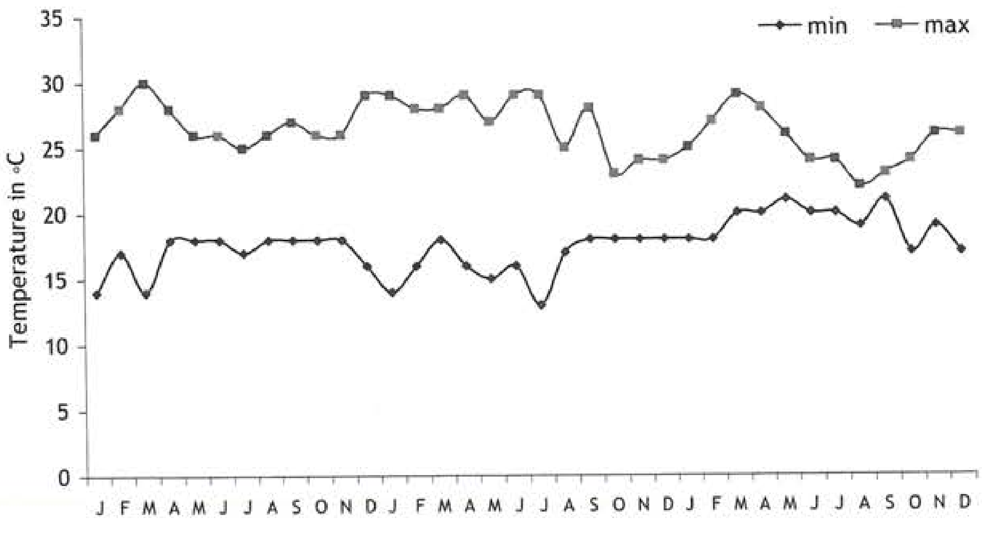


Figure 2. 7 Mean monthly variation in temperature in SVNP during 2002-2004

2.2.6 Geology

Very little is known about the area's geology, except those which addressed Western Ghats at a gross regional scale by Kerala Forest Research Institute and Geological Survey of India. The broad lithological formation of the area consists of peninsular granite-genesis towards the Western Ghats scarp and above the Ghats isolated mainly by Archean Charnokites, although Dharwan Schists and genesis also occur as intrusion.

2.2.7 Drainage

The River Kunthi has three tributaries namely Korempuzha, Karingathode and Valiyaparathode. From 2400 m, it suddenly descends to 1150 m and then meanders southwards to cascade down to the Mannarkkad plains. The area is drained towards the west through Kunthi which joins Thuthapuzha which in turn flows into Bharathapuzha.

2.2.8 Flora

The forests of SVNP fall under the category of Malabar Rain forest Realm according to the world classification of Udvardy (1975). Vegetation of Silent Valley area comprises mainly of the west-coast tropical evergreen and semi-evergreen forests as described by Champion and Seth (1968). At higher elevations southern montane wet temperate (Shola) forests and grasslands predominate. Cane, reed beds and bamboo brakes are interspersed with the evergreen and semi-evergreen forests in many localities. Mixed moist deciduous forest and savannah woodland also exist in some areas. The genetic diversity of plants is extremely rich. A total of 666 species of flowering plants have been identified from Silent Valley (Manilal 1988) and later Vajravelu (1990) added several species. The Botanical Survey of India has described many new plant species as well as new genera from the area. There are four major forest types occurring in different habitats. The flora of the area is remarkable from the phyto-geographical point of view with Asiatic, endemic and Indo-Sri Lankan elements dominating the scenario. These are followed by Pan-tropic, Australo-Asian, Afro-Asian, Indo-African and other forms. This is a proof of homobioclimate, which existed in the past, and also of previous land connections. Endemism is significant, thus Silent Valley serves as an area where different species have evolved and are still evolving. Three detailed floral surveys were undertaken in or near the study area before independence (Gamble 1928). Sispara along the Nilgiri border must be one of the richest locations in the entire Western Ghats for the number of the species that are restricted to the Western Ghats.

The tree speces such as *Cullenia exarillata, Mesua ferrea, Palaquium ellipticum* are dominant in the evergreen forests at Sairandhri (Manilal 1988). *Dimocarpus longan*, Elaeocarpus *munroni*, Syzygium *cumini*, and *Syzygium laetum* are some of the other major trees present here, whereas in the broad leaved hill forest *Calophyllum polyanthum, Canthium neilgherrense and Casearia bourdillonii* showed its dominance. *Rhododendron arboretum* was the characteristic of shola forest at Sispara along with *Elaeocarpus recurvatus, Ternstroemia japonica* and endemic species such as *Ilex wighitiana, Cinnamomum perotteti* and *Syzygium densiflorum*.

2.2.9 Fauna

Endangered mammals, such as the Lion-tailed Macaque, Tiger and Leopard and the rare and elusive Nilgiri Marten are present in this area besides other mammals of the Peninsular India. The Western Ghats endemic Nilgiri tahr was also recorded from Sispara and Neelikkal. The occurrence of other mammals such as Sambar deer, Barking deer, Common langur, Common Palm civet, Small Indian Civet, Malabar giant squirrel, Gaur and Elephant has also been reported (Balakrishnan 1999). Smaller mammals such as some species of bats, which are very rare, have also been recorded here. Bird fauna of this area is very rich. More than 75% of the birds (Vijayan *et al.* 2001) reported from Western Ghats have been recorded in SVNP. The area harbours most of the endemic species *i.e.* 15 out of the 16 occurring in the Western Ghats (Islam and Rahmani 2004). A recent report showed herpetofauna comprising endangered species such as the Indian Rock Python, Bengal Monitor Lizard, four species of the pit vipers, and two members of the cobra family. Non-venomous snakes such as Keelbacks and Whip snakes are also reported. There is a sighting record of the recently described Pig-nosed frog which is very rare in SVNP (Das 2006a). The SVNP is known for its highly diversified insect fauna (ZSI 1986), with high diversity of aquatic insects (Burton and

Sivaramakrishnan 1993). The lepidopteran fauna is very rich as it holds more than 400 species of moths and 155 species of butterflies (Mathew 1990, Das and Vijayan 2007).

2.2.10 Human Activities

Though tribes have been living in the adjacent valley of Attappady Reserve Forest, there is no evidence of permanent human habitations within the core of the Silent Valley probably due to the harsh climate, inaccessible terrain and impenetrability of the forests. The local tribes in the adjacent areas are Erulas, Kurumbas and Mudukas, whose existence in the harsh environment depends upon marginal agricultural activities and collection of non-wood forest products.

2.4 LOCATIONS OF THE INTENSIVE STUDY

Regular monthly bird sampling was carried out in different habitats such as evergreen forest in lower altitudes, mid-elevation broad-leaved hill forest, shola forest and grasslands. Six sites had been established in different altitudes in the region (Figure 2.8), representing a variety of habitat classes across each of the major vegetation types (Table 2.1).

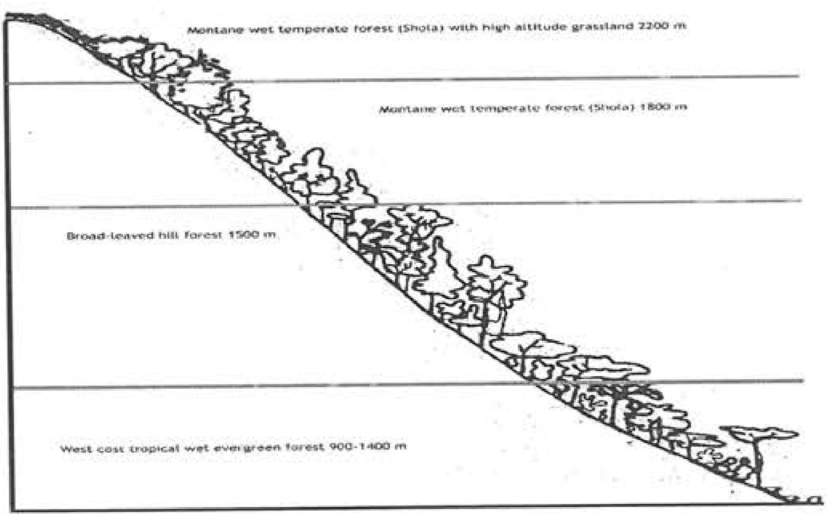


Figure 2.8 The schematic diagram of the various habitats along different altitudes of survey stations in SVNP.

Table 2.1 Details of intensive study sites in SVNP.

Code	Location	Altitude (m)	Habitat matrix	Place
EGGL	N 11° 05' 16" E 76° 26' 89"	1019-1227	West cost tropical wet evergreen + low altitude grassland interface with history of disturbance such as fire, being the park border	Aruvampara
EGD	N 11° 05' 77" E 76° 26' 96"	1011-1056	West cost tropical wet evergreen logged, tourist zone	Sairandhri
EG	N 11° 06' 01" E 76° 26' 67"	0962-0998	West cost tropical wet evergreen (undisturbed)	Parathode
BLHF	N 11° 10' 89" E 76° 25' 44"	1560-1675	Broad-leaved hill forest (secondary forest in succession)	Walakkad Pass
SHOLA	N 11° 12' 10" E 76° 26' 32"	1858-2034	Southern montane wet temperate forest (Shola)	Sispara
SHOLAG	N 11° 12' 03" E 76° 26' 32"	1974-2136	Southern montane wet temperate forest (Shola) + high altitude grassland	Upper Sispara

Profiles of Silent Valley National Park

CHAPTER III

HABITAT STRUCTURE ALONG THE ALTITUDINAL GRADIENT

CHAPTER III

HABITAT STRUCTURE ALONG THE ALTITUDINAL GRADIENT

3.1 INTRODUCTION

Variation in plant community structure and diversity across space is a common focus of many tropical studies (Gaston 2000). Vegetation structure and composition are the most important features that are likely to influence the habitat selection of birds (Cody 1985) and the relationship between the distribution and abundance of birds and habitat have long been a focal theme of avian ecological research (Block and Brennan 1993). While correlations between bird community and vegetation characteristics have been widely established, underlying causal factors rarely have been identified (Holmes *et al.* 1986). It is also demonstrated that the primary forests are vanishing at an alarming rate, and that we are now living through the last decades of a vegetation which dates back as early as 300 million years ago (Halle 1978). The proposed mechanisms for the maintenance of the high levels of tropical tree diversity are wide ranging (Gentry 1982; Dumont *et al.* 1990) and have illuminated the fact that although there are certain constants, factors promoting diversity are variable across habitats. Vegetation is often considered an important habitat component for birds because it provides foraging opportunities, diversity of food, shelter, or nesting substrate, and other conditions suitable for successful reproduction (Rotenberry 1981).

Successful conservation of the forest ecosystems ultimately depend upon an understanding of the ecosystem dynamics (Swamy *et al.* 2000). Evaluation of perturbations, either manmade or natural in the forest ecosystems can be studied only by long-term monitoring of permanent plots (Sukumar *et al.* 1997). These studies are very essential as they provide an increased understanding of the spatio-temporal forest composition, structure and dynamics (Ayyappan and Parthasarathy 1999, 2001 and *references* *therein*). Such investigations are expected to contribute much on the procurement of the scientific information and to evaluate the prevailing management tactics and their responses on the forest ecosystems (Chandrashekara and Ramakrishnan 1994; Dallmeier and Comiskey 1998).

Plant communities are not a random assemblage of plants. Their composition is dependent on a wide range of factors, both biotic and abiotic. Classification and description methods frequently group plant species together by environmental and/or resource gradients (Tilman *et al.* 1997; Barbra 2004). These can be indirect environmental gradients (altitude, aspect and slope) or direct environmental gradients (*pH* and temperature) as described by Austin (1971), Austin and Smith (1989). These classification schemes are often based on the established phase of the life history of the individual species within a community and may not be directly applicable to the developing vegetation on the sites being studied.

Topography is one among the variables that affects vegetation distribution (Basnet 1992; Burns and Leathwick 1996; Chazdon *et al.* 1998). Differences in hydrology, soil structure or exposure may influence the survival of seedlings and trees, thereby selecting the species capable of tolerating those microhabitats.

To recognize the nature and distribution of various habitat types in the SVNP, it is necessary to have an accurate area inventory, species composition list, and classification of plant communities, which has been largely accomplished by Manilal (1988). Detailed tree community studies have already been done in SVNP (Manilal 1988; Manoharan *et al.* 1999). The present study we describe the structure and composition of tropical forest in SVNP with emphasis on the different altitudes and habitats. The objective of vegetation assessment was to examine forest structure, dynamics of various habitats and scrutinize variability of tree diversity and its size classes across SVNP and relate them to the bird communities.

3.2 METHODS

3.2.1 Plot design and sampling

In the present study three major vegetation clusters of habitats in the study area (details are given in Chapter 2) were separated based on elevation between 900 and 2300 m. Below 1400 m, the major habitats are grasslands and evergreen forests. Between 1400 and 1800 m, broadleaved hill forests are dominant. Above 1800 m, shola forest can be seen and above 2000 m shola forest interspersed with the grasslands are prominent.

A range of habitat or vegetation structure variables were measured using the standard sampling protocol called Multiple Stage Quadrat (Sykes and Horrill 1977). Sampling took place in all those sites, which occupied an area of 2.4 ha (sixty 20 x 20 m plots along six, one km transect) with the major corners permanently demarcated with metal plates. Each site was located in the field with a compass and clinometer and subsequently latitude, longitude and elevation of the center of the plot were recorded with a handheld Global Positioning System (Garmin 12XL). Square plots were preferred to rectangular plots since the former have less edge-area ratio and eased the consideration of inclusions of trees in or outside plot edges.

Birds were sampled at the point count stations along the entire transect (10 point count stations at 100 m interval), while habitat structure variables were sampled in single sub-plots at alternate sides along the transects. Density (stems / plot) of all woody plants, having GBH (Girth at Breast Height) ≥ 30 cm were measured. Trees were defined as large woody plants having one (or a few) supporting trunk and potentially reaching diameter ≥ 30 cm (Petrides 1986). Trees were considered inside the sampling plot if more than 50% of the roots were inside the plot. Multi-stemmed trees were measured only on the largest stem i.e. > 30 cm diameter at 1.30 m height. Tree girth measurement of buttressed trees was recorded as the diameter from just above the buttress or any other malformations in the stems, which are facilitated by means of a single legged bamboo ladder. All the trees were permanently marked with the metal tags and nails. Shrubs were distinguished from trees (and saplings) as those woody plants that generally will be smaller than a tree and will consist of a number of small stems originating from or near the ground (Petrides 1986). Trees were assigned to one of the three height categories: lower-canopy (4-15 m height), mid-canopy (15-25 m height), and top-canopy (> 25 m height) trees (Chandrashekara and Ramakrishnan 1994). Each 20 x 20 m plots consisted of two, 5 x 5 m and four 1 x 1m plots. Bamboo clumps, saplings, culms, etc. were measured in the 5 x 5 m sub-plots. In the 1 x 1 m plots fern, grass and herb cover were measured. I measured organic litter depth at five points, spaced at four corners and centre inside the plots.

The plant species were identified in the field with the help of standard guides pertinent to the study area (Gamble 1928; Manilal 1988; Vajravelu 1992) and field keys prepared by Pascal and Ramesh (1987). Field work was done with assistance from Dr. V. S. Ramachandran, a reputed plant taxonomist. The identity was later verified with the reference materials (herbarium specimens) at the Botanical Survey of India, Southern Circle (MH), Coimbatore. Voucher specimens for all species and morpho-species were collected, catalogued and curated at the herbarium of the Forest Department, Mukkali.

3.2.2 Statistical Analyses

Various indices have been used to designate the two components of species diversity: species richness and evenness or equitability (Magurran 1988). The data from each plots were analyzed separately and Shannon-Weaver diversity, Simpson's index, Margalef's index and Equitability were calculated. Fisher's alpha was also calculated for each plot to represent the degree of habitat heterogeneity.

Species accumulation curves were plotted for each habitat; it is a plot of the cumulative number of species, S (n), collected against a measure of the sampling effort (n). Shannon-Weaver diversity index for each plot is calculated using the formula.

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

where p_i = the proportion of individuals in the i^{th} species.

Margalef's D has been calculated as the species number minus 1 divided by the logarithm of the total number of individuals.

Species diversity was also calculated using the equation (Margalef 1968), a function devised to determine the amount of information in a code or signal, and defined as:

$$D = \frac{(S-1)}{\ln N}$$

where S is species number for each sample.

The index of dominance of the community was calculated by the Simpson's index (Simpson 1949) as:

$$C = \Sigma\ (ni/N^2)$$

where C = index of dominance; ni and N being the same as in the Shannon index of general diversity. The index of species richness was calculated by adopting Menhinick (1964) as:

$$d = S/\sqrt{n}$$

where S = number of species, n= number of individuals. For calculating the evenness index of the community (E) I followed Pielou (1966) as:

$$E = H'/\log S$$

where S= number of species, H'= Shannon index.

Frequency, density, dominance and importance value index (IVI) of all woody species were determined according to Muller-Dombois and Ellenberg (1974). Basal area, relative density, relative frequency, relative dominance and importance value indices were calculated following the formulae of Cottam and Curtis (1956), Curtis and Cottam (1962), where:

- Basal area (m^2) = area occupied at breast height (1.3 m) = (Π X $(dbh/2)^2$)
- Relative density = number species of tree / total number of trees
- Relative frequency = number of times the species occurs / total number of species
- Relative dominance = total basal area of a species / total basal area of all species
- Importance value index (IVI) = sum of (relative density + relative frequency + relative dominance) X 100

3.3 RESULTS

3.3.1 Species richness, abundance and diversity

I identified and tagged 1872 individuals which comprised 152 species of trees belonging to 109 genera in 41 families (Appendix 3.1). The gradient of species area curve suggests that more sampling by increasing the number of plots would have resulted in more number of species being encountered (Figure 3.1).

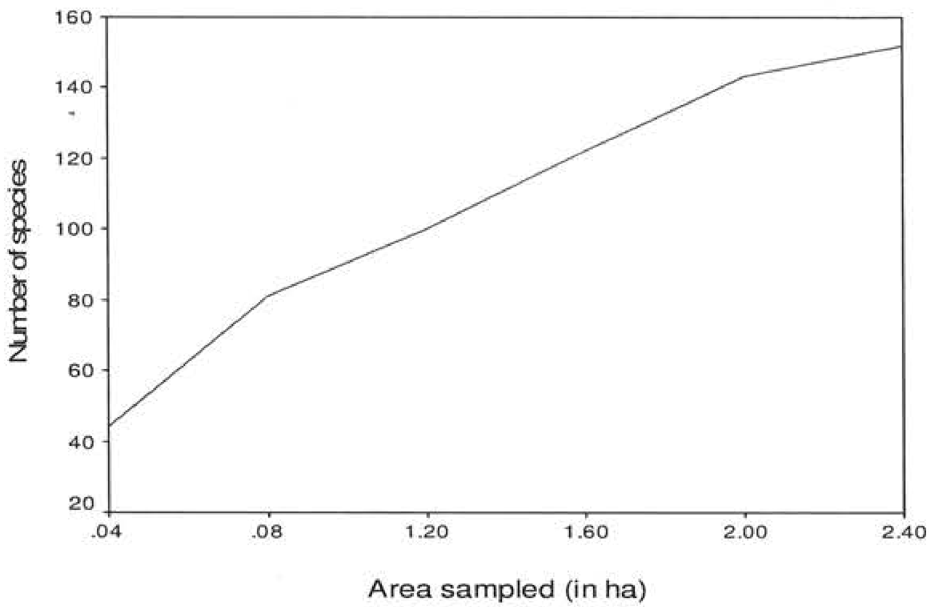


Figure 3.1 Sample effort curve showing number of species collected with respect to the area sampled. Species-accumulation curves indicated that species number increases with area sampled along the vegetation. Note the hike in species numbers corresponding to the transition zones between two forest types (at 1.6 ha).

The species richness of vegetation was found to be more in the EG (72) followed by EGD (68) and then BLHF (55) (Table. 3.1) with an average species numbers of 16.7, 13.2, and 8.4 respectively in the plots (Figure 3.2). The EGD and EG did not differ in terms of their distribution (Kolmogorov-Smirnov test D=0.062, $p > 0.05$), whereas BLHF and EG showed high variation (Kolmogorov- Smirnov test D=0.115, $p < 0.05$). Meantime EG and SHOLAG showed high variation (Kolmogorov- Smirnov test D=0.169, $p < 0.05$). SHOLA and SHOLAG also differed significantly (Kolmogorov- Smirnov test D=0.091, $p < 0.05$) (Figure 3.2). Comparison of the distribution pattern of girth classes in different habitats showed significant variation as observed in EGD with BLHF, EGGL with EGD (Table 3.2).

Table 3.1 Summary of diversity statistics observed in the trees of various habitats at different elevations at SVNP.

	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
Taxa S	44	68	72	55	49	37
Shannon H'	3.265	3.685	3.801	3.184	3.222	2.959
Simpson 1-D	0.947	0.961	0.968	0.935	0.942	0.927
Evenness e^ H/S	0.595	0.586	0.621	0.439	0.512	0.521
Margalef D	7.793	11.36	12.28	9.341	8.239	6.426
Equitability E	0.863	0.873	0.889	0.795	0.828	0.820
Fisher's alpha	15.51	24.66	28.65	19.01	15.72	11.58

There was no significant difference in the tree abundance among the different habitats (One-way ANOVA F_5=0.869, $p = 0.502$). The abundance was high at the EGD with 368 trees followed by SHOLA with 339 then by EG with 325 trees. BLHF was with 324 trees, whereas SHOLAG harbored 271 trees and the least was observed in the EGGL (249) (Table 3.1). The diversity followed a different pattern. Highest diversity was found in the EG with Fisher's alpha 28.7 and then in EGD (24.7) followed by BLHF (19), SHOLA (15.7), EGGL (15.5) and least diversity was observed in SHOLAG (11.6). Other diversity indices such as Simpson and Shannon also followed same pattern (Table 3.1).

Table 3.2 Correlation (*r*-values) observed in the GBH classes of trees of various habitats in SVNP.

Habitats	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
EGGL	1	*	*	*	*	*
EGD	-0.004	1	*	*	*	*
EG	0.161	-0.069	1	*	*	*
BLHF	0.066	-0.005	0.07	1	*	*
SHOLA	-0.070	-0.069	0.08	0.157	1	*
SHOLAG	0.355	-0.054	0.28	0.208	0.013	1

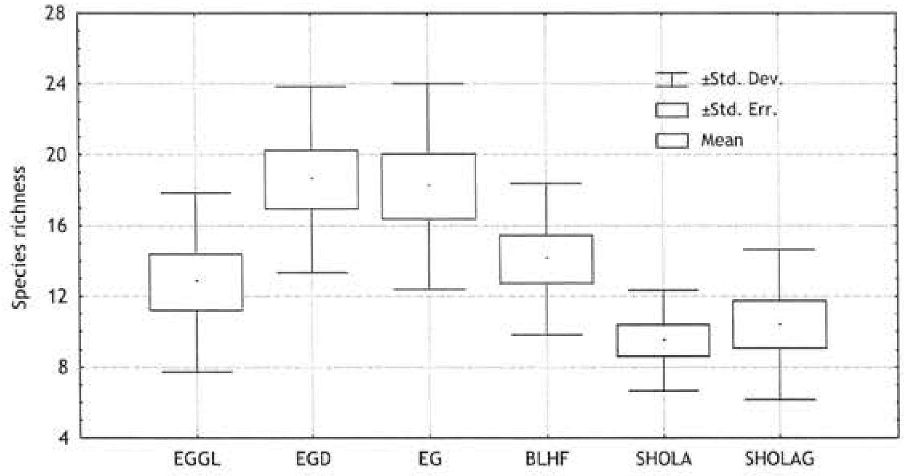


Figure 3.2 Species richness of trees in various habitats at different elevations at SVNP.

3.3.2 Tree density and basal area

Stem density was markedly higher at EGD (910 ha^{-1}, extrapolated) than in SHOLAG (677 ha^{-1}) (Table 3.3). High stem density was also reported from EG, BLHF and the SHOLA (812, 810, and 847 ha^{-1}) respectively. Mean stem density in the plots (0.4 ha) showed the maximum value of 36 in EGD and the minimum in EGGL (Figure 3.3).

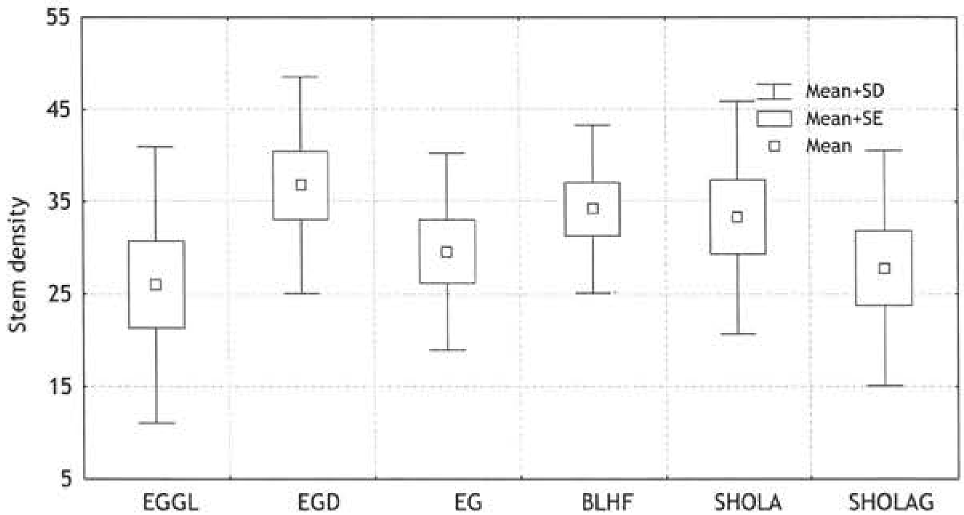


Figure 3.3 Stem densities of trees in various habitats at different elevations at SVNP.

The overall mean basal area of trees in all the habitats studied was 43.5 m^2 ha^{-1}. The highest basal area was reported from the EGD (70.52 m^2 ha^{-1}) followed by EG (62.35 m^2 ha^{-1}) and then by EGGL (57.97 m^2 ha^{-1}) in the mid-elevation plots. The gradual reduction in the basal area was noticed with an increase in altitude as the BLHF was with 33.18 m^2 ha^{-1} and SHOLA with 27 m^2 ha^{-1}, whereas the least was noticed in the SHOLAG 19.96 m^2 ha^{-1} (Table 3.3).

Table 3.3 Tree density and basal area observed in various habitats at different elevations at SVNP.

Habitat	Density ha^{-1}	Basal area m^2 ha^{-1}
EGGL	625.5	57.97
EGD	910	70.52
EG	812.5	62.35
BLHF	810	33.17
SHOLA	847.5	27.00
SHOLAG	677.5	19.96
Mean	780	43.50

3.3.3 Dominance and rarity

Casearia bourdillonii is the only species which has been reported from all the transects. The occurrence of the predominant species, *Cullenia exarillata* and *Elaeocarpus tuberculatus*, in all the low-altitude sites and 5 species in any of the five sampling sites, 16 species in any of the 4 sites, and 35 species in only one site explains the heterogeneity of tree species community of SVNP and demonstrates the patchiness in distribution of the species Appendix (3.2). The contribution of species to each plot, their frequency, basal area, relative frequency, density, dominance and importance values are presented in the Appendix (3.3).

3.3.4 Importance value index (IVI)

The IVI portrays the sociological structure of a species in its totality in the given community; 39 species having IVI scores more than 10 are given in Table 3.4. The maximum IVI value was for *Elaeocarpus tuberculatus* in EG (43). The IVI of *Cullenia exarillata* was higher in EGGL and EGD (41, 39.6

respectively) which decreased in EG (19.7) (Table 3.4). There were 11 species with IVI values ranging between 10 and 45 in EGGL, eight in EGD and EG, nine species in SHOLA and 10 species in BLHF and SHOLAG. The dominant species in EGGL and in EGD were *Cullenia exarillata* (IVI 41, 39.6 respectively) and *Elaeocarpus tuberculatus* (IVI 25.7, 24.4 respectively). In EG, *Elaeocarpus tuberculatus* (IVI 43.2) and *Cullenia exarillata* (IVI 19.7) showed high dominance, whereas in BLHF *Canthium neilgherrense* (IVI 27.79), and *Myristica dactyloides* (IVI 24.8) were the dominant species. In SHOLA, species such as *Olea glandulifera* (IVI 37.6) and *Litsea stocksii* (IVI 25) and in SHOLAG *Syzygium palghatense* (IVI 37.3) and *Michelia nilagirica* (IVI 36.66) showed their dominance.

Table 3.4 Importance value index (IVI) of trees (> 10) with ≥ 30 cm of GBH from various habitats at different elevations in SVNP.

Species	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
Actinodaphne lawsonii	-	-	-	-	17.7	-
Agrostistachys borneensis	-	12.3	-	-	-	-
Antidesma menasu	10.2	-	-	-	-	-
Apodytes dimidiata	-	-	-	-	-	16.9
Bischofia javanica	-	-	12	-	-	-
Calophyllum apetalum	-	-	-	13	-	-
Canthium neilgherrense	-	-	-	27.8	-	-
Casearia bourdillonii	-	-	-	12.1	-	-
Cinnamomum sulphuratum	-	-	-	-	11.3	20.1
Clerodendrum viscosum	13.3	-	-	-	-	-
Cullenia exarillata	41	39.6	19.7	-	-	-
Dimocarpus longan	10.6	-	12	-	-	-
Elaeocarpus oblongus	-	-	-	11.2	-	-
Elaeocarpus recurvatus	-	-	-	-	-	10.7
Elaeocarpus tuberculatus	25.7	24.4	43.2	-	-	-
Eurya nitida	-	-	-	12.4	-	-
Garcinia gummi- gutta	-	-	-	-	11.3	-
Garcinia pictoria	10.8	-	-	-	-	-
Gomphandra tetrandra	-	-	13	-	-	-
Gordonia obtusa	-	-	-	-	-	11.9
Knema attenuata	-	10.8	-	-	-	-
Litsea floribunda	11.3	-	-	-	-	-
Litsea leavigata	-	-	-	11.3	-	-
Litsea stocksii	-	-	-	19.9	25	23.2
Macaranga peltata	13.4	-	-	16.4	-	-
Memecylon sisparense	-	-	-	-	-	10.8
Myristica dactyloides	12.7	10.3	11	24.7	-	-
Mesua ferrea	-	13.5	-	-	-	-
Michelia nilagirica	-	-	-	-	15.8	36.7
Olea glandulifera.	-	-	-	-	37.6	-
Oreocnide integrifolia	-	-	10	-	-	-
Palaquium ellipticum	19.5	18.9	12	-	-	-
Rapanea wightiana	-	-	-	-	-	12.2
Syzygium laetum	16.3	-	-	-	-	-
Syzygium cumini	-	-	12.4		-	-
Syzygium palghatense	-	-	-	20.9	17.1	37.3
Ternstroemia japonica	-	-	-	-	17.5	12.2
Turpinia malabarica	-	13.8	-	-	-	-
Turpinia nipalensis	-	-	-	-	10.6	-

3.3.5 Family diversity

The inventory reported 41 tree families from all the study sites, and the family Lauraceae had the highest representation (18 species) (Figure 3.4). followed by Euphorbiaceae (15 species). Myrtaceae and Clusiaceae were represented by eight and seven species respectively; a single genus (*Syzygium* sp.) contributed much for the Myrtaceae. While considering the density of trees in different families, Myrtaceae ranked first with 103 individuals followed by Lauraceae with 92 trees

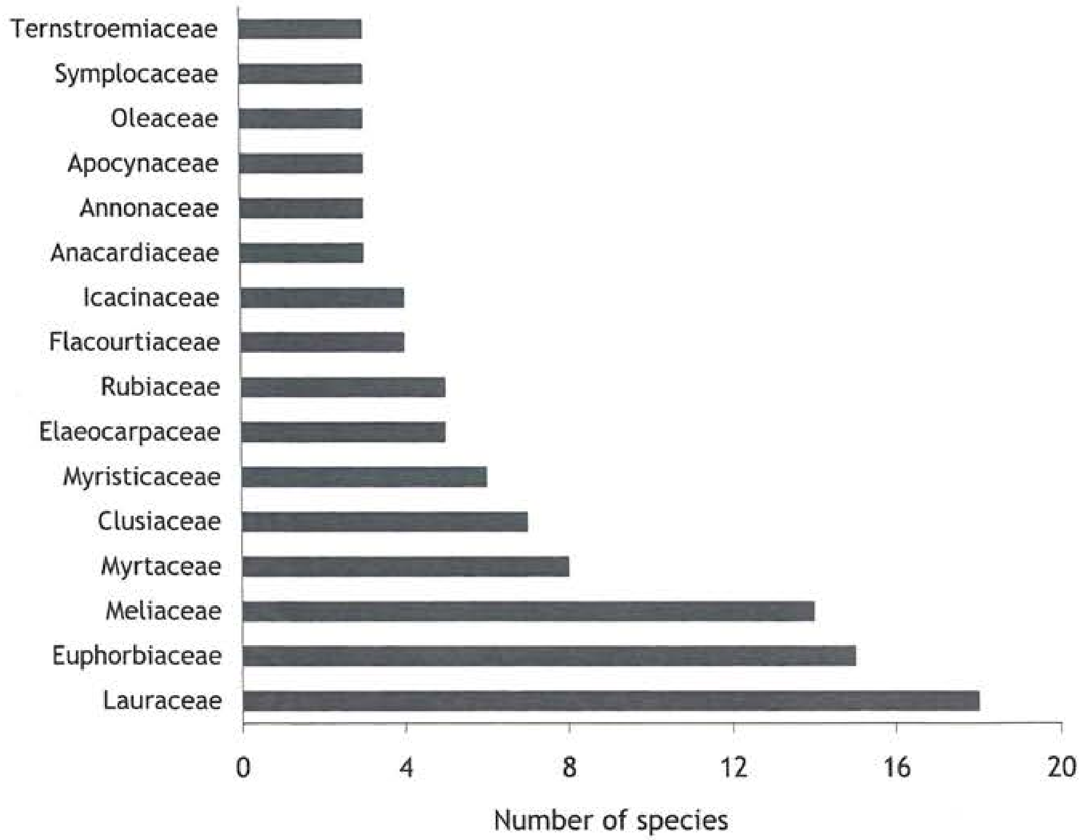


Figure 3.4 Major plant families represented by at least three species in 2.4 hectares of forest sampled in SVNP.

3.3.6 Girth-class distribution

GBH of trees in different habitats showed statistically significant difference (One-way ANOVA $F_5 = 15.52$, $p < 0.001$). Average stem diameter was significantly different among the forest types (Kruskal-Wallis test, $p > 0.05$). Maximum GBH was recorded in the EG forest. Species richness and density decreased with increasing girth classes. Girth class distribution of trees showed a skewed pattern with the maximum numbers in lower girth classes. Contribution of lower girth class (30-60) trees was in the whole data and, with increasing girth classes species richness and density decreased (Table 3.1, Figure 3.5). Lower size class trees (30-60 cm GBH) formed 44.19% of trees sampled in EGGL, 58.7% in EGD and 59.8% in EG. In SHOLA and SHOLAG, trees of lower size class formed 60% and 68.4% respectively of entire stands (Figures 3.6 - 3.11). Though not proportionate, most of the GBH classes had representation in all the habitats. Meantime, they showed high variation in the distribution of their GBH classes. But the stem density in different GBH classes per transect was significantly different between EGD and the EGGL (Wilcoxon signed rank test: $Z = -1.48$, $p < 0.001$), EGD and SHOLAG (Wilcoxon signed rank test: $Z = -1.42$, $p < 0.001$), EGGL and SHOLA (Wilcoxon signed rank test: $Z = -.460$, $p < 0.001$).

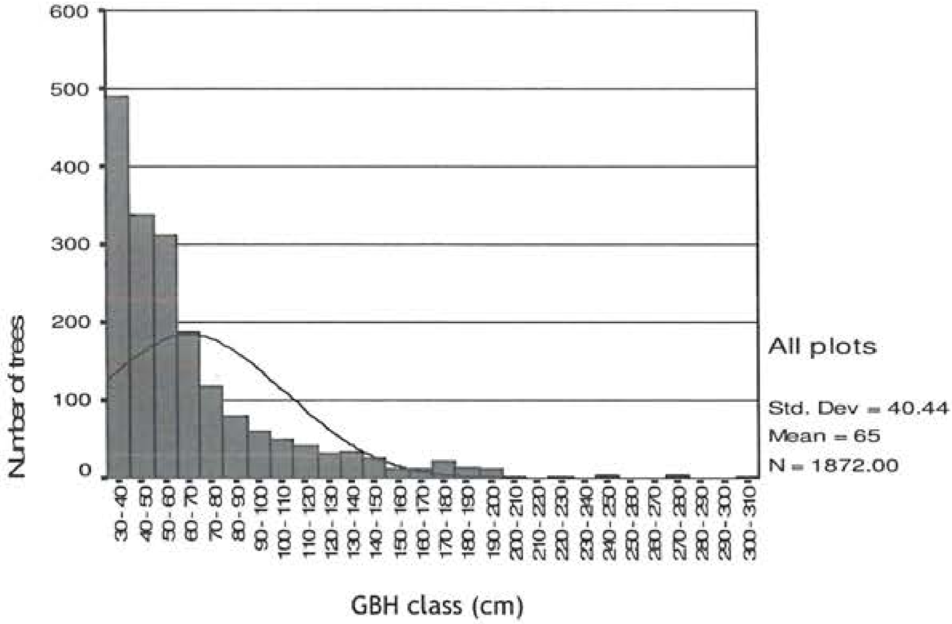


Figure 3.5 Population structure of woody species with ≥ 30 cm of GBH based on girth-frequency in all plots together.

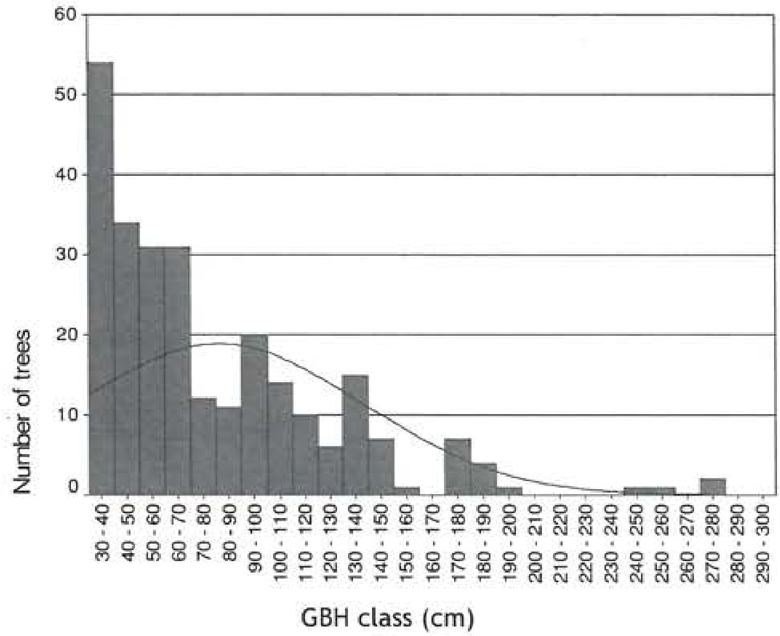


Figure 3.6 Population structure of woody species with ≥ 30 cm of GBH based on girth-frequency in EGGL.

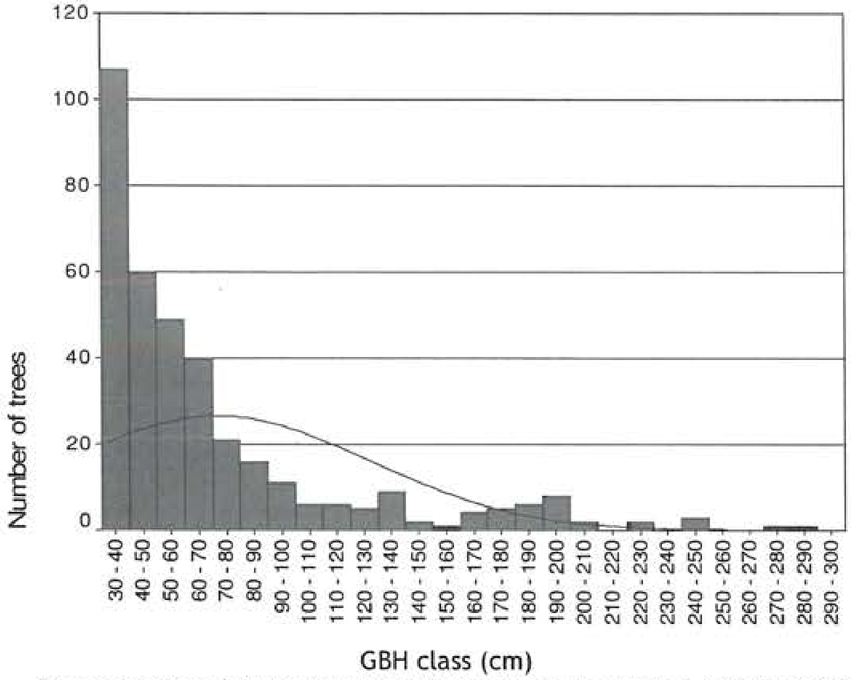


Figure 3.7 Population structure of woody species with ≥ 30 cm of GBH based on girth-frequency in EGD.

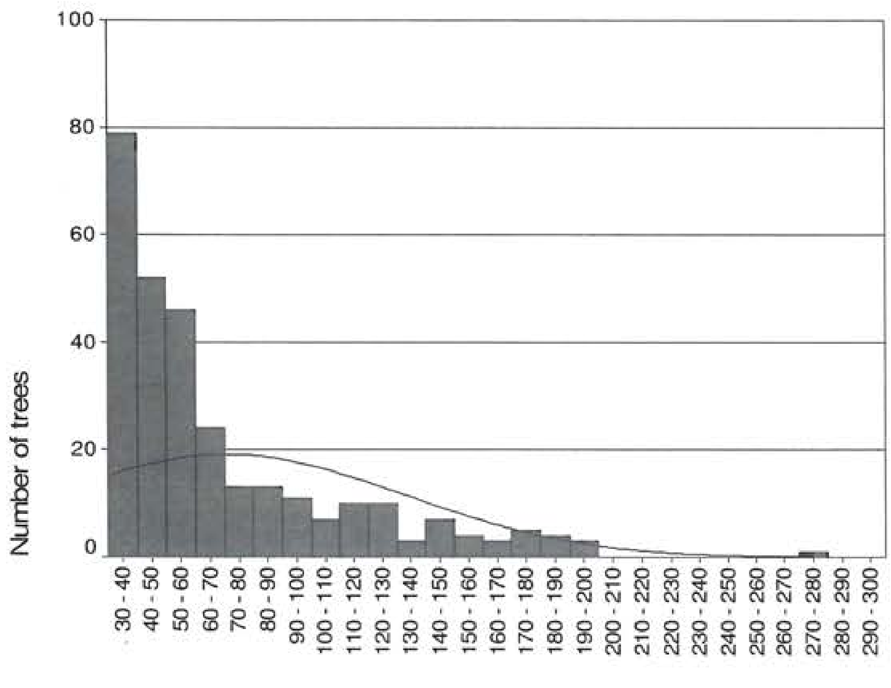
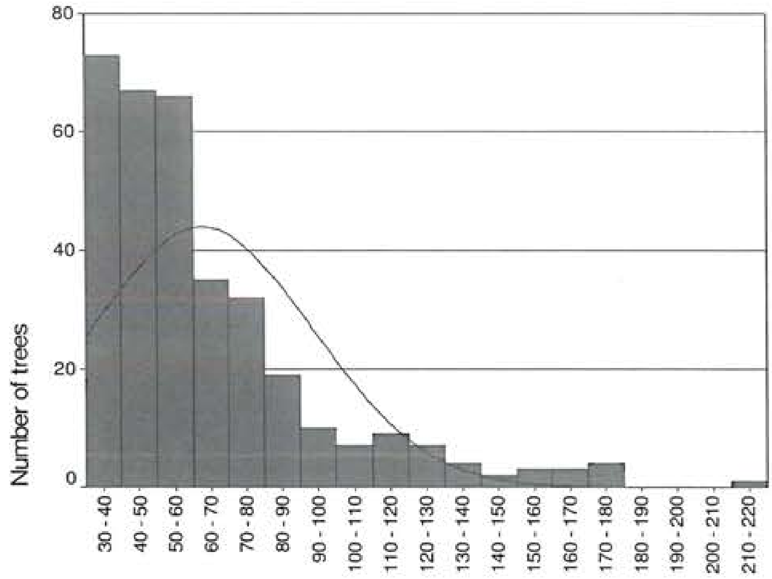
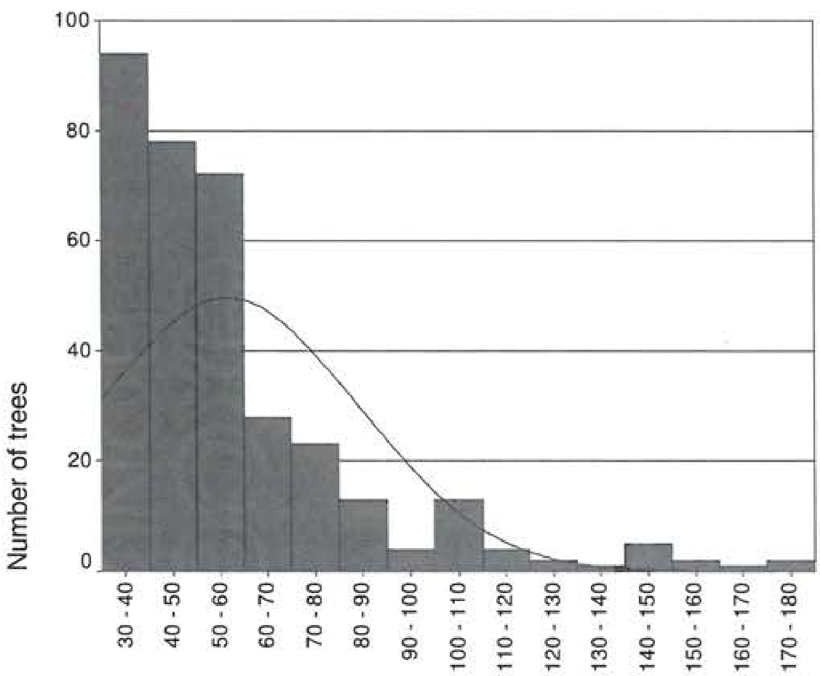


Figure 3.8 Population structure of woody species with ≥ 30 cm of GBH based on girth-frequency in EG.



GBH class (cm)
Figure 3.9 Population structure of woody species with ≥ 30 cm of GBH based on girth-frequency in BLHF.



GBH class (cm)
Figure 3.10 Population structure of woody species with ≥ 30 cm of GBH based on girth-frequency in SHOLA

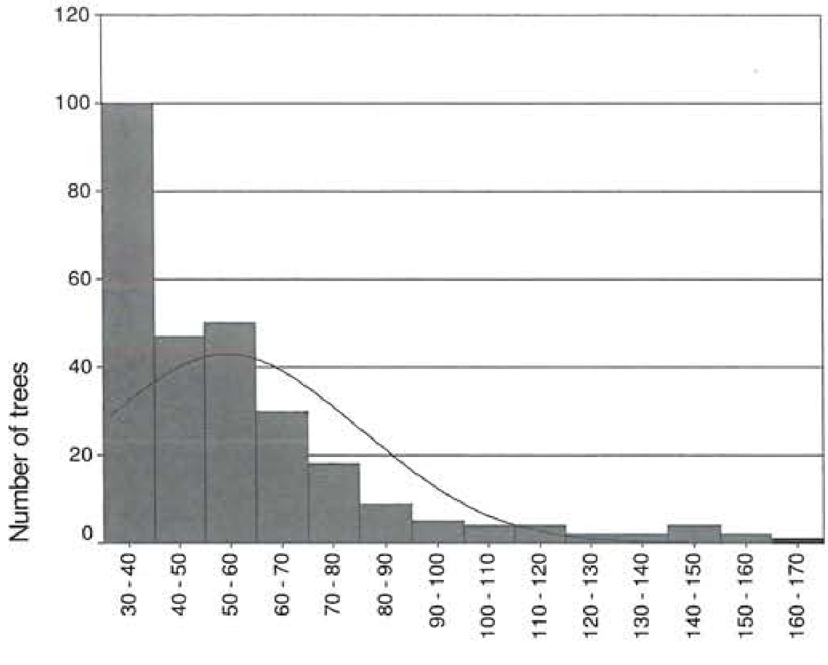


Figure 3.11 Population structure of woody species with ≥ 30 cm of GBH based on girth-frequency in SHOLAG

5.3.7 Vertical Stratification of trees

Profiles of trees in different height intervals are shown in Figure 3.12. The highest mean tree height was at EG (18.23 m) and EGD (16.73 m) and the lowest at SHOLAG (6.44 m). The tallest trees were *Cullenia exarillata* and *Elaeocarpus tuberculatus* which are the renowned emergents in the region. The vertical structure of a forest is difficult to summarise as it relies heavily upon ecological characteristics of concerned species, particularly the height attributes of mature individuals. However, I attempted to find a generalized height profile of typical vegetation of SVNP. The vertical stratification of trees in SVNP is given in the Figure 3.13. Maximum variation was seen in EGGL. SHOLA and SHOLAG had trees of lower heights.

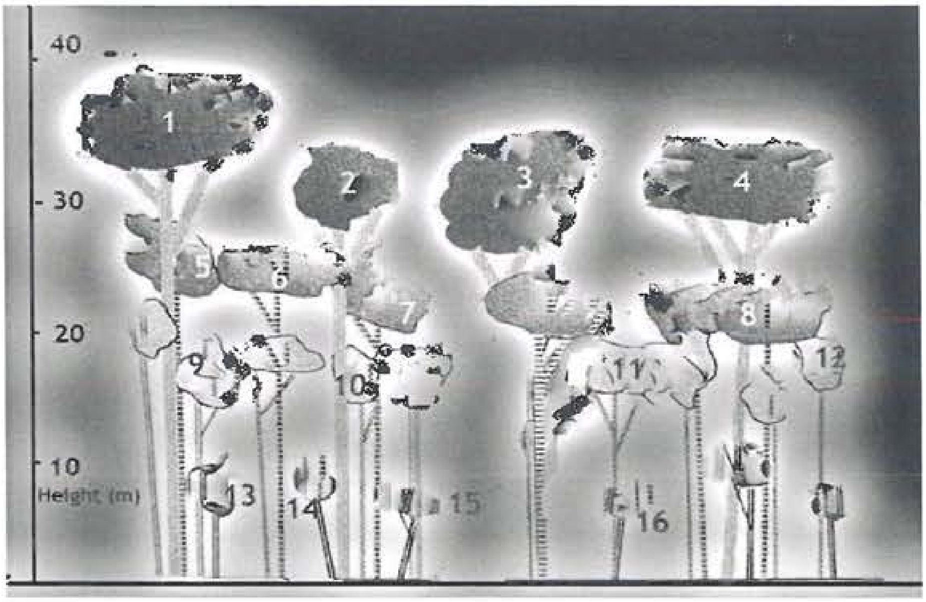


Figure 3.12 Vertical profile diagram of the wet evergreen forest of SVNP.

1-4: Emergents: *Cullenia exarillata, Elaeocarpus tuberculatus, Myristica dactyloides, Mesua ferrea.*

5-8: Canopy: *Bischofia javanica, Palaquium ellipticum, Dimocarpus longan, Persea macrantha.*

9-12: Sub-canopy: *Phoeba lanceolata, Meliosma pinnata, Syzygium sp, Turpinia malabarica.*

13-16: Understorey: *Oreocnide integrifolia, Agrostistachys borneensis, Scolopia crenata.*

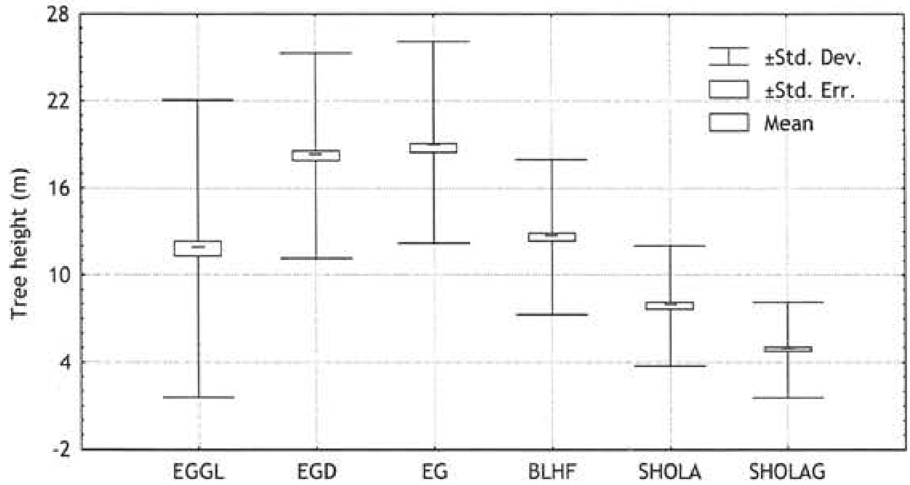


Figure 3.13 Variation in mean tree (≥ 30 cm of GBH) heights in different habitats at SVNP.

5.3.8 Trends in species composition

A chi squared test conducted to enumerate the measure of patchiness in the community revealed 72 aggregated species and 80 randomly distributed species (Appendix 3.3). Trees such as *Cullenia exarillata, Mesua ferrea* and *Palaquium ellipticum* were the dominant species in the evergreen forests (EG) at Sairandhri (SVNP) as observed in many previous studies (Ayyar 1935; Manilal 1988). *Dimocarpus longan, Elaeocarpus munroni,* Syzygium *cumini* and *Syzygium laetum* were some of the major trees species present in the EG. In BLHF *Calophyllum polyanthum, Canthium neilgherrense* and *Casearia bourdillonii* were dominant. *Rhododendron arboretum var nilagirica* was the characteristic of shola forest at Sispara along with *Elaeocarpus recurvatus, Ternstroemia japonica* and so on. Endemic species such as *Ilex wighitiana, Cinnamomum perotteti* and *Syzygium densiflorum* were recorded from here.

The highest number of singletons were noticed from BLHF and EG with 26 and 25 respectively. EGD and EG had highest number of doubletons (13 and 12 species respectively). In total, 35 species (23%) out of total number of 152 species sampled, were singletons and 19 species (12.5%) were doubletons (Table 3.5). The unique species, i.e species recorded only once from a given locality were high in EG (12) followed by SHOLAG (8). 52 species found in the low elevation forest were not recorded from the other forest types. Most of the mid and high altitude species (n=51) were restricted in their distribution to the upper reaches.

Table 3.5 Occurrence of the trees with ≥ 30 cm of GBH in different habitats

Habitat	Number of quadrats	Tree species recorded	Singletons	Doubletons	Unique species
EGGL	10	44	12	8	1
EGD	10	68	18	13	4
EG	10	72	25	12	12
BLHF	10	55	26	8	3
SHOLA	10	49	20	5	7
SHOLAG	10	37	14	5	8
Total	60	152	115	51	35

Similarity in the species dynamics between any two sites were measured by the Bray-Curtis similarity index. It indicated 43.2% similarity between EGGL and EGD in their tree community composition and 16.8% between BLHF and EG, although the two habitats formed a continuous stretch. As expected there was notable difference in the vegetation of SHOLAG with EGGL with only 2.7% similarity, whereas maximum similarity (57.2%) was observed between EG and EGGL (Table 3.6).

Table 3.6 Similarity values (S) for habitats (note that higher values represent greater ecological similarities between sites).

Habitats	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
EGGL	*	43.16	57.20	20.63	5.10	2.67
EGD	*	*	50.08	17.81	9.99	5.96
EG	*	*	*	16.77	9.12	5.24
BLHF	*	*	*	*	30.93	25.54
SHOLA	*	*	*	*	*	52.02
SHOLAG	*	*	*	*	*	*

The whole vegetation community formed two major clusters (Figure 3.14) one comprising high altitude SHOLA and SHOLAG and BLHF and, the second of all evergreen habitats (EG, EGD and EGGL); but BLHF stood separate from SHOLA and SHOLAG.

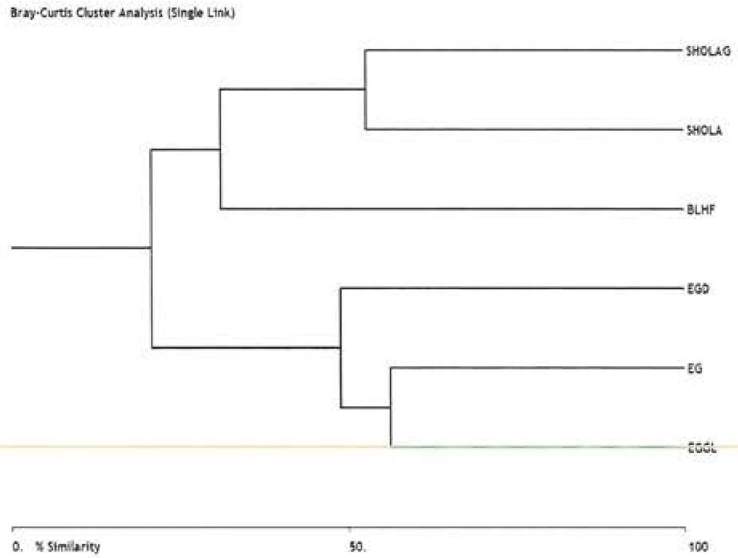


Figure 3.14 Tree species similarity among different habitats in SVNP.

3.4 DISCUSSION

Tropical forests are structurally complex plant communities (Condit *et al.* 2002) with high species richness (Ayyappan and Parthasarathy 1999). A high species richness amounting to 152 species (by measuring 1872 stems from a sampling area of 2.4 ha and having a density of 781 trees/ha) in SVNP is typical of tropics as suggested by studies done elsewhere (Ayyappan and Parthasarathy 2004 and *references therein*). Species accumulation curves suggest a uniform addition of tree species for unit sampling effort, i.e. almost equal number of taxa were recorded in all the samples. An abrupt shift in vegetation structure and composition was evident when transects approached BLHF above mid-elevation. The upward movement of the curves shows the rate of accumulation of taxa which is an effect of such a shift in the habitat. The species accumulation curve showed an upward trend suggesting that more sampling in these areas would have detected more species in these representative areas.

The mean tree density of 780 individuals/ha found at SVNP in the present investigation is in concert with other similar studies in the Western Ghats. For example, at Sengaltheri (Parthasarathy 2001) mean tree density was recorded as 851 ha^{-1}, while at high-elevation forest of Kalakkad (Parthasarathy 1999) it was 716 ha^{-1}. However, Ghate *et al.* (1998) reported a mean tree density of 419 ha^{-1} for closed-canopy evergreen forest of the Western Ghats in Nelliyampathy. A comparison of results from Mylodai site in Courtallum Reserved Forest (482 ha^{-1}; Parthasarathy and Karthikeyan 1997), and Kakachi (583 ha^{-1}; Ganesh *et al.* 1996) in the southern Western Ghats and that of Uppangala in the central Western Ghats (635 ha^{-1}; Pascal and Pelissier 1996) affirms that the SVNP region is unique in terms of its plant density.

As observed from other studies conducted in the Western Ghats from low and medium elevation forests, the present study also yielded the basal area at different habitats falling within the range of 36 to 94 m^2 ha^{-1}. (Pascal and Pelissier 1996; Ganesh *et al.* 1996; Parthasarathy and Karthikeyan 1997; Sukumar *et al.* 1997; Ayyappan and Parthasarathy 1999; Parthasarathy 1999; 2001; Vijayan *et al.* 1999; Srinivas and Parthasarathy 2000; Swamy *et al.*

2000; Davidar *et al.* 2007). The very high basal area (102.7 m^2 ha^{-1}) in SVNP as noted by Singh *et al.* (1986) might be an outcome of the smaller plot size or restriction of sampling to selected mature evergreen forest stands. However, in the present study, sampling in EGGL and SHOLAG resulted in a relatively reduced basal area. The high basal area noted in EGD (70.5 m^2 ha-1) substantiates this. Thus, the sampling in different habitats at SVNP partly explains the drop in overall basal area.

Overall ecological dominance in SVNP suggests that a minority of species dominates the majority of the available resources. The occurrence of small tree species population, principally mono-individual species at SVNP, largely contribute to tree species diversity of the local forest vegetation and they are fundamental elements of enrichment of local biodiversity (Cao and Zhang 1997; Chittibabu and Parthasarathy 2000). Hubbell and Foster (1983) incidentally suggest that many tropical species tend to be locally abundant in certain areas and relatively rare in others (Hubbell and Foster 1983). The greater species rarity of the present study site flag marks the corresponding significance to the site value and its conservation (Chittibabu and Parthasarathy 2000).

Similarities at family level dominance exists among tropical rain forests worldwide (Gentry 1988). Davidar *et al.* (2007) noted that families such as Dipterocarpaceae are dominant in tropical forests of Asia, whereas, at medium elevations, Lauraceae, Euphorbiaceae and Clusiaceae tend to replace these families. Corroborating their observation, Lauraceae and Euphorbiaceae were found to be the two dominant families in the tropical habitats of SVNP.

The population structure of a species in a forest reflects its regeneration behaviour (Grubb 1977, 1986; Saxena *et al.* 1984) and such a data is inevitable to interpret successional patterns. Emergent trees, as represented by species of *Elaeocarpus tuberculatus*, are very large, frequently in excess of 50 m in height and 350 cm GBH. There was even an individual of the species having a GBH of 850 cm. Canopy trees such as *Cullenia exarillata* have a diverse population distribution. The size class distributions of the stems at all the transects are exhibiting roughly negative exponential or inverse J curve, a typical characteristic of the rain forest (Richards 1996). The GBH class distribution from most of the plots yielded a typical L shaped curve (except for the BLHF) as observed in many other studies conducted in the Western Ghats such as Kakachi (Ganesh *et al.* 1996), Uppangala (Pascal and Pelissier 1996), Mylodai and Kourtallum, (Parthasarathy and Karthikeyan 1997), Sengaltheri, (Parthasarathy 2001) and in high elevation forest of the Kalakkad as well as in other places (Parthasarathy 1999).

Occurrence of reverse J-shaped curves in the stand indicates predominance of lower diameter classes, which may be attributed to high regeneration, less tree mortality and high density. A bimodal mound shaped curves in certain species in the undisturbed stand appears to be species dependent, while in the disturbed stand it is the result of selective cutting of certain girth classes which varies from species to species. Reverse J-shaped curve represents the typical behaviour of species in a climax undisturbed forest.

Comparison of the six sites in the SVNP, of which three separated by approximately 25 km of contiguous forest, disclosed that there are several similarities attached with some differences among their communities (Appendix 3.2). The pattern observed here could be attributed to varied microclimates or environmental heterogeneity. Some of the sites have unstable or frequently disturbed areas either steep slopes, grasslands or treefall gaps. Frequency of occurrence of species as a measurement of species composition indicated that SVNP vegetation was not homogeneous at sites. The frequency of occurrence of individual species however, both dominant and rare, raised interesting questions about distribution patterns and their causes. Patterns in vegetation were shown to have a relationship to spatial distribution and frequency of individual species. There were small groups of plant species that appeared to be indicative of distinct limiting factors within the measured environmental ranges as observed in one plot at BLHF with more than 32 individuals of the *Macaranga peltata*, as a function of a tree fall (Appendix 3.3). The results suggested that species associations were influenced by environmental features. Altitude, angle of slope and aspect of surfaces and percentage of bare ground recorded in quadrats may be important factors in the outcome of vegetation patterns. The collection of further environmental data, including soil depth, *pH* and nutrients, may show more light on the obvious clines in vegetation relating to these gradients.

The tree species composition at the different altitudes and habitats of the study area sampled is typical of, and unique to, the remaining forest habitats in the Western Ghats which is of high conservation value. Several of the species found are limited in their distribution across Western Ghats and have been allocated to Red Data Book (Nayar 1996). Distribution of species such as *Baccaurea courtallensis* which occur in Karuvarakkundu region, lie outside the park boundary. Adjacent sites to this region have been occupied or cleared for plantation activities. There is only a limited amount of suitable habitat remaining for such uniquely uncommon, rare or narrowly distributed species and this must be considered in future land use decisions.

The pattern of diversity demonstrated a greater variation of tree species at any site along the altitudinal gradients, which indicates that the species have their own distributional limits. The large variation of species between the quadrats in each step support the individualistic hypothesis of community organization (Gleason 1922) and posits that the distribution of each species is determined by its own ability to survive and compete successfully in different environments, resulting in each species having its own distinctive distribution, and community composition changing more or less continuously along ecological and altitudinal gradients.

A decreasing trend in species diversity was evident at SVNP along altitude with increasing species diversity in transition zones (Behra and Kushwaha 2007; Das *et al.* 2005). The pattern observed in the present study might be due to the presence of microclimates or environmental heterogeneity, which resulted in different number of individuals at different altitudes (Gotelli and Colwell 2001).

3.5 Conclusion

The tree species community of the SVNP is very rich in diversity and density. The tree species diversity indices (Shannon-Weaver, the complement of Simpson's index, Fisher's alpha and Evenness E) of the tropical forests in this area decreased in the order: evergreen forest > slightly disturbed evergreen forest > broad-leaved hill forest > tropical montane shola forest > evergreen- grassland > shola-grassland. There are variations in the tree species diversity across samples in the same forest type, especially when the samples are taken from the ecotone or near the forest edge. Evergreen forest has a very high canopy cover which results in a sparse understorey cover and a very heterogeneous microclimate that inturn permits development of a species-rich understorey and maintains high tree species diversity. Tree species with small population sizes, especially the species represented by only one individual, are key components in maintaining species diversity of the forest vegetation studied. The pattern of distribution of tree species of different girth classes displayed a long tail at the end of the curve, showing high regeneration and a healthy population.

The chapter that follows will discuss the bird community composition of the various habitat types discussed above and would attempt to decipher the influence of the vegetation in structuring the bird community.

Evergreen forest

Broad-leaved hill forest

Shola forest

Shola grassland

CHAPTER IV

BIRD COMMUNITY STRUCTURE AS A FUNCTION OF ALTITUDINAL GRADIENT

CHAPTER IV

BIRD COMMUNITY STRUCTURE AS A FUNCTION OF ALTITUDINAL GRADIENT

4.1 INTRODUCTION

A major goal of community ecology is to find whether ecological communities are structured in space and time and to reveal the underlying processes and mechanisms (MacArthur and Wilson 1967; Cody 1974; Wiens 1989; Rosenzweig 1995; Whittaker 1998; Drake *et al.* 2002). Tropical communities offer particularly interesting and more refined tests of both ecological and evolutionary hypotheses (Stacy *et al.* 1996). However, the best studied tropical ecosystems are not thoroughly understood (Patterson *et al.* 1998). Quantitative studies of the relationship between birds and their habitats are important because they provide understanding of the impacts of natural and human factors on avian diversity (Heikkinen *et al.* 2004). Many studies have investigated seasonal variations in bird species richness or bird community composition at a given place (e.g., Karr 1976; Karr and Freemark 1983; Braithwaite *et al.* 1989; Loiselle and Blake 1991).

Daniels *et al.* (1989), Johnsingh and Joshua (1994), Jayson (1994), Pramod (1995), Javed (1996), Gokula (1998), Gokula and Vijayan (2000, 2007) and Raman (2004) investigated bird community-habitat relationships in India. Raman (2004) also emphasized the role of coffee and cardamom shade plantation and rain forest fragments in bird conservation outside protected areas in the Western Ghats. Vijayan *et al.* (1999) and Vijayan and Gokula (2006) examined the changes in the bird community structure in different gradients of disturbance in the major forest types in the Nilgiri Biosphere Reserve. Prasad *et al.* (1998) prioritized localities for conservation using birds as one of the major indicators of habitats. Raman and Sukumar (2002) examined the effects of alterations of tropical rainforest vegetation structure and composition on bird community structure in the Western Ghats.

4.1.1 Why altitudinal gradient analysis?

Altitude is an important determinant of species richness in terrestrial communities. It is established among the ornithologists who compared communities in the tropics that diversity and abundance vary greatly among the habitats and along elevation gradients (Ding *et al.* 2005). Elevational range is correlated with habitat diversity because variation in elevation provides different climatic, edaphic and vegetative conditions. As elevation affects the condition of the physical environment and the kinds and amounts of resources available for breeding and foraging activities, the composition and structure of bird communities will change along elevational gradients (Able and Noon 1976; Cody 1981; Stevens 1992). Physical conditions become more adverse for some birds at higher elevations. As elevation increases, the availability of resources for birds diminishes reflecting differences in forest stand structure, site productivity, plant species composition, stand disturbance patterns, secondary biotic interactions, and available land area (McCoy 1990; Rahbek 1995; Hofer *et al.* 1999).

Many studies have noted the decline in the bird species richness with increasing elevation in general (Begon *et al.* 1996; Blake and Loiselle 2000). The observed declines may largely be attributed to the direct decline of the forest areas at higher elevations, declines in the abundance and size distribution of the vertebrates, competition and changes in the environmental conditions (Terborgh 1971; Blake and Loiselle 2000). The effect of area is very important as the areas of equal sized elevational belts may vary with elevation. In other words areas often decrease with elevations because of steeper terrain towards the highest peaks (Rahbek 1995). Even though some investigations have shown the relationship between species richness and elevation to be monotonic (e.g., Wolda 1987; Navarro 1992; Patterson *et al.* 1998), Rahbek, 1997, Fleishman *et al.* 1998, Lees *et al.* 1999, Raman (2006), Acharya (2008) the other reviews (e.g. McCoy 1990; Rahbek 1995) demonstrate the species richness to be peaked toward the middle elevation and hump-shaped. Studies on different taxa along elevational gradients reveal that there is large variation in diversity patterns and important differences exist in the patterns of change among the functional groups (i.e. foraging guilds, migrant status) of birds

(Blake and Loiselle 2000). Even though diversity generally decreases at higher elevations in plants (Hamilton and Perrott 1981; Kessler 2001) and animals (Rahbek 1995; 1997; Gaston 2000; Heaney 2001; McCain 2005) they exhibit maximum diversity at mid-elevations, leading to a hump-shaped diversity distribution pattern.

In this context, the present study was attempted to find out whether assemblage structure, species richness and composition, and distribution of bird species differ among six habitat types namely evergreen-grassland interface (EGGL), evergreen disturbed (EGD), evergreen (EG), broad-leaved hill forest (BLHF), southern montane wet temperate forest (SHOLA), and shola-grassland (SHOLAG) (*see* chapter 2 for explanations) in SVNP along an altitudinal gradient.

4.2 METHODOLOGY

4.2.1 Fixed radius point count

Regular monthly sampling was carried out in different habitats namely shola forest, grasslands, mid-elevation broad-leaved hill forest, and evergreen forest in lower altitudes. Six sampling sites were established in the study area, representing a variety of habitat classes across each of the major vegetation types (See chapter 2). Sixty point count stations were established within an elevation gradient of 900 m to 2200 m which were accessed from three of the forest surveillance camps of the forest department. Of the six sampling sites, three were accessed from the camp located at Sairandhri, one from Walakkad and two from Sispara.

Bird data were collected during 2002-2005 from 60 point count stations. Fixed distance point counts of 30 m radius were used to sample bird communities. Point count stations were laid out systematically at a minimum distance of 100 m (Bibby *et al.* 2000). A total of 60 points were marked and numbered (10 points each in three transects of evergreen forest, 10 points each in broad leaved hill forest, shola forest and shola with grassland at different altitudes). Point count stations were established at least 40-50 m away from the habitat edges (e.g. forest edges). Species, number of individuals and vertical stratum were recorded for each bird encountered lasting for 10 minutes at each point. Counts were conducted between 07:00 and 11:00 in the morning except for days with heavy rain, mist or strong wind. Counts at each station were replicated in different days in a month, thus the total data set was for 2314 point counts. Points were scanned for birds while entering and leaving the point to spot any undetected birds (Raman 2003).

4.2.2 Statistical analyses

There are three approaches to estimate species richness from samples, (Williams *et al.* 2007) namely (1) fitting parametric models of relative abundance (e.g. log normal distribution), and using the shape of the species abundance distribution to deduce the total species richness, (2) non-parametric estimators, and (3) extrapolation of species accumulation or species-area curves (Magurran 2004). All these methods had been worked out in this chapter. Bird species diversity, richness and evenness were calculated using the statistical package- Species Diversity and Richness (SDR) programme (Henderson and Seaby 2007, Pisces conservation LTD). For comparisons of mean species diversity among the sites, programme PAST (Hammer *et al.* 2007) was used. Species richness using non-parametric estimators such as first and second order Chao, first and second order Jackknife were used to determine the estimated species richness with the software EstimateS, version 7 (Colwell 2004).

Species richness can be measured as number of species, usually of selected groups of organisms, or species diversity may be combined with the evenness of the abundance distribution of the species. The best known diversity indices are the Shannon-Weaver, the Simpson's and the Fisher's alpha (Magurran 1988). To compare species diversity among sampling units and between habitats, I used the Fisher's logarithmic series parameter, alpha (α) (Fisher *et al.* 1943). Fisher's alpha is regarded as a robust, reliable measure of diversity, relatively unaffected by sample size, and widely used in biodiversity studies (Hayek and Buzas 1997; Magurran 2004). Shannon-Weaver diversity (H') and evenness (E) were calculated for all the habitats (*See* Chapter 3). These indices were also computed separately for each stations in order to correlate with diversity and other habitat variables calculated in the corresponding points. Equitability or evenness refers to the pattern of distribution of the individuals between the species.

The application of species abundance models in biological indication can be useful when one knows *a priori* that a change in the observed pattern can be associated with some type of ambient degradation (Tokeshi 1993). It is clear that the interest in describing and explaining distributions of species abundance extends beyond a basic desire to understand factors influencing community structure. Thus, I have tested the goodness-of-fit of species-abundance distributions of the bird guilds to the log-series and truncated lognormal models (*see also* Pielou 1975; Magurran 2004). The lognormal model represents distributions where species of intermediate abundance are more common, while log-series assumes that rare species occur more frequently in a sample (May 1975; Tokeshi 1993). The lognormal species abundance distribution is widely used to describe patterns in community structure. Log series distribution displays observed and expected abundances of the species.

k-dominance curve is a graphical method of representing diversity, wherein percentage cumulative abundance is plotted against log species rank. Higher dominance and hence lower diversity is represented by curves that originate away from the origin and tend to remain above other curves (Srinivasa *et al.* 2004).

Rarefaction curves were used to estimate the number of species expected [E(S)] in a random sample of individuals taken from a census or collection and to compare species richness among sites. Chi-squared tests were used to determine the patchiness in species populations or in whole communities (i.e. whether the organisms were distributed randomly through out the samples, aggregated, or uniformly distributed) with Biodiversity Pro (McAleece *et al.* 1997).

Bray-Curtis measure of similarity (Krebs 1989) was calculated to compare the distribution patterns of bird species across the six plant communities and to compare community structure and functional groups. To verify how sampling units were related to each other in species composition, cluster analysis was performed, using the unweighted pair group method with arithmetic mean

(UPGMA) as the aggregation algorithm to the matrix of inter-specific Bray-Curtis distances (McGarigal *et al.* 2000).

To examine the association between habitat on avifauna composition, the Bray-Curtis index of similarity (Bray and Curtis 1957; expressed equivalently as dissimilarity by subtraction from 100) was calculated pairwise for all sites from pooled data for birds and vegetation adopted from Clarke and Warwick (1994). We then investigated the effects of habitat on this similarity matrix in the following way.

The multiple axes based polar ordination indices were calculated for the vegetation and bird community respectively. The algorithm used was the Bray-Curtis or Wisconsin ordination which was initially developed for comparing vegetation across habitats and was further refined and applied in many animal community studies (Uehara-Prado *et al.* 2007). Similarity Index Ratio (SIR) of *bird community similarity* upon *vegetation similarity* across habitats was calculated as:

Similarity Index Ratio (SIR) = S1/S2

Where, S1= Bird similarity index, and

S2= Vegetation similarity index.

SIR would yield a value of 1 if two habitats resemble each other with respect to vegetation and bird community. The value of SIR will increase or decrease as a function of dissimilarity between habitats by way of vegetation or bird community structure. The value will increase from 1 when there is a higher similarity between the bird community structures than the vegetation similarity between habitats and will decrease from 1 when the reverse is true.

All analyses were performed using the Statistica 6.1 (Statsoft, Tulsa, OK, USA) and SPSS Version 11.0 (Norusis 2001). Mean and standard deviations (± SD) and averages and standard errors (± SE) are given throughout the chapter. Significance levels were set at $p < 0.05$ for all analyses. Chi-square test was used to detect any significant difference in the abundance of different trophic groups and major bird species among the six habitats. One-way ANOVA and t tests were used to find significant differences of bird and habitat variables between these habitats. Pearson's correlation was used to test the bird-altitude relationship separately. Seasonal differences in species richness and total abundance, as well as abundance of more common species (over all sites), were tested. Depending on these seasonal differences, species were classified as migrants (summer visitors and winter visitors) and residents. Bird classification and nomenclature follow Grimmett *et al.* (1998).

4.3 RESULTS

4.3.1 Bird community structure

A total of 5253 individuals belonging to 108 species from six habitats were recorded, 14 of which are endemic to the Western Ghats. Opportunistic observations added 37 species which were not recorded from the transects totaling to a list of 145 species (Appendix 4.1). The species accumulation curve showed an increasing trend even after 36 months of the study (Figure 4.1).

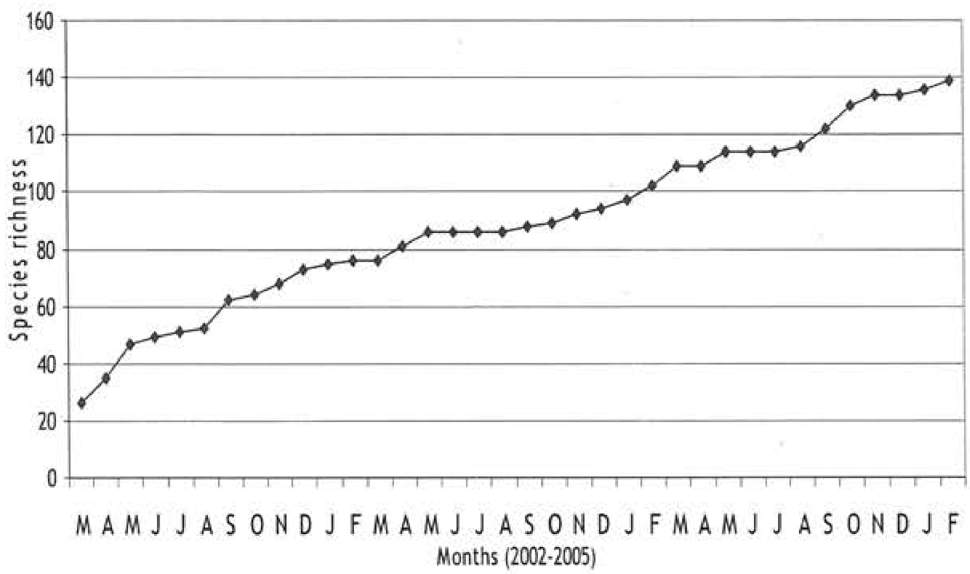


Figure 4.1 Bird species accumulation curve from the various habitats in SVNP during 2002-2005, including opportunistic observations.

Of the various estimators denoted the species richness, Chao 1 yielded 140 species, the second order Jackknife yielded a maximum of 157 species and bootstrap yielded the minimum of 123 species (Table 4.1).

Table 4.1 Summary of diversity measures for each habitat. Species observed is observed species richness. Ch1 and 2 refers to the Chao 1 and 2 richness estimator ICE refers to the value for the incidence-based richness estimator, calculated using the programme EstimateS (Colwell 2004).

Species observed	Ch 1	Ch 2	Jack 1	Jack 2	Bootstrap	ACE	ICE
108	140.02	147.05	141.33	157.87	123.25	139.07	146.97

Variation was prominent in terms of the numbers of species and individuals among different transects (*see* Table 4.2). While comparing transects in the same elevation or sites, EGGL, EGD and EG, EG had the highest species richness (58, 60 and 64 respectively). Of the species detected, 53.7% was recorded at the EGGL site, 55.5 % at the EGD site and 59.2% at the EG site. The species contribution in SHOLA was 45.3% followed by SHOLAG with 36% and BLHF with 22.8%. Of the total individuals, 18.6% were recorded at the EGGL site, 25.6% at the EGD site, 27.2% at the EG site 11% at the SHOLAG, 11.8% at the SHOLA and the least was at BLHF with 5.73%. Evergreen forest at lower altitudes had the highest mean species diversity, whereas BLHF at mid-elevation was least diverse (Figure 4.2).

In the evergreen forest, 82% (79 species) were forest-affiliated species and only 14.5% (9 species) were open-country species. Species richness was significantly lower in BLHF and then SHOLAG than the other habitat types (Figure 4.2).

From 2314 point counts in the six habitats, 3746 detections of 85 species were made in the wet evergreen forest (Table 4.2), 300 detections of 34 species were made in the BLHF, 578 detections of 50 species were reported from the SHOLA and 612 detections of 38 species in SHOLAG. The minimum number of species and individuals was reported from BLHF (Table 4.2, Figure 4.2).

A strong negative correlation was observed between rainfall and species richness ($r_s = -.488$, $p < 0.01$). Species richness varied significantly among the altitudinal ranges. Although species richness was negatively correlated with elevation there was a dearth in species richness and abundance at BLHF (Figure 4.3). Significant differences were found in species richness among the six vegetation types ($F = 4.43$, d.f. =5, $p < 0.001$).

Table 4.2 Bird species richness and abundance observed, in relation to habitat types.

Habitat	Mean Individuals	S D±	S E ±	Total Individuals	Total Species
EGGL	9.046	28.872	2.778	977	58
EGD	12.565	35.275	3.394	1357	60
EG	13.241	37.412	3.6	1430	64
BLHF	2.778	6.454	0.621	300	34
SHOLA	5.352	14.937	1.437	578	50
SHOLAG	5.667	16.964	1.632	612	38

Bird abundance varied across habitats and altitudes in the park with a negative correlation with respect to altitude (Figure 4.2) (rs = -.845, p <0.01). Total bird abundance was the highest within the evergreen habitat of SVNP.

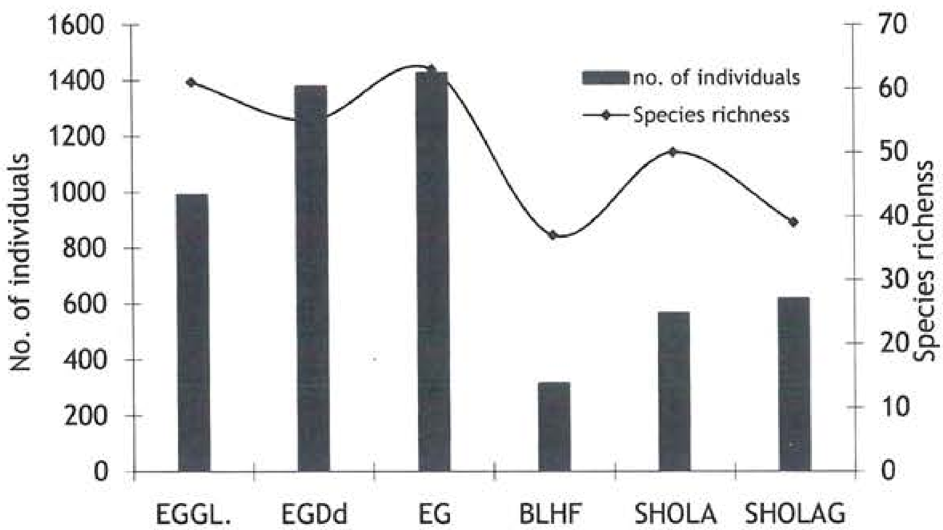


Figure 4.2 Bird species richness and abundance observed, in relation to forest types at the SVNP.

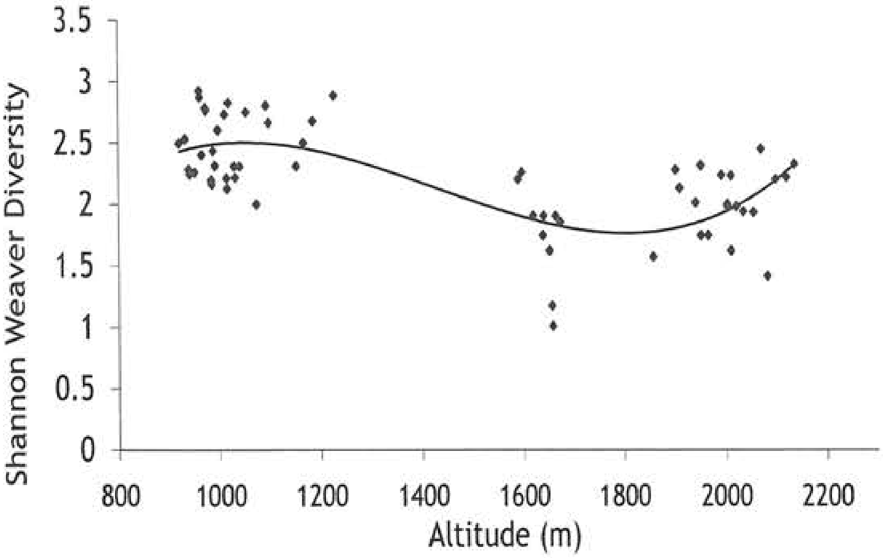


Figure 4.3 The bird species diversity plotted against altitude in SVNP.

Shannon - Weaver diversity was the highest in SHOLAG (3.098) and minimum in BLHF (2.89). Significant difference in the diversity indices (H') and Fisher's alpha (α) of various habitats surveyed is shown in Table 4.3 Shannon-Weaver diversity index differed significantly among the different habitats (One-way ANOVA, F= 13.63, df = 5, p = < 0.001). The highest Fisher's alpha (14.12) was reported from EGGL, whereas the lowest was from BLHF (9.25). The difference in diversity was the highest between EG and BLHF (t= -0.278, p<0.001). It was not statistically different when we compared the Shannon-Weaver diversity index of EGD and EG (t=-1.33, p = 0.183) whereas EGD and BLHF was significantly different (t=1.886, p < 0.001). It was clear that all the high elevation transects were not significantly different in terms of their species diversity as shown between SHOLA and SHOLAG (t=-2.96, p = 0.06).

Table 4.3 Important diversity estimators and equitability of the birds in the habitats surveyed.

Sample	Fisher's α	Shannon H'	Equitability E
EGGL	14.122	2.941	0.628
EGD	12.347	2.984	0.637
EG	13.761	3.047	0.651
BLHF	09.259	2.893	0.662
SHOLA	12.804	3.034	0.648
SHOLAG	10.250	3.098	0.618

Several species showed seasonal trends. Species fall generally into groups as residents and winter visitors, such as Indian Blue Robin, Leaf Warblers. Seasonal differences of some species was observed in the entire altitudinal transect (Figure 4.4). For example, the Crimson-backed Sunbird was common in all seasons other than in monsoon, while Indian Pitta is a migrant recorded during winter and leaves during monsoon. Species richness and total abundance both were slightly higher in winter than in summer, although these differences were not significant.

Figure 4.4 Bird species diversity from the various months during 2003-2004 in SVNP.

4.3.2 Endemics

Of the 16 species considered endemic to the Western Ghats (Stattersfield *et al.* 1998; Daniels 2003), 15 species were recorded from the study area while only

14 were recorded during the present study. A comparison of the status of the endemic birds in the study area is shown in Table 4.4. Of the total 14 endemics, 11 were observed at EG site, nine each at the EGD site, and EGGL site, followed by eight each at the SHOLAG and SHOLA and the least was at BLHF with six species (Table 4.4). However, in a recent revision of classification of Indian Sub-continent birds by Rasmussen and Anderton (2005) identified 25 species endemic to the Western Ghats.

Table 4.4 List of endemic birds of Western Ghats and their occurrence in SVNP.

	Common Name	Scientific Name	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
1	Black-and- orange Flycatcher	*Muscicapa nigrorufa*		*	*		*	*
2	Broad-tailed Grass-Warbler †#	*Shoenicola platyura*						
3	Crimson-backed Sunbird	*Nectarinia minima*	*	*	*	*	*	*
4	Grey-headed Bulbul	*Pycnonotus priocephalus*	*	*	*	*		
5	Malabar Grey Hornbill	*Ocyceros griseus*	*	*	*	*		
6	Malabar Parakeet	*Psittacula columboides*	*	*	*	*		
7	Nilgiri Pipit#	*Anthus nilghiriensis*					*	*
8	Nilgiri Laughingthrush#	*Garrulax cachinnans*					*	*
9	Nilgiri Wood-pigeon#	*Columba elphinstonii*	*	*	*	*	*	*
10	Nilgiri Flycatcher#	*Eumyias albicaudata*	*		*	*	*	*
11	Rufous Babbler	*Turdoides subrufus*			*			
12	White-bellied Shortwing#	*Brachypteryx major*	*	*			*	*
13	White-bellied Blue-flycatcher	*Cyornis pallipes*	*	*	*		*	*
14	White-bellied Treepie	*Dendrocitta leucogastra*	*	*	*			
15	Wynaad Laughingthrush	*Garrulax delesserti*			*			
	Total		9	9	11	6	8	8

Note: # = Vulnerable († = not recorded in the present study, * = Present).

There was a variation in the distribution of the endemic birds along the altitudes, for e.g. Rufous Babbler was found only in the evergreen forest of the low to medium altitudes, and Nilgiri Laughingthrush an inhabitant of the SHOLA in higher altitudes. Species that were not detected during point count sampling but recorded from the study area are presented in Appendix 4.1

4.3.3 Migrants

The occurrence of the latitudinal migrants was more or less same at both the low and high altitudes, with a record of 15 species of migrants in the EGGL site and SHOLA. But their species composition was different. Only eight species of migrants used BLHF (Figure 4.5). The proportionate abundance of latitudinal migrant species was high at 2000 m but was low at 1500 m. This distribution was statistically different across the sites (λ^2= 5.53, d.f =5, p < 0.05). The arrival of winter migrants during September- December significantly influenced the bird fauna of the park contributing much to the species richness (Figure 4.5)

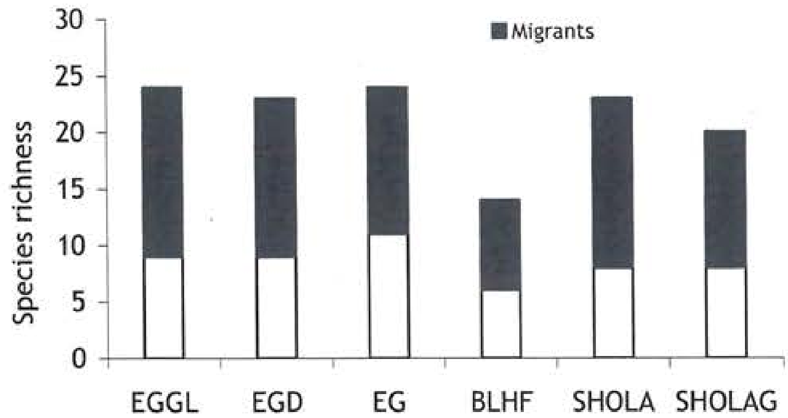


Figure 4.5 Comparison on the occurrence of endemics and migrants along different habitats in SVNP.

4.3.4 Trophic groups

A total of 14 trophic groups or guilds were identified. The species richness of omnivores dominated the community with 32 species followed by carnivore. It was followed by 14 each of aerial and understorey insectivores (Figure 4.6a and b). Fewer groups were present in the BLHF, but granivore-frugivore guild was more here. Aerial insectivores were not recorded during this study in the EG site, and no carnivores were recorded from the BLHF (Figure 4.7). There was a significant difference in the distribution of species across different guilds (λ^2=45.83, df=13, p <. 001) in different habitats (Appendix 4.4).

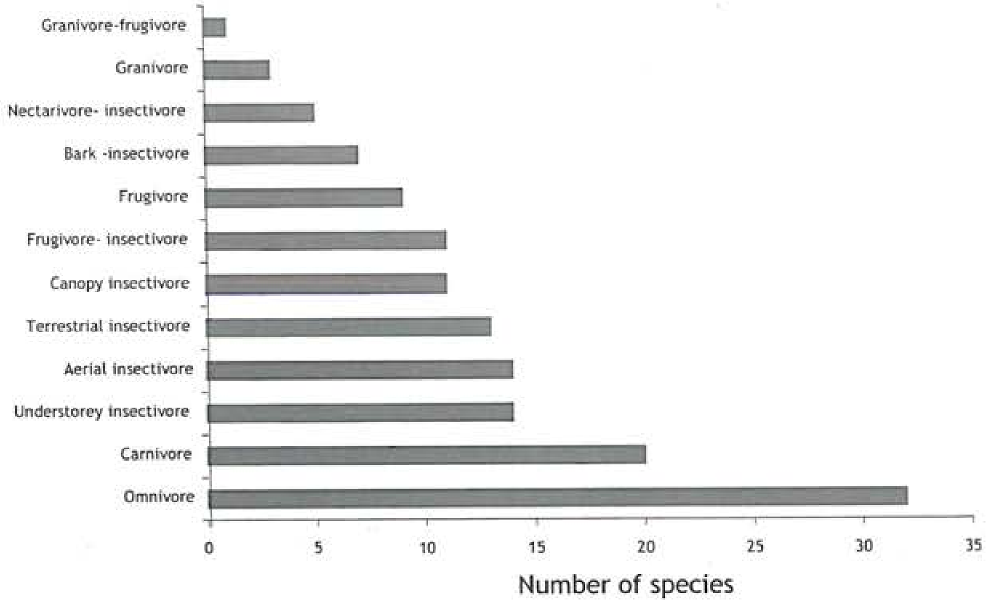


Figure 4.6a Total number of species represented in different trophic categories.

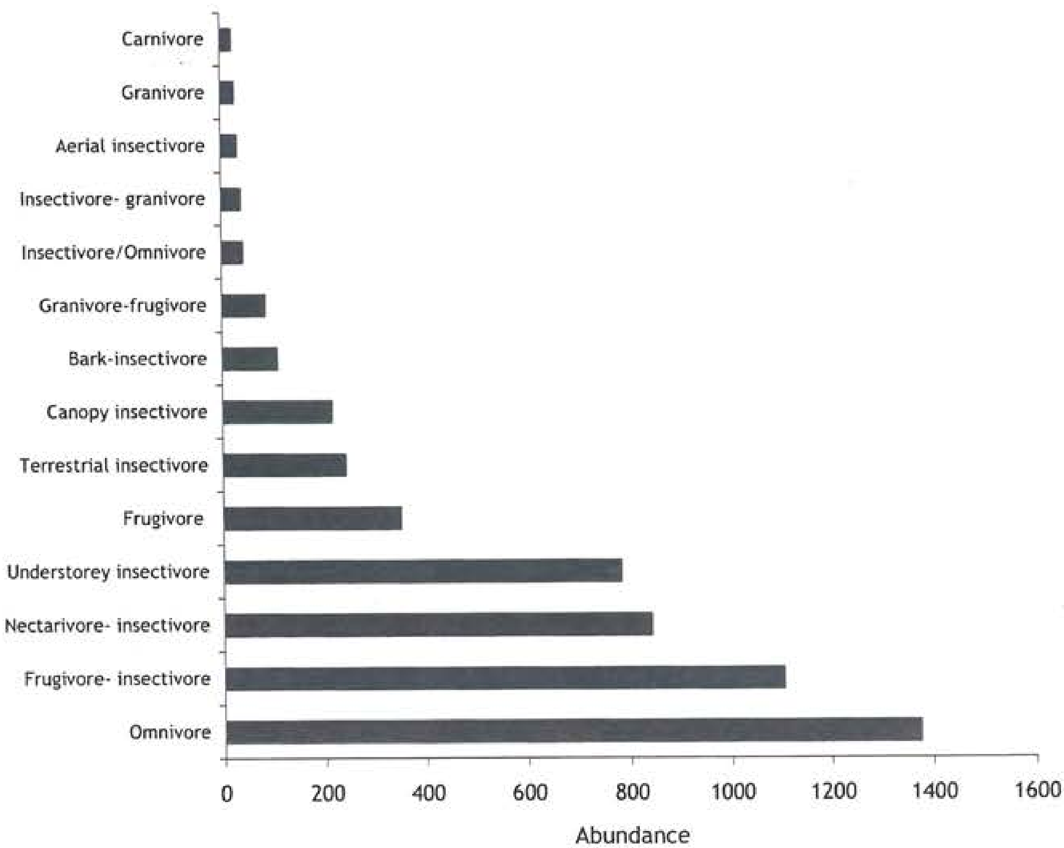


Figure 4.6b Total number of individuals represented in different trophic categories.

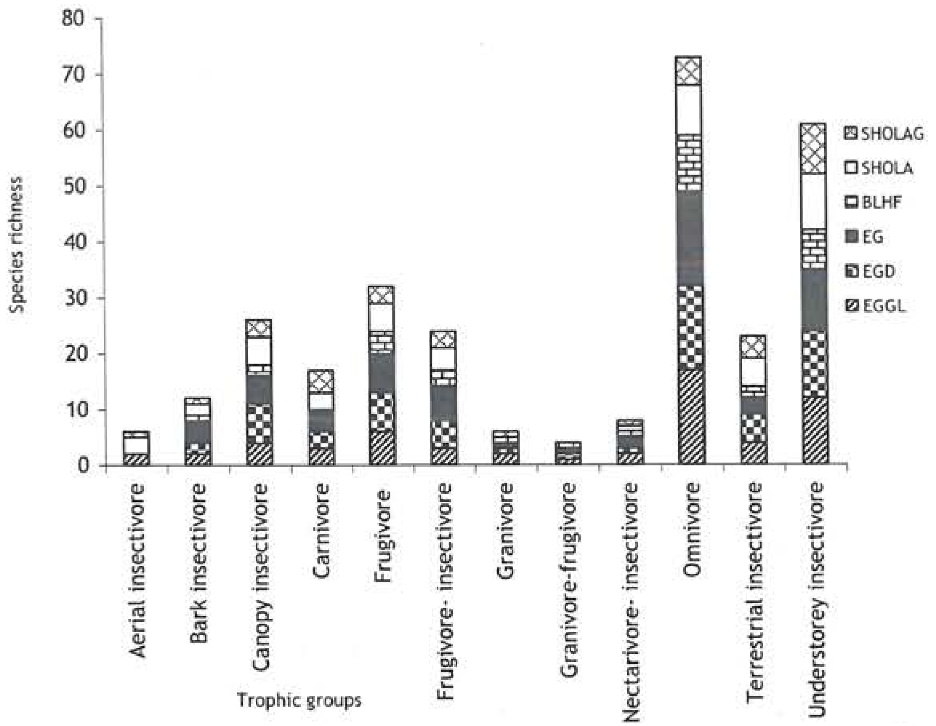


Figure 4.7 Species richness in different trophic categories in various habitats.

The abundance scenario was totally different with the frugivore-insectivore in the first rank, followed by nectarivore-insectivore, omnivore, understorey insectivore, and then frugivore (Figure 4.7). Granivore-frugivore was the dominant trophic group in the EG (Figure 4.8) and this group was less represented in the EGGL where the dominant group was aerial insectivores. There was significant variation in the occurrence among the habitats. (One-way ANOVA, F= 2.26, d.f. = 5, $p < 0.01$).

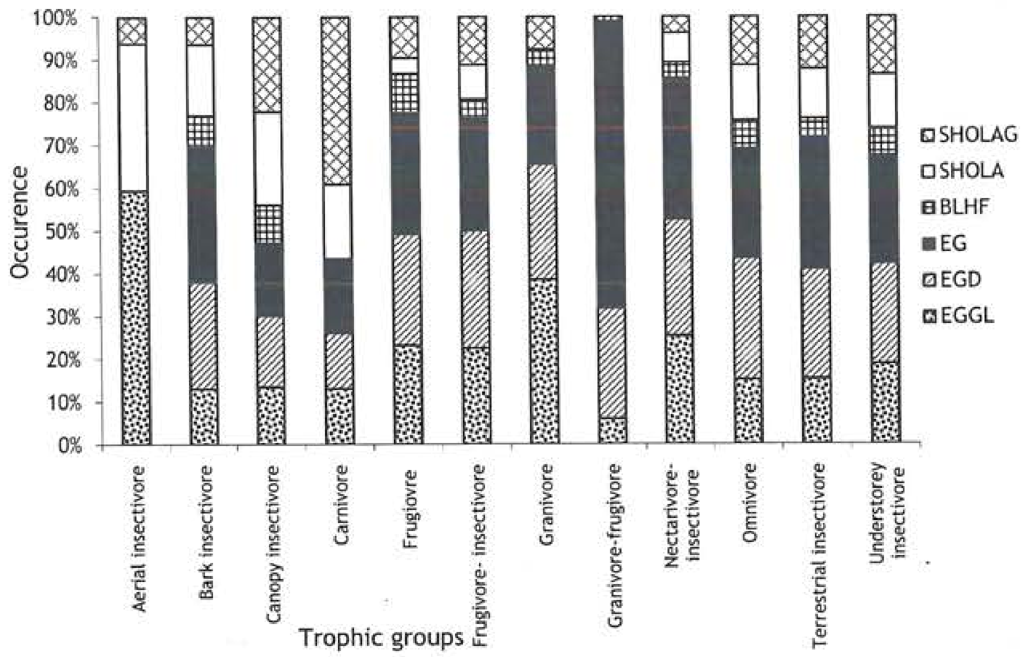


Figure 4.8 Variation in the proportional abundance represented by different trophic categories along an altitudinal gradient.

Diversity of the trophic groups was very high in the SHOLAG with the highest H' (2.35) and Fisher's alpha value of 8 which was very poor in EG with 3.92 (Table 4.5).

Table 4.5 Diversity of different trophic categories represented in different habitats.

	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
Number of Guilds	12	12	11	10	13	14
Shannon H'	2.13	2.12	2.099	1.958	2.303	2.353
Fisher's alpha	4.594	4.511	3.918	4.993	5.705	8.007

4.3.5 Distribution pattern of birds in different habitats.

In this study many species were of rare occurrence in singletons (i.e. species recorded only once) and doubletons (i.e. species recorded twice). EG reported more singletons, whereas the EGGL was with more doubletons (Figure 4.9).

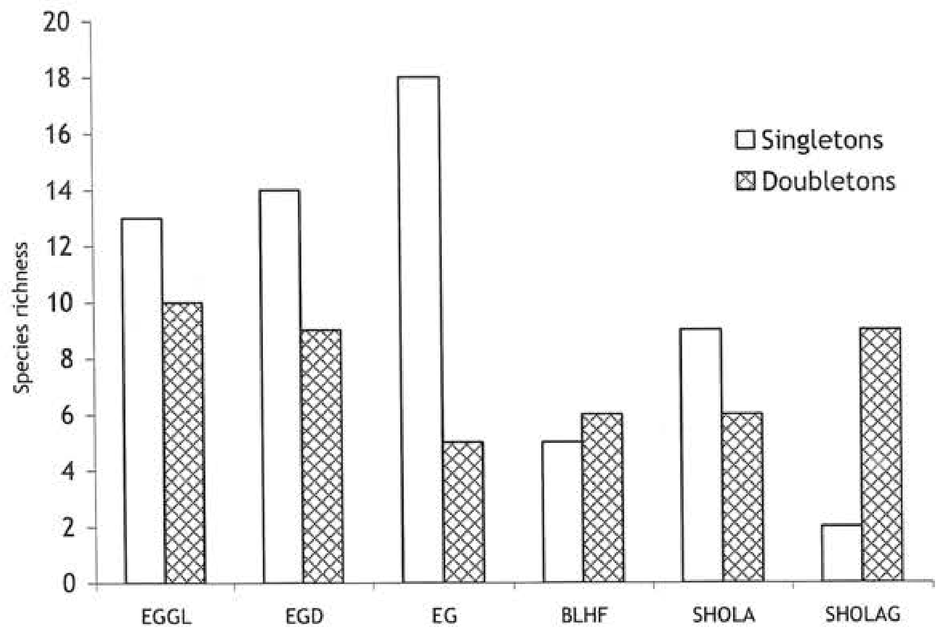


Figure 4.9 Occurrence of doubletons and singletons of birds in SVNP.

In this investigation both log series model fit and log normal fit were shown in all habitats (Table 4.6). Log series model fit showed by EGGL (p = 0.972), EG (p = 0.831), SHOLA (p = 0.442 and SHOLAG (p = 0.615) (Figure 3.10). But it was different for EGD (p = 0.194), and BLHF (p = 0.113) (Figure 4.10).

Table 4.6 Log normal model fit observed in bird communities of SVNP.

	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
Total predicted species in Community	67.33	73.03	80.48	35.26	54.30	39.42
Total observed species	58	60	64	34	50	38
Species behind the veil line	9.33	13.03	16.48	1.26	4.30	1.42
Diversity statistic lambda	88.191	82.779	88.10	66.105	86.559	65.003
λ^2 value	2.760	6.318	2.794	5.527	2.503	2.308
Degrees of freedom	6	6	6	4	5	5
p value	0.838	0.389	0.834	0.237	0.776	0.805

Abundance and frequency of occurrence of birds in SVNP showed great variation. The number of species was the highest at the lowest abundance and thereafter to taper somewhat in the manner of the empirical distribution shown in (Figure 4.11) which generally is known as the reverse "J-curve".

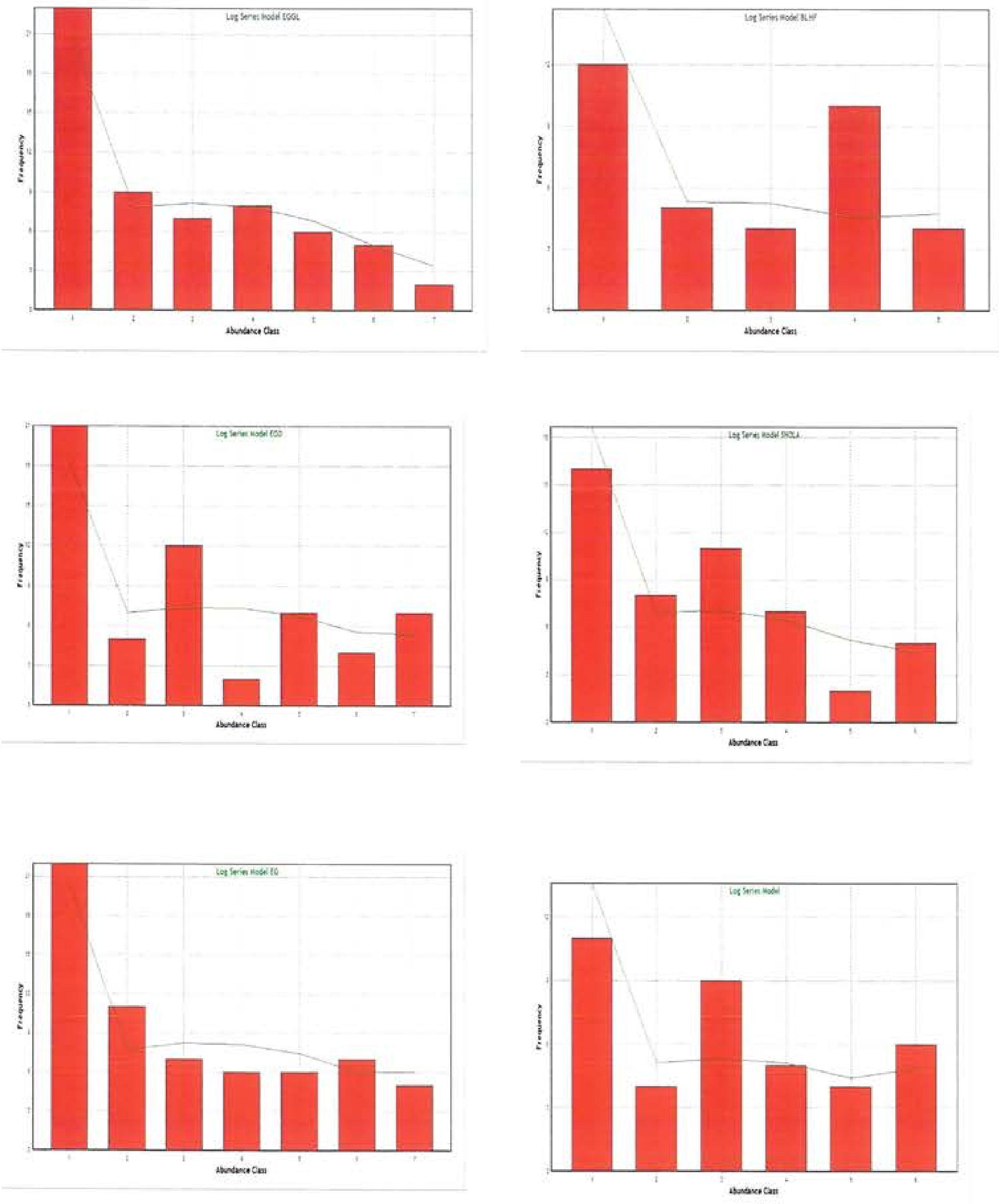


Figure 4.10 Log series model distributions of birds in the various habitats in SVNP.

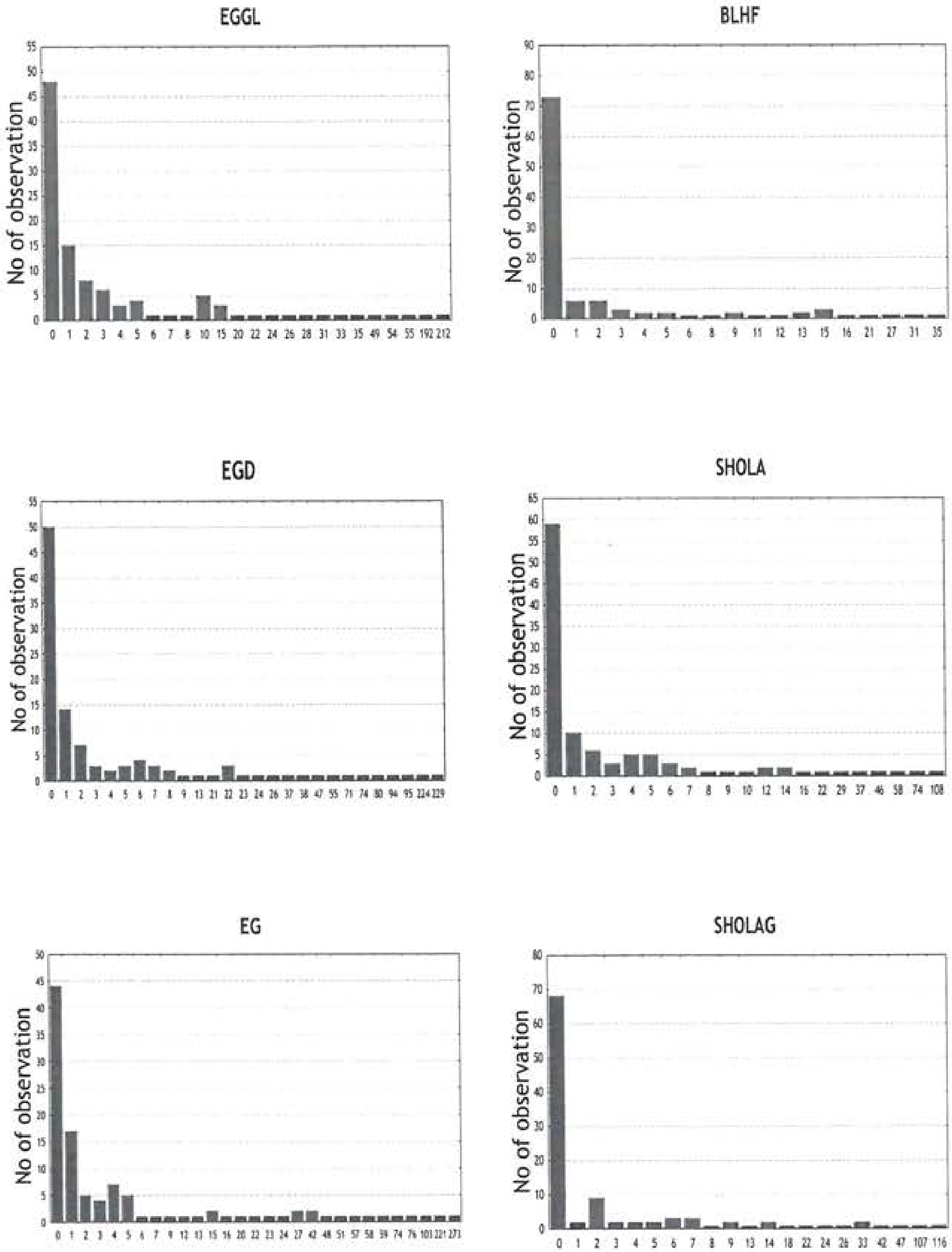


Figure 4.11 Abundance and frequency of occurrence of birds in SVNP in various habitats. Note the zero in x axis depict the absence of species.

In the present study, *k*-dominance curves showed that maximum diversified habitat was in EG transect and minimum diversity was in BLHF. The curves of EGGL, EG, and EGD showed the intermediate diversity in consonance with intermediate level of disturbance. However, these sites cannot be discriminated among themselves, because their curves intersected each other (Figure 4.12).

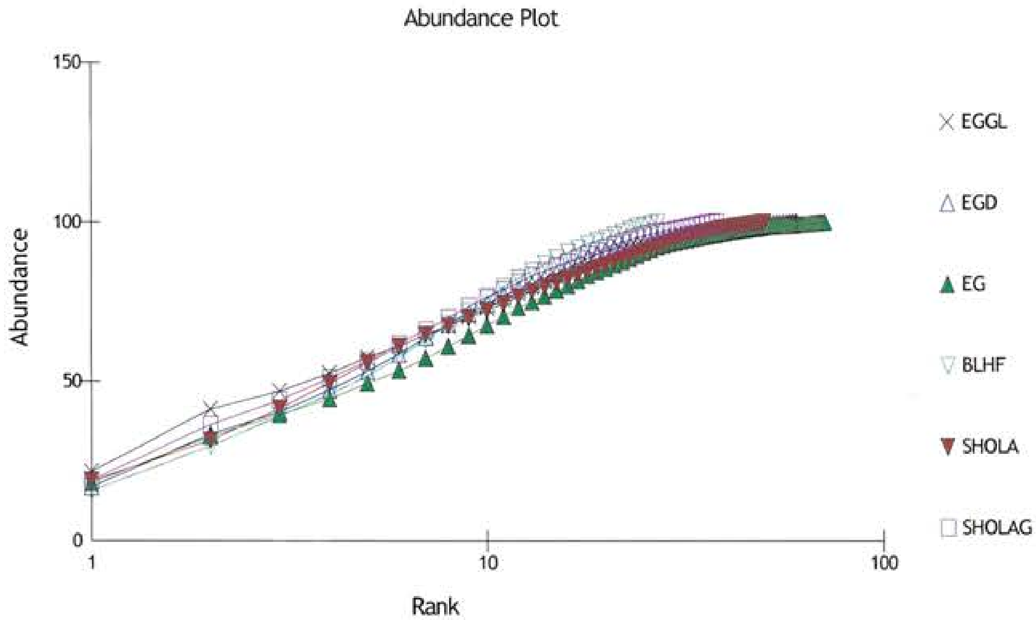


Figure 4.12 Ranked proportional abundance of birds (comparison of the dominance pattern through *k*- dominance curves) across different transects within SVNP.

Rarefaction curves were generated for each sample in order to compare species richness for a standard sample size (Ludwig and Reynolds 1988). Note the high species richness of the EG site and the species poor BLHF. Species richness estimates from rarefaction curves indicate that EGGL and EGD contained more species than BLHF. Rarefaction analysis showed that EG was the richest habitat for bird species, followed by EGD and EGGL sites (Figure 4.13). This analysis also showed that low land forests are richer in species than the other vegetation strips investigated while BLHF was the poorest habitat for bird species.

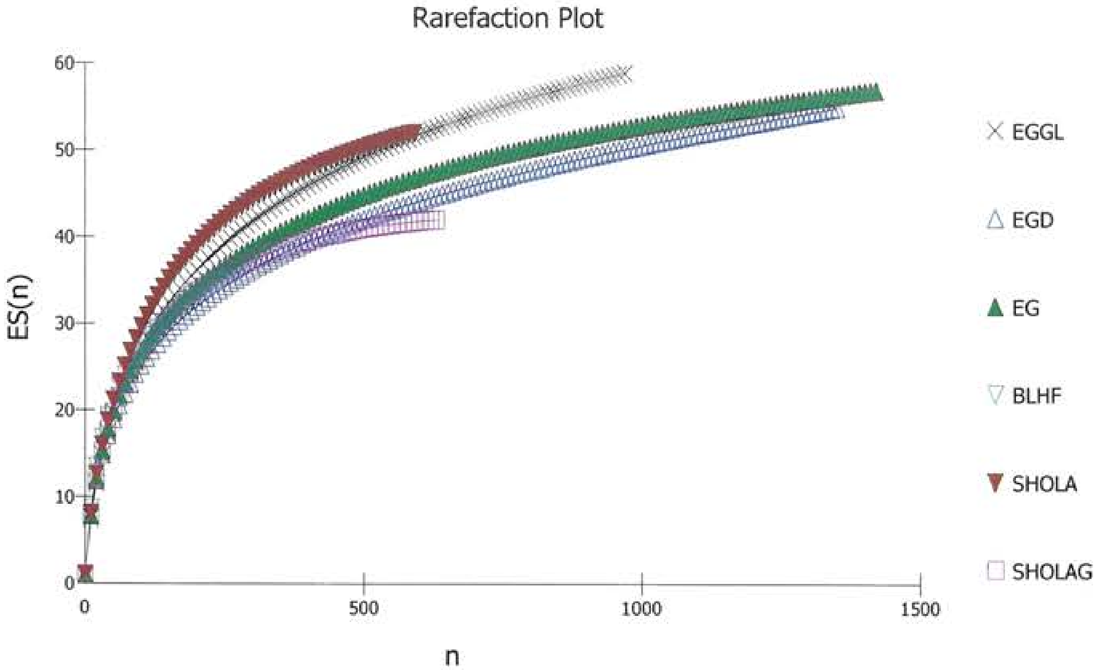


Figure 4.13 Rarefaction curves for the expected number of bird species in six samples from equal areas in different forest types investigated at SVNP. Numbers on the x-axis correspond to the total sample of individuals; total rarefied species richness of all individuals encountered in each habitat. Dissimilar trajectories of curves from each forest type indicate significant differences in diversity.

Table 4.7 shows the distribution of some major species along the altitudinal gradient. Species that were frequently recorded beyond 1800 m were those with loud and distinctive calls, such as the Nilgiri Laughingthrush (Appendix 4.2). The Common Rosefinch was recorded only once in lower altitude. The Great Hornbill was strongly associated with evergreen forest in this study, and has been shown to avoid high altitude. In contrast, the Crimson-backed Sunbird was strongly associated with all forest types and has been shown to be an important pollinator of most of the shrub species which are associated. The mean density of each species, sampled from the point counts, is given in Appendix 4.2. Chi-squared tests revealed that ten bird species had significantly greater abundance in the evergreen forest than in the high altitude forest (Appendix 4.3). They were White-bellied Treepie, Black-naped Monarch, Malabar Whistling Thrush, Grey-headed Canary Flycatcher, White-bellied Blue

Table 4.7 Distribution of some species along an altitudinal gradient from the various elevations/ habitats studied in SVNP

	Altitudinal range (msl) in meters					
Species	1019-1227	1011-1056	0962-0998	1560-1675	1858-2034	1974-2136
Brown-cheeked Fulvetta	*	*	*	*		
Black-and-orange Flycatcher			*			*
Common Flame-back	*	*	*	*		
Crimson-backed Sunbird	*	*	*	*	*	*
Dark-fronted Babbler	*	*	*	*		
Greater Racket-tailed Drongo	*	*	*	*		
Greenish Warbler	*	*	*	*	*	*
Grey-headed Canary Flycatcher	*	*	*	*	*	*
Grey Jungle Fowl	*	*	*	*		
Grey-headed Bulbul	*	*	*	*		
House swift	*	*	*	*	*	*
Indian Blue Robin	*	*	*	*	*	*
Indian Scimitar Babbler	*	*	*	*		
Malabar Parakeet	*	*	*			
Malabar Trogon	*	*	*			
Malabar Whistling Thrush	*	*	*	*		
Mountain Imperial Pigeon	*	*	*	*	*	*
Nilgiri Laughingthrush					*	*
Nilgiri Pipit					*	*
Nilgiri Wood Pigeon	*	*	*	*	*	*
Oriental White Eye	*	*	*	*	*	*
Pied Bushchat					*	*
Pompadour Green Pigeon	*	*	*			
Red-whiskered Bulbul	*	*	*			
Southern Hill Myna	*	*	*	*		
South-Indian Black bulbul	*	*	*	*	*	*
Thick-billed Flowerpecker	*	*			*	*
Tickle's Leaf Warbler	*	*	*	*	*	*
White-bellied Blue Flycatcher		*	*		*	*
White-bellied Treepie	*			*		
White-cheeked Barbet	*	*	*	*		
Yellow-browed Bulbul	*	*	*	*		

Flycatcher, Large-billed Leaf Warbler, Puff-throated Babbler, Indian Scimitar Babbler, Dark-fronted Babbler and Brown-cheeked Fulvetta. Eleven species exhibited significantly greater abundance in the SHOLA than in the EG forest of which four major species were Nilgiri Laughingthrush, Greenish Warbler, Black Bulbul, and Oriental White-eye. Chi-squared tests showed the patchiness in species populations or in whole communities with more than 50 species in aggregated form and the rest of 58 species had random distribution in the six habitats studied (Appendix 4.3). Sixteen species (14%) were common for all the altitudinal strips studied, five species (4%) were recorded from five habitats, 10 species (10.87%) from four habitats, ten species (10.8%) were recorded from three habitats and 23 (21.3%) species from two habitats, whereas 37 (34.2%) species were recorded from only a single habitat.

Bray-Curtis cluster analysis indicated maximum similarity between the EG and EGD (86.4%) and minimum (26.4%) between EGD and SHOLAG in their bird community composition although the forest is a continuous stretch. As expected there was a remarkable similarity in the avifauna of SHOLA with SHOLAG, 80.5% (Table 4.8).

Table 4.8 Bray-Curtis cluster analysis showing the similarity of birds of different sampling locations.

Habitats	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
EGGL	*	74.58	73.78	43.00	35.88	30.20
EGD	*	*	86.43	34.71	29.21	26.36
EG	*	*	*	33.70	29.17	27.12
BLHF	*	*	*	*	39.64	34.39
SHOLA	*	*	*	*	*	80.50
SHOLAG	*	*	*	*	*	*

The Bray-Curtis cluster analysis for the species composition among different habitats showed two major clusters (Figure 4.14). (1) Low to medium altitudes including all evergreen forest and BLHF and (2) High altitude areas having SHOLA and SHOLAG. However BLHF showed a distinct pattern and stood separate from the evergreen forests.

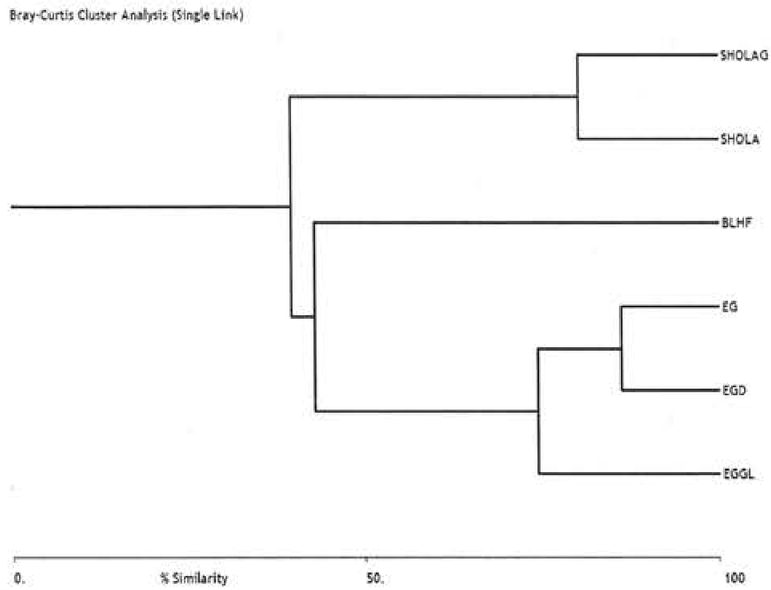


Figure 4.14 Bray-Curtis Cluster diagram to show the similarity of birds of different sampling locations in SVNP.

4.3.6 Bird-habitat relationships

Polynomial regression model of vegetation diversity with the bird species diversity showed that the relationship is not stronger R^2=0.1258. However, on the whole tree and bird communities in SVNP had similar patterns with a clear distinction between the evergreen forest types (EG, EGD and EGGL) and the Shola forest types (SHOLA, SHOLAG), and the BLHF forest type falling in between the two groups. At a finer scale similarities were same in the case of trees and birds in the high altitude areas, SHOLA and SHOLAG (Figure 3.14 and 4.14). In the case of evergreen forests, tree community of EG was closer to EGGL while in birds it was closer with EGD. BLHF showed closer link with high altitude areas in tree community, whereas in the case of birds it had closer link with evergreen habitats.

Table 4.10 provides the Similarity Index Ratio (SIR) of *Bird community similarity* (see Table 4.9) upon *vegetation similarity* across habitats (see Table 3.6; Chapter 3). The SIR showed that all the patterns were not similar as all the values were above one; the difference was more between SHOLA and EGGL, followed by EG - SHOLAG having similarity between habitats with respect to bird community structure is not as marked as the similarity between them by way of vegetation composition.

Table 4.10 Similarity Index Ratio of bird upon vegetation between forest types in Silent Valley National Park.

Habitats	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
EGGL	*	1.72	1.28	2.08	7.03	11.31
EGD			1.72	1.94	2.92	4.42
EG				2.00	3.19	5.17
BLHF					1.28	1.34
SHOLA						1.54
SHOLAG						*

4.4 DISCUSSION

The species richness in a species assemblage is a significant measure of biodiversity at the habitat level (Bunge and Fitzpatrick 1993; Colwell and Coddington 1994; Mao and Colwell 2005). The total record of 140 species in the present study is approximately 30% of the known avifauna in the Western Ghats according to the recently updated checklist (Anon. 2006). The present study recorded 68% of total species that have been reported from the park. The species richness of birds in the study area at SVNP (n=145) is comparable with similar habitats in the Western Ghats such as Periyar Tiger Reserve (181 species; Nair *et al.* 1985), Chinnar Wildlife Sanctuary (143 species; Nair *et al.* 1997), Siruvani foothills (129 species; Vijayan *et al.* 1998), Anamalai Hills (106 species; Raman 2006), Parambikulam Wildlife Sanctuary (134 species; NEST 2004), Nelliyampathy (109 species; Zaibin 2005) and Muthikulam Reserve forest (197 species; Balakrishnan 2006). The total of 211 bird species listed from Silent Valley, so far has been the result of the concerted efforts of independent observers and groups during the past decades (Sugathan 1999, Vijayan and Das 2006, Appendix 3.1). The lack of record of the rest of the species during my sampling in the park was partly an outcome of rarity of those unrecorded species and restriction of sampling to the six habitat types at a very localized scale. It is well known, that observed species richness can seriously underestimate actual species richness due to under-sampling of rare species (Williams 1964). Consequently, the species accumulation curve, i.e., the plot of the expected number of detected species as a function of sampling effort (Sanders 1968; Palmer 1993), has shown the probability of presence of more species. Thus, the estimated species richness of all the habitats when pooled together was higher than the observed richness, and the values obtained with the different estimators were fairly similar.

4.4.1 Community structure

The results of the study suggested that the bird communities in various habitats along the altitudinal gradient varied significantly in terms of bird species composition, abundance and diversity. There were prominent differences in bird community structure among the high and low altitude forest sites at SVNP.

At mid-elevation sites EG had the highest and EGGL had the lowest bird abundance and diversity. This pattern is in concert with the other community analyses elsewhere which suggested that structural and compositional complexity of habitats determine the bird species richness (Holmes 1981; Rotenberry 1985; Raman and Sukumar 2002). High degree of rarity in EG was reflected by the large number of singleton species detected from the habitat. Rarefaction curves did not approach an asymptote indicating that some new species were still being added to the list at all the sites except in SHOLAG.

A very high similarity between EGGL, EGD and EG in bird community composition can be the result of similar plant community and other environmental conditions. Raman and Sukumar (2002) noted that habitats with similar tree species composition had more similar bird communities. Similarity of some point count stations across these habitats in their major vegetation attributes, accounts for the very high resemblance in avian composition. Same explanation can be given for the lack of any significant difference in the bird species richness, diversity and evenness between the habitats at low elevations.

Derived species richness values yielded an estimate that is not very different from the other estimators. Higher richness and diversity of birds, though not significantly different, in the EG than the EGGL or EGD, were influenced by the occurrence of less abundant open-country species in the forest such as Eurasian Golden Oriole and Common Rosefinch, and other more open-wooded species such as Common Flameback, Rufous Babbler, Rusty-tailed Flycatcher and Verditer Flycatcher. Most of the bird species had significantly greater abundance in the wet evergreen forests than the shola forest possibly due to the microhabitat variations between the sites which in turn determine the occurrence of habitat specialists.

This investigation is in concert with the findings of Raman (2001) who reported that the pronounced turnover of bird species leads to a very different community composition at high elevations as compared to the lower elevations. As observed in this study, research elsewhere has shown that there is generally an inverse relationship between altitude and bird species richness (Gall and Longmore 1978; Hawkins 1999; Lan and Dunbar 2000), due to the reduced variety of habitats and area at high altitude. Chettri (2000) reported that bird species richness and diversity showed strong negative and linear trend with increasing elevations. The relationships of bird species richness and diversity were stronger with elevation than with tree species richness and diversity (Acharya 2008). I observed a pattern where more endemic species were found at low-middle altitude and were having a highly restricted distribution which was similar to the findings of Able and Noon (1976), who demonstrated a pattern in which low-elevation communities contained higher proportions of rare species,.

Presence of a few generalist and open-country species such as Red-whiskered Bulbul and Blyth's Reed Warbler within the low-land forest sites ('biological infiltration', Raman 2001) can be regarded as an indirect indication to the effect of localized man made disturbance undergone due to the conversion of surrounding landscape and the past history of selective logging in the site. It should be noted that Red-vented Bulbul, an open country species, was not recorded in the present study while there are records of the Red-vented bulbul, even breeding in these areas before two decades (Ramakrishnan

1983). It must be mainly attributed to the presence of the human occupancy associated with the dam construction in the area, which was later abandoned, which in turn resulted in a total dearth of human intervention and disappearance of the species too.

Ten bird species showed significantly greater abundance in the lowland forest site (Appendix 4.2) possibly due to the microhabitat difference of the lowland from that of the high land sites. EG had significantly greater tree density, canopy cover, canopy height and high proportion of lower-canopy trees and trees falling in smaller girth classes, more open and spacious under-storey (Chapter 5), and varying degree of ground cover than present in the BLHF site. The significantly low abundance of these bird species in the BLHF point to the fact that most of them are highly sensitive to microhabitat changes which usually accompanies increase of elevation. The transition tree-line between the evergreen habitat and BLHF lies at 1400 to 1500 m, and very few species were recorded above this. Several species showed seasonal trends (Figure 4.4).

Significantly greater abundance of 23 bird species in EG (Table 4.7) than SHOLA forest might be due to more stable climatic conditions, increased availability of resources or foraging opportunities in the different strata as compared to that in BHLF, and SHOLAG which have lower diversity of canopy profiles. However, it should be noted that limited visibility of birds moving in the upper-canopy of the forest would probably have underestimated the abundance of some of the forest-affiliated species in the forest (e.g. Asian Fairy Bluebird, Pompadour Green Pigeon).

While analyzing the bird community structure and composition, it is very important to classify the component species on the basis of their ecological attributes and habitat occupancy (Kitahara 2000). The present study demonstrates that species assemblages were significantly correlated to the habitat variability as shown by Daniels (1992).

Bird species richness and the numerical dominance of single bird species also decreased with increase in altitude. For instance at BLHF (1500 m), the relative abundance of Nilgiri Laughingthrush was nil, which abruptly increased up to 43% at SHOLAG (2200 m), and 47% at the highest elevation (2200 m). Highly significant difference between the relative abundance of this species at

BLHF and SHOLAG was obvious. However, Brown-cheeked Fulvetta showed an opposite trend to that of Nilgiri Laughingthrush; its relative abundance decreased with an increase in altitude. This difference may be attributed to adaptation for living in the unique microhabitats available (Vijayan *et al.* 1999).

4.4.2 Migrants

Migrants formed a smaller proportion of avifauna at SVNP, but the relative abundance of latitudinal migrants differed among elevations as observed by Loiselle and Blake (2000). Species composition of migrants was different at different elevational ranges, as most of them would be highly specific to their microhabitat preferences. Their seasonality was very pronounced as observed in Asian Paradise Flycatcher and Indian Blue Robin which used to arrive by mid-October and stay back up to March-April.

4.4.3 Endemics

High degrees of altitudinal preferences among the species such as White-bellied Treepie and Rufous Babbler might have affected the low endemic species richness in the high altitudes. Birds such as Nilgiri Laughingthrush showed consistency in their occurrence irrespective of seasonality coupled with harsh climate, largely because of their low behavioral plasticity (Vijayan *et al.* 2001).

Endemism is critical to the understanding and conservation of biological diversity, since these species are habitat specialists and are more sensitive to disturbance and prone to extinction (BirdLife International 2001, Vijayan and Gokula 2001). The birds of Western Ghats show moderate rates of endemism and this could be attributed in part to its location near the Pleistocene refugia. The basic idea of the refuge theory (Hamilton 1982) is that certain restricted areas, generally mountain ranges with high precipitation, have continuously supported the same vegetation type (with associated fauna) throughout the periods of generally unfavourable climatic conditions that have been associated with glacial cycles over the past two million years. The refuge theory is relevant both to an understanding of current distribution patterns and to the evolution of tropical species, because of isolation and subsequent allopatric speciation.

4.4.4 Trophic groups

Nectarivores and frugivores usually contributed more to the tropical avifauna and shows an increase in the relative importance with respect to elevation (Terborgh 1971; Stiles 1985). The greater abundance of the nectarivores, such as Oriental White-Eye shows the importance of the birds in the pollination. The total absence of the carnivores in the BLHF further strengthens the argument that it is a species poor habitat.

The temporal and spatial variation in the resource availability is a major controlling factor for the bird assemblages, which in turn affects the distribution patterns in various dimensions. Fruit and nectar may be more easily obtained than many invertebrate preys and are typically bound to have not much short-term, weather induced fluctuations in the abundance and availability (Loiselle and Blake 2000). This might be the reason of the less pronounced variation in these guilds along the altitudinal belts. The absence of most of the resident birds during monsoon indicates highly specialized seasonality of the birds in the SVNP as observed by Jayson (2000). Most of the fruits such as *Oreocnide integrifolia*, and *Maesa india* will decay or swell up due to endosmosis, during the monsoon and are likely to have little nutritional value. The observed local migration of the species such as Crimson-backed Sunbird and Yellow-browed Bulbul might be an artifact of this resource scarcity. Studies by Balakrishnan (2007) on Grey-headed Bulbul in SVNP also supported this argument. Somasundaram (2006) demonstrated the positive correlation of Nilgiri Woodpigeon population with fruit abundance.

The high diversity of trophic groups in SHOLAG could be largely attributed to the structural complexity of the habitat. The presence of the feeding guilds such as frugivore-granivore, insectivore-granivore are particular to this region. There is a great deal of variation in the estimation of the density of birds depending up on their feeding guilds. A tentative explanation for this may be that for nectarivores, transect edges with ambient light conditions and the bloomed flowers are a functional habitat than the frugivores that depend mostly on the food sources such as *Syzygium* sp. The conspicuousness of these groups, in comparison with the other groups of frugivores, which are largely dependent on the rainforest canopy also support this argument.

4.4.5 Distribution pattern of birds

Log normal distributions of communities, which are very common in the ecological data sets, was evident in the present study. This was demonstrated by dividing species into classes such as rare species (65%), species with intermediate population (25%) and very abundant species (10%) (Ugland and Gray 1982).

The species abundance models had been a hot topic for discussion with a question of which model is the best predictor of disturbance (*See* Hill and Hamer 1998; Nummelin 1998). Species abundance distributions of communities in undisturbed habitats are claimed generally to fit log normal models, whereas those of disturbed habitats generally fits log-series models (Hill and Hamer 1998, and *references therein*). Hill and Hamer (1998) illustrate that log-series and log normal models cannot be differentiated unless the community has been adequately sampled. If not, most of the abundance distribution will be concealed and data from the tail of the distribution may be equally well described by the log series or log normal models (Magurran 1988). In this study it is clear that neither the sites can be considered as the disturbed in its real sense as it is following both models. Log normal distributions are proposed as the characteristic of the equilibrium communities (Ugland and Gray 1982; Hill and Hamer 1998) and this might not be true in all the cases also. However, species abundance models are proposed to be the easiest to interpret provided when it is applied to the fairly limited, well defined taxonomic groups such as birds and butterflies as suggested by Hill and Hamer (1998). Only 15% species were recorded in more than half of the sites where migrants were found, although 26% of migrants occurred in one or two sites. This situation resulted in a unique assemblage at a given site. Since most sites were characterized by some specific assemblages, I could not find a good explanation for the variation trends in the migrant assemblages.

There was much debate on the relationship between species abundance in communities and the species geographical range size (Spitzer *et al.* 1993). In the present study, a positive association was found between abundance / distribution in EG zone which might be either due to habitat heterogeneity or habitat specialization of different species. According to Brown (1997), generalist species should be simultaneously abundant and widely distributed, as a consequence of their ability to exploit a wide range of resources on both local and regional scales. Gaston and Lawton (1990) supported the argument by suggesting that in rare and distinct habitats largely different from 'average' environmental conditions existing in the given area, specialists (with small geographical area) are more efficient, which permits them to attain higher population sizes than generalists. As a result the abundance / distribution correlation is likely to be negative in rare habitats and positive in common habitats (Novotny 1991; Spitzer *et al.* 2003).

Rarefied species richness also showed similar results as found in the observed values which show adequate sampling of the habitats. The expected number of species for a given number of randomly sampled individuals (McCabe and Gotelli 2000) and facilitates comparison of areas in which densities may differ. Using the number of individuals as the basic unit of comparison by rarefying, furthermore, helps to avoid problems such as the impact of observer bias, which can confound genuine differences in species richness between sites (Willott 1999). Although the best way to explain the presence or absence of species was through the mist net use, this was not done due to logical reasons. Although there was no difference between the numbers of the species in the EG and EGD the compositions of the forest species or species found at the closed forests were different again from the species found at the EGGL. A possible explanation of the phenomenon can be the resident nature of the restricted species such as butterflies which confine their flight over definite areas, say a few hundred meters in distance (Lein and Yuan 2003). The present research supports hypothesis that the most characteristic climax forest species have the smallest geographical range of distribution. The opportunistic birds with wide range of distribution, are mostly associated with the disturbed habitats. The characteristic seasonal patterns and abundance fluctuations may be closely linked to the prevailing monsoonal climatic conditions (Gokula 1998). MacFaden and Capen (2002) found that the communities were primarily associated with local microhabitat characteristics and secondarily to coarser scale characteristics in North American birds. In contrast, Seoane *et al.* (2004) found that landscape-scale vegetation variables describing the surrounding habitat matrix were better predictors of bird abundance and distribution than the local vegetation cover on sampling sites.

Physical environments (Hawkins 1999), vegetation composition (e.g. Loiselle and Blake 1991; Estades 1997), and vegetation structure (e.g. Lescourret and Genard 1994) have frequently been considered the major factors influencing avian distribution and community organization. Temperature is important as it strongly influences species distributions either directly through physiological effects (e.g. Repasky 1991), or indirectly through its influence on the distribution of vegetation and availability of food (e.g. Root 1988). For a given physiographic region or specific landform, elevation is usually regarded as a rough indicator of climatic factors, being especially close to mean temperature (either annual or monthly). In general, mean temperature extremely monotonically declines with increasing elevation (e.g. Terborgh 1971) and is commonly used as an indicator. It is not surprising that both elevation and mean temperature contributed significantly in explaining the resident assemblages along the elevational gradients in this study as found elsewhere.

Understanding the biological mechanisms underlying different types of zonation allows a prediction of how these major patterns of biodiversity on landscapes will change through time (Huston 1994). Austin and Smith (1989) contended that altitude has no direct influence on small mammal distribution; it is a 'factor complex' gradient. Altitude is correlated with a variety of resources and regulators that affect animal diversity, including precipitation and temperature. The number of species was found to decrease with increasing altitude. Changes in altitude are associated with several important biological changes in the Western Ghats. The climate becomes progressively more temperate as altitude increases, with seasonal frosts at night (Vinod 2007). These changes in altitude result in a series of vegetation zones. She further argues that increasing altitude results in a decline in grass biomass and growth forms. The ability of many species to coexist in degraded habitats can be attributed to the presence of several microhabitats and their diverse resources. Areas of forest relics interspersed with dense vegetation and several phases of regenerating forest might have provided numerous microhabitats for different bird species, leading to the observed higher diversity at SHOLAG. The dense understorey of lowland (evergreen) forests at SVNP might have provided more protective cover, nest sites and more food resources for birds at ground level than in the BLHF which had relatively sparse understorey similar to secondary forest.

Elevational gradients in the tropics have a more or less stable condensation zone (cloud zone) at a certain level, causing favorable conditions for certain taxa (e.g. epiphytes) at mid-elevation, which in turn create microhabitats and food for other taxa. As local climate can vary prominently over a few kilometers or hundred meters in the tropics, the exact location of a "climatic optimum" can vary considerably regionally and locally, causing differences in the pattern of the elevational gradient even within the same taxa (Rahbek 1995). Presence of relatively higher number of bird species in SHOLA than BLHF could be an effect of variation in incidence of direct sunlight and various other micro climatic factors that differ between top and middle portion of the hill (Raman 2001). Another important factor in the pattern observed may be an outcome of scale of elevation gradient considered here (900 - 2220 m) while major studies in the Neotropics had a broader spectrum of altitudinal gradients (Terborgh 1971, 1977; Rahbek 1997). When we consider the Western Ghats in general the altitude of all evergreen habitat studied here are of mid-elevation and hence the pattern of decline with the increase in altitude, as found in many studies explained above. The existence of a "plateau" or a "hump" on a curve comparing species richness with elevation should not be regarded as unexpected considering that - although temperature declines with elevation, another life support factor, stable water supply, increases (at least to a certain elevation). The relationships for bird species richness and diversity were negative with increasing elevation but not so strongly negative as in the case of trees.

Calculation of the same similarity index between six forest types using the vegetation composition and bird community composition has given an opportunity to decipher the key features of the dynamics of vegetation-bird community relationship across habitats. Similarity Index Ratio (SIR) (Table 4.10) provides a better and amplified picture of the dynamics of relationship of vegetation and bird community similarities across habitats. It can be observed that all SIR values are above 1 and nearer to one indicating better similarity in bird community and vegetation similarity between habitats. Moreover, it can be noticed that the values are nearer to 1 ($\leq$ 2) within the evergreen and shola groups of forest types. However, between these groups the SIR values are high, attaining a maximum value between SHOLAG and EGGL, followed by EG - SHOLAG. This indicates that these two communities, of trees and birds, behaved differently within the SVNP and many other habitat features also play important role in the deciding the bird communities. The results also demonstrate the unique nature of the BLHF forest.

4.5 Conclusions

This study was undertaken in a large area of continuous forest without obvious habitat discontinuities. The lack of significant association between community composition and geographic distance confirmed that no dispersal barriers were present. Instead, bird community composition was most strongly associated with spatial variance in the environment, implying that deterministic ecological processes such as habitat and altitude are of greater importance in structuring spatial variation observed in the bird assemblage. It is likely that spatial contrasts in vegetation, elevation and slope are influencing distributions of essential resources for bird species including food, shelter and territorial space, and thus also influencing the strength of ecological interactions.

From a conservation management perspective these results indicate that attention should be given for maintaining (i) structurally complex forest with variation in gap-phase structure and tree size variables, (ii) forest in upper and lower/middle slope habitats and (iii) large areas of continuous forest with an altitudinal gradient.

The subsequent chapter deals with the breeding and nest-site analysis of the breeding birds of the SVNP, which is a subset of the population discussed in the current section.

Crimson-backed Sunbird

White-cheeked Barbet

CHAPTER V

SPATIO-TEMPORAL PATTERNS IN THE BREEDING OF BIRDS

CHAPTER V
SPATIO-TEMPORAL PATTERNS IN THE BREEDING OF BIRDS

5.1 INTRODUCTION

Concern for the future persistence of many avian species is indispensable because of the extensive threats to populations across their breeding, migratory, and wintering habitats (Askins 1993). In the midst of these threats, habitat fragmentation and devastation are often cited as the most critical threats contributing to the decline of many species (Robinson and Wilcove 1994, BirdLife International 2001). Many threats to birds are related to changes in land use patterns; hence, biologists seek to understand how habitat changes and loss affect avian communities. Identifying and understanding the mechanisms that link forest management to bird population processes will help protect species that use these ecosystems (Newton 1984, Marzluff *et al.* 2000). To understand the relationships between forest management and bird populations, rigorous well designed experiments relating forest management to avian demography, and exploring the interactions at expanded temporal and spatial scales are necessary (Gram *et al.* 2003).

It is often assumed that there is a direct relationship between species distribution or abundance and the associated habitat characteristics. Although this correlative relationship between observed patterns may be misleading (Wiens 1989), Rotenberry (1981) concludes that quantitative measurement of the habitat is essential to comprehend "patterns of life history, adaptation, and evolution of any species". For a forest manager, species-habitat associations are important in developing management plans for target species. It is all the more relevant in nest-site selection which may vary adaptively among co-existing species as a result of several factors.

Nest-site selection may be influenced by a variety of factors, including nest predation risk (Reitsma and Whelan 1999), physiological tolerances to abiotic factors (Martin 2001) and inter-specific competition (MacArthur 1972, Martin and Martin 2001). The responses of different species to these selective factors will likely differ due to differences in morphology, physiology and behaviour among species. Although competitive interactions may account for many patterns of species composition and abundance in natural communities (MacArthur 1972), other processes, particularly nest predation, have been suggested to structure bird assemblages (Martin 1988a, 1988b, 1996). Nest predation may particularly be important because it is often considered to be the primary reason for nest failure for open-nesting birds (Ricklefs 1969, Martin 1993a). It is therefore considered as the strongest selective force in nest-site selection. Nest predation may be avoided or minimized in at least three ways: (1) by individual birds selecting cryptic nest sites (Rands 1988) (2) by scattering nests in space or time to reduce potential density-dependent predation (Reitsma and Whelan 1999), and (3) by timing nesting when predation pressure is lowest or synchronized breeding to swindle predators. Species are expected to diverge in their nest placement to avoid density-dependent predation as a result of the development by predators of clearly-defined search images (Ford 1999). This latter mechanism, generated by the effects of shared predators among co-occurring species, has been referred to as the concept of competition for enemy-free space (Jeffries and Lawton 1984).

The structuring of bird species assemblages has been explained by competition for food (Wiens 1989, Martin 1995), by the partitioning of nest sites among co-occurring species in response to density-dependent nest predation (Reitsma and Whelan 1999), or by abiotic influences on the differing physiological tolerances of coexisting species (James *et al.* 1984, Wiens 1989, Martin 2001). These ideas remain both influential and attractive in understanding the factors that may have led to the observed patterns of resource partitioning among co-existing species. Thus nest sites are a resource that has important fitness consequences for birds (Martin 1988a).

The intensity of predation may influence the relative abundance of co-existing species, the degree of overlap and the intensity of competition between competing species (Holt 1984; Diamond 1978). For this reason, most birds select nest sites that reduce the probability of clutch predation. The frequency that a microhabitat type is chosen by a bird for nesting represents its use. I define microhabitats as reported by Martin (1998) based on vegetation, but birds could have been choosing other environmental features (e.g., microclimate). Nests were generally placed under or in specific plants, suggesting that birds were choosing specific vegetation, and vegetation is known to directly influence nest survival (*see* Martin 1992, 1993). Although nesting success has been estimated in many bird species, only a few studies have considered nesting success at the community level (*but see* Gates and Gysel 1978; MacKenzie *et al.* 1982; Martin 1995; Powel and Steidel 2000; Nalwanga *et al.* 2004). This must have been influenced by the factors such as continuous labour required for the nest monitoring through out the season, that in turn requires a lot of funding which is an important limiting factor in research in developing countries and finally, in tropical rain forests the difficult terrain and adverse climate are always considered as extremely challenging.

5.1.1. Indian Scenario

Detailed studies on the breeding biology of Indian birds are available only on certain species or groups. Initial efforts were made by Baker (1934) and Ali and Ripley (1987). The rest of the studies mainly concentrated on the biology and breeding seasonality of specific birds or groups (Vijayan *et al.* 1998, 1999). The breeding seasonality and clutch size of Indian passerines has been worked out by Pramod and Yom-Tov (1999). Gaston and Vijayan (1986) compared the data on the breeding seasonality of the birds in different regions of India. Such studies will render a thorough assessment for the better understanding of geographical and seasonal variation in the breeding of birds and have immense conservation significance. Although detailed bird community studies have already been done in SVNP (Ramakrishnan 1983, Jayson 1994, Pramod 1995), none had studied the breeding strategies or requirements. However, a short-term study by Basheer and Nameer (1990) reported breeding of 29 species. Later on, Das and Vijayan (2003, 2004) examined the breeding requirements of Malabar whistling Thrush and breeding biology of Brown-cheeked Fulvetta in SVNP. Das and Vijayan (2005) investigated breeding seasonality of the rainforest birds in SVNP.

In this chapter, I examine the nest-site selection and nest-site partitioning among the major 12 nesting species of the breeding-bird community at SVNP. These birds were the subset of the most abundant birds in the SVNP (Appendix 4.1, 5.1). The study design allowed a comparison of bird abundance patterns along different elevations.

In order to fill the existing lacunae in information on the breeding requirements of birds in wet evergreen forest and associated habitats, and the effects of altitude on the avifauna, a three-year study was initiated in 2002 with the following goals:

(1) To determine the abundance and habitat associations of breeding species in different habitats in SVNP,

(2) To determine the effect of seasonality, and altitude on species richness abundance, and diversity of breeding birds.

5.2 METHODS

5.2.1 Nest sampling

Standard method of nest searching was used and intensive nest searches were made during March 2002 to June 2005 (Martin and Geupel 1993). Nest searches were done for five hectare area in each of the six transects; thus with an overall searching effort of 30 ha (0.3 sq km) in all the transects together. The six transects were laid in different habitats and elevation ranges: three transects in the evergreen forests (around 1000 m), one in the broad-leaved hill forest (BLHF around 1500 m), and two in the shola forests (2000 - 2200 m) (details are given in Chapter 2). Each study site was divided into ten 50 x 50 m plots on alternate sides of the sampling transects. Each plot was surveyed twice monthly during January to June in each year and once a month during other months. Along with a trained field assistant, I spent 3-4 hours each morning, beginning at dawn, in each plot. Plots were surveyed in rotation to avoid temporal biases.

Nests were located by following adult birds seen carrying the nesting material or food, and by searching suitable vegetation and location as described by Martin and Geupel (1993). Located nests were marked and monitored thereafter at 4-6 day intervals as many days as possible to determine nest fate. I located and monitored nests through deliberate searching. Additional nests were also found while monitoring. Care was taken to avoid trampling or disturbance to vegetation at nest sites. A mirror attached at the tip of a graduated pole was used to view contents of otherwise inaccessible nests. The graduated pole allowed easy measurement of nest heights. Only nests within the height of eight meter from the ground were sampled. I marked nest locations on a toposheet of the study sites, and also in the field by flagging to facilitate monitoring (Ralph *et al.* 1993). I noted predation events from the clues such as the bird and egg remains and magnitude of nest damage.

5.2.2 Nest-site selection

After the completion of nesting activity, nest-site variables were measured at two spatial scales: at microhabitat level (i.e., nest site attributes such as plant size and location of the nest with reference to the plant) and mesohabitat level (attributes of habitat patch surrounding the nest). The nest site was defined as that area within 1 m radius of the nest, whereas the nest patch was that area within a 5 m radius of the nest.

Microhabitat (Nest-site) variables

Nest-site characteristics measured and their codes used in analysis (in brackets) are given below:

a. Nest substrate (e.g. plant species, grass, ground or rock).
b. Nest height above ground, determined using a measuring stick (zero for ground nests) (NESTHT).
c. Height of plant or substrate that nest was on (NPLANTHT)
d. Relative nest height, ratio of nest height to nest plant height (RELTINHT).
e. Concealment, determined by observing the nest in four cardinal directions, at four different distances by ocular estimation. Points are given when the nest is not seen (CONCEAL).
f. Distance of nest from the lateral edge of foliage (DFOLIAGE).

g. Distance of nest from the main trunk of the nest plant (DTRUNK).

Mesohabitat (Nest-patch) variables

Habitat was measured in a circle of 5 m radius around the nest. The 5 m radius circle was divided into four sections using string and stakes to increase accuracy and to eliminate duplication of shrub counts. Percent ground cover was visually estimated in each section and averaged for each patch.

h. Total shrub cover in percentage by visual estimation (SHRUBCOV).
i. Canopy cover as measured by visual grading (4 readings in percentage) (CANOPY).
j. Ground cover (%) (grass, fern, log, leaf litter, rock, bare ground, and water) (GROUND).
k. Leaf litter depth (taken at 4 locations within 5 m from the nest) (LITTER).
l. Distance to trek path (DTREKPAT).
m. Distance to the nearest tree with more than 30 cm GBH (DTOTREE).

5.2.3. Statistical analyses

Habitat variables were analysed using correlation analysis to reduce the number of variables. Measurements of concealment in four cardinal directions were averaged and used in the correlation analysis. Univariate analysis of variance (by entering species as a fixed factor and habitat variable as independent variable and repeating the analysis for each of 12 habitat variables) was used to test for overall differences among the nest sites of the 12 species. It is also used to test the null hypothesis of no difference in the nest sites among the species.

Wilks' Lambda and F-tests were used to determine the combination of variables providing the best group separation. The 12 variables for all 442 nest sites were collectively subjected to PCA to determine the relationships of the 12 species in the "habitat space" (*sensu* James 1971) of SVNP. The principal components were orthogonally rotated toward "simple structure" (*sensu* Thurstone 1947) using the varimax criterion of Kaiser (1958). Analysis of this was followed by the Stepwise Discriminant Function Analysis (SDFA) of each subset to characterize the basis of statistical separation of the species. Habitat variables that discriminated between species were identified using SDFA.

Species centroids were projected into three dimensional discriminate spaces. A minimum spacing tree (Rholf 1970), computed from the Euclidean matrix distance based on species univariate means, was superimposed on each ordination to emphasize species relationships and to indicate where distortion might have occurred in the reduction of the original multi dimensional space to fewer dimensions. Distinctive clusters of species in the ordinations were isolated using the analysis (Sale 1971), based on the euclidean distance between group centroids.

To determine the influence of habitat structure on bird nesting attributes, changes in vegetation across the nest sites in the habitats were analyzed by performing Principal Component Analysis (Javed 1996, Raman 2001). This multivariate statistical technique reduces the dimensionality by deriving a few uncorrelated components from a set of variables. It has been widely used to compute the most meaningful basis to re-express a noisy data set. The first few components (with eigen values above one) explain most of the variation in the data. Ordination of sites in the habitats was based on vegetation characteristics such as canopy cover, shrub cover, distance to the trek-path and distance to the next tree, etc.

All analyses were performed using the STATISTICA software version 6.1 (Statsoft Inc. 2002). Significance levels were set at $p < 0.05$ for all analyses. Percentage data were arcsine-transformed to meet assumptions of normality and counts were log transformed. An orthogonal rotation (Varimax) was used to maximize dispersion of the ordination to facilitate interpretation (Allen 2001).

5.3 RESULTS

5.3.1 Breeding species richness, abundance and diversity

In total, 517 nests belonging to 32 species with seven endemic species (Appendix 5.1) were found during March 2002 to April 2005. At higher altitudes, Sispara (2200 m), I recorded nesting of only five species, namely

Nilgiri Laughingthrush, Nilgiri Pipit, Pied Bushchat, Oriental White-eye and Black Bulbul while at 1500 m, the species found nesting include Malabar Whistling Thrush, Indian Scimitar Babbler, Yellow-browed Bulbul, Black Bulbul and Crimson-backed Sunbird. The rest of the 25 species nested within the altitudinal range of 1000 to 1200 m. Chi-square tests revealed that out of the 32 breeding bird species only nine species showed significantly greater aggregation (Appendix 5.2).

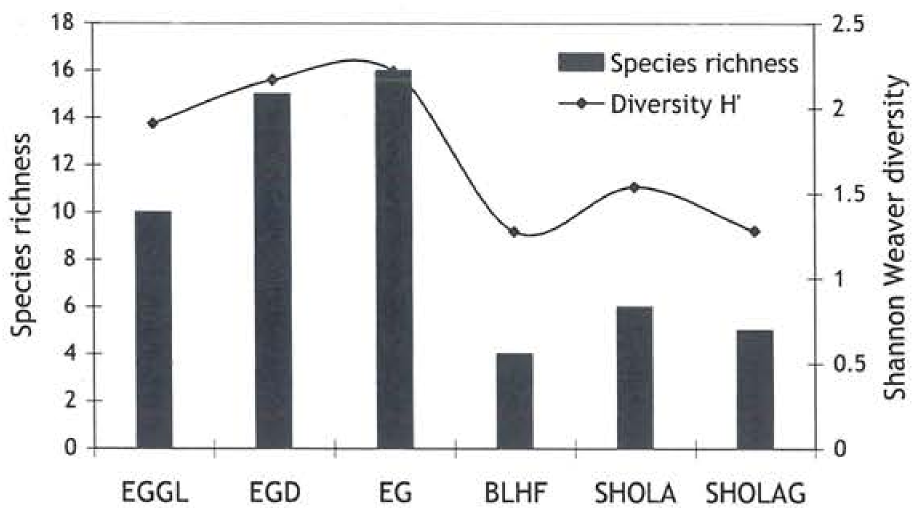


Figure 5.1 Nesting bird species richness and diversity in different habitats in SVNP during 2002-2005.

I related the habitats and number of nesting species (Figure 5.1) and found that the wet evergreen forests in the mid-elevation (1000 to 1200 m) harbored more nesting species (50%), whereas in BLHF it was the least with only four species with 1.4 nests ha^{-1}. SHOLA had 30 nests of five species. Nest density was the highest at EGGL with 18.4 nests ha^{-1} followed by 13.8 nests ha^{-1} at EGD and 11.4 nests ha^{-1} at EG (Figure 5.2). The SHOLAG and SHOLA site at Sispara showed relatively low nesting density 3.6 and 2.4 nests ha^{-1}, whereas in BLHF nesting density was 2.8 nests ha^{-1}.

Breeding bird diversity (Shannon-Weaver Index) was the maximum in EG (2.21) and minimum in BLHF (1.27). As a whole the evergreen forests showed high diversity without much variation among the transects.

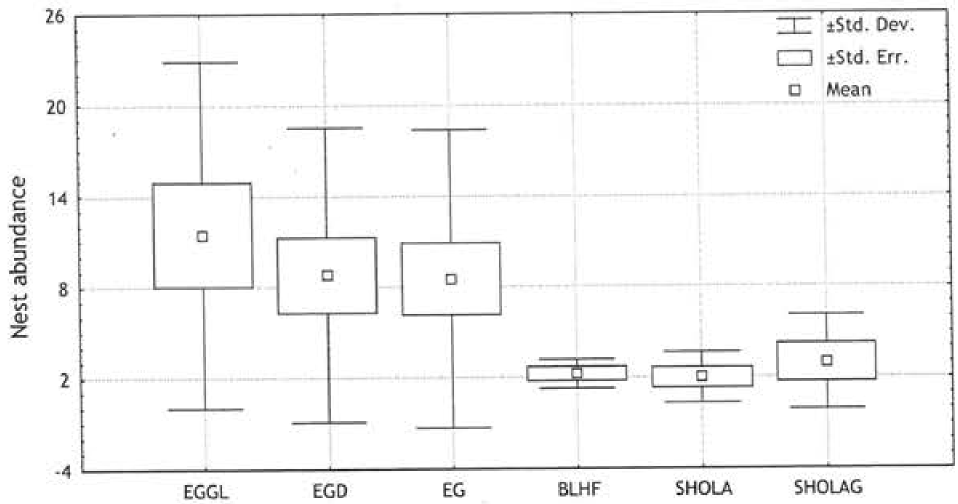


Figure 5.2 Nest abundance at various transects in SVNP.

Sorenson's quantitative index indicates 76.1% similarity between EGGL and EGD in their breeding bird community composition and 73.5% between EGGL and EG. As expected there was a notable difference in the nesting species of SHOLAG that had no similarity with all other habitats except SHOLA with similarity 62% was SHOLA (Table 5.1). SHOLA had very low similarity with the EGD (1.45%) and EG (1.3%).

Table 5.1 Similarity Matrix of breeding birds in different habitats in SVNP.

	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG
EGGL	*	76.19	73.56	4.51	0	0
EGD	*	*	88.12	10.53	1.45	0
EG	*	*	*	9.86	1.36	0
BLHF	*	*	*	*	0	0
SHOLA	*	*	*	*	*	62.07
SHOLAG	*	*	*	*	*	*

5.3.2 Seasonality

Although breeding was recorded throughout the year (Figure 5.3) most species bred in summer. Maximum number of species nested was in March (n=32) followed by April (n=28) and May (n=16). In SVNP a decline in nesting of birds was found with rainfall (Spearman's rank correlation, r^2 =0.004, $p<$ 0.01). Out of the 517 nests observed the maximum number of nests was (43%) in March and minimum in October. No significant correlation was obtained between the temperature and abundance of nesting.

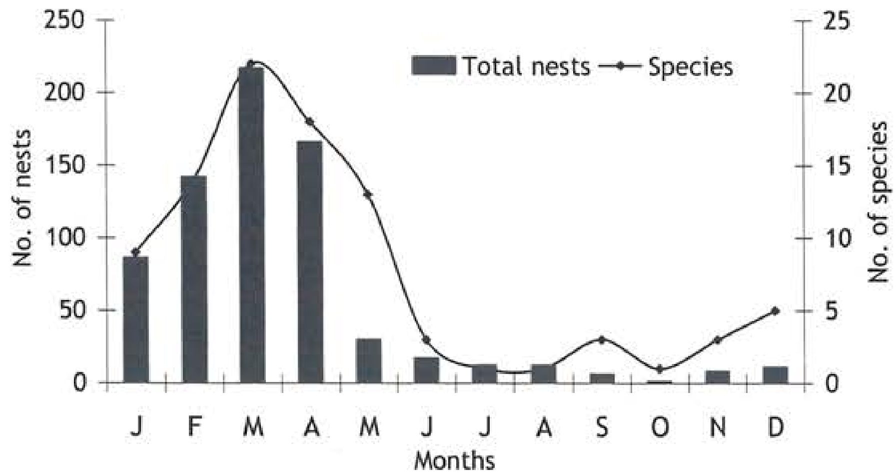


Figure 5.3 Breeding seasonality of birds at SVNP during, 2002-2005 (pooled for all breeding seasons).

5.3.3 Nest types

The cup nesters was the dominant group (n=231 nests; 14 species), followed by the platform nesters (n=92; 5 species). Pendent nests were chiefly built by the Crimson-backed Sunbird and one by Little Spiderhunter (n=91). It was followed by the wall-nesters (n= 61; 5 species). Ball, hole and ground nesters contributed to the remaining proportion of nest types (Figure 5.4).

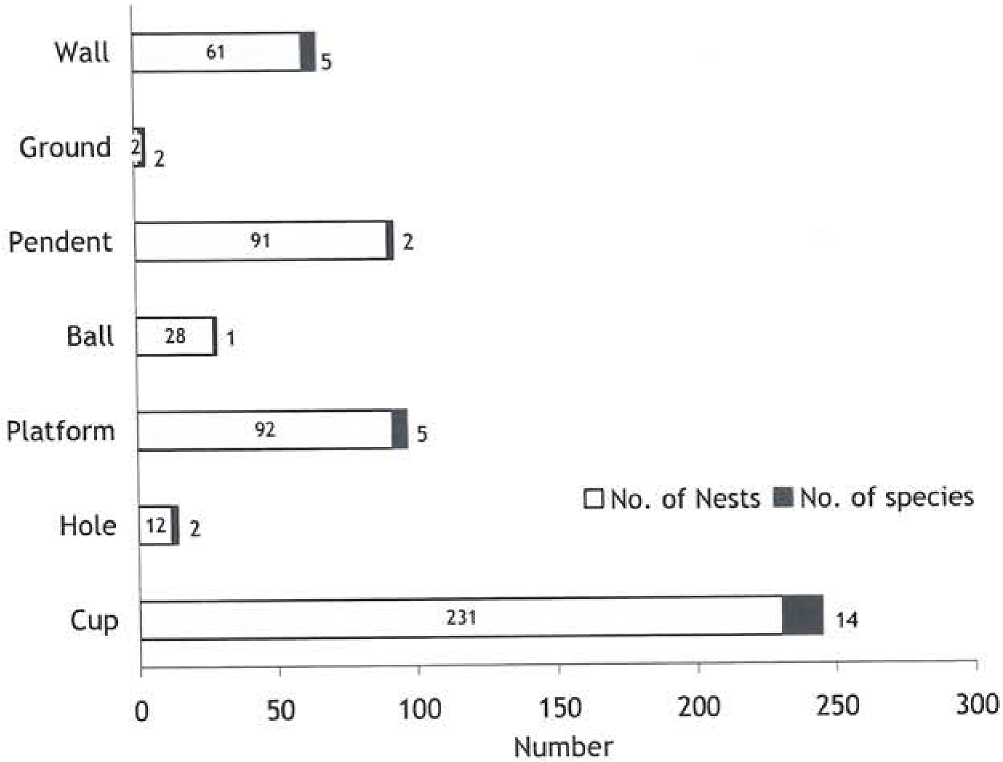


Figure 5.4 Abundance of nest types and the species recorded at SVNP during 2002-2005.

5.3.4 Major nesting birds of SVNP

Breeding birds with more than ten nest records are given in Table 5.2 (except Nilgiri Wood Pigeon n=7). The highest number of nests recorded was for the Yellow-browed Bulbul (n=78) followed by Crimson-backed Sunbird (n=77) and Brown-cheeked Fulvetta (n=68).

Table 5.2 Common nesting birds in the avian community of the SVNP

Sl. No	Common name	Scientific name	Species Code	No. of Nests observed
1	Crimson-backed Sunbird	*Nectarinia minima*	CBS	77
2	Emerald Dove	*Chalcophaps indica*	IED	23
3	Nilgiri Wood Pigeon	*Columba elephinstonii*	NWP	07
4	Mountain Imperial Pigeon	*Dacula badia*	MIP	14
5	Brown-cheeked Fulvetta	*Alcippe poioicephala*	BCF	68
6	Dark-fronted Babbler	*Rhopocichla atriceps*	DFB	28
7	Yellow-browed Bulbul	*Iole indica*	YBB	78
8	Black Bulbul	*Hypsipetes leucocephalus*	BB	22
9	Red-whiskered Bulbul	*Pycnonotus jocosus*	RWB	43
10	Indian Scimitar Babbler	*Pomatorhinus horsfieldii*	ISB	11
11	Malabar Whistling Thrush	*Myiophonus horsfieldii*	MWT	47
12	Pacific Swallow	*Hirundo tahitica*	PS	24

5.3.4 Comparison of nest-site characteristics of major nesting species.

I recorded 442 nests (85.5%) of 12 major breeding species (35.5%) in the SVNP and the nest-site characteristics of these species are analyzed in detail. Habitat characteristics differed among all species for all variables (One-way ANOVA; $p < 0.001$). Each nest parameter is discussed below.

5.3.5.1 Nesting substrate

In general, all birds used a range of plant species as nesting substrates (Appendix 5.3). The subset of substrate types chosen differed among the 12 major bird species (Table 5.3). Maximum diversity of habitats / plants used was in the Yellow-browed Bulbul (25 species, H'=2.74) and minimum in Pacific Swallow which used only wall for nesting. Equitability or evenness also followed the same pattern. Although more than 100 species of plants were used for nesting most used plants were *Lasianthus celiatus, Thottea siliquosa and Saprosma fragrans* (Appendix 5.3). Besides plants, rock, ground and building were also used by the species such as Grey Jungle fowl, Grey-Nightjar, Malabar Whistling Thrush and Pacific Swallow. The 12 species used more than 56 species of plants for nesting apart from other substrates. Maximum diversity of plants used was in Yellow-browed Bulbul (H'=2.74) followed by Red-whiskered Bulbul (H'=2.5) and Brown-cheeked Fulvetta (H'=2.4), whereas Pacific Swallow had no diversity as it used only wall (Table 5.3).

Table 5.3. Diversity in the nest plant / substrate selection by the 12 bird species in SVNP during 2002-2005. Nest sample sizes are given in parenthesis for each species. See table 5.2 for species codes.

Species	Mean Individuals	SD±	SE±	Total plant Species/ Substrate	H'	Equitability
CBS (77)	1.525	5.437	0.708	15	2.019	0.493
ED (23)	0.390	0.965	0.126	13	2.341	0.572
NWP (07)	0.119	0.326	0.042	7	1.946	0.475
MIP (14)	0.237	0.652	0.085	9	2.069	0.505
BCF (68)	1.153	3.095	0.403	16	2.389	0.583
DFB (28)	0.475	2.087	0.272	4	1.224	0.299
YBB (78)	1.322	2.849	0.371	25	2.741	0.669
BB (22)	0.373	1.691	0.220	4	1.151	0.281
RWB (43)	0.729	1.750	0.228	17	2.505	0.612
ISB (14)	0.237	1.579	0.206	2	0.410	0.100
MWT (47)	0.797	5.47	0.712	4	0.451	0.110
PS (24)	0.407	3.125	0.407	1	0.000	0.000

5.3.3.2 Nest height

The 12 nesting species in SVNP differed significantly in their nest heights (One-way ANOVA F_{11}= 39.45, $p < 0.001$). Indian Scimitar Babbler, Dark-fronted Babbler, Brown-cheeked Fulvetta, and Yellow -browed Bulbul nested closest to the ground (1.48 ± 0.75 m) and were classified as low-nesting group (Table 5.4). The Red-whiskered Bulbul, Crimson-backed Sunbird, Indian Emerald Dove and Pacific Swallow made their nests at moderate heights (2.05 ± 0.72 m) and were categorized under the mid-height nesting group. The remaining species namely Nilgiri Wood Pigeon, Mountain Imperial Pigeon, Black Bulbul and Malabar Whistling Thrush nested at greater heights (5.42 ± 2.98 m) compared to others. Nest height variation was maximum for the Malabar Whistling Thrush but for Nilgiri Wood Pigeon it was minimum being more specific (Figure 5.5).

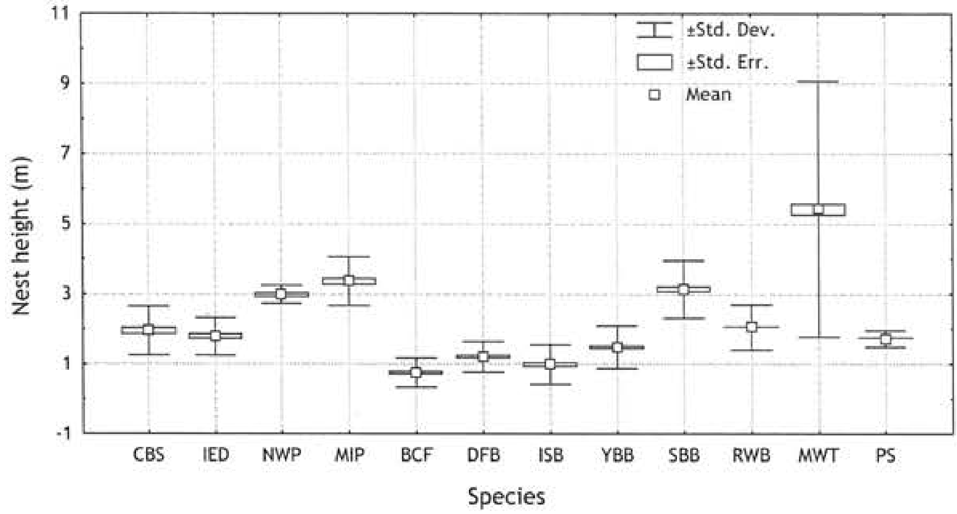


Figure 5.5. Comparison of nest heights among 12 bird species breeding in SVNP (ANOVA F_{11}=7.25, p < 0.001). Descriptions of species codes are given in Table 5.2.

The nest height had a positive correlation with the body mass of the birds investigated. (Spearman's r= 0.61, p < 0.05). Most of the species with higher body mass tended to have higher nest heights than those with smaller body mass (Figure 5.6).

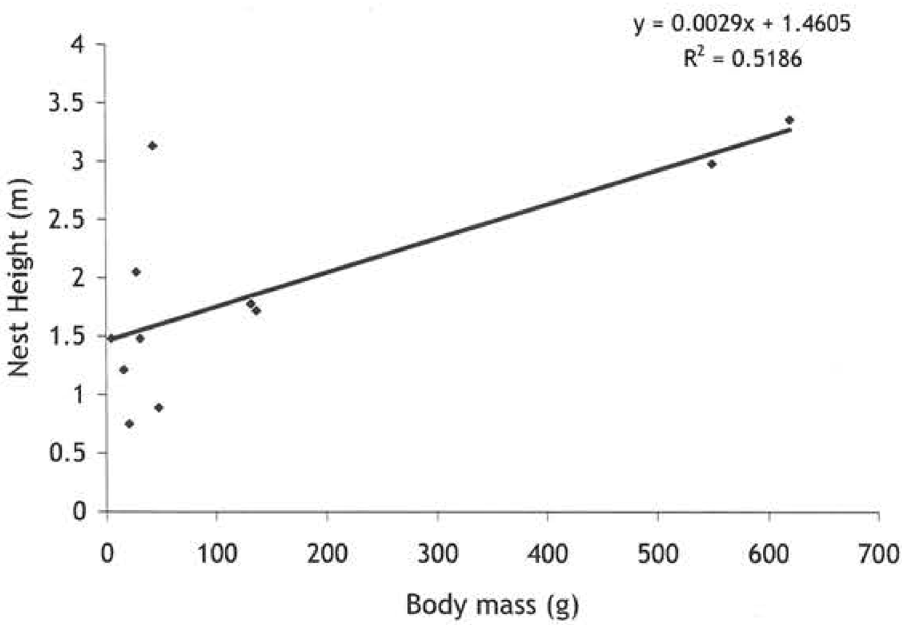


Figure 5.6 Relationships of nest heights and body mass among 12 most common breeding bird species in SVNP (Excluding Malabar Whistling Thrush).

Table 5.4 Mean and SD of different nest-site variables of 12 major nesting species in three height categories in SVNP during 2002-2005.

a) Low-nesting group

	BCF n= 68		YBB n=78		DFB n=28		ISB n=11	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
NESTHT	0.75	0.42	1.48	0.61	1.21	0.44	0.98	0.59
NPLANTHT	1.72	1.10	2.78	2.24	3.35	2.60	1.31	0.999
RELTINHT	0.51	0.18	0.59	0.17	0.55	0.30	0.46	0.32
CONCEAL	8.78	2.65	8.10	2.47	9.57	2.25	13.00	1.27
DFOLIAGE	0.31	0.17	0.40	0.26	2.03	8.82	0.09	0.30
DTRUNK	0.23	0.30	0.30	0.43	0.74	3.39	0.03	0.10
SHRUBCOV	63.97	18.70	50.55	11.06	57.00	11.68	76.36	12.86
CANOPY	69.71	15.74	54.32	13.66	59.28	11.94	76.36	13.62
GROUND	52.79	11.67	44.50	10.88	41.97	9.62	24.55	11.28
LITTER	6.83	1.15	4.94	1.25	6.85	0.81	5.79	0.79
DTREKPAT	20.28	12.04	11.72	9.00	13.29	6.80	2.27	0.91
DTOTREE	3.35	1.71	4.17	2.75	4.32	1.87	3.18	1.17

b) Mid-height nesting group

	CBS n=77		IED n=23		RWB n=43		PS n=24	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
NESTHT	1.95	0.70	1.78	0.54	2.05	0.65	1.72	0.23
NPLANTHT	3.13	1.59	3.03	1.80	3.52	1.89	2.44	0.27
RELTINHT	0.68	0.18	0.69	0.22	0.66	0.25	0.71	0.10
CONCEAL	7.44	1.63	9.61	1.67	9.49	1.98	13.25	1.54
DFOLIAGE	1.39	6.91	0.60	0.57	0.57	0.39	2.09	0.99
DTRUNK	1.38	4.86	0.62	0.74	0.62	0.45	3.26	0.69
SHRUBCOV	49.22	14.21	49.71	12.45	44.23	11.15	12.92	5.50
CANOPY	55.97	18.08	46.54	7.35	40.52	11.47	97.50	8.47
GROUND	50.65	14.27	41.39	2.89	41.70	8.17	94.58	9.77
LITTER	3.34	1.06	5.30	0.79	4.47	1.20	6.20	1.86
DTREKPAT	3.42	2.67	7.04	4.15	7.49	3.36	17.63	4.91
DTOTREE	3.74	1.80	3.39	1.95	4.72	2.02	9.71	2.58

c) High-nesting group

	MIP n=14		NWP n=7		BB n=22		MWT n=47	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
NESTHT	3.36	0.72	2.98	0.27	3.13	0.84	5.42	3.69
NPLANTHT	7.51	4.01	5.53	3.22	5.91	1.97	10.27	6.60
RELTINHT	0.54	0.21	0.66	0.27	0.55	0.12	0.60	0.24
CONCEAL	9.43	2.28	11.43	1.51	8.18	1.76	11.13	2.15
DFOLIAGE	1.15	1.09	1.06	0.66	1.01	0.78	4.48	2.72
DTRUNK	1.06	0.90	0.86	1.11	1.20	0.73	1.57	1.64
SHRUBCOV	43.57	13.36	39.81	10.68	40.52	9.19	29.80	15.37
CANOPY	56.71	10.77	70.30	12.64	39.72	4.87	56.20	21.93
GROUND	44.78	17.61	48.90	10.15	48.38	7.56	56.34	20.14
LITTER	6.25	0.70	6.49	0.89	3.78	1.14	2.91	2.42
DTREKPAT	6.71	4.38	6.86	5.84	8.82	6.26	10.85	6.91
DTOTREE	4.64	1.34	4.43	1.81	7.00	3.67	6.28	5.15

5.3.3.3 Nest-plant height

The heights of the plants or substrates in which the nests were placed also differed significantly among the species. (One-way ANOVA F_{11}= 32.17, $p < 0.001$), although there was apparent overlap among individual species in nest-height selection (Figure 5.7., Table 5.4). Maximum variation in nest-plant height was recorded in Malabar Whistling Thrush and minimum in Indian Scimitar Babbler.

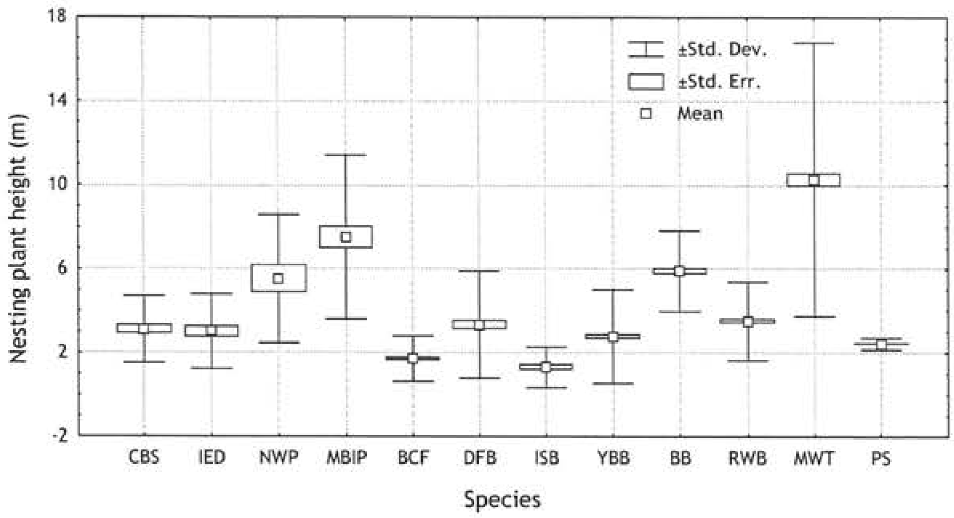


Figure 5.7 Comparison of nest plant heights among 12 bird species breeding in SVNP. Descriptions of species codes are given in Table 5.2.

5.3.3.4 Relative nest height

There was notable differences in the relative nest heights of the birds (One-way ANOVA F_{11}= 4.5, $p < 0.001$), (Figure 5.8). Crimson-backed Sunbird, Indian Emerald Dove and Red-whiskered Bulbul had high relative nest heights as their nests were usually placed towards the top of the nest plants, whereas Indian Scimitar Babbler and Brown-cheeked Fulvetta nested within the lower half, and Yellow-Browed Bulbul and Malabar Whistling Thrush placed nests at intermediate heights of the nesting plant (Table 5.4).

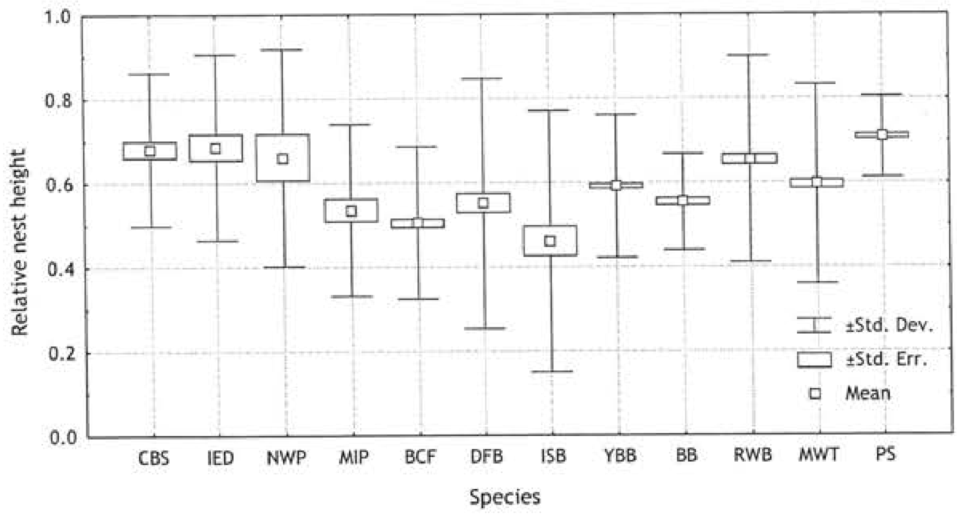


Figure 5.8. Comparison of relative nest heights among 12 breeding bird species in SVNP. Species codes as in Table 5.2.

5.3.3.5 Concealment of the nest

Considerable variation in relative nest concealment was observed as these species had mean concealment ranging from 7.4-13.2 (Figure 5.9, Table 5.4). However, nest concealment in the vicinity of the nest was significantly different among the species (One-way ANOVA F_{11}= 23.02, $p < 0.001$). Crimson-backed Sunbird nests were clearly outliers in that they are by far the least concealed (mean concealment was 7.4). By contrast, Pacific Swallow and Indian Scimitar Babbler had the most concealed nests (mean concealment 13.2 and 13 respectively).

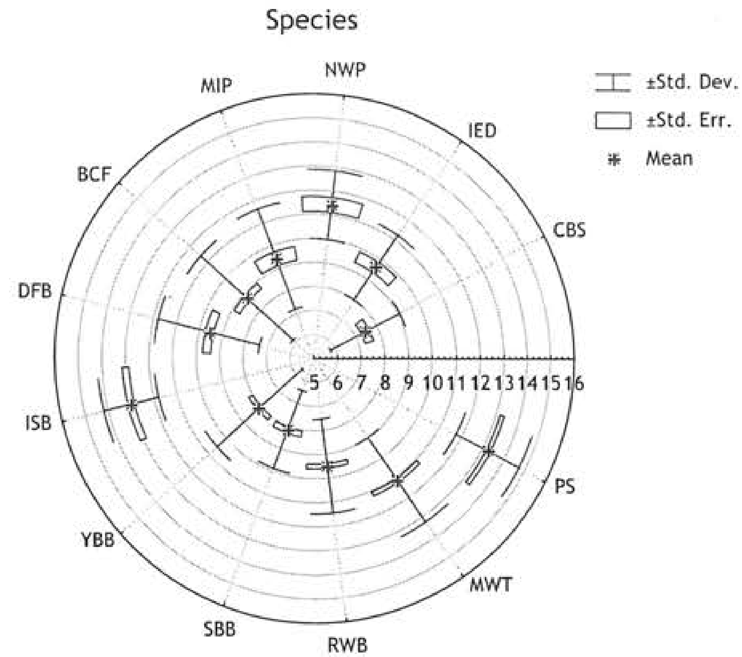


Figure 5.9. Comparison of average nest concealment (in points) among 12 breeding bird species in SVNP (ANOVA F_{11}= 23.02, p < .001). Species abbreviations as in Table 5.2.

5.3.3.6 Distance of the nest from the lateral foliage edge

Although most of the species nested at a wide range of distances from the lateral edge of plant foliage, there were significant differences in the distances from the edge at which the different species placed their nests (One-way ANOVA, F_{11}= 7.25, p < 0.001). Crimson-backed Sunbird and Red-whiskered Bulbul often nested near the lateral edge of foliage but in contrast Yellow-browed Bulbul and Nilgiri Wood Pigeon preferred to be away from the lateral foliage edge (±1.07-1.47 m) (Table 5.4).

5.3.3.7 Distance from main trunk.

Variation in the distance from trunk was also significant (One-way ANOVA F_{11}= 4.37, p < 0.001). The lowest distance from trunk was recorded in Indian Scimitar Babbler and maximum in Crimson-backed Sunbird (Table 5.4). The high nesters such as Mountain Imperial Pigeon, Nilgiri Wood Pigeon and

Malabar Whistling Thrush placed their nest at mean distances of 1.06- 1.5m from trunk.

5.3.3.8 Shrub cover

The analysis showed that shrub cover at the nest sites also varied significantly (One way ANOVA $F_{11}=38.22$, $p < 0.001$). Brown-cheeked Fulvetta had nest sites with highest shrub cover and Pacific Swallow nest sites had the lowest. All bulbul species constructed nests in patches with similar shrub cover, ranging from 40% to 50% (Figure 5.10, Table 5.4).

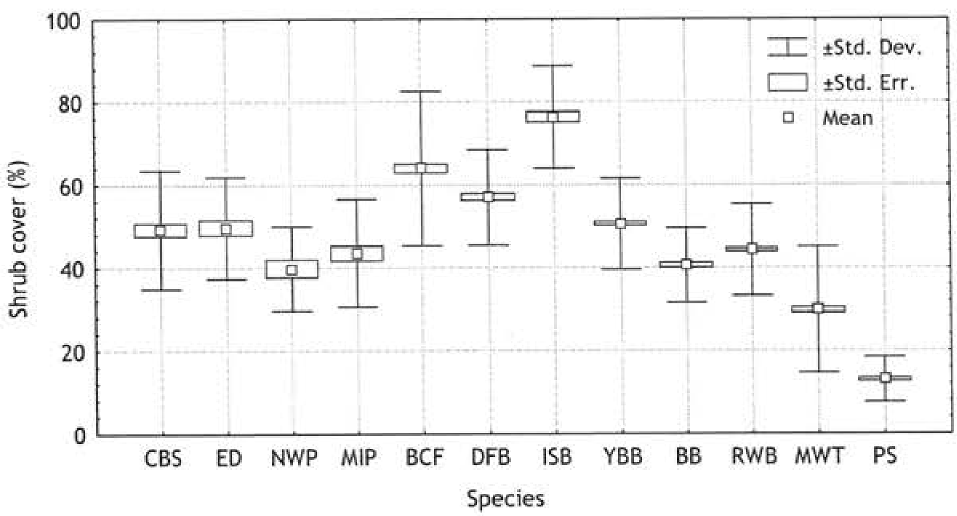


Figure 5.10.Comparison of shrub cover among 12 bird species breeding in SVNP (ANOVA $F_{11}=38.22$, $p < .001$). Species numbers as in Table 5.2.

5.3.3.9 Canopy cover

Canopy cover at the nest sites varied significantly (One-way ANOVA $F_{11}=31.53$, $p < 0.001$) with a mean range of 40% in Black Bulbul and 69.7% in Brown-cheeked Fulvetta. Canopy exposure of the nests of pigeons and doves varied widely (Figure 5.11., Table 5.4).

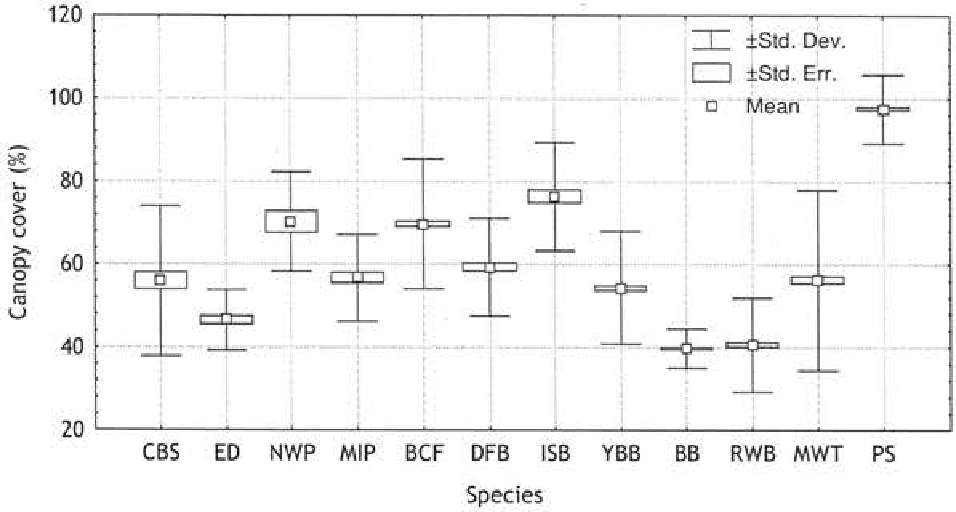


Figure 5.11. Comparison of canopy cover among 12 bird species breeding in SVNP. Species codes as in Table 5.2.

5.3.3.10 Ground cover

As expected there was a negative correlation in the shrub cover and the ground cover (Spearman's correlation r = -0.472, $p < 0.01$). The ground cover also varied significantly (F_{11}= 38.75, $p < 0.001$). The nest sites of Indian Scimitar Babbler showed lowest ground cover with 24% and Brown-cheeked Fulvetta showed the highest. Among the bulbuls nest site of Black Bulbul had the highest mean ground cover (48%) followed by Red-whiskered Bulbul (41%) and Yellow-browed Bulbul (44%). Doves and pigeons showed relatively similar ground cover (Figure 5.12, Table 5.4).

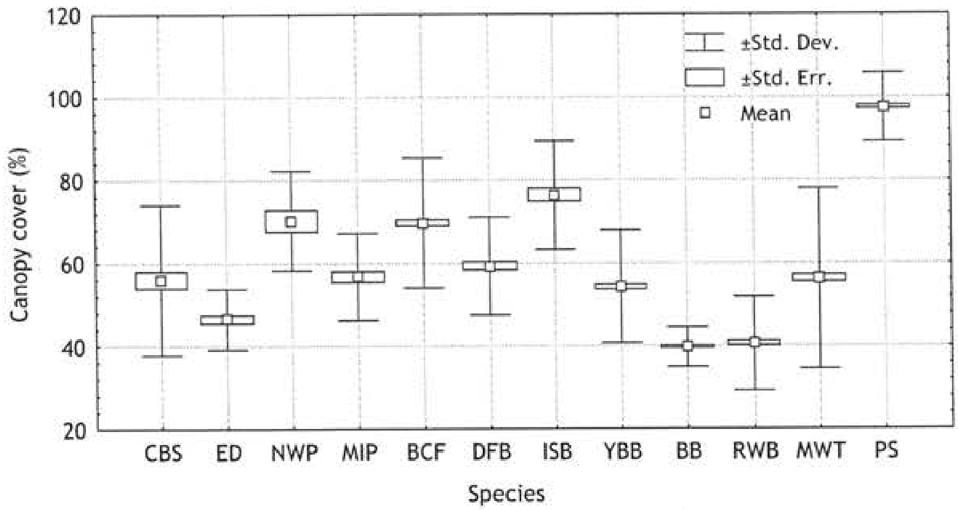


Figure 5.12. Comparison of ground cover among 12 bird species breeding in SVNP (ANOVA F_{11}=38.75, $p < 0.001$). Species abbreviations as in Table 5.2.

5.3.3.11 Leaf litter depth

The presence of leaf litter and its depth at the nest sites varied significantly (One-way ANOVA, F_{11}= 43.56, p <0.001). Analysis showed the lowest leaf litter depth at the nest sites of the Malabar Whistling Thrush (2.9 cm), Crimson-backed Sunbird (3.3 cm) and the bulbul group ; Black Bulbul (3.7 cm) Red-whiskered Bulbul (4.4 cm), Yellow-browed Bulbul (4.9 cm). But Indian Emerald Dove showed low litter depth, whereas the Mountain Imperial Pigeon and Nilgiri Wood Pigeon nest sites recorded litter depth as 6.2 and 6.48 cm respectively. The highest leaf litter depth was observed at the nest site of the Brown-cheeked Fulvetta and Dark-fronted Babbler (6.8 cm; Figure 5.13, Table 5.4).

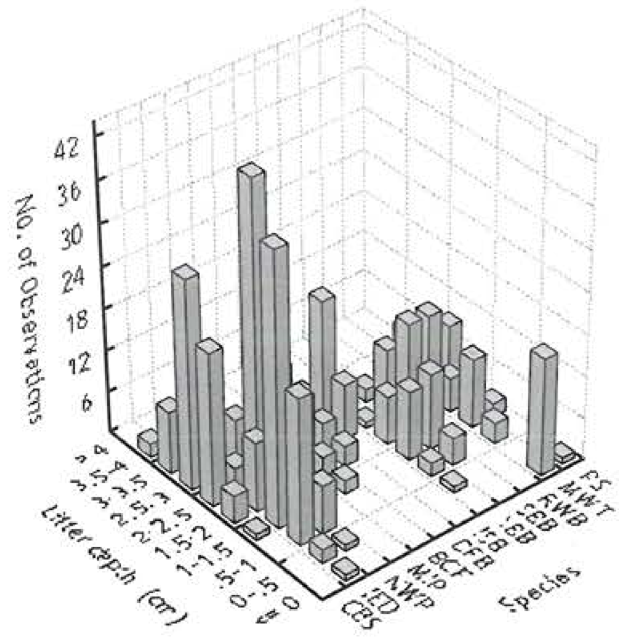


Figure 5.13. Comparison of leaf litter depth among 12 bird species breeding in SVNP (ANOVA F_{11}= 43.56, p < 0.001). Species abbreviations as in Table 5.2.

5.3.3.12 Distance to trek-path

The distance to the trek-path also varied significantly among the bird species (One-way ANOVA F_{11}= 23.63, p < 0.001). This variable correlated significantly with the canopy cover (r^2 = 0.779, p = < 0.001). The Indian Scimitar Babbler and Crimson-backed Sunbird nested very close to the trek path with a mean of 2.27 and 3.41 m respectively. Brown-cheeked Fuvetta nests were seen about 20 m away from trek-path.

5.3.3.13 Distance to the nearest tree

The distance to the next tree also varied significantly among the bird species (One-way ANOVA F_{11}= 14.22, p < 0.001). The Indian Scimitar Babbler nested with a mean distance of 3.18 m from the nearest tree. The Black Bulbul and

Red-whiskered Bulbul nested at a mean distance of 7 and 4.7 m respectively from the nearest tree (Table 5.4).

5.3.3.14 Nest-site partitioning

To summarize the differences in the nest site "gestalts" (*sensu* James 1971, *See also* MacKenzie *et al.* 1982) of the species, and to identify the best contributing variables of their statistical separation, Stepwise Discriminant Function Analysis (SDFA) was performed on the entire set of 12 variables. A highly significant Wilks' lamda indicated that the DFA was appropriate (Wilks' Lambda: 0.0124 approx. F (132, 3446) =18.516 p <0.001) (Table 5.5). Eight significant functions explained a total of 52% variance.

Habitat characteristics of nest sites differed significantly among species indicating a strong nest-site partitioning. The principal variables that discriminate nest-site attributes among species were features that distinguished tall-shrubs patches from short-shrub ones. Tall shrubs were associated with dense vegetation while short-shrub species were associated with open patches with low vegetation cover. Two groups of species which differed primarily in their selection of habitat patch type within the patchy nesting landscape were identified. One group, including Brown-cheeked Fulvetta and Emerald Dove nested predominantly in low shrubs associated with dense areas. A second group comprising the Mountain Imperial Pigeon and Nilgiri Wood Pigeon nested at a variety of heights within tall-shrub species associated with thickets. Species within each of these groups differed from each other in their relative nest height, distance of nest from foliage edge, nest concealment and choice of particular substrate plant species. On average, SDFA classified 52.6% of the nest sites correctly as belonging to one of the 12 species.

Table 5.5 Discriminant Function Analysis Summary, for the major nesting species in SVNP.

Nest-site attributes	Wilks' Lambda	Wilks' Partial Lambda	*p*-level	Root 1
NESTHT	0.014	0.874	0.001	1.437
TREEHT	0.012	0.956	0.067	0.024
RELNESHT	0.014	0.885	0.001	-1.383
CONCEAL	0.015	0.805	0.001	0.222
DFOLIAGE	0.015	0.802	0.001	0.314
DTRUNK	0.015	0.785	0.001	-0.246
SHRUB	0.024	0.516	0.001	-0.571
CANOPY	0.019	0.653	0.001	0.451
GROUND	0.018	0.667	0.001	0.368
LITTER	0.02	0.592	0.001	-0.002
DTREKPATH	0.015	0.786	0.001	0.019
DTREE	0.013	0.891	0.00001	0.098

Eigen value = 3.38

The PCA (Table 5.6, Figure 5.14) illustrates the degree of variability in three principal component variables (Eigen values > 1) with respect to major breeding species in the community.

From the 12 nest-site variables collected from 442 nests of 12 breeding bird species, PCA extracted three components explaining 78.5% of total variation (Table 5.6). The first three components explain a variation of 46.5%, 18.5% and 13.7% respectively in the data set. PC1 (Figure 5.14) exhibited strong positive relationships to ground cover, distance to trek path and distance to the next tree, and a negative correlation to shrub cover (Table 5.6). PC2 showed high positive loadings with relative nest height and PC3 had significant negative correlation with distance to foliage edge.

These results depicts the degree of inter and intra species variation in nest site parameters at community levels. The high shrub cover (PC1 variable) suggests a negative impact on breeding birds. A positive correlation to ground cover, trek path and nearest tree distances also implies significance of microhabitat features on breeding birds. Figure 5.14 indicates a high overlap in component variables among different species.

Table 5.6 Eigenvectors from principal components analysis of physical features of nest-site characteristics. (Factor Loadings- Varimax normalized, marked loadings are >0.800, which are considered as significant. Only principal components with Eigen values greater than 1.0 are reported).

	Components		
Variables	PC1	PC2	PC3
NESTHT	-0.659	0.560	0.170
NPLANTHT	-0.522	-0.550	0.228
RELTINHT	-0.175	**0.942**	-0.025
CONCEAL	0.779	0.488	0.191
DFOLIAGE	0.081	-0.010	**-0.892**
DTRUNK	-0.331	-0.256	0.481
SHRUBCOV	**-0.944**	-0.048	-0.219
CANOPY	-0.079	-0.121	0.607
GROUND	**0.944**	0.048	0.219
LITTER	0.695	-0.588	-0.180
DTREKPAT	**0.976**	-0.110	-0.020
DTOTREE	**0.948**	0.210	0.095
Cumulative variance	46.6%	65.1%	78.8%
Eigen values	5.6	2.2	1.7

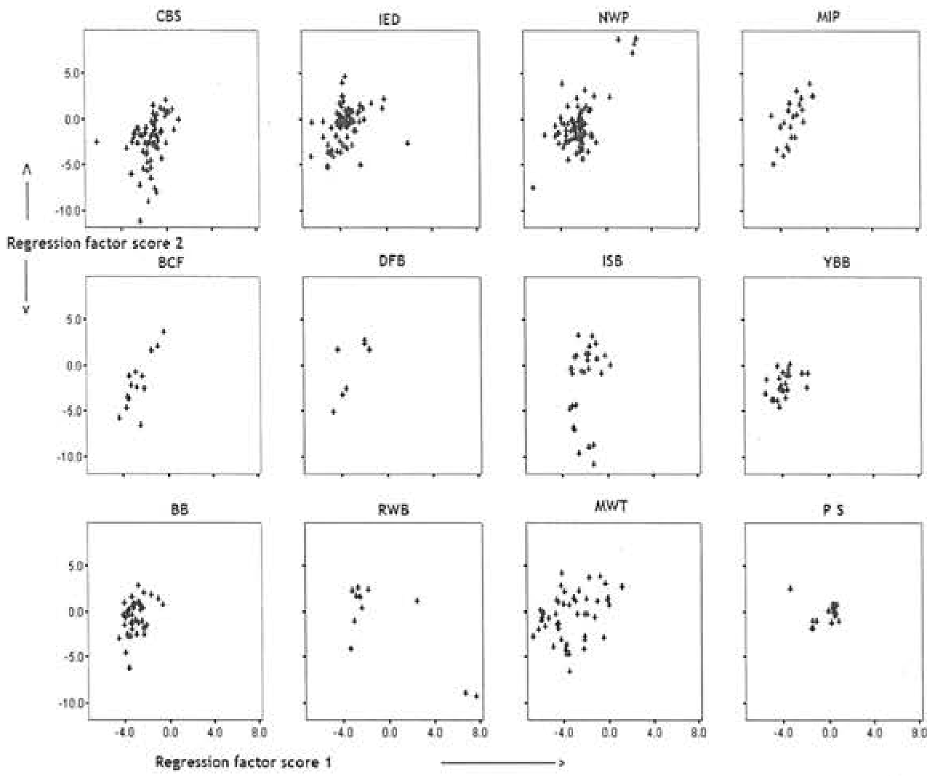


Figure 5.14 Projections of regression factor scores from PCA of nest patch variables of each major breeding species in SVNP. See Table 5.6 for component loadings.

5.4 DISCUSSION

This study has brought out the nest-site partitioning in the major nesting species in SVNP.

5.4.1 Breeding species richness, abundance and diversity

The overall proportions of breeding bird abundance and richness were higher in the mid-elevation forests (Figures 5.1 and 5.2). Lower number of breeding bird species recorded at higher altitudes corresponded with avifauna could be an outcome of reduced structural complexity of habitat and poor floristic diversity which in turn are influenced by climatic factors. For instance, high altitude shola forests are inferior in structural complexity and more exposed to extreme climatic conditions when compared to the medium elevation evergreen forests. Accordingly species richness is also low in shola forests (Figure 5.1) relative to wet evergreen forests (Ahmed 2005; Vinod 2007). The number of nests was very high at the evergreen-grassland interface (EGGL). Diverse and heterogeneous vegetation structures in these ecotones contribute to this high nesting density in the habitat. More than 100 species of nesting plants used by different bird species found in this study (see Appendix 5.3.) strongly suggest that plant species composition is an important determinant of breeding bird community in the southern Western Ghats as elsewhere in the tropics (Balakrishnan 2007). This further supports the hypothesis that habitat heterogeneity along with compositional diversity of vegetation (MacArthur 1972; Rotenberry 1979) influences the number of species and inturn their breeding.

The random distribution of most of the breeding bird population in SVNP (Appendix 5.2.) indicates that the nesting and feeding resources may be ubiquitous or randomly distributed in the habitats studied. The aggregated pattern exhibited in their nesting regions by nine bird species may be attributed to their life history traits.

As expected, adjacent habitats showed greater similarity in their breeding bird composition than the distant ones. Distinct breeding bird community structure in disjunct habitats such as shola forest and evergreen forest-grassland interface is an indication of the overall habitat specialization of birds studied (Table 5.1).

5.4.1.1 Seasonality

The breeding season extended from mid-November to mid-June during 2002 to 2005. Very high incidence of breeding in summer as in SVNP is in conformity with other studies conducted elsewhere in the Western Ghats (Ali and Ripley 1987; Gokula 1998; Vijayan *et al.* 1998b; Nirmala 2002) or in other tropical regions Young (1994). This may be largely attributed to the increased fruiting of vegetation in summer in case of frugivores and they tended to finish breeding before the onset of south-west monsoon as observed by Balakrishnan (2007) in Western Ghats. The nesting pattern was similar to that found in Thekkady (Vijayan 1984) and in Siruvani (Vijayan *et al.* 1998b). Major factors determining breeding seasonality of birds in Siruvani were humidity, abundance of fruit and temperature (Vijayan *et al.* 1998b). As found in most of the tropical rain forests with heavy rainfall, rainfall is the main factor for the termination of breeding (Lack 1968) except for a few species such as Malabar Whistling Thrush (Das and Vijayan 2003). However, Gaston (1981) found a sharp increase in the number of nesting birds with the onset of rains at the end of June. Shukkur and Joseph (1981) and Vijayan (1981) found that rainfall has strong influence on the breeding of the birds. This is the case in low rainfall areas where abundance of insects increases with onset of rain as observed in Anaikatty by Nirmala (2002) and in Mudumalai (Gokula 1998). Young (1994) studied the effects of food, nest predation and weather on the timing of breeding in tropical house wrens in Costa Rica and reported that the termination of breeding was not correlated with climatic changes. Birds may time their breeding to avoid periods of harsh weather that increase the physiological costs of reproduction. For example, cold weather, wind, or rain could reduce foraging time (Foster 1974) or increase the incubation needs of eggs (Tye 1991). In the tropics, temperature varies little throughout the year and therefore cannot be an important factor as found in the present study (*but see* Vijayan *et al.* 1998 *also*). Annual rainy periods could be detrimental to open or ground nesting species by washing out nests, but probably do not affect Malabar Whistling Thrush which nest in rock cavities.

5.4.1.2 Nest types

Forest birds showed a great diversity in nest types (Ali and Ripley 1987). Vijayan *et al.* (1998b, 2000) studied the nest types of birds in moist deciduous forest at Siruvani, India. Although there was a similarity in the proportion of cup nesters in both places, the proportion of hole and platform nesters differed between the areas. Percentage of hole nesters was maximum at Siruvani (39.53%, n= 489), whereas in SVNP it was 6.25% (n=517) (Vijayan *et al.* 1998b). This could be largely attributed to the habitat studied. This may be also an outcome of sampling bias, as it was very difficult to locate hole nests in dense evergreen forest. Nesting of species such as Malabar Whistling Thrush, Crimson-backed Sunbird, Pacific Swallow and House swift at SVNP resulted in relatively higher proportion of platform, pendant and wall nests respectively when compared to Siruvani (Vijayan *et al.* 1998b, 2000) which must be the result of the dense canopy and less disturbance as found in some other studies. However, the percentage contributions of some generalist species such as Red-whiskered Bulbul, Jungle Babbler and Purple-rumped Sunbird were more in Siruvani, which reflects the disturbance.

5.4.2 Comparison of nest-site characteristics of 12 major nesting species

A number of characteristics consistently explained the differences in the nesting habitat among the birds. Most of the species nested with in high vegetation cover and largely confined to their respective height strata. Nest placement is shaped by adaptive responses to the selection pressures of predation (Ricklefs 1969, Martin 1995), as well as other factors including microclimate, competition, and parasitism (*see* Yeh *et al.* 2007). Parody and Parker (2002) quantified variation in habitat preferences within and between populations of *Vireo bellii* in Mexico. Their analyses of nest placement data showed a general trend towards use of dense vegetation. And there was substantial variation in nest placement and vegetation at nest sites between three localities studied. A similar pattern was documented in a study on Grey-headed Bulbul in Western Ghats, conducted in the same study area also, with comparatively good discussion on its adaptive nature (Balakrishnan 2007). Their review of literature on nest placement data suggested strong differences in nest heights and species of trees even between populations less than 100 km apart.

A few species used wall, ground or rocks which would have been evolved over a long period. Diversity in the use of substrate or plant species shows the adaptability of the species as found in Yellow-browed Bulbul. Nilgiri Wood Pigeon and Mountain Imperial Pigeon nested usually on *Garcinia* sp., a species with abundant horizontal branches, which could provide adequate nest support for the twig nests of pigeons and the same was observed by Somasundaram (2006) also.

Riparian trees with large volume and complex growth forms provide birds with a good substrate for foraging and nesting, and support a large prey base (Bock and Bock 1984). This finding is in concert with the observations on the nesting requirements of Malabar Whistling Thrush, as they prefer riparian regions and usually nest during the monsoon when preys such as earthworms are more abundant. MacKenze *et al.* (1982) suggests that an important aspect of the selection of a breeding habitat by a species is the perception of the availability of a suitable nest site.

As supported by Mezquida and Marone (2001) the species of plant supporting the nest also affected nest success. The frequently used nesting plant species in the area, both in terms of the number of nests and bird species using them, were *Lasianthus celiatus, Actinodaphne lawsoni, Saprosma fragrans* and *Psychotria* sp. These plants were strongly selected by five bird species analyzed, whereas *Brachistachis* sp. and *Callicarpa racemosa* were rarely used in spite of its availability. Schmidt and Whelan (1999) reported differential nest survival depending upon plant species for songbirds in deciduous woodlands of eastern North America. In this study, Crimson-backed Sunbird frequently used exotic plant *Lantana camara* that provide a branch structure suitable for nest construction mostly adjacent to disturbed areas. The birds seemed to avoid nesting in weak shrubs due to the plant's slender upright branches, which provide few suitable forks to support nests. The few nests recorded in *Lasianthus celiatus* had lower predation rates than those in other plant species may be because of high concealment and predators do not direct their search to these plants simply as they are not hospitable for insects and have hairy stems. Predators would be expected to direct their search efforts toward those substrates that represent potential sites for encountering prey (Martin 1988b, 1993b). Another important factor which regulates the nesting plant preferences may be the architectural suitability to make the nest. Further studies are envisaged in this line, to have an authoritative judgment.

Although presence and proximity of other species' nest is supposed to be an important regulatory factor of nest building of another species, I had an interesting observation of five species such as Yellow-browed Bulbul, Crimson-backed Sunbird, Dark-fronted Babbler, Brown-cheeked Fulvetta and Little Spiderhunter nesting with in 10 x 10 m plot in the same breeding season. Clustering or flocking may be another strategy helping them in detecting and chasing predators. Association of nesting species needs to be studied in detail.

Nest height is considered to be an important characteristic distinguishing the habitat use among the co-existing species. A statistically significant difference in nest heights of species in the community studied suggests that vertical nest position can be used as the most predictable characteristic of the bird habitat (Powel and Steidl 2000). Several hypotheses have been developed concerning how nest placement evolved as a result of predators developing search images for nests (Filliater *et al.* 1994). Balakrishnan (2007) reviewed this hypothesis in the context of nesting behaviour of Grey-headed Bulbul, an endemic bird of Western Ghats.

A major component of variation in nesting behaviour is the height at which a nest is built. The nesting heights of the Red-whiskered Bulbul showed considerable variations as they nested at very low heights (0.5 m) near the base camp in the bushes, but in the grasslands they placed their nests at 2.5 m on *Glochidion* sp. and *Phyllanthus* sp. The probable reason of this height selection may be an adaptation to escape from predation. To avoid ground foraging predators, selection should favor nests higher off the ground (nest height hypothesis; Li and Martin 1991). The highest standard deviation in nest heights was observed in the Malabar Whistling Thrush, which is considered as a high nesting species with a mean nest height of 5.42 m. The low profile of the foraging height in the low nesting groups might be a determining factor of their height preference.

Body size and the mean nest heights had a significant relationship. The nest heights of Indian Emerald Dove are lower than Nilgiri Wood Pigeon which in turn is lower than Mountain Imperial Pigeon. This may be largely due to their strategy to escape from the predators, since lesser body size increases the chances of escape and ability for swift movements from the nest. For colonial herons, the existence of a vertical nest stratification of species within mixed colonies in relation to body size has been suggested, with the larger species nesting at higher levels (Fasola and Alieri 1992).

The highest nest height in Malabar Whistling Thrush is probably dependent on the availability of the nesting substrates such as rocks and trees. The high nesting plant height of the Dark-fronted Babbler is largely attributed to their selection for the reed and *Ochlandra* patches for nest placement, which is relatively higher than the shrubs or bushes in which other birds nested. These reeds are much branched and hence provide safe location for the placement of nest. Crimson-backed Sunbird nests were usually found on *Lantana camara* and *Maesa indica*, which are shrubs. They were also found nesting on trees and *Cyathea gigantea* which resulted in higher standard deviation in nest plant height. The relative nest height of the Indian Emerald Dove was moderate because it preferred nesting on top of the crowns of the plants such as *Saprosma* mainly because of foliage cover for concealment to reduce predation as found by Martin (1992). The relative nest height of the Indian Scimitar Babbler was low as it used to nest on mud walls just above the ground.

Nests that are easy to find and have access should be depredated more frequently, resulting in selection for more concealed nests (concealment hypothesis; Cresswell 1997) and nest concealment can inhibit transmission of visual, chemical or auditory cues to predators (Martin 1993).

Eventhough, there are numerous studies demonstrating the positive effects of concealment on nest survival (*reviewed in* Martin 1992), other studies were unable to find such an effect (e.g. Willson and Gende 2000). Bayne and Hobson (1997) also concluded that there was no evidence of concealment influencing the nest success in their investigation in Canada.

Because all species studied were nesting concurrently, and most nests were sighted in mature, evergreen patches, differences in nest concealment were not due to time of season. The measured nest concealment was found to decrease with nest height. Götmark *et al.* (1995) found that nest sites with intermediate concealment were chosen by Song Thrushes possibly so that incubating adults could see the approaching predators. Brown-cheeked Fulvetta nested in well-concealed positions just under or within the foliage crown, whereas Yellow-browed Bulbul nested lower within the plant, relatively visible for the observer. The concealment of the Indian Scimitar Babbler was also very striking as it kept its nest well camouflaged with the dead leaves around. This concealment calculation can be debatable as we are assuming the visual spectrum of the bird's predators are also the same as we have, and most of the mammalian predators are depending on the olfactory cues for their search.

Mountain Imperial Pigeon and Nilgiri Wood Pigeon usually nested in the center (away from the edge) of patches that are often more dense than those in which Yellow-browed Bulbul nested. Larger birds nested towards the centre with thicker branches for supporting the parent and chick as found in the Nilgiri Wood Pigeon (Somasundaram 2006). Out of these Indian Emerald Dove showed an interesting pattern by nesting mostly on the crowns of the shrub species such as *Saprosma fragrans* as explained earlier. Crimson-backed Sunbird associated with *Lantana camara* usually selected locations in the relatively open centre (near the edge) of very large shrubs or thickets, whereas Brown-cheeked Fulvetta nested deep inside shrubs associated with under-storey providing more concealment. Such a behaviour is also dependent on the nature of aggressiveness of the species.

The Mountain Imperial Pigeon nests were generally found on the platform of more than one species of plant mostly with the vines and lianas.

This may probably be an adaptation to escape from the predators like viverrids and snakes as their movement can be detected by the movements of the vines. Mezquida (2004) found that plant size and nest location inside the plant did not affect the fate of nests in any bird species. Murphy (1983) and Alonso *et al.* (1991) found that nests located at intermediate heights in the canopy of trees, and far from the main trunk, but not on the canopy periphery, showed greatest survival, and Collias (1997) suggested that such nest placement reduces predation. However, other studies have failed to find differences in nest success related to nest position inside the supporting plant (*see* Mezquida 2004).

The highest shrub cover as recorded in the Brown-cheeked Fulvetta nest sites indicates their strong preferences to understorey for nesting, which could be largely attributed to their foraging height preferences and concealment. Their fledglings were seen feeding *Gryllotalpa* and *Pentatomid* bugs etc. which is abundant after rains on the forest floor. Members of the Bulbul family nested within similar conditions in terms of the shrub cover, as they tended to nest in relatively open space. The reduction of suitable habitat area and the fragmentation of habitats into smaller patches are likely to increase the probability of local extinction of some species and reduce species richness (Boulinier *et al.* 1998). Understorey birds such as Brown-cheeked Fulvetta are regarded as being sensitive to forest alteration and habitat disturbance (Das and Vijayan 2005) and ground-nesting birds are often the first to disappear after the fragmentation of tropical forests (Pangau-Adam *et al.* 2000; Pangau-Adam 2003).

Canopy cover is correlated with most of the other habitat parameters since it largely determines other microhabitat environment such as leaf litter depth concealment etc. This was not true in nest sites adjacent to the trek-path, where periodic removal of the leaf litter, is performed as a part of the forest management, as a part of the fire prevention programme.

The lowest ground cover in the nest sites of Indian Scimitar Babbler was because of their preference for sites close to the trek path. Most of the bulbuls nest sites had moderate ground cover as they might have been attracted by the foraging opportunities associated with it.

Dark-fronted Babbler nests were found in reed / *Ochlandra* patches, in the proximity of water and were having high leaf litter depth. The lowest leaf litter depth was at Malabar Whistling Thrush nest sites because of the rock substratum. Crimson-backed Sunbird nest sites had very less leaf litter as it favored the habitat edges and trek-paths for easy escape from predators.

High rates of nest predation along edges is common in forest landscapes (Margaretha *et al.* 2006) and so nests placed farther from edges are expected to face reduced predation, however evidence for this remains equivocal (*see* Fisher and Wiebe 2006). Results of studies examining the relationship between distance to edges and nest success have been inconsistent. In this study, Brown-cheeked Fulvetta preferred to keep the nest away from the trek-path, whereas Crimson-backed Sunbirds kept their nests in the edges. Such individual variations can be attributed to their behaviour.

5.4.2.1 Nest-site partitioning

A number of characteristics consistently explained differences in nesting habitat among the bird species. This study showed that although there was a broad overlap among bird species in each of the nest-site habitat variables measured (Figures 5.5 to 5.12), SDFA (Table 5.5) provides strong evidence of nest-site partitioning in the breeding bird community of SVNP, given that all species had access to the full range of potential nest sites. It has been demonstrated by Lack (1971) that for open nesting birds nest sites are not limited because the generalized nest site requirements of species are easily met in their nesting habitats.

Three of the most important variables in the SDFA (nest height, nest tree height, and distance to the next tree) are features that distinguish plant species associated primarily with evergreen patches (large, tall shrubs, often aggregated into thicket patches). Thus, there was one group of species (Brown Cheeked Fulvetta, Yellow-browed Bulbul) that nested mostly on plant species associated with evergreen, and a second group of species (Red-whiskered Bulbul, Crimson-backed Sunbird) that nested mostly in plant species associated with open areas of SVNP. Relative nest height, substrate type and concealment were important for distinguishing sites within a patch (Table 5.5). Although there was less variation in the distance from the lateral foliage edge, and nest concealment among species, these characteristics also contributed to the differentiation of the nest sites by SDFA (Table 5.5). This suggests that all the variables considered in this analysis play important role in nest-site partitioning.

Although density-dependent predation in a multidimensional nesting niche space (not just three-dimensional space but also substrate type, distance from edge) could theoretically select for entirely random nest-site selection. Differential nest-site selection among species is more likely to arise because of differences in species-specific morphology, physiology, behavior and nest architecture, which ensure that each species is best adapted to a different type of nest site (James *et al.* 1984, Martin 1998). High density-dependent nest predation pressure can thus select for limited overlap in nest-site characteristics among co-existing species as a mechanism to inhibit the development of a search image for nest sites of a particular type by a predator (Jeffries and Lawton 1984; Martin 1988b; Reitsma 1992). However, density-dependent predation can also induce variation in nest-site characteristics within a species for the same reason. The extent of this variation is expected to depend on the relative abundance of that species to the total abundance of all other co-existing species. All the species considered in this study at SVNP had large standard deviations for all nest-site variables (Table 5.4), suggesting their selection of a relatively wide range of nest sites probably to reduce the chance of predation.

Selection of nesting habitat is a mere behavioral decision which has been done by the bird. As demonstrated by Parody and Parker (2002) it has to be noted that correlational studies, even when based on careful comparisons across a species' range, can never conclusively demonstrate that members of a species make decisions based on a particular habitat variable for their nesting. Generally, studies reporting evidence for the adaptive basis of nest-site selection are very scarce (Clark and Shutler 1999). There will always be the possibility that unmeasured correlates are the important proximate cues. In all species, finding what exactly determines settlement and habitat use patterns will be impossible without manipulative experimentation. This is probably true for a wide variety of species because most do not seem to show unambiguous correlations with habitat variables. The real meaning of these intrinsic relationships is still not clear, and is a promising topic for future research. This will show us how important is the knowledge of natural history and field ecology of tropical birds in helping us to understand the observed patterns that emerge from conservation studies.

5.5 Summary

Very high incidence of breeding in summer as observed in SVNP is in accordance with other studies elsewhere in the Western Ghats. Types of nest built by forest birds showed a great diversity with high representation of cup nests. The results of this study provide strong evidence for nest-site partitioning in the breeding bird community of SVNP. The major factors were nest height, nest tree height and distance to the next tree. The study suggests that plant species composition is an important determinant of breeding bird community in the southern Western Ghats. The random distribution of most of the breeding bird population in SVNP indicates that the nesting and associated feeding resources are ubiquitous or randomly distributed in the habitats studied.

Nest of Little Spiderhunter

Nest of Brown-cheeked Fulvetta

CHAPTER VI

SUMMARY AND CONCLUSION

My research on bird community along the altitudinal-habitat gradients and their nest-site partitioning across habitats in Silent Valley National Park (SVNP) has portrayed several patterns. The work has explored some aspects of the processes which accounted for the patterns of variations in the community structure of birds in a pristine forest representative of the post Miocene and Pleistocene uplifted Western Ghats of India. In particular, the study addressed how altitude affected the distribution of birds and how the breeding birds shared their resources. This chapter synthesizes the hitherto information presented in the early chapters and articulate the argument of the thesis.

Three variants of the evergreen forest at an altitude of 900 to 2200 m - evergreen with grassland (EGGL), disturbed evergreen (EGD) and evergreen (EG), two variants of the southern montane wet temperate (shola) forests between 2000 - 2200 m - shola forests (SHOLA) and shola with grassland (SHOLAG), and the broad-leaved hill forests (BLHF) located between 1500 - 1700 m were the specific habitat types selected within the SVNP for the study.

A range of habitat variables were measured in these six habitats in order to relate patterns of bird-habitat interactions. A total of 1872 trees of 152 species were recorded from the six localities studied with the maximum species richness (72) in evergreen followed by EGD (68) and then BLHF (55) with an average species numbers of 16.7, 13.2, and 8.4 respectively in the plots. Tree density was high with a mean of 780 ha^{-1} in SVNP and a maximum of 910 ha^{-1} in EGD. The tree species diversity indices of the tropical forests in this area decreased in the order: evergreen forest, slightly disturbed evergreen forest, broad-leaved hill forest, shola forest, evergreen with grassland, shola grassland habitats. There were variations in the tree species diversity between different samples of the same forest type, especially when the samples were taken from the ecotone or near the edges of forests. This depended greatly on the microenvironment of the habitats which resulted in a species-rich community. Tree species with small population sizes, especially the species represented by only one individual, substantially contributed to the tree species diversity.

The upward progression of the species area curves showed rate of accumulation of more taxa which is an effect of the shift in the habitat when transects approached BLHF and above mid-elevation. The mean tree density (780 individuals/ha) found at SVNP in the present study is in accordance with studies elsewhere in the Western Ghats. Analysis of plant dominance in the communities studied at SVNP suggested that a minority of species dominated the majority of the available resources, a characteristic of tropical forest. Plant families namely, Lauraceae and Euphorbiaceae were the two dominant families in the study area. A reverse J-shaped curves in girth glass abundance in the plant communities indicate predominance of lower diameter classes, which is the typical pattern exhibited by tree species in climax undisturbed forests.

The present study resulted in 5253 birds of 108 species, including 14 endemic species, from the 2314 point counts conducted in six habitats. The total number of species observed was 145 including opportunistic observations. Bird community structure of various habitats in corresponding altitudes varied significantly in terms of composition, abundance and diversity. The maximum species (59.2%) and individuals (27.2%) were in evergreen forest habitat and minimum in BLHF (22.8 % and 5.73% respectively). Shola habitats located at higher altitudes in the study area possessed higher species richness than mid-elevation broad leaved hill forest, which occurs within the altitudinal range of 1500- 1700 m. BLHF could be considered as a transitional zone between evergreen and shola forest. The significant difference in tree species richness of BLHF with adjacent EG and SHOLA habitats partly explain the reduction in number of bird species in this transitional zone.

Elevational gradients in the tropics have a more or less stable condensation zone (cloud zone) at a certain level, causing favorable conditions for certain taxa (e.g epiphytes) at mid-elevation, which in turn create microhabitats and food for other taxa. As local climate can vary prominently over a few kilometers or hundred meters in the tropics, the exact location of a "climatic optimum" can vary considerably regionally and locally, causing differences in the pattern of the elevational gradient even within the same taxa (Rahbek 1995). Presence of relatively higher number of bird species in SHOLA than BLHF could be also an effect of variation in incidence of direct sunlight and various other microclimatic factors that differ between top and middle portion of the hill. Another important factor in the pattern observed may be an outcome of scale of elevation gradient considered (900-2220 m), while major studies in the Neotropics had a broader spectrum of altitudinal gradients (Terborgh 1971, 1977, Rahbek 1977). The existence of a "plateau" or a "hump" on a curve comparing species richness with elevation should not be regarded as unexpected considering that - although temperature declines with elevation, another life support factor, stable water supply, increases (at least to a certain elevation).

The number of migrants was almost equal in the lowland evergreen habitats and the upland shola. Out of 14 Western Ghats endemics recorded from the study area, 11 were observed at EG site, nine each at the EGD site, and EGGL site, followed by eight each at the SHOLAG and SHOLA and the least was at BLHF with six species. Each habitat differed in their endemic species composition, despite the lack of significant differences in the endemic species richness among habitat-altitude gradients.

The study delineated 14 trophic guilds of birds in SVNP. The upland shola habitats grasslands harboured more number of feeding guilds of birds than any other habitat types. The evergreen with grasslands and disturbed evergreen closely followed them in feeding guild diversity while the evergreen and broad leaved hill forests showed further poor feeding guild diversity. The study strongly indicated high guild richness in habitats having greater structural complexity irrespective of the elevation gradient.

It was found that bird community composition is correlated to the species richness of trees and not to its abundance and also that the population size of bird species is unaffected by tree diversity.

Comparison between the bird community and vegetation structure has yielded significant results. It is observed that the clustering of the six vegetation types based on species similarity does not match the similar clustering of bird species across the habitats, although on the whole tree and bird communities in SVNP had similar patterns with a clear distinction between the evergreen forest types (EG, EGD and EGGL) and the Shola forest types (SHOLA, SHOLAG), and the BLHF forest type falling in between the two groups. At a finer scale similarities were same in the case of trees and birds in the high altitude areas, SHOLA and SHOLAG (Figure 3.14 and 4.15). In the case of evergreen forests, tree community of EG was closer to EGGL while it was with EGD in birds. BLHF showed closer link with high altitude areas in tree community, whereas it had with evergreen habitats in the case of birds.

Comparison of similarity indices (*Similarity Index Ratio- SIR*) between the vegetation composition and bird community composition in six forest types along the altitudinal gradient has given an opportunity to decipher the key features of the dynamics of vegetation and bird community across habitats. The index has provided a better and amplified picture of the dynamics of relationship of vegetation and bird community similarity across habitats. SIR values indicated similarity in the pattern of bird community structure and vegetation within the evergreen and shola groups of forest types. However, between these groups the SIR values were high between SHOLAG and EGGL followed by EG - SHOLAG. This indicates that these two communities, of trees and birds, behaved differently within the Silent Valley National Park and many other habitat features also play important role in deciding the bird communities which needs further investigation. The results also demonstrate the unique nature of the BLHF forest.

The spatial and temporal variation of breeding of the species in the SVNP was examined with special attention on nest-site partitioning. A total of 517 nests of 32 species were observed during the study period. It was found that nesting species richness and diversity were higher in the evergreen habitats compared to the other forest types. Highest number of nests was found in the evergreen with grassland while highest number of nesting species was in the evergreen forests. Among various nest types recorded in the area, cup nests were most common and ground nests were rare. While there were high similarities of nesting birds among the three types of evergreen forests, there was absolutely no similarity of them with the shola habitats. Though breeding bird species occurred in adjacent habitats, they were very habitat specific in placing nests. The broad leaved hill forests shared breeding species with the evergreen forest habitats but not with shola. Breeding was found throughout year but peaked during summer while it was less pronounced during the rainy season in accordance with other studies elsewhere in the Western Ghats. The random distribution of most of the breeding bird population in SVNP indicated that the nesting and associated feeding resources are ubiquitous or randomly distributed in the habitats studied.

From the total of 517 nests documented, a subset of 442 nests belonging to 12 commonest nesting species were selected and characterized based on 12 nest-site attributes in order to determine principal parameters influencing nest-site selection. The results of this study provide strong evidence for nest-site partitioning in the breeding bird community of SVNP. The major factors were nest height, nest tree height and distance to the next tree. The study also found that plant species composition could be an important determinant of breeding bird community in the southern Western Ghats. The habitat specificity of many species brings out the significance of the variety of habitats.

The study has thus brought out a new understanding on the dynamic relationship between vegetation and bird community composition. Looking at six different habitat types which reflect the elevation gradient of Silent Valley National Park, the study showed increased abundance of birds at mid-elevation evergreen habitats and the highest shola habitats with an unique dip at the intermediate broad-leaved hill forests. Delineating 14 trophic guilds of birds and by correlating them with vegetation structure, the study shows that guild richness is a direct function of habitat complexity irrespective of altitudinal status. The study demonstrated the overwhelming preference of birds to evergreen habitats for nest building. Apart from the new understanding on the nuances of vegetation-bird community interaction, the study has brought into focus the importance of maintaining and enriching the vegetation complexity as a major objective of the overall Park Management plan. From a conservation management perspective these results indicate that attention should be given for maintaining (i) structurally complex forest with variation in gap-phase structure and tree size variables, (ii) forest in upper and lower/middle slope habitats and (iii) large areas of continuous forest with an altitudinal gradient.

REFERENCES

Able KP, BR Noon (1976) The structure of avian communities along elevational gradients in the northwestern United States. Oecologia 26:275-294

Acharya BK (2008) Bird community and their distribution pattern along the elevation of Teesta Valley, Sikkim. Ph.D Thesis. Bharathiar University, Coimbatore

Ahmed A (2005) Ecology of Nilgiri Laughingthrush (*Garrulax cachinnans*) in Nilgiris, Western Ghats. Ph. D. Thesis, University of Mumbai, Mumbai

Ali S, Ripley SD (1987) Handbook of the birds of India and Pakistan. Compact edition, Oxford University Press, New Delhi

Allen JC, (2001) Species-habitat relationships for the breeding birds of a longleaf pine ecosystem. M.S. Thesis, Virginia Polytechnic Institute and State University, Virginia

Alonso JA, Muñoz-Pulido R, Bautista LM (1991) Nest-site selection and nesting success in the Azure-winged Magpie in Central Spain. Bird Study 38:45-51

Anon. (2006) Checklist of birds of Kerala. www.birdskerala.com/html/kbl.pdf

Askins RA (1993) Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1-34

Austin MP (1971) Role of regression analysis in plant ecology. Proceedings of Ecological Society of Australia 6:63-75

Austin MP, Smith TM (1989) A new model for the continuum concept. Vegetatio 83:35-47

Ayyappan N, Parthasarathy N (1999) Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. Biodiversity and Conservation 8:1533-1554

Ayyappan N, Parthasarathy N (2001) Patterns of tree diversity within a large-scale permanent plot of tropical evergreen forest, Western Ghats, India. Ecotropica 7:61-76

Ayyappan N, Parthasarathy N (2004) Short-term changes in tree populations in a tropical evergreen forest at Varagalaiar, Western Ghats, India. Biodiversity and Conservation 13:1843-1851

Ayyar VTV (1935) Working plan for Ghat forests of Palghat Division. Government Press, Thiruvananthapurarm

Baker ECS (1934) The nidifiaction Pattern of the birds of the Indian Empire, vol II. Taylor and Fransis, London

Balakrishnan M (1999) Mammals of Silent Valley. In: Manoharan TM, Biju SD, Nayar TS, Easa PS (eds) Silent Valley: Whispers of reason. Kerala Forest Department, Thiruvananthapuram, pp 286-290

Balakrishnan P (2007) Status, distribution and ecology of Grey-headed Bulbul *Pycnonotus priocephalus* in the Western Ghats, India. Ph.D. Thesis. Bharathiar University, Coimbatore

Balasubramanian P (1990) Plant-animal interactions at Point Calimere Sanctuary. Ph.D. Thesis, University of Bombay, Bombay

Balasubramanian P, Maheswaran B (2003) Frugivory seed dispersal and regeneration by birds in south Indian forests. Journal of Bombay Natural History Society 100:411-431

Balmford A, Long A (1994) Avian endemism and forest loss. Nature 372:623-624

Barbra H (2004) The Mechanisms and Processes of Vegetation Dynamics on Oil-Shale Spoil Bings in West Lothian, Scotland. Ph.D. Thesis. University of Edinburgh, United Kingdom.

Basheer CA, Nameer PO (1990) Some observations on the birds of the Silent Valley National Park. In: Vergheese A, Sridhar S, Chakravarthry A K (eds) Bird conservation. Strategies for nineties and beyond. Ornithological Society of India, Bangalore, India, pp 131-136

Basnet K (1992) Effect of topography on the pattern of trees in Tabonuco (Dacryodes excelsa) dominated rain forest of Puerto Rico. Biotropica 24:31-42

Bayne EM, Hobson KA (1998) The effects of habitat fragmentation by forestry and agriculture on the abundance of small mammals in the southern boreal mixedwood forest. Canadian Journal of Zoology 76:62-69

Beehler BM, Krishna Raju KS, Ali S (1981) Avian use of man disturbed forest habitats in the Eastern Ghats, India. Ibis 29:197-211

Begon M, Harper JL, Townsend CR (1996) Ecology: individuals, populations, and communities. Blackwell Science, London.

Behera MD, Kushwaha SPS (2007) An analysis of altitudinal behavior of tree species in Subansiri district, Eastern Himalaya. Biodiversity and Conservation 16:1851-1865

Bibby CJ (1999) Making the most of birds as environmental indicators. In: Adams NJ, Slotow RH (eds) Proc. 22 International Ornithological Congress, Durban Ostrich 70(1):81-88

Bibby CJ, Burgess ND, Hill DA (1992) Bird census techniques. Academic Press, London

Bibby CJ, Burgess ND, Hill DA, Mustoe SH (2000) Bird census techniques, 2nd edn. Academic Press, London

BirdLife International (2001) Threatened Birds of Asia. BirdLife International, Cambridge

Blake JG, Loiselle BA (2000) Diversity of birds along an elevational gradient in the Cordillera Central, Costa Rica. The Auk 117:663-686

Block WM, Brennan LA (1993) The habitat concept in ornithology, theory and applications. Current Ornithology 11:35-91

Bock CE, Bock JH (1984) On the geographical ecology and evolution of the Three-toed Woodpeckers, *Picoides tridactylus* and *P. arcticus*. American Midland Naturalist 108:397-405

Boulinier T, Nichols JD, Sauer FR, Hines JE, Pollock KH (1998) Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79:1018-1028

Braithwaite LW, Austin MP, Clayton M, Turner J, Nicholls AO (1989) On predicting the presence of birds in Eucalyptus forest types. Biological Conservation 50:33-50

Brown KS (1997) Diversity, disturbance and sustainable use of Neotropical forests: insects as indicators for conservation monitoring. Journal of Insect Conservation 1:25-42

Bunge J, Fitzpatrick M (1993) Estimating the number of species: A review. Journal of the American Statistical Association 88:364-373

Burns BR, Leathwick JR (1996) Vegetation-environment relationships at Waipoua Forest, Northland, New Zealand. New Zealand Journal Botany 34:79-92

Burton MT, Sivaramakrishnan KG (1993) Composition of the insect community in the streams of the Silent Valley National Park in Southern India. Tropical Ecology 34:1-16

Canterbury GE, Martin TE, Petit DR (2000) Bird community and habitat as ecological indicators of forest conditions in regional monitoring. Conservation Biology 14(2):544-558

Cao M, Zhang J (1997) Tree species diversity of tropical forest vegetation in Xishuangbanna, SW China. Biodiversity and Conservation 6:995-1006

Champion HG, Seth SK (1968) A revised survey of the forest types of India. Government of India Press, New Delhi

Chandran MDS (1997) On the ecological history of the Western Ghats. Current Science 73:146-155

Chandrashekara UM, Ramakrishnan PS (1994) Vegetation and gap dynamics of a tropical wet evergreen forest in the Western Ghats of Kerala, India. Journal of Tropical Ecology 10:337-354

Chattopadhyay S (1985) Deforestation in parts of Western Ghats region (Kerala), India. Journal of Environmental Management 20:219-230

Chazdon RL, Colwell RK, Denslow JS, Guariguata MR (1998) Statistical methods for estimating species richness of woody regeneration in primary and secondary rain forests of NE Costa Rica. In: Dallmeier F, Comiskey JA (eds) Forest Biodiversity Research, Monitoring and Modeling: Conceptual Background and Old World Case Studies. Parthenon Publishing, Paris, pp 285-309

Chettri N (2000) Impact of habitat disturbances on bird and butterfly communities along the Yuksam-Dzongri trail in Khanchendzonga Biosphere Reserve. Ph.D. Thesis. North Bengal University, India

Chittibabu CV, Parthasarathy N (2000) Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India. Biodiversity and Conservation 9:1493-1519

Clark RG, Shutler D (1999) Avian habitat selection: pattern from process in nest-site use by ducks? Ecology 80:272-287

Clarke KR, Warwick RM (1994) Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. Plymouth Marine Laboratory, Plymouth

Cody ML (1974) Competition and the Structure of Bird Communities. Monographs in Popular Biology. Princeton University Press, Princeton, New Jersey 7:1-318

Cody ML (1981) Habitat selection in birds: the roles of vegetation structure, competitors and productivity. BioScience 31:107-111

Cody ML (1985) Introduction to habitat selection in birds. In: Cody ML (ed) Habitat selections in birds. Academic Press, London, pp 4-6

Collar NJ, Crosby MC, Stattersfield AJ (1994) Birds to Watch 2: The World List of Threatened Birds. Cambridge, UK, BirdLife International.

Collias NE (1964) The evolution of nests and nest-building in birds. American Zoologist 4:175-190

Collias NE (1997) On the origin and evolution of nest building by passerine birds. Condor 99:253-270

Colwell RK (2004) EstimateS: Statistical Estimation of Species Richness and Shared Species from Samples, Version 7 (http://purl.oclc.org/ estimates)

Colwell RK, Coddington JA (1994) Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of Royal Society of London 345:101-118

Condit R, Pitman N, Leigh EG, Chave J, Terborgh J, Foster RB, Nunez P, Aguilar S, Valencia R, Villa G, Muller-Landau HC, Losos E, Hubbell SP (2002) Beta-Diversity in Tropical Forest Trees. Science 295 (5555):666-669

Connell JH (1975) Some mechanisms producing structure in natural communities. In: Cody ML, Diamond JM (eds) Ecology and Evolution of Communities. Harvard University Press, Cambridge, pp 460-490

Cottam G, Curtis JT (1956) The use of distance measures in phytosociological sampling. Ecology 37:451-460

Cresswell W (1997) Nest predation: the relative effects of nest characteristics, clutch size and parental behaviour. Animal Behaviour 53:93-103

Crick HQP (2004) The impact of climate change on birds. Ibis 146:48-56

Curtis JT, Cottam G (1962) Plant Ecology Workbook. Burgess Publishing Co., Minneapolis, Minnesota

Dallmeier F, Comiskey JA (1998) Forest biodiversity assessment monitoring and evaluation for adaptive management. In: Dallmeier F, Comiskey JA (eds) Forest Biodiversity Research, Monitoring and Modelling: Conceptual Background and Old World Case Studies. Parthenon Publishing, Paris, France, pp 3-15

Daniels RJR (1989) A conservation strategy for the birds of Uttara Kannada district, South India. Ph.D. Thesis. Centre for Ecological Sciences, Indian Institute of Science, Bangalore

Daniels RJR (2003) Biodiversity of the Western Ghats - An Overview. In: Gupta AK, Kumar A, Ramakantha V (eds) ENVIS Bulletin: Wildlife and Protected Areas, Conservation of Rainforests in India, WII, Dehradun, pp 25-40

Daniels RJR, Joshi NV, Gadgil M (1992) On the relationship between bird and woody plant species diversity in the Uttara Kannada district of south India. Proc National Academy of Sciences, USA 89:5311-5315

Das KSA (2006a) Record of Nasikabatrachus in Northern Western Ghats. Zoo's print Journal 21(9):2410

Das KSA (2006b) Spatial and temporal variation in bird community structure in Silent Valley National Park, Western Ghats, India. Proc Student Conference on Conservation Science, University of Cambridge, United Kingdom, pp 16-17

Das KSA, Ramachandran VS, Vijayan L (2005) Tree species richness, diversity and abundance as a function of altitudinal gradient in Silent Valley National Park. Proc 18th Kerala Science Congress, pp 420-422

Das KSA, Vijayan L (2003) Nests and nest site selection of Malabar Whistling Thrush in Silent Valley National Park. Proc 28th Conference of the Ethological Society of India, Mundanthurai, Tirunelveli. Annamalai R, Narayanan M, Juliet V (eds) Sara Tucker College, Tirunelveli & Tamil Nadu Forest Dept, KMTR, Tirunelveli, pp 83-86

Das KSA, Vijayan L (2004a) Breeding seasonality of birds in SVNP, Western Ghats, Kerala. Muthunayagam AE (ed) Proc 17th Kerala Science Congress. pp 183-185

Das KSA, Vijayan L (2004b) The nest-site and breeding biology of an under storey bird, Brown-cheeked Fulvetta in SVNP, Southern India. Proc International conference on bird and Environment, Haridwar, India, pp 59

Das KSA, Vijayan L (2007) Evaluation of butterflies as bioindicators in Western Ghats, India. Final Technical report Submitted to the Wildlife Trust, USA

Davidar P, Mohandass D, Vijayan L (2007) Floristic inventory of woody plants in a tropical montane (shola) forest in the Palni hills of the Western Ghats, India. Tropical Ecology 48:15-25

Devy MS, Davidar P (2001) Response of wet forest butterflies to selective logging in Kalakad-Mundanthurai Tiger Reserve: Implications for conservation. Current Science 80-3

Diamond JM (1975) Assembly of species communities. Cody ML, Diamond JM (eds) Ecology and evolution of communities. Harvard University Press, Cambridge, MA, USA, pp 342-444

Diamond JM (1978) Niche shifts and the rediscovery of inter-specific competition. American Scientist 66:322-331

Ding TS, Yuan HW, Geng S, Koh CN, Lee PF (2005) Primary productivity, body size, density to bird species richness along an elevational gradient in Yushan. Global Ecology and Biogeography 14(4):299-306

Ding TS, Yuan HW, Geng S, Koh CN, Lee PF (2006) Macro-scale bird species richness patterns of the East Asian mainland and islands: energy, area and isolation. Journal of Biogeography 33:683-693

Dobson AP, Rodriguez JP, Roberts WM, Wilcove DS (1997) Geographic distribution of endangered species in the United States. Science 275:550-553

Drake JB, Dubayah RO, Clark DB, Knox RG, Blair JB, Hofton MA, Chazdon RL, Weishampel JF, Prince S (2002) Estimation of tropical forest structural characteristics using large-footprint Lidar. Remote Sensing of Environment 79: 305-319

Dumont JF, Lamotte S, Kahn F (1990) Wetland and upland forest ecosystems in Peruvian Amazonia: plant species diversity in the light of some geological and botanical evidence. Forest Ecology and Management 33/34:125-139

Estades CF (1997) Bird-habitat relationships in a vegetational gradient in the Andes of central Chile. Condor 99:719-727

Faaborg J (1982) Avian population fluctuations during draught conditions in Puerto Rico. Wilson Bulletin 94:20-30

Faaborg J, Arendt W, Kaiser MS (1984) Rainfall correlates of bird population fluctuations in a Puerto Rican Dry forest : A nine year study. Wilson Bulletin 96(4):575-593

Fasola M, Alieri R (1992) Nest site characteristics in relation to body size in herons in Italy. Colonial Waterbirds 15:185-192

Filliater TS, Brettwisch R, Nealen PM (1994) Predation on Northern Cardinal nests: does choice of nest site matter? Condor 96:761-768

Fisher R, Corbert AS, Williams CB (1943) The relation between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology 12:42-58

Fisher RJ, Wiebe KL (2006) Nest site attributes and temporal patterns of northern flicker nest loss: effects of predation and competition. Oecologia 147: 744-753

Fleishman E, Austin GT, Weiss AD (1998) An empirical test of Rapoport's rule: elevational gradients in montane butterfly communities. Ecology 79:2482-2493

Ford AH (1999) Nest-site selection and breeding success in large Australian Honeyeaters: are there benefits from being different? Emu 99:91-99

Foster M (1974) Rain, feeding behavior and clutch size in tropical birds. Auk 91:722-726.

Gadgil M, Meher-Homji VM (1986) Land use and productive potential of Indian savannas. In: Tothill JC, Mott JC (eds) Ecology and management of world's savannas. Australian Academy of Science, pp 107-113

Gall BC, Longmore NW (1978) Avifauna of the Thredbo Valley, Kosciusko National Park. Emu 78:189-196

Gamble J (1928) The Flora of Presidency of Madras. Botanical survey of India, Calcutta, pp 2017

Ganesh T, Ganesan R, Soubadra Devy M, Davidar P, Bawa KS (1996) Assessment of plant biodiversity at a mid-elevation evergreen forest of Kalakad-Mundanthurai Tiger Reserve, Western Ghats, India. Current Science 71:379-391

Gaston (2000) Global patterns in biodiversity. Nature 405:220-227

Gaston AJ (1981) Seasonal Breeding, moulting and weight changes among birds of dry deciduous forest in North India. Journal Zoological Society of London 194: 219-243

Gaston AJ, Vijayan VS (1986) Breeding seasonality of the birds of the Indian Sub-continent. Paper presented at the 19th International Ornithological congress, Ottawa, Canada

Gaston KJ (ed) (1996) Biodiversity: A Biology of Numbers and Difference. Blackwell Scientific Publications, London

Gaston KJ, Lawton JH (1990) Effects of scale and habitat on the relationship between regional distribution and local abundance. Oikos 58:329-335

Gates JE, Gysel LW (1978) Avian nest dispersion and fledgling success in field-forest ecotones. Ecology 59:871-883

Gauch HG, Jr (1982) Multivariate analysis in community analysis. Cambridge University Press, Cambridge, England

Gentry AH (1982) Patterns of neotropical plant species diversity. Hecht MK, Wallace B, Prance GT (eds) Evolutionary biology, Vol 15. Plenum Press, New York, New York, USA, pp 1-84

Gentry AH (1988) Changes in plant community diversity and floristic composition of environmental and geographical gradients. Annals of the Missouri Botanical Garden 75:1-34

Ghate U, Joshi NV and Gadgil M (1998) On the patterns of tree diversity in the Western Ghats of India. Current Science 75:594-604

Gleason AH (1922) On the relation between species and area. Ecology 3:158-162

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 (2001a) Foraging and nesting behaviour of Baybacked Shrike *Linius vittatus* in southern India. Journal of South Asian Natural History 5:97-100

Gokula V (2001b) Nesting ecology of the Spotted Munia *Lonchura punctulata* in Mudumalai Wildlife Sanctuary (Southern India). Acta Ornithologica 36:1-4

Gokula V (2001c) Nest-site selection of White-browed Fantail *Rhipidura aureola* in Mudumalai Wildlife Sanctuary. Journal of Bombay Natural History Society 98(2): 179-183

Gokula V, Vijayan L (2000) Foraging pattern of birds during the breeding season in thorn forest of Mudumalai Wildlife Sanctuary, Tamil Nadu, Southern India. Tropical ecology 41:195-208

Gokula V, Vijayan L (2003) Foraging and nesting behaviour of Asian Paradise - flycatcher *Terpsiphone paradises* in Mudumalai wildlife sanctuary, Tamil Nadu, India. Forktail 19:142-144

Gokula V, Vijayan L (2007) Foraging strategies of birds in partioning of food resources in dry deciduous forest of Mudumalai Wildlife Sanctuary, Tamil Nadu, India. Journal of Scientific Transactions in Environment and Technovation 1:36-42

Gotelli NJ, Colwell RK (2001) Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4:379-391

Götmark F, Blomquist D, Johansson OC, Bergkvist J (1995) Nest-site selection - a trade-off between concealment and view of the surroundings. Journal of Avian Biology 26:305-312

Gram WK, Porneluzi PA, Clawson RL, Faaborg J, Richter SC (2003) Effects of Experimental Forest Management on Density and Nesting Success of Bird Species in Missouri Ozark Forests. Conservation Biology 17 (5):1324-1337

Grimmett R, Inskipp C, Inskipp T (1998) Birds of the Indian subcontinent. Oxford University Press

Grubb PJ (1977) The maintenance of species-richness in plant communities: the importance of the regeneration niche. Biological reviews of the Cambridge Philosophical Society 52:107-145

Grubb PJ (1986) Problems posed by sparse and patchily distributed species in species-rich plant communities. Diamond J, Case TJ (eds) Community ecology. Harper & Row, New York, pp 207-225

Hallé F, Oldeman RAA, Tomlinson PB (1978) Tropical Trees and Forests: an Architectural Analysis. Berlin: Springer-Verlag

Hamilton AC, Perrott RA (1981) A study of altitudinal zonation in the montane forest belt of Mt. Elgon, Kenya/Uganda. Vegetation 54:107-125

Hamilton AC (1982) Environmental History of East Africa, Academic Press, London, p. 328.

Hammer, Harper DAT, Ryan PD (2007) PAST - PAlaeontological STatistics, ver. 1.71 http://folk.uio.no/ohammer/past/

Hawkins AFA (1999) Altitudinal and latitudinal distribution of east Malagasy forest bird communities. Journal of Biogeography 26:447-458

Hayek LC, Buzas MA (1997) Surveying natural populations. Columbia University Press, New York

Heaney LR (2001) Small mammal diversity along elevational gradients in the Philippines: an assessment of patterns and hypotheses. Global Ecology and Biogeography 10:15-39

Heck KL, van Belle G, Simberloff D (1975) Explicit calculation of the rarefaction diversity measurement and the determination of sufficient sample size. Ecology 56:1459-1461

Heikkinen RK, Luoto M, Virkkala R, Rainio K (2004) Effects of habitat cover, Landscape structure and spatial variables on the abundance of birds in an agricultural-forest mosaic. Journal of Applied Ecology 41:824-835

Henderson PA, Seaby RMH (2007) Species Diversity and Richness 4.0 Pisces Conservation Ltd, Lymington, UK.

Hill JK, Hamer KC (1998) Using species abundance models as indicators of habitat disturbance in tropical forests. Journal of Applied Ecology 35:458-460

Hofer U, Bersier L.F, Borcard D (1999) Spatial organization of a herpetofauna on an elevational gradient revealed by null model tests. Ecology 80:976-988

Holmes R, Robinson SK (1988) Spatial patterns, foraging tactics, and diets of ground-foraging birds in a northern hardwoods forest. Wilson Bulletin 100:377-394

Holmes RT, Robinson SK (1981) Tree species preferences of foraging insectivorous birds in a northern hardwoods forest. Oecologia 48:31-35

Holmes RT, Sherry TW (2001) Thirty-year bird population trends in an unfragmented temperate deciduous forest: importance of habitat change. Auk 118:589-609

Holmes RT, Sherry TW, Sturges FW (1986) Bird community dynamics in a temperate deciduous forest: long-term trends at Hubbard Brook. Ecological Monographs 56(3):201-220.

Holt RD (1984) Spatial heterogeneity, indirect interactions, and the co-existence of prey species. The American Naturalist 124:377-406

Hubbell SP and Foster RB (1983) Diversity of canopy trees in a neotropical forest and implication for conservation. In: Sutton SL, Whitmore TC and Chadwick AC (eds) The Tropical Rain Forest: Ecology and Management, Blackwell, Oxford, pp 25-41

Huston MA (1994) Biological diversity – the coexistence of species on changing landscapes. Cambridge University Press, Cambridge

Islam ZM, Rahmani AR (2004) Important bird areas in India: priority sites for conservation. Bombay Natural History Society, Mumbai

Jame FC (1971) Ordination of habitat relationships among breeding birds. Wilson Bulletin 83:215-236

James FC 1971 Ordination of habitat relationships among breeding birds. Wilson Bulletin 83:215-236.

James FC, Johnson RF, Wamer NO, Niemi GJ and Boecklen WJ (1984) The Grinnellian niche of the Wood Thrush. The American Naturalist 124:17-30

Jathar GA, Rahmani AR (2006) Endemic birds of India.Buceros 11 (2&3) 53 pp

Javed S (1996) A study on the Bird community structure at Terai forest in Dudwa National Park . Ph.D. Thesis. Aligarh Muslim University, Aligarh, India

Jayson EA (1994) Synecological and behavioural studies on the forest birds of Kerala. Unpublished Ph.D. Thesis, Calicut University, Calicut

Jayson EA, Mathew DN (2000a) Seasonal changes of tropical forest birds in Southern Western Ghats. Journal of Bombay Natural History Society 97(1):52-51

Jayson EA, Mathew DN (2000b) Diversity and species abundance distribution of birds in the tropical forests of Silent Valley, Kerala. Journal of Bombay Natural History Society 97(3):390-400

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

Jayson EA, Mathew DN (2003) Vertical stratification and its relation to foliage in tropical forest birds in Western Ghats (India). Acta Ornithologica 38(2):111-116

Jeffries MJ, Lawton JH (1984) Enemy free space and the structure of ecological communities. Biological Journal of the Linnean Society 23:269-286

Jha CS, Dutt CBS, Bawa KS (2000) Deforestation and landuse changes in Western Ghats, India. Current Science 79:231-238

Johns AD (1992) Tropical Deforestation and Species Extinction. Whitmore TC, Sayer JA (eds) Chapman and Hall, London, pp 15-53

Johnsingh AJT, Joshua J (1994) Avifauna in three vegetation types on Mundanthurai Plateau, South India. Journal of Tropical Ecology 10:323-335

Kaiser HF (1958) The varimax criterion for analysis rotation in factor analysis. Psychometrika 23: 187-200

Kannan R (1994) Ecology and conservation of the Great Pied Hornbill (*Buceros bicornis*) in the Western Ghats of southern India. Ph. D. Thesis, University of Arkansas, Arkansas

Karr JR (1976a) Within-and between-habitat avian diversity in African and Neotropical lowland habitats. Ecological Monographs 46:457-481

Karr JR (1976b) Seasonality, resource availability, and community diversity in tropical bird communities. American Naturalist 110:973-994

Karr JR, Freemark KE (1983) Habitat selection and environmental gradients: dynamics in the "stable" tropics. Ecology 64:1481-1494

Kattan GH, Franco P (2004) Bird diversity along elevational gradients in the Andes of Colombia: area and mass effects. Global Ecology and Biogeography 13:451-458

Kessler M (2001a) Patterns of diversity and range size of selected plant groups along an elevational transect in the Bolivian Andes. Biodiversity and Conservation 10:1897-1902

Kessler M, Herzog SK, Fjeldsa J, Bach K (2001) Species richness and endemism of plant and bird communities along two gradients of elevation, humidity and land use in the Bolivian Andes. Diversity and Distribution 7:61-77

Khan MAR (1978) Ecology of Balck-and-Orange Flycatcher Journal of Bombay Natural History Society 75:773-791

Khan ML, Menon S, Bawa KS (1997) Effectiveness of the protected area network in biodiversity conservation: a case-study of Meghalaya state. Biodiversity and conservation 6:853-868

Kitahara M (2000) Food resource usage patterns of adult butterfly communities in woodland habitats at the northern foot of Mt. Fuji, central Japan. Japanese Journal of Environmental Entomology and Zoology 11, 61-81. (In Japanese with English Summary.)

Krebs CJ (1989) Ecological Methodology. Harper and Row, New York

Kumar A, Konstant WR, Mittermeier RA (1999) Western Ghats and Sri Lanka. In: Mittermeier RA, Myers N, Mittermeier CG (eds) Hotspots: Earth's Biologically

Richest and Most Endangered Terrestrial Ecoregions. CEMEX and Conservation International, London, pp 354-365

Kumar A, Pethiyagoda R, Mudappa D (2004) Western Ghats and Sri Lanka. In: Mittermeier RA, Gil PR, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, da Fonseca GAB (eds), Hotspots Revisited: Earth's Biologically Richest and Most Threatened Terrestrial Ecoregions. CEMEX and Conservation International, London, pp 152-157

Kunte K, Joglekar A, Ghate U, Pramod P (1999) Patterns of Butterfly, Birds and Tree Diversity in the Western Ghats. Current Science 77:577-586

Lack D (1968) Ecological adaptations of breeding in birds. Methuen and Co. Ltd. London

Lack D (1971) Ecological isolation in birds. Blackwell Scientific Publications, Oxford and Edinburgh

Lan D, Dunbar R (2000) Bird and mammal conservation in Gaoligongshan region and Jongdong country, Yunnan, China: patterns of species richness and nature reserves. Oryx 34:275-286

Lawton JH, Bignell DE, Bolton B, Bloemers GF, Eggleton P, Hammond PM, Hodda M, Holt RD, Larsen TB, Mawdsley NA, Stork NE, Srivastava DS, Watt AD (1998) Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. Nature 391:72-76

Lees DC (1999) A null model for species richness gradients: bounded range overlap of butterflies and other rainforest endemics in Madagascar. Biological Journal of the Linnean Society. 67:529-584

Legris P, Meher-Homji VM (1977) Phytogeographic outlines of the hill ranges of peninsular India. Tropical Ecology 18:10-24

Lein VV, Yuan D (2003) The differences of butterfly (Lepidoptera, Papilionoidea) communities in habitats with various degrees of disturbance and altitudes in tropical forests of Vietnam. Biodiversity and Conservation 12:1099-1111

Lescourret F, Genard M (1994) Habitat, landscape and bird composition in mountain forest fragments. Journal of Environmental Management 40:317-328

Li P, Martin TE (1991) Nest site selection and nesting success of cavity-nesting birds in high elevation forest drainages. Auk 108:405-418.

Loiselle BA, Blake JG (1991) Resource abundance and temporal variation in fruit-eating birds along a wet forest elevational gradient in Costa Rica. Ecology 72:180-193

Lomolin MV (2001) Elevational gradients of species-density: historical and prospective views. Global Ecology and Biogeography 10:3-13

MacArthur RH (1972) Geographical ecology. Princeton University Press

MacArthur RH, Mac Arthur JW (1961) On bird species diversity. Ecology 42:594-598

MacArthur RH, Wilson EO (1967) The Theory of Island Biogeography. Princeton University Press, Princeton, New Jersey

MacFaden SW, Capen DE (2002) Avian habitat relationships at multiple scales in a New England forest. Forest Science 48:243-253

MacKenzie DI, Sealy SG, Sutherland GD (1982) Nest-site characteristics of the avian community in the dune-ridge forest, Delta Marsh, Manitoba: a multivariate analysis. Canadian Journal of Zoology 60:2212-2223

Magurran AE (1988) Ecological diversity and its measurement. Croom Helm, Australia

Magurran AE (2004) Measuring biological diversity. Blackwell Science, London

Maheswaran B (2002) Habitat utilization by Malabar Grey Hornbill at Mudumalai Wildlife Sanctuary, Western Ghats. Ph.D. Thesis, Bharathiar University, Coimbatore, India

Mani MS (1974) Ecology and biogeography of India. Dr. W. Junk Publishers, Hague

Manilal KS (1988) Flora of Silent Valley: Tropical rain forests of India. The Mathrubhumi Press, Calicut

Manoharan TM, Biju SD, Nayar TS, Easa PS (eds) (1999) Silent Valley; Whispers of reason. Kerala Forest Department, Thiruvananthapuram

Mao CX, Colwell RK (2005) Estimation of species richness: Mixture models, the role of rare species, and inferential challenges. Ecology in press

Margalef R (1959) Information theory in ecology. General systematics 3:36-71

Margaretha Z, Pangau-Adam, Waltert M, Mũlenberg M (2006) Nest predation risk on ground and shrub nests in forest margin areas of Sulawesi, Indonesia. Biodiversity and Conservation 15:4143-4158

Martin PR and Martin TE (2001) Behavioral interactions between two coexisting wood warblers (Parulidae: Vermivora): experimental and empirical tests. Ecology 82, 207-218.

Martin TE (1988a) On the advantage of being different: Nest predation and the coexistence of bird species. Proceedings of the National Academy of Sciences, USA 85, 2196-2199

Martin TE (1988b) Habitat and area effects on forest bird assemblages: Is nest predation an influence? Ecology 69:74-84

Martin TE (1992a) Breeding season productivity considerations: what are the appropriate habitat features for management? In: Hagan JM, Johnston DW (eds) Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institute Press, Washington D.C pp 445-473

Martin TE (1992b) Interaction of nest predation and food limitation in reproductive strategies. Current Ornithology 9:163-197

Martin TE (1993a) Nest predation and nest sites: new perspective and old patterns. Bioscience 43:523-532

Martin TE (1993b) Nest predation among vegetation layers and habitat types: revising the dogmas. American Naturalist 141:897-913

Martin TE (1995) Avian life history evolution in relation to nest sites, nest predation and food. Ecological Monographs 65:101-127

Martin TE (1998) Are microhabitat preferences of coexisting species under selection and adaptive? Ecology 79:656-670

Martin TE, Geupel GR (1993) Nest-monitoring plots: Methods for locating nests and monitoring success. Journal of Field Ornithology 64(4):507-519

Marzluff JM, Raphael MG, Sallabanks R (2000) Understanding the effects of forest management on avian species. Wildlife Society Bulletin 28:1132-1143

Mathew G (1990) Studies on the Lepidopteran fauna. In: Ecological studies and long term monitoring of biological processes in the Silent Valley National Park. Report submitted to MoEF, Government of India, Kerala Forest Research Institute, Peechi

May RM (1975) Patterns of species abundance and diversity. In Ecology and Evolution of Communities. Cody ML, Diamond JM (eds) Cambridge, Mass: Harvard University Press

McAleece N, Lambshead PJD, Paterson GLJ (1997) Biodiversity Pro The Natural History Museum. London URL: http://www.sams.ac.uk/

McCabe DJ, Gotelli NJ (2000) Effects of disturbance frequency, intensity, and area on assemblages of stream invertebrates. Oecologia 124:270-279

McCain CM (2005) Elevational gradients in diversity of small mammals. Ecology 86: 366-372

McCoy ED (1990) The distribution of insect along elevational gradients. Oikos 58:313-322

McGarigal K, Cushman S, Stafford S (2000) Multivariate statistics for wildlife and ecology research. Springer, New York

McGuinness KA (1984) Species-area relations of communities on intertidal boulders: Testing the Null Hypothesis. Journal of Biogeography 11(5):439-456

Mezquida ET, Marone L (2001) Factors affecting nesting success of a bird assembly in the central Monte Desert, Argentina. Journal of Avian Biology 32:287-296

Mittermeier, Russell A, Gil PR, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, da Fonseca GAB (2005) Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions. Published by Cimex , Mexico

Molleman F (2006) Patterns of Biodiversity and Life History evolution in fruit-feeding butterflies. Ph.D. Thesis. Leiden University, The Netherlands

Muller-Dombois DD, Ellenberg H (1974) Aims and Methods of Vegetation Analysis. John Wiley and Sons, New York

Murphy J (2000) Improving the value of conservation programs. Conservation Biology 14(6):1569

Murphy MT (1983) Nest success and nesting habits of Eastern Kingbirds and other flycatchers. Condor 85:208-219

Myers N (2003) Biodiversity hotspots revisited. Bioscience 53:916-917

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kents J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853-858

Nagarajan R (2000) Nesting and breeding ecology of Barn Owls. Ph.D. Thesis Barathidasan University, Trichy, India

Nair PV, Ramachandran KK, Vijayan VS, Easa PS, Balakrishnan PV (1985) An ecological study in Periyar Tiger Reserve with special reference to wildlife. Report, Kerala Forest Research Institute, Peechi

Nair SC (1991) The Southern Western Ghats: A Biodiversity Conservation Plan. INTACH, New Delhi

Nalwanga D, Lloyd P, Plessis MA, Martin TE (2004) Nest-site partitioning in a strandveld shrubland bird community. Ostrich 75(4):250-258

Navarro SAG (1992) Altitudinal distribution of birds in the Sierra Madre del Sur, Guerrero, Mexico. Condor 94:29-39

Nayar MP (1996) "Hot Spots" of endemic plants of India, Nepal and Bhutan. Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram, p 195

NEST1994. Checklist of birds of Parambikulam. Accessed on June 12, 2005 http://www.parambikulam.org/assets/checklists/birds.pdf.

Newton I (1984) Life time reproduction in birds. Acadamic press, New York

Nirmala T Sr (2002) Ecology of bird communities in the Anaikatty hills, Coimabtore. Ph.D. Thesis. Bharathiar University. Coimbatore

Norusis MJ (2001) SPSS Professional Statistics. SPSS Inc., Chicago

Novotny´V (1991) Effects of habitat persistence on the relationship between geographic distribution and local abundance. Oikos 61:431-433

Nummelin M (1998) Log-normal distribution of species abundances is not an universal indicator of rainforest disturbance. Journal of Applied Ecology 35:454-457

Olson DM, Dinerstein E (1998) The Global 200: A representation approach to conserving the earth's most biologically valuable resources. Conservation Biology 12:502-515

Palmer MW (1993) Putting things into even better order: the advantages of canonical correspondence analysis. Ecology 74:2215-2230

Pangau-Adam MZ (2003) Avian nest predation in forest margin areas in Lore Lindu National Park, Central Sulawesi, Indonesia. Ph.D. Thesis. George August University of Göttingen, published at http://webdoc.sub.gwdg.de/diss/2003/pangau/index.html

Pangau-adam MZ, Waltert M, Hlenberg MM (2000) Nest predation risk on ground and shrub nests in forest margin areas of Sulawesi, Indonesia. Biodiversity and Conservation 15:4143-4158

Parody JM, Parker TH (2002) Biogeographic variation in nest placement: a case study with conservation implications. Diversity and Distributions 8:11-20

Parthasarathy N (1999) Tree diversity and distribution in undisturbed and human-impacted sites of tropical wet evergreen forest in southern Western Ghats, India. Biodiversity and Conservation 8:1365-1381

Parthasarathy N (2001) Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. Current Science 80:389-393

Parthasarathy N, Karthikeyan R (1997) Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandel coast, South India. Biodiversity and Conservation 6:1063-1083

Pascal JP (1988) Wet Evergreen Forests of the Western Ghats of India: ecology, structure, floristic composition and succession. French Institute of Pondicherry, Pondicherry, India, pp 294

Pascal JP, Pelissier R (1996) Structure and floristic composition of a tropical evergreen forest in southwest India. Journal of Tropical Ecology 12:191-214

Pascal JP, Ramesh BR (1987) A field key to the trees and lianas of the evergreen forests of the Western Ghats (India). Institut Francais de Pondichery, Travaux de la section Scientifique et Technique, Tome XXIII, Pondicherry

Pasitschniak-Arts M, Messier F (1996) Predation on artificial duck nests in a fragmented prairie landscape. Ecoscience 3:436-441

Patterson BD, Stotz DF, Solari S, Fitzpatrick JW,Pacheco V (1998) Contrasting patterns of elevational zonation for birds and mammals in the Andes of southeastern Peru. Journal of Biogeography 25:593-607

Pearson D (1971) Vertical stratification of birds in a tropical dry forest. Condor 73:46-55

Pearson L, Ghorpade K (1989) Geographical Distribution and Ecological History of Tiger Beetles (Coleoptera: Cicindelidae) of the Indian Subcontinent. Journal of Biogeography 16:333-344

Petrides GA (1986) A Field Guide to Trees and Shrubs: northeastern and north-central United States and southeastern and south-central Canada, 2nd edn. Houghton Miffling Company, Boston, MA

Pielou EC (1966) The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13:131-144

Pielou EC (1975) Ecological diversity. Wiley, New York

Powell BE, Steidl RJ (2000) Nesting Habitat and Reproductive Success of Southwestern Riparian birds. The Condor 102:823-831

Pramod P (1995) Ecological studies of bird communities of Silent Valley and neighbouring forests. Ph.D. Thesis, University of Calicut, Calicut

Pramod P, Joshi NV, Ghate U, Gadgil M (1997) On the hospitality of Western Ghats habitats for bird communities. Current Science 73:122-127

Pramod P, Yom-Tov Y (1999) The breeding season and clutch size of Indian passerines. Ibis 142:75-81

Prasad SN, Vijayan L, Joshua J, Balachandran S, Ronald J, Varghese CPA, Ramachandran VS (1998) Conservation planning for the Western Ghats of Kerala. Project Report, Sálim Ali Centre for Ornithology and Natural History, Coimbatore

Premkumar V (2002) Management Plan: Silent Valley National Park *2002-2012*. Kerala Forest Department, Mannarkkad.

Prendergast JR (1997) Species richness covariance in higher taxa: empirical tests of the biodiversity indicator concept. Ecography 20:210-216

Rahbek C (1995) The elevational gradient of species richness: a uniform pattern? Ecography 18:200-205

Rahbek C (1997) The relationship among area, elevation, and regional species richness in Neotropical birds. American Naturalist 149:875-902

Ralph CJ, Geupel GR, Pyle P, Martin TE, DeSante DF (1993) Handbook of field methods for monitoring landbirds. Gen. Tech. Rep. Pacific Southwest Research Station, Forest Service, U. S. Department of Agriculture, Albany, CA PSW-GTR-144

Ramakrishnan P (1983) Environmental studies on the birds of Malabar Forests. Ph.D. Thesis, University of Calicut, Calicut

Raman TRS (2001) Community ecology and conservation of tropical rainforest birds in the southern Western Ghats, India. Ph.D. Thesis, Centre for ecological Sciences, Indian Institute of Science, Bangalore

Raman TRS (2003) Assessment of census techniques for inter-specific comparisons of tropical rainforest bird densities: a field evaluation in the Western Ghats, India. Ibis 145:9-21

Raman TRS (2004) Effects of landscape matrix and plantations on birds in tropical rainforest fragments of the Western Ghats, India. CERC Technical Report no. 9. Nature Conservation Foundation, Mysore, India

Raman TRS (2006) Effects of habitat structure and adjacent habitats on birds in tropical rainforest fragments and shaded plantations in the Western Ghats, India. Biodiversity and Conservation 15:1577-1607

Raman TRS, Mudappa D (2003) Correlates of hornbill distribution and abundance in rainforest fragments in the southern Western Ghats, India. Bird Conservation International 13:199-212

Raman TRS, Sukumar R (2002) Responses of tropical rainforest birds to abandoned plantations, edges and logged forest in the Western Ghats, India. Animal Conservation 5:201-216

Rasmussen PC, Anderton JC (2005) Birds of South Asia. The Ripley Guide 1 & 2 Smithsonian Institution and Lynx Editions, Washington DC and Barcelona

Reitsma LR (1992) Is nest predation density dependent? A test using artificial nests. Canadian Journal of Zoology 70:2498-2500

Reitsma LR, Whelan CJ (1999) Does vertical partitioning of nest site decrease nest predation? Auk 117:409-415

Repasky RR (1991) Temperature and the northern distributions of wintering birds. Ecology 72:2274-2285

Rholf FL (1987) Numerical taxonomy and multivariate analysis system. Exeter publishing Setauket, New York

Richards PW (1996) The Tropical Rain Forest: an Ecological Study, 2nd edn Cambridge University Press, Cambridge

Ricklefs RE (1969) An analysis of nesting mortality in birds. Smithsonian Contributions to Biology, no. 9, Washington

Robin VV, Sukumar R (2002) Status and habitat preference of White-bellied Shortwing *Brachypteryx major* in the Western Ghats (Kerala and Tamil Nadu) India. Bird Conservation International 12:335-351

Robinson SK, Wilcove DS (1994) Forest fragmentation in the temperate zone and its effects on migratory songbirds. Bird Conservation International 4:233-249

Rodgers WA, Panwar HS (1988) Planning a Wildlife Protected Area Network in India. Wildlife Institute of India, Dehradun

Root RB (1967) The niche exploitation pattern of the Blue-gray Gnatcatcher. Ecological Monographs 37:317-350

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

Rosenzweig ML (1995) Species diversity in space and time. Cambridge University Press, New York

Rotenberry JT (1981) Why measure bird habitat? In: Capen, D.E. (Eds.) The Use of Multivariate Statistics in Studies of Wildlife Habitat. General Technical Report RM-87, USDA Forest Service, Rocky Mountain Forest and Range

Rotenberry JT (1985) The role of habitat in avian community composition: physiognomy or floristics? Oecologia 67:213-217

Rotenberry JT, 1981. Why measure bird habitat? In: Capen, D.E. (Eds.). The Use of Multivariate Statistics in Studies of Wildlife Habitat. General Technical Report RM-87, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, pp. 29-32.

Sale AHJ (1971) Algorithm 65. An improved clustering algorithm Computation Journal 14: 104-106

Sanders HL (1968) Benthic marine diversity: a comparative study. American Naturalist 102:660-668

Saxena AK, Singh SP, Singh JS (1984) Population structure of forests of Kumaon Himalaya: implications for management. Journal of Environmental management 190:307-324

Schmidt KA, Whelan CJ (1999) Effects of Exotic *Lonicera* and *Rhamnus* on Songbird Nest Predation. Conservation Biology 13 (6):1502-1506

Sekercioglu CH (2002) Forest Fragmentation Hits Insectivorous Birds Hard. Directions in Science 1:62-64

Sekercioglu CH, Daily GC, Ehrlich PR (2004) Ecosystem consequences of bird declines. Proc National Academy of Sciences, USA 101:18042-18047

Seoane J, Bustamente J, Diaz-Delgado R (2004) Competing roles for landscape, vegetation, topography and climate in predictive models of bird distribution. Ecological Modelling 171:209-222

Shukkur EAA, Joseph KJ (1980) Breeding biology of Black Drongo. Journal of Bombay Natural History Society 75:1212-1226

Shreeve TG, Dennis RLH, Pullin AS (1996) How marginal is the British butterfly fauna and what are the implications for research opportunities and conservation? Biodiversity and Conservation 5:1131-1141.

Simpson EH (1949). Measurement of diversity. Nature 163:688

Singh J.S., Singh S.P., Saxena A.K. and Y.S. 1986. The Silent Valley Forest Ecosystem and Possible Impact of Proposed Hydroelectric Project. Reports on the Silent valley Study. Ecology Research Circle, Kumaun University, Nainital, India, pp 86.

Somasundaram S (2006) Status and ecology of Nilgiri Wood Pigeon in the Western Ghats. Ph.D. Thesis, Bharathiar University, Coimbatore

Spitzer K, Jaros J, Havelka J, Leps J (1997). Effect of small-scale disturbance on butterfly communities of an Indochinese montane rainforest. Biological Conservation 80: 9-15.

Spitzer K, Novotny V, Tonner M, Leps J (1993) Habitat preferences, distribution and seasonality of the butterflies (Lepidoptera, Papilionoidea) in a Montane tropical rain-forest, Vietnam. Journal of Biogeography 20:109-121

Srinivas V, Parthasarathy N (2000) Comparative analysis of tree diversity and dispersion in the tropical lowland evergreen forest of Agumbe, central Western Ghats, India. Tropical Biodiversity 7: 45-60

Srinivasa YB, Kumar AN, Prathapan KD (2004) Canopy arthropods of *Vateria indica* L. and *Dipterocarpus indicus* Bedd. in the rainforests of Western Ghats, South India. Current Science 86:10-25

Stacy EA, Hamrick JL, Nason JD, Hubbel SP, Foster RB, Condit R (1996) Pollen dispersal in low-density populations of three neo-tropical trees species. American Naturalist 148:275-298

Stattersfield AJ, Capper DR (eds) (2000) Threatened Birds of the World. BirdLife International, Cambridge, United Kingdom.

Stattersfield AJ, Crosby MJ, Long AJ, Wege DC (1998) Endemic bird areas of the world. BirdLife International, Cambridge, United Kingdom.

Stevens GC (1992) The elevational gradient in altitudinal range: an extension of Rapoport's latitudinal rule to altitude. American Naturalist 140:893-911

Stiles FG (1985) Altitudinal movements of birds on the Caribbean slope of Costa Rica: implications for conservation. In: Almeda F, Pringle CM (eds) Tropical rain forest: diversity and conservation. San Francisco: California Academy of Sciences, pp 243-258

Sugathan R (1999) An introduction to the avifauna of Silent Valley. In: Manoharan TM, Biju SD, Nayar TS, Easa PS (eds) Silent Valley whispers of reason. Kerala Forest Department, Thiruvananthapuram, pp 349-362

Sukumar R, Suresh HS, Dattaraja HS and Joshi NV (1997) Dynamics of a tropical deciduous forest: population changes (1988 through 1993) in a 50-ha plot at Mudumalai, southern India. In: Dallmeier F and Comiskey JA (eds) Forest Biodiversity Research, Monitoring and Modelling Conceptual Background

Sultana A, Hussain MS, Khan JA (2007) Bird communities of the proposed Naina and Pindari wildlife sanctuaries in the Kumaon Himalaya, Uttarakhand, India. Journal of Bombay Natural History Society 104:19-29

Swamy PS, Sundarapandian SM, Chandrasekar P, Chandrasekaran S (2000) Plant species diversity and tree population structure of a humid tropical forest in Tamil Nadu, India. Biodiversity and Conservation 9:1643-1669

Sykes JM, Horrill AD (1977) Vegetation monitoring in Indian tiger reserves; A report to the WWF. Merlewood research station

Terborgh J (1971) Distribution on environmental gradients: theory and a preliminary interpretation of distributional patterns in the avifauna of the Cordillera Vilcabamba, Peru. Ecology 52:23-40

Terborgh J (1977) Bird species diversity on an Andean elevational gradient. Ecology 58:1007-1019

Terborgh J, Robinson SK, Parker TA, Munn CA, Pierpont N (1990) Structure and organization of an Amazonian bird community Ecological Monographs 60 (2):213-238

Thiyagesan K (1991) Ecology of cavity nesting birds in and around Mayiladuthurai, Tamil Nadu, South India. Ph.D. Thesis, Bharathidasan University, Tiruchirapalli.

Thurstone LL (1947) Multiple factor analysis. University of Chicago Press, Chicago

Tilman D, Lehman CL, Thomson KT (1997) Plant diversity and ecosystem productivity: Theoretical considerations. Ecology 94:1857-1861

Tokeshi M (1993) Species abundance patterns and community structure. Advances in Ecological Research. University Press, Melbourne 2:4111-185

Tye H (1991) Reversal of breeding season by lowland birds at higher altitudes in western Cameroon. Ibis 114:154-161.

Udvardy MDF (1975) A Classification of the Biogeographical Provinces of the World. Occasional Paper of the IUCN Species Survival Commission no.18, IUCN, Morges, Switzerland

Uehara-Prado M., Brown K.S.J. and Freitas A.V.L. 2007. Species richness, composition and abundance of fruit-feeding butterflies in the Brazilian Atlantic Forest: comparison between a fragmented and a continuous landscape. Global Ecology and Biogeography 16: 43-54

Ugland KI, Gray JS (1982) Lognormal distributions and the concept of community equilibrium Oikos 39:171-178

Unnikrishnan PN (1991) Management Plan: Silent Valley National Park 1991-2001. Kerala Forest Department, Mannarkkad.

Vajravelu E (1992) Flora of Palghat, including Silent Valley National Park, Kerala. Botanical Survey of India, Culcutta

Vijayan and Balakrishnan (1977) Impact of hydro-electric project on wildlife. A report of the first phase of study. KFRI Research Report No. S1. Kerala Forest Research Institute, Peechi.

Vijayan L (1984) Comparitive Ecology of the Drongos with thre special referance to Ecological isolation. Ph.D. Thesis, University of Bombay, Bombay

Vijayan L, Bhupathy S, Balasuramanian P, Nórmala T, Ravikumar S (2000) A Bird Survey in the Silent Valley National Park, Kerala, Sálim Ali Centre for Ornithology and Natural History, Coimbatore , pp 19

Vijayan L, Das KSA (2006) Bird monitoring in the Silent Valley National Park, Kerala. Report submitted to the Kerala Forest and Wildlife Department. Sálim Ali Centre for Ornithology and Natural History, Coimbatore

Vijayan L, Gokula V (2006) Human Impact on forest Bird Communities in the Western Ghats, India. Acta Zoologica Sinica. Proc of the 23rd International Ornithological Congress, Beijing 2002, pp 692-696

Vijayan L, Gokula V, Prasad S N (2001) Study of Nilgiri Laughing Thrush, Tamil Nadu, India. Oriental Bird Club bulletin 34:18-19

Vijayan L, Prasad SN, Balasubramanian P, Gokula V, Ramachandran NK, Stephen D, Mahajan MV (1999) Impact of human interference on the plant and bird communities in the Nilgiri Biosphere Reserve. Project Report, Sálim Ali Centre for Ornithology and Natural History, Coimbatore

Vijayan L, Prasad SN, Balasuramanian P, Gokula V, Ramachandran NK, Stephen D, Mahajan MV (1998) Impact of Human Interference on the Plant and Bird Communities in the Nilgiri Biosphere Reserve. In: Maikhuri RK, Rao KS & Rai RK (ed) Biosphere reserves and management in India. (Proc workshop, 11-15 June 1997, Joshimath, UP) GB Pant Institute of Himalayan Environment & Development, Almora,U.P, pp 155-162

Vijayan L, Umamaheshwary J, Somasundaram S (2005) Status and Ecology of the Nilgiri Wood Pigeon and Nilgiri Pipit in the Western Ghats, Sálim Ali Centre for Ornithology and Natural History, Coimbatore , pp 91

Vijayan L, Vijayan VS, Arun PR, Venkatraman C (2000) Breeding strategies of birds in a moist deciduous forest at Siruvani in the Nilgiri Biosphere Reserve. Report, Salim Ali Centre for Ornithology and Natural History, Coimbatore

Vijayan VS (1975) Ecological isolation of Bulbuls with special reference to *Pycnonotus cafer cafer* and *P. luteolus luteolus* at Point Calimere, Tamil Nadu. Ph.D. Thesis, University of Bombay, Bombay

Vijayan VS (1980) Breeding biology of bulbuls, *Pycnonotus cafer* and *Pycnonotus luteolus* (Class: Aves, Family: Pycnonotidae) with special reference to their ecological isolation. Journal of Bombay Natural History Society 75:1090-1117

Vijayan VS, Balakrishnan P (2005) Status, distribution and ecology of the Grey-headed Bulbul *Pycnonotus priocephalus* in Western Ghats, India. Technical Report, Sálim Ali Centre for Ornithology and Natural History, Coimbatore

Vinod UJ (2007) Status and Ecology of the Nilgiri Pipit in the Western Ghats. Ph.D. Thesis. Bharathiar University, Coimbatore

Whittaker RJ (1998) Island Biogeography. Oxford New york, Tokyo, Oxford University Press

Wiens JA (1989) Determining pattern and process: the logical structure of community ecology. Wiens JA (ed) The Ecology of Bird Communities, Volume 1: Foundations and Patterns. Cambridge University Press, Cambridge pp 18- 36

Williams VL, Edward TF, Witkowski KB (2007) The use of incidence-based species richness estimators, species accumulation curves and similarity measures to appraise ethnobotanical inventories from South Africa Biodiversity and Conservation 16:2495-2513

Willott SJ (1999) The effects of selective logging on the distribution of moths in a Bornean rainforest. Philosophical Transactions of the Royal Society B, 354:1783-1790.

Willson MF, Gende SM (2000) Nesting success of forest birds in southeast Alaska and adjacent Canada. Condor 102:314-325

Wolda H (1987) Altitude, habitat and tropical insect diversity. Biological Journal of the Linnean Society 30:313-323

Woltmann S (2003) Bird community responses to disturbances in a forestry concession in lowland Bolivia. Biodiversity and conservation 12: 1921-1936

Wunderle JM Jr, Willig MR, Henriques LMP (2005) Avian distribution in treefall gaps and understorey of terra firme forest in the lowland Amazon. Ibis 147:109-129

Yahya HSA (1980) A comaparative study of ecology and biology of barbets *Megalaima* sp. (Capitonidae: piciformes) with special reference to *Megalaima viridis* (Boddaert) and *M. rubricapilla malabarica* (blyth) at Periyar Tiger Reserve, Kerala. Ph. D. Thesis, University of Bombay, Bombay, India

Yeh PJ, Hauber ME, Price (2007) Alternative nesting behaviours following colonisation of a novel environment by a passerine bird. Oikos 116:1473-1480

Young BE (1994) The effects of food, nest predation and weather on the timing of breeding in tropical House Wrens. The Condor 96(2):341-353

Zacharias VJ (1979) Ecology of certain species of babblers (*Turdois* spp.) Ph. D Thesis. Calicut University, Calicut

Zacharias VJ, Mathew DN (1988) Ecology of Babblers. Journal of Bombay Natural History Society 85:50-64

Zaibin AP (2005) Vertical stratification and community structure of birds in the southern Western Ghats: a study in forest and plantation. MSc. Thesis. Department of Wildlife Sciences, Aligarh Muslim University, India

Zar JH (1999) Biostatistical Analysis. 4th Edition. Prentice-Hall, New Jersey

ZSI (1986) Fauna of Silent Valley, Kerala, India. Records of the Zoological Survey of India. Special Issue No. 84

Appendix 3.1 Checklist of trees recorded in each transects in SVNP

Sl.No	Plant species	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG	Fruit Type
1	*Acronychia laurifolia#*	-	1	-	-	-	-	D
2	*Acronychia pedunculata#*	2	2	2	-	-	-	B
3	*Actinodaphne bourdillonii#*	-	2	-	1	-	-	B
4	*Actinodaphne hirsuta*	-	1	2	-	-	-	B
5	*Actinodaphne lawsonii*	1	7	6	5	28	-	F
6	*Aglaia anamalayana*	-	-	10	-	-	-	D
7	*Aglaia indica #*	-	2	1	-	-	-	C
8	*Aglaia spp #*	1	5	-	-	-	-	D
9	*Aglaia barberi #*	-	-	2	-	-	-	D
10	*Agrostistachys borneensis*	-	27	20	1	-	-	D
11	*Agrostistachys longifolia #*	-	9	-	-	-	-	C
12	*Aidia gardneri #*	-	1	2	-	-	-	D
13	*Alseodaphne semecarpifolia #*	-	-	-	1	14	-	D
14	*Alstonia scholaris #*	-	3	-	1	-	-	D
15	*Antidesma menasu*	9	7	8	1	1	-	B
16	*Apodytes dimidiata*	-	3	-	1	7	16	B
17	*Apollonias arnottii*	-	-	-	2	1	-	B
18	*Artocarpus gomezianus*	-	2	2	-	-	-	B
19	*Artocarpus integrifolia #*	-	-	-	2	-	-	C
20	*Bischofia javanica*	2	3	8	-	-	-	C
21	*Blachia dendata #*	0	1	1	-	-	-	N
22	*Callicarpa tomentosa #*	1	-	-	-	-	-	D
23	*Calophyllum apetalum*	-	-	-	9	-	-	D
24	*Calophyllum polyanthum #*	3	1	1	-	-	1	D
25	*Calophyllum tomentosum*	-	-	-	1	-	-	D
26	*Canarium strictum*	1	6	5	-	-	-	D
27	*Canthium neilgherrense #*	-	-	-	46	5	1	C
28	*Casearia bourdillonii*	5	2	1	16	3	6	C
29	*Celtis timorensis*	-	3	4	1	-	-	C
30	*Celtis trinervia*	-	-	-	-	2	-	D
31	*Cinnamomum sulphuratum*	-	-	-	2	15	21	B
32	*Cinnamomum wightii*	1	-	1	1	-	-	C
33	*Clerodendrum viscosum #*	19	2	8	1	-	-	C
34	*Croton malabaricus #*	-	5	2	1	-	-	D
35	*Cryptocarya spp #*	-	5	-	-	-	-	D
36	*Cullenia exarillata*	22	37	26	-	-	-	C
37	*Daphniphyllum neilgherrense*	-	-	-	9	-	-	S
38	*Dimocarpus longan #*	14	10	16	-	-	-	S
39	*Drypetes elata*	-	1	2	-	-	-	D
40	*Dysoxylum beddomei*	-	-	-	-	1	-	C
41	*Elaeocarpus munroni*	3	2	2	8	2	-	C
42	*Elaeocarpus oblongus*	-	-	-	12	1	-	N
43	*Elaeocarpus recurvatus*	-	-	-	-	10	12	B
44	*Elaeocarpus serratus*	3	8	1	-	-	-	C
45	*Elaeocarpus tuberculatus*	26	6	19	-	-	-	P
46	*Epiprinus mallotiformis #*	-	1	10	-	-	-	C
47	*Euphorbia antiquorum*	-	-	2	-	-	-	C
48	*Eurya nitida #*	-	-	-	14	8	3	C
49	*Ficus beddomei*	1	-	1	-	-	-	B
50	*Ficus nervosa*	2	-	3	-	-	-	D

Sl.No	Plant species	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG	Fruit Type
51	*Ficus hispida*	1	-	1	-	1	-	D
52	*Ficus sp.*	-	-	1	-	-	-	D
53	*Ficus virens*	3	-	3	-	-	-	D
54	*Flacourtia montana*	-	7	3	1	-	5	D
55	*Garcinia gummi- gutta #*	-	-	-	1	10	-	B
56	*Garcinia morella #*	3	4	-	1	1	-	B
57	*Garcinia pictoria*	13	2	3	3	1	-	B
58	*Glochidion ellipticum*	5	3	9	-	4	1	B
59	*Gnetum ula*	-	-	-	2	1	-	B
60	*Gomphandra coriasia*	9	-	4	-		-	B
61	*Gomphandra tetrandra #*	1	2	17	1		-	B
62	*Gordonia obtuse #*	-	-	-	-	1	9	B
63	*Hemicyclia elata*	2	5	2	-	-	-	B
64	*Heynea trijuga*	-	1	1	-	-	-	B
65	*Holigarna arnottiana*	1	3	1	2	-	-	B
66	*Holigarna nigra*	-	4	-	-	-	-	B
67	*Homalium travancoricum*	-	-	-	-	7	-	B
68	*Hopea parviflora #*	-	3	-	-	-	-	B
69	*Ilex wightiana*	-	-	-	-	-	1	B
70	*Karimaram*	-	-	-	5	-	-	B
71	*Kingiodendron pinnatum*	-	-	1	-	-	-	B
72	*Knema attenuata*	-	13	-	3	-	-	B
73	*Laportea crenulata*	-	-	6	1	-	-	B
74	*Lasianthus jackianus*	-	-	-	-	-	2	B
75	*Litsea bourdillonii #*	-	-	3	-	-	-	F
76	*Litsea floribunda #*	11	5	3	4	-		B
77	*Litsea leavigata #*	-	2	5	12	1		B
78	*Litsea stocksii*	-	-	-	27	37	28	B
79	*Litsea wightiana*	-	-	-	-	8	2	B
80	*Macaranga peltata*	17	2	4	29	-	-	B
81	*Machilus macrantha*	-	-	2	-	-	-	C
82	*Mallotus albus*	4	-	4	-	-	-	C
83	*Nothopegia travancorica*	-	-	1	-	-	-	C
84	*Mappia foetida*	-	-	-	-	1	-	C
85	*Meiogyne pannosa*	-	1	-	-	-	-	A
86	*Memecylon sisparense*	-	-	-	-	1	14	A
87	*Myristica dactyloides*	11	15	12	33	-	-	
88	*Myristica malabarica var magnifica*	2	5	-	1	-	-	
89	*Mesua ferrea #*	3	10	3	1	-	-	s
90	*Persea americana*	-	-	2	-	14	36	
91	*Microtropis densiflora*	-	-	-	-	13	7	S
92	*Myristica canarica*	-	3	-	4	-	-	
93	*Neolitsea fischeri #*	3	-	3	-	-	-	
94	*Neolitsea scrobiculata #*	-	1	-	4	6	-	
95	*Olea dioica #*	-	2	3	-	-	-	B
96	*Olea glandulifera #*	-	-	-	1	38	-	B
97	*Olea sp*	-	-	-	-	-	1	B
98	*Oreocnide integrifolia*	2	8	12	-	-	-	B
99	*Orophea uniflora*	-	1	-	-	-	-	B
100	*Palaquium ellipticum #*	21	32	9	-	-	-	B
101	*Persea macrantha*	5	11	4	1	-	-	B
102	*Phoebe lanceolata*	1	-	1	1	-	-	B

	Plant species	EGGL	EGD	EG	BLHF	SHOLA	SHOLAG	Fruit Type
103	*Phyllanthus emblica*	1	-	-	-	-	-	B
104	*Pithecellobium bigeminum*	-	1	-	-	-	-	B
105	*Pittosporum neilgherrense*	-	-	-	-	-	1	D
106	*Poeciloneuron pauciflorum*	-	-	-	-	1	2	D
107	*Polyalthia spp.*	-	2	-	-	-	-	D
108	*Rapanea striata*	-	-	-	-	-	1	C
109	*Rapanea wightiana*	-	-	-	1	4	14	B
110	*Rhododendron arboreum*	-	-	-	-	-	1	
111	*Rhodomyrtus tomentosa*	-	-	-	-	2	10	B
112	*Saprosma corymbosum*	-	-	-	1	4	7	B
113	*Saprosma spp*	-	-	-	-	1	1	B
114	*Schefflera stellata*	-	-	-	-	2	-	
115	*Schleichera oleosa*	2	1	1	-	-	-	C
116	*Scolopia crenata*	5	4	1	2	-	-	C
117	*Sterculia guttata*	-	-	-	-	1	-	C
118	*Symphyllia mallotiformis*	-	5	-	-	-	-	B
119	*Symplocos cochinchinensis*	2	-	-	-	-	-	B
120	*Symplocos macrophylla*	-	-	-	-	-	2	B
121	*Symplocos racemosa*	1	-	-	5	-	-	C
122	*Syzygium cumini*	4	1	5	2	-	-	D
123	*Syzygium mundakam*	-	-	-	1	-	-	B
124	*Syzygium laetum*	-	12	8	1	-	-	D
125	*Syzygium occidentale*	-	-	-	-	4	2	C
126	*Syzygium lanceolatum*	-	1	-	-	-	-	D
127	*Syzygium sp.*	-	-	1	-	-	-	D
128	*Syzygium palghatense*	-	-	-	30	34	39	B
129	*Terminalia crenulata*	-	-	-	1	-	-	D
130	*Ternstroemia japonica*	-	-	-	4	17	10	D
131	*Toona ciliata*	-	6	-	-	-	-	A
132	*Turpinia malabarica*	-	18	8	-	13	7	B
133	*Turpinia nepalensis*	-	-	-	-	2	-	D
134	*unidentified*	-	-	3	-	1	-	-
135	*unidentified 1*	-	-	-	-	1	-	-
136	*unidentified 1*	-	-	-	-	-	1	-
137	*unidentified 10*	-	-	1	-	-	-	-
138	*unidentified 2*	-	-	-	-	1	-	-
139	*unidentified 2*	-	-	1	-	-	-	-
140	*unidentified 3*	-	-	1	-	-	-	-
141	*unidentified 3*	-	-	-	-	-	1	-
142	*unidentified 4*	-	-	-	-	1	-	-
143	*unidentified 4*	-	-	1	-	-	-	-
144	*unidentified 5*	-	-	1	-	-	-	-
145	*unidentified 6*	-	-	1	-	-	-	-
146	*unidentified 7*	-	-	-	-	1	-	-
147	*unidentified 7*	-	1	-	-	-	1	-
148	*unidentified 8*	-	1	-	-	-	1	-
149	*unidentified 9*	-	1	-	-	-	1	-
150	*Vaccinium leschenaultii*	-	-	-	-	6	3	-
151	*Vettica*	-	-	1	-	-	-	-
152	*Viburnum coriaceum*	-	-	-	2	-	-	-

= Endemic to Western Ghats, B =Berry, C= Capsule, D=Drupe, F=Follicle, N=Nut

Appendix. 3.2. Chi-squared tests to demonstrate the measure of patchiness in species populations in the community.

Sl.No	Species	Variance	Mean	Chi-sq, d.f=5	*P*-value
1	*Actinodaphne lawsonii*	105.37	7.83	67.26	0.001
2	*Aglaia anamalayana*	16.67	1.67	50.00	0.001
3	*Aglaia spp*	4.00	1.00	20.00	0.001
4	*Agrostistachys borneensis*	118.17	4.83	122.24	0.001
5	*Agrostistachys longifolia*	13.50	1.50	45.00	0.001
6	*Alseodaphne semecarpifolia*	31.90	2.50	63.80	0.001
7	*Antidesma menasu*	16.67	4.33	19.23	0.002
8	*Apodytes dimidiata*	38.70	4.50	43.00	0.001
9	*Bischofia javanica*	9.77	2.17	22.54	0.001
10	*Calophyllum apetalum*	13.50	1.50	45.00	0.001
11	*Canarium strictum*	7.60	2.00	19.00	0.002
12	*Canthium neilgherrense*	338.27	8.67	195.15	0.001
13	*Casearia bourdillonii*	29.90	5.50	27.18	0.001
14	*Cinnamomum sulphuratum*	85.87	6.33	67.79	0.001
15	*Clerodendrum viscosum*	56.00	5.00	56.00	0.001
16	*Croton malabaricus*	3.87	1.33	14.50	0.013
17	*Cryptocarya spp*	4.17	0.83	25.00	0.001
18	*Cullenia exarillata*	264.97	14.17	93.52	0.001
19	*Daphniphyllum neilgherrense*	13.50	1.50	45.00	0.001
20	*Dimocarpus longan*	57.07	6.67	42.80	0.001
21	*Elaeocarpus munroni*	7.37	2.83	13.00	0.023
22	*Elaeocarpus oblongus*	23.37	2.17	53.92	0.001
23	*Elaeocarpus recurvatus*	32.67	3.67	44.55	0.001
24	*Elaeocarpus serratus*	10.00	2.00	25.00	0.001
25	*Elaeocarpus tuberculatus*	127.90	8.50	75.24	0.001
26	*Epiprinus mallotiformis*	16.17	1.83	44.09	0.001
27	*Eurya nitida*	32.97	4.17	39.56	0.001
28	*Flacourtia montana*	8.27	2.67	15.50	0.009
29	*Garcinia gummi- gutta*	16.17	1.83	44.09	0.001
30	*Garcinia pictoria*	22.27	3.67	30.36	0.001
31	*Glochidion ellipticum*	10.27	3.67	14.00	0.016
32	*Gomphandra coriasia*	13.77	2.17	31.77	0.001
33	*Gomphandra tetrandra*	44.30	3.50	63.29	0.001
34	*Gordonia obtusa*	13.07	1.67	39.20	0.001
35	*Hemicyclia elata*	3.90	1.50	13.00	0.023
36	*Holigarna nigra*	2.67	0.67	20.00	0.001
37	*Homalium travancoricum*	8.17	1.17	35.00	0.001
38	*Hopea parviflora*	1.50	0.50	15.00	0.010
39	*Karimaram*	4.17	0.83	25.00	0.001
40	*Knema attenuata*	27.07	2.67	50.75	0.001
41	*Laportea crenulata*	5.77	1.17	24.71	0.001
42	*Litsea bourdillonii*	1.50	0.50	15.00	0.010
43	*Litsea floribunda*	16.57	3.83	21.61	0.001
44	*Litsea leavigata*	21.47	3.33	32.20	0.001
45	*Litsea stocksii*	294.27	15.33	95.96	0.001
46	*Litsea wightiana*	10.27	1.67	30.80	0.001
47	*Macaranga peltata*	139.87	8.67	80.69	0.001
48	*Mallotus albus*	4.27	1.33	16.00	0.007
49	*Memecylon sisparense*	31.90	2.50	63.80	0.001

Sl.No	Species	Variance	Mean	Chi-sq, d.f=5	*P*-value
50	*Myristica dactyloides*	147.77	11.83	62.44	0.001
51	*Myristica malabarica*	3.87	1.33	14.50	0.013
52	*Mesua ferrea*	14.17	2.83	25.00	0.001
53	*Persea americana*	209.07	8.67	120.62	0.001
54	*Microtropis densiflora*	30.27	3.33	45.40	0.001
55	*Myristica canarica*	3.37	1.17	14.43	0.013
56	*Neolitsea scrobiculata*	6.57	1.83	17.91	0.003
57	*Olea glandulifera*	238.30	6.50	183.31	0.001
58	*Oreocnide integrifolia*	26.27	3.67	35.82	0.001
59	*Palaquium ellipticum*	181.07	10.33	87.61	0.001
60	*Persea macrantha*	17.90	3.50	25.57	0.001
61	*Rapanea wightiana*	30.57	3.17	48.26	0.001
62	*Rhodomyrtus tomentosa*	16.00	2.00	40.00	0.001
63	*Saprosma corymbosum*	8.40	2.00	21.00	0.001
64	*Symphyllia mallotiformis*	4.17	0.83	25.00	0.001
65	*Symplocos racemosa*	4.00	1.00	20.00	0.001
66	*Syzygium laetum*	27.10	3.50	38.71	0.001
67	*Syzygium occidentale*	2.80	1.00	14.00	0.016
68	*Syzygium palghatense*	361.77	17.17	105.37	0.001
69	*Ternstroemia japonica*	48.97	5.17	47.39	0.001
70	*Toona ciliata*	6.00	1.00	30.00	0.001
71	*Turpinia malabarica*	50.67	7.67	33.04	0.001
72	*Vaccinium leschenaultii*	6.30	1.50	21.00	0.001
	Random				
73	*Acronychia laurifolia*	0.17	0.17	5.00	0.417
74	*Acronychia pedunculata*	1.20	1.00	6.00	0.306
75	*Actinodaphne bourdillonii*	0.70	0.50	7.00	0.220
76	*Actinodaphne hirsuta*	0.70	0.50	7.00	0.220
77	*Aglaia indica*	0.70	0.50	7.00	0.220
78	*Aglaia barberi*	0.67	0.33	10.00	0.074
79	*Aidia gardneri*	0.70	0.50	7.00	0.220
80	*Alstonia scholaris*	1.47	0.67	11.00	0.051
81	*Apollonias arnottii*	0.70	0.50	7.00	0.220
82	*Artocarpus gomezianus*	1.07	0.67	8.00	0.155
83	*Artocarpus integrifolia*	0.67	0.33	10.00	0.074
84	*Blachia dendata*	0.27	0.33	4.00	0.551
85	*Callicarpa tomentosa*	0.17	0.17	5.00	0.417
86	*Calophyllum polyanthum*	1.20	1.00	6.00	0.306
87	*Calophyllum tomentosum*	0.17	0.17	5.00	0.417
88	*Celtis timorensis*	3.07	1.33	11.50	0.042
89	*Celtis trinervia*	0.67	0.33	10.00	0.074
90	*Cinnamomum wightii*	0.30	0.50	3.00	0.703
91	*Drypetes elata*	0.70	0.50	7.00	0.220
92	*Dysoxylum beddomei*	0.17	0.17	5.00	0.417
93	*Euphorbia antiquorum*	0.67	0.33	10.00	0.074
94	*Ficus beddomei*	0.27	0.33	4.00	0.551
95	*Ficus nervosa*	1.77	0.83	10.60	0.059
96	*Ficus hispida*	0.30	0.50	3.00	0.703
97	*Ficus sp.*	0.17	0.17	5.00	0.417
98	*Ficus virens*	2.40	1.00	12.00	0.035
99	*Garcinia morella*	2.70	1.50	9.00	0.108
100	*Gnetum ula*	0.70	0.50	7.00	0.220

Sl.No	Species	Variance	Mean	Chi-sq, d.f=5	P-value
101	*Heynea trijuga*	0.27	0.33	4.00	0.551
102	*Holigarna arnottiana*	1.37	1.17	5.86	0.320
103	*Ilex wightiana*	0.17	0.17	5.00	0.417
104	*Kingiodendron pinnatum*	0.17	0.17	5.00	0.417
105	*Lasianthus jackianus*	0.67	0.33	10.00	0.074
106	*Machilus macrantha*	0.67	0.33	10.00	0.074
107	*Nothopegia travancorica*	0.17	0.17	5.00	0.417
108	*Mappia foetida*	0.17	0.17	5.00	0.417
109	*Meiogyne pannosa*	0.17	0.17	5.00	0.417
110	*Neolitsea fischeri*	2.40	1.00	12.00	0.035
111	*Olea dioica*	1.77	0.83	10.60	0.059
112	*Olea sp*	0.17	0.17	5.00	0.417
113	*Orophea uniflora*	0.17	0.17	5.00	0.417
114	*Phoebe lanceolata*	0.30	0.50	3.00	0.703
115	*Phyllanthus emblica*	0.17	0.17	5.00	0.417
116	*Pithecellobium bigeminum*	0.17	0.17	5.00	0.417
117	*Pittosporum neilgherrense*	0.17	0.17	5.00	0.417
118	*Poeciloneuron pauciflorum*	0.70	0.50	7.00	0.220
119	*Polyalthia spp.*	0.67	0.33	10.00	0.074
120	*Rapanea striata*	0.17	0.17	5.00	0.417
121	*Rhododendron arboreum*	0.17	0.17	5.00	0.417
122	*Saprosma spp*	0.27	0.33	4.00	0.551
123	*Schefflera stellata*	0.67	0.33	10.00	0.074
124	*Schleichera oleosa*	0.67	0.67	5.00	0.417
125	*Scolopia crenata*	4.40	2.00	11.00	0.051
126	*Sterculia guttata*	0.17	0.17	5.00	0.417
127	*Symplocos cochinchinensis*	0.67	0.33	10.00	0.074
128	*Symplocos macrophylla*	0.67	0.33	10.00	0.074
129	*Syzygium cumini*	4.40	2.00	11.00	0.051
130	*Syzygium mundakam*	0.17	0.17	5.00	0.417
131	*Syzygium lanceolatum*	0.17	0.17	5.00	0.417
132	*Syzygium sp.*	0.17	0.17	5.00	0.417
133	*Terminalia crenulata*	0.17	0.17	5.00	0.417
134	*Turpinia nepalensis*	0.67	0.33	10.00	0.074
135	*unidentified 1*	1.47	0.67	11.00	0.051
136	*unidentified 2*	0.17	0.17	5.00	0.417
137	*unidentified 3*	0.17	0.17	5.00	0.417
138	*unidentified 4*	0.17	0.17	5.00	0.417
139	*unidentified 5*	0.17	0.17	5.00	0.417
140	*unidentified 6*	0.17	0.17	5.00	0.417
141	*unidentified 7*	0.17	0.17	5.00	0.417
142	*unidentified 8*	0.17	0.17	5.00	0.417
143	*unidentified 9*	0.17	0.17	5.00	0.417
144	*unidentified 10*	0.17	0.17	5.00	0.417
145	*unidentified 11*	0.17	0.17	5.00	0.417
146	*unidentified 12*	0.17	0.17	5.00	0.417
147	*unidentified 13*	0.17	0.17	5.00	0.417
148	*unidentified 14*	0.27	0.33	4.00	0.551
149	*unidentified 15*	0.27	0.33	4.00	0.551
150	*unidentified 16*	0.27	0.33	4.00	0.551
151	*Vettica*	0.17	0.17	5.00	0.417
152	*Viburnum coriaceum*	0.67	0.33	10.00	0.074

Appendix 3.3. Floristic informations pertaining to the trees recorded in each transects in SVNP. 1 **EVERGREEN GRASSLAND**

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Acronychia pedunculata	1	2	0.73	2	2.61	0.2	0.75	0.624	0.3	1.74
Actinodaphne lawsonii	1	1	0.73	1	1.3	0.1	0.37	0.286	0.1	1.22
Aglaia spp	1	1	0.73	1	1.3	0.1	0.37	0.199	0.1	1.18
Antidesma menasu	8	9	5.84	1.13	1.47	0.9	3.37	2.31	1	10.2
Bischofia javanica.	2	2	1.46	1	1.3	0.2	0.75	3.55	1.5	3.7
Calophyllum polyanthum	3	3	2.19	1	1.3	0.3	1.12	11.02	4.6	7.92
Canarium strictum.	1	1	0.73	1	1.3	0.1	0.37	0.928	0.4	1.49
Casearia bourdillonii	3	5	2.19	1.67	2.18	0.5	1.87	1.18	0.5	4.56
Cinnamomum verum	3	3	2.19	1	1.3	0.3	1.12	1.69	0.7	4.02
Cinnamomum wightii	1	1	0.73	1	1.3	0.1	0.37	1.96	0.8	1.92
Clerodendrum viscosum	7	19	5.11	2.71	3.53	1.9	7.12	2.65	1.1	13.3
Cullenia exarillata	6	22	4.38	3.67	4.78	2.2	8.24	67.88	28	41
Dimocarpus longan	5	14	3.65	2.8	3.65	1.4	5.24	4.03	1.7	10.6
Elaeocarpus munroni	3	3	2.19	1	1.3	0.3	1.12	12.94	5.4	8.73
Elaeocarpus serratus	2	3	1.46	1.5	1.95	0.3	1.12	3.38	1.4	3.99
Elaeocarpus tuberculatus	7	26	5.11	3.71	4.83	2.6	9.74	25.9	11	25.7
Ficus hispida	1	1	0.73	1	1.3	0.1	0.37	13.57	5.7	6.78
Ficus virens	3	3	2.19	1	1.3	0.3	1.12	0.327	0.1	3.45
Garcinia morella	3	3	2.19	1	1.3	0.3	1.12	23.9	1	4.31
Garcinia pictoria	6	13	4.38	2.17	2.83	1.3	4.87	3.6	1.5	10.8
Glochidion ellipticum	4	5	2.92	3.5	4.55	0.5	1.873	3.77	1.6	6.35
Gomphandra coriasia	3	9	2.19	3	3.91	0.9	3.37	1.94	0.8	6.37
Gomphandra tetrandra	1	1	0.73	1	1.3	0.1	0.37	1.61	0.1	1.17
Hemicyclia elata Bedd.	2	2	1.46	1	1.3	0.2	0.75	0.326	0.1	2.35
Holigarna arnottiana	1	1	0.73	1	1.3	0.1	0.37	1.39	0.6	1.68
Litsea floribunda	7	11	5.11	1.57	2.05	1.1	4.12	4.84	2	11.3
Macaranga peltata	6	17	4.38	2.83	3.69	1.7	6.37	6.4	2.7	13.4

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Mallotus albus	1	4	0.73	4	5.21	0.4	1.50	0.716	0.3	2.53
Myristica dactyloides	8	11	5.84	1.38	1.8	1.1	4.12	6.44	2.7	12.7
Meristica sp.	1	1	0.73	1	1.3	0.1	0.37	1.56	0.7	1.75
Myristica malabarica (magnifica)	1	1	0.73	1	1.3	0.1	0.37	1.45	0.6	1.71
Mesua ferrea L.	3	3	2.19	1	1.3	0.3	1.12	0.654	0.3	3.58
Neolitsea fischeri	2	3	1.46	1.5	1.95	0.3	1.12	0.296	0.1	2.7
Oreocnide integrifolia	1	2	0.73	2	2.61	0.2	0.75	0.303	0.1	1.61
Palaquium ellipticum	4	21	2.92	5.25	6.84	2.1	7.87	20.72	8.7	19.5
Persea macrantha	4	5	2.92	1.25	1.63	0.5	1.87	4.38	1.8	6.62
Phoebe lanceolata	1	1	0.73	1	1.3	0.1	0.37	0.484	0.2	1.3
Phyllanthus emblica	1	1	0.73	1	1.3	0.1	0.37	0.0716	0	1.13
Schleichera oleosa	2	2	1.46	1	1.3	0.2	0.75	0.736	0.3	2.52
Scolopia crenata	3	5	2.19	1.67	2.18	0.5	1.87	2.23	0.9	4.99
Symplocos cochinchinensis	2	2	1.46	1	1.3	0.2	0.75	2.82	1.2	3.39
Symplocos racemosa Roxb.	1	1	0.73	1	1.3	0.1	0.37	0.673	0.3	1.38
Syzygium cumini	2	4	1.46	2	2.61	0.4	1.50	2.69	1.1	4.09
Syzygium laetum	7	17	5.11	2.43	3.17	1.7	6.37	11.59	4.9	16.3
unidentified	2	2	1.46	1	1.3	0.2	0.75	1.88	0.8	3

2. EVERGREEN DISTURBED

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Acronychia laurifolia	1	1	0.5	1	0.97	0.1	0.27	3.150	1.12	1.89
Actinodaphne bourdillonii	2	2	1	1	0.97	0.2	0.54	0.763	0.27	1.81
Actinodaphne hirsuta	1	1	0.5	1	0.97	0.1	0.27	0.161	0.06	0.83
Actinodaphne lawsonii	6	7	2.99	1.17	1.14	0.7	1.90	1.050	0.37	5.26
Aglaia indica	2	2	1	1	0.97	0.2	0.54	1.360	0.48	2.02
Aglaia spp	3	5	1.49	1.67	1.63	0.5	1.36	0.593	0.21	3.06
Agrostistachys borneensis	7	27	3.48	3.86	3.76	2.7	7.34	4.282	1.52	12.3
Agrostistachys longifolia	3	9	1.49	3	2.92	0.9	2.45	2.847	1.01	4.95
Aidia gardneri	1	1	0.5	1	0.97	0.1	0.27	0.241	0.09	0.86
Alstonia scholaris.	3	3	1.49	1	0.97	0.3	0.82	0.458	0.16	2.47
Antidesma menasu	6	7	2.99	1.17	1.14	0.7	1.90	1.031	0.37	5.26
Apodytes dimidiata	3	3	1.49	1	0.97	0.3	0.82	1.047	0.37	2.68
Artocarpus gomezianus	2	2	1	1	0.97	0.2	0.54	0.197	0.07	1.61
Bischofia javanica	2	3	1	1.5	1.46	0.3	0.82	0.287	0.1	1.92
Blachia dendata	1	1	0.5	1	0.97	0.1	0.27	0.127	0.05	0.82
Calophyllum polyanthum	1	1	0.5	1	0.97	0.1	0.27	0.215	0.08	0.85
Canarium strictum	4	6	1.99	1.5	1.46	0.6	1.63	1.608	0.57	4.19
Casearia bourdillonii	1	2	0.5	2	1.95	0.2	0.54	0.413	0.15	1.19
Celtis timorensis	3	3	1.49	1	0.97	0.3	0.82	0.371	0.13	2.44
Cinnamomum verum	4	9	1.99	2.25	2.19	0.9	2.45	2.245	0.8	5.24
Cleidion spiciflorum	1	1	0.5	1	0.97	0.1	0.27	0.241	0.09	0.86
Clerodendrum viscosum	1	2	0.5	2	1.95	0.2	0.54	3.047	1.08	2.12
Croton malabaricus	4	5	1.99	1.25	1.22	0.5	1.36	3.384	1.2	4.55
Cryptocarya spp	4	5	1.99	1.25	1.22	0.5	1.36	1.168	0.41	3.76
Cullenia exarillata	10	37	4.98	3.7	3.61	3.7	10.05	69.312	24.59	39.6
Dimocarpus longan	5	10	2.49	2	1.95	1	2.72	1.382	0.49	5.7
Drypetes elata	1	1	0.5	1	0.97	0.1	0.27	0.109	0.04	0.81

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Elaeocarpus munroni	2	2	1	1	0.97	0.2	0.54	0.274	0.1	1.64
Elaeocarpus serratus	2	2	1	1	0.97	0.2	0.54	0.563	0.2	1.74
Elaeocarpus serratus	4	6	1.99	1.5	1.46	0.6	1.63	2.701	0.96	4.58
Elaeocarpus tuberculatus	4	6	1.99	1.5	1.46	0.6	1.63	58.541	20.77	24.4
Epiprinus mallotiformis	1	1	0.5	1	0.97	0.1	0.27	0.109	0.04	0.81
Flacourtia montana	4	7	1.99	1.75	1.71	0.7	1.90	2.052	0.73	4.62
Garcinia morella	4	4	1.99	1	0.97	0.4	1.09	0.659	0.23	3.31
Garcinia pictoria	2	2	1	1	0.97	0.2	0.54	0.431	0.15	1.69
Glochidion ellipticum	2	3	1	1.5	1.46	0.3	0.82	0.276	0.1	1.92
Gomphandra tetrandra	1	2	0.5	2	1.95	0.2	0.54	0.336	0.12	1.16
Hemicyclia elata	2	5	1	2.5	2.44	0.5	1.36	1.283	0.46	2.82
Heynea trijuga	1	1	0.5	1	0.97	0.1	0.27	0.659	0.23	1
Holigarna arnottiana	3	3	1.49	1	0.97	0.3	0.82	1.156	0.41	2.72
Holigarna nigra	3	4	1.49	1.33	1.3	0.4	1.09	1.263	0.45	3.03
Hopea parviflora	2	3	1	1.5	1.46	0.3	0.82	2.021	0.72	2.54
Knema attenuata	5	13	2.49	2.6	2.53	1.3	3.53	13.560	4.81	10.8
Litsea floribunda	3	5	1.49	1.67	1.63	0.5	1.36	3.692	1.31	4.16
Litsea leavigata	2	2	1	1	0.97	0.2	0.54	0.545	0.19	1.73
Macaranga peltata	2	2	1	1	0.97	0.2	0.54	0.806	0.29	1.83
Meiogyne pannosa	1	1	0.5	1	0.97	0.1	0.27	0.082	0.03	0.8
Myristica dactyloides	6	14	2.99	2.33	2.27	1.4	3.80	9.856	3.5	10.3
Myristica sp.	1	1	0.5	1	0.97	0.1	0.27	0.296	0.11	0.88
Myristica malabarica	2	5	1	2.5	2.44	0.5	1.36	4.905	1.74	4.1
Mesua ferrea	6	10	2.99	1.67	1.63	1	2.72	21.814	7.74	13.5
Myristica canarica	1	3	0.5	3	2.92	0.3	0.82	1.338	0.47	1.79
Neolitsea scrobiculata	1	1	0.5	1	0.97	0.1	0.27	0.092	0.03	0.8
Olea dioica	2	2	1	1	0.97	0.2	0.54	0.607	0.22	1.76
Oreocnide integrifolia	4	8	1.99	2	1.95	0.8	2.17	2.204	0.78	4.94

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Orophea uniflora	1	1	0.5	1	0.97	0.1	0.27	0.087	0.03	0.8
Palaquium ellipticum	8	32	3.98	4	3.9	3.2	8.70	17.57	6.23	18.9
Persea macrantha	7	11	3.48	1.57	1.53	1.1	2.99	2.875	1.02	7.49
Pithecellobium bigeminum	1	1	0.5	1	0.97	0.1	0.27	0.127	0.05	0.82
Polyalthia spp.	2	2	1	1	0.97	0.2	0.54	0.447	0.16	1.7
Schleichera oleosa	1	1	0.5	1	0.97	0.1	0.27	0.140	0.05	0.82
Scolopia crenata	3	4	1.49	1.33	1.3	0.4	1.09	1.245	0.44	3.02
Symphyllia mallotiformis	4	5	1.99	1.25	1.22	0.5	1.36	1.272	0.45	3.8
Syzygium cumini	1	1	0.5	1	0.97	0.1	0.27	0.092	0.03	0.8
Syzygium laetum	6	12	2.99	2	1.95	1.2	3.26	8.303	2.95	9.2
Toona ciliata	5	6	2.49	1.2	1.17	0.6	1.63	1.148	0.41	4.53
Turpinia malabarica	7	18	3.48	2.57	2.51	1.8	4.89	15.338	5.44	13.8

3. EVEGREEN FOREST

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Acronychia pedunculata	1	2	0.51	2	2.35	0.2	0.68	1.565	0.75	1.94
Actinodaphne hirsuta	2	2	1.03	1	1.18	0.2	0.68	0.195	0.09	1.8
Actinodaphne lawsonii	5	6	2.56	1.2	1.41	0.6	2.03	1.105	0.53	5.12
Aglaia indica	1	1	0.51	1	1.18	0.1	0.34	1.263	0.61	1.46
Aglaia spp	7	10	3.59	1.43	1.68	1	3.38	3.238	1.56	8.53
Agrostistachys borneensis	1	1	0.51	1	1.18	0.1	0.34	0.127	0.06	0.91
Aidia gardneri	2	2	1.03	1	1.18	0.2	0.68	0.481	0.23	1.94
Antidesma menasu	2	8	1.03	4	4.7	0.8	2.70	1.351	0.65	4.38
Artocarpus gomezianus	3	3	1.54	1	1.18	0.3	1.01	1.161	0.56	3.11
Bischofia javanica	6	8	3.08	1.33	1.56	0.8	2.70	12.806	6.15	11.9
Blachia dendata	1	1	0.51	1	1.18	0.1	0.34	0.115	0.06	0.91

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Calophyllum polyanthum	1	1	0.51	1	1.18	0.1	0.34	0.161	0.08	0.93
Canarium strictum	4	5	2.05	1.25	1.47	0.5	1.69	3.405	1.64	5.38
Casearia bourdillonii	1	1	0.51	1	1.18	0.1	0.34	0.336	0.16	1.01
Celtis timorensis	3	4	1.54	1.33	1.56	0.4	1.35	0.490	0.24	3.13
Cinnamomum verum	1	1	0.51	1	1.18	0.1	0.34	0.232	0.11	0.96
Cinnamomum wightii	1	1	0.51	1	1.18	0.1	0.34	0.092	0.04	0.89
Cleidion spiciflorum	2	2	1.03	1	1.18	0.2	0.68	0.499	0.24	1.95
Clerodendrum viscosum	6	8	3.08	1.33	1.56	0.8	2.70	0.920	0.44	6.22
Croton malabaricus	1	2	0.51	2	2.35	0.2	0.68	0.813	0.39	1.58
Cullenia exarillata	9	26	4.62	2.89	3.4	2.6	8.78	13.010	6.25	19.7
Dimocarpus longan	10	16	5.13	1.6	1.88	1.6	5.41	3.547	1.7	12.2
Drypetes elata	2	2	1.03	1	1.18	0.2	0.68	3.345	1.61	3.32
Elaeocarpus munroni	2	2	1.03	1	1.18	0.2	0.68	6.014	2.89	4.6
Elaeocarpus serratus	1	1	0.51	1	1.18	0.1	0.34	0.092	0.04	0.89
Elaeocarpus tuberculatus	9	19	4.62	2.11	2.48	1.9	6.42	66.840	32.12	43.2
Epiprinus mallotiformis	4	10	2.05	2.5	2.94	1	3.38	3.851	1.85	7.28
Euphorbia antiquorum	2	2	1.03	1	1.18	0.2	0.68	3.118	1.5	3.21
Ficus hispida	1	1	0.51	1	1.18	0.1	0.34	1.052	0.51	1.36
Ficus virens	3	3	1.54	1	1.18	0.3	1.01	0.665	0.32	2.87
Flacourtia montana	3	3	1.54	1	1.18	0.3	1.01	3.548	1.7	4.25
Garcinia pictoria	3	3	1.54	1	1.18	0.3	1.01	1.302	0.63	3.18
Glochidion ellipticum	4	9	2.05	2.25	2.64	0.9	3.04	1.503	0.72	5.81
Gomphandra coriasia	3	4	1.54	1.33	1.56	0.4	1.35	0.531	0.26	3.15
Gomphandra tetrandra	6	17	3.08	2.83	3.33	1.7	5.74	7.913	3.8	12.6
Hemicyclia elata	2	2	1.03	1	1.18	0.2	0.68	2.809	1.35	3.06
Heynea trijuga	1	1	0.51	1	1.18	0.1	0.34	0.250	0.12	0.97
Holigarna arnottiana	1	1	0.51	1	1.18	0.1	0.34	1.165	0.56	1.41

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Kingiodendron pinnatum	1	1	0.51	1	1.18	0.1	0.34	0.127	0.06	0.91
Laportea crenulata	2	6	1.03	3	3.53	0.6	2.03	0.885	0.43	3.49
Litsea bourdillonii	3	3	1.54	1	1.18	0.3	1.01	0.690	0.33	2.88
Litsea floribunda	3	3	1.54	1	1.18	0.3	1.01	0.815	0.39	2.94
Litsea leavigata	4	5	2.05	1.25	1.47	0.5	1.69	1.924	0.92	4.66
Macaranga peltata	4	4	2.05	1	1.18	0.4	1.35	2.257	1.08	4.48
Machilus macrantha	2	2	1.03	1	1.18	0.2	0.68	1.737	0.83	2.54
Mallotus albus	4	4	2.05	1	1.18	0.4	1.35	0.647	0.31	3.71
Manjakadamba	1	1	0.51	1	1.18	0.1	0.34	0.223	0.11	0.96
Myristica dactyloides	8	12	4.1	1.5	1.76	1.2	4.05	6.790	3.26	11.4
Mesua ferrea	3	3	1.54	1	1.18	0.3	1.01	0.304	0.15	2.7
Persea americana	2	2	1.03	1	1.18	0.2	0.68	0.635	0.31	2.02
Neolitsea fischeri	3	3	1.54	1	1.18	0.3	1.01	0.673	0.32	2.87
Olea dioica	2	3	1.03	1.5	1.76	0.3	1.01	0.363	0.17	2.21
Oreocnide integrifolia	5	12	2.56	2.4	2.82	1.2	4.05	7.224	3.47	10.1
Palaquium ellipticum	5	9	2.56	1.8	2.12	0.9	3.04	14	6.73	12.3
Persea macrantha	3	4	1.54	1.33	1.56	0.4	1.35	2.982	1.43	4.32
Phoebe lanceolata	1	1	0.51	1	1.18	0.1	0.34	0.161	0.08	0.93
Schleichera oleosa	1	1	0.51	1	1.18	0.1	0.34	0.368	0.18	1.03
Scolopia crenata	1	1	0.51	1	1.18	0.1	0.34	0.082	0.04	0.89
Syzygium cumini	5	5	2.56	1	1.18	0.5	1.69	4.637	2.23	6.48
Syzygium laetum	6	8	3.08	1.33	1.56	0.8	2.70	5.391	2.59	8.37
Turpinia malabarica	5	8	2.56	1.6	1.88	0.8	2.70	3.847	1.85	7.11
Vettica (?)	1	1	0.51	1	1.18	0.1	0.34	0.092	0.04	0.89
unidentified	3	3	1.54	1	1.18	0.3	1.01	0.358	0.17	2.72

4. BROAD-LEAVED HILL-FOREST

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Actinodaphne bourdillonii	1	1	0.7	1	0.96	0.1	0.29	0.673	0.51	1.5
Actinodaphne lawsonii	4	5	2.82	1.25	1.2	0.5	1.46	2.388	1.8	6.08
Agrostistachys borneensis	1	1	0.7	1	0.96	0.1	0.29	0.082	0.06	1.05
Alseodaphne semecarpifolia	1	1	0.7	1	0.96	0.1	0.29	0.616	0.46	1.45
Alstonia scholaris	1	1	0.7	1	0.96	0.1	0.29	0.232	0.17	1.16
Antidesma menasu	1	1	0.7	1	0.96	0.1	0.29	0.082	0.06	1.05
Apodytes dimidiata	1	1	0.7	1	0.96	0.1	0.29	0.183	0.14	1.13
Apollonias arnottii	1	2	0.7	2	1.92	0.2	0.58	0.375	0.28	1.56
Artocarpus integrifolia	2	2	1.41	1	0.96	0.2	0.58	0.919	0.69	2.68
Calophyllum apetalum	5	9	3.52	1.8	1.73	0.9	2.63	9.035	6.81	12.96
Calophyllum tomentosum	1	1	0.7	1	0.96	0.1	0.29	0.121	0.09	1.08
Canthium neilgherrense	8	46	5.63	5.75	5.51	4.6	13.45	11.548	8.71	27.79
Casearia bourdillonii	7	16	4.93	2.29	2.2	1.6	4.68	3.337	2.52	12.13
Celtis timorensis	1	1	0.7	1	0.96	0.1	0.29	1.407	1.06	2.05
Cinnamomum sulphuratum	2	2	1.41	1	0.96	0.2	0.58	0.351	0.27	2.26
Cinnamomum verum	3	4	2.11	1.33	1.28	0.4	1.17	1.076	0.81	4.09
Cinnamomum wightii	1	1	0.7	1	0.96	0.1	0.29	0.082	0.06	1.05
Clerodendrum viscosum	2	2	1.41	1	0.96	0.2	0.58	0.181	0.14	2.13
Croton malabaricus	1	1	0.7	1	0.96	0.1	0.29	0.191	0.14	1.13
Daphniphyllum neilgherrense	4	9	2.82	2.25	2.16	0.9	2.63	3.328	2.51	7.96
Elaeocarpus munroni	4	8	2.82	2	1.92	0.8	2.34	5.104	3.85	9.01
Elaeocarpus oblongus	3	11	2.11	3.67	3.52	1.1	3.22	7.752	5.85	11.18
Elaeocarpus tuberculatus	1	1	0.7	1	0.96	0.1	0.29	0.134	0.1	1.09
Eurya nitida	6	14	4.23	2.33	2.23	1.4	4.09	5.444	4.11	12.43
Flacourtia montana	1	1	0.7	1	0.96	0.1	0.29	0.092	0.07	1.06
Garcinia gummi- gutta	1	1	0.7	1	0.96	0.1	0.29	1.016	0.77	1.76
Garcinia morella	1	1	0.7	1	0.96	0.1	0.29	0.087	0.07	1.06

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Garcinia pictoria	2	3	1.41	1.5	1.44	0.3	0.88	1.611	1.21	3.5
Gnetum ula	2	2	1.41	1	0.96	0.2	0.58	0.212	0.16	2.15
Gomphandra tetrandra	1	1	0.7	1	0.96	0.1	0.29	0.357	0.27	1.26
Holigarna beddomei	1	2	0.7	2	1.92	0.2	0.58	0.671	0.51	1.79
Hydnocarpus macrocarpa	3	6	2.11	2	1.92	0.6	1.75	1.537	1.16	5.02
Karimaram	2	5	1.41	2.5	2.4	0.5	1.46	4.190	3.16	6.03
Knema attenuata	2	3	1.41	1.5	1.44	0.3	0.88	1.906	1.44	3.73
Laportea crenulata	1	1	0.7	1	0.96	0.1	0.29	0.161	0.12	1.11
Litsea floribunda	2	4	1.41	2	1.92	0.4	1.17	1.283	0.97	3.55
Litsea leavigata	5	12	3.52	2.4	2.3	1.2	3.51	5.633	4.25	11.28
Litsea stocksii	8	27	5.63	3.38	3.24	2.7	7.89	8.501	6.41	19.93
Macaranga peltata	4	29	2.82	7.25	6.95	2.9	8.48	6.717	5.07	16.37
Meliosma pinnata	4	5	2.82	1.25	1.2	0.5	1.46	6.508	4.91	9.19
Meliosma simplicifolia	1	1	0.7	1	0.96	0.1	0.29	0.232	0.17	1.16
Myristica dactyloides	7	32	4.93	4.57	4.38	3.2	9.36	13.835	10.44	24.73
Myristica dactyloides	1	1	0.7	1	0.96	0.1	0.29	0.368	0.28	1.27
Myristica malabarica	1	1	0.7	1	0.96	0.1	0.29	0.484	0.37	1.36
Mesua ferrea	1	1	0.7	1	0.96	0.1	0.29	0.115	0.09	1.08
Myristica canarica	2	4	1.41	2	1.92	0.4	1.17	1.757	1.33	3.91
Neolitsea scrobiculata	3	4	2.11	1.33	1.28	0.4	1.17	0.630	0.48	3.76
Olea glandulifera	1	1	0.7	1	0.96	0.1	0.29	0.306	0.23	1.22
Persea macrantha	1	1	0.7	1	0.96	0.1	0.29	0.326	0.25	1.24
Phoebe lanceolata	1	1	0.7	1	0.96	0.1	0.29	0.326	0.25	1.24
Rapanea wightiana	1	1	0.7	1	0.96	0.1	0.29	0.115	0.09	1.08
Saprosma corymbosum	1	1	0.7	1	0.96	0.1	0.29	0.268	0.2	1.19
Scolopia crenata	1	2	0.7	2	1.92	0.2	0.58	1.667	1.26	2.54
Symplocos racemosa	3	5	2.11	1.67	1.6	0.5	1.46	1.889	1.42	4.99
Syzygium cumini	1	2	0.7	2	1.92	0.2	0.58	1.154	0.87	2.15
Syzygium laetum	1	1	0.7	1	0.96	0.1	0.29	0.336	0.25	1.24

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Syzygium palghatense	7	30	4.93	4.29	4.11	3	8.77	9.556	7.21	20.91
Terminalia crenulata	1	1	0.7	1	0.96	0.1	0.29	1.672	1.26	2.25
Ternstroemia japonica	2	4	1.41	2	1.92	0.4	1.17	1.484	1.12	3.7
Viburnum coriaceum	1	2	0.7	2	1.92	0.2	0.58	0.248	0.19	1.47
unidentified	2	2	1.41	1	0.96	0.2	0.58	0.694	0.52	2.51

5. SHOLA

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Actinodaphne lawsonii	2	28	1.61	14	11.99	2.8	8.16	8.558	7.93	17.7
Alseodaphne semecarpifolia	3	14	2.42	4.67	4	1.4	4.08	3.150	2.92	9.42
Antidesma menasu	1	1	0.81	1	0.86	0.1	0.29	0.336	0.31	1.41
Apodytes dimidiata	4	7	3.23	1.75	1.5	0.7	2.04	0.921	0.85	6.12
Apollonias arnottii	1	1	0.81	1	0.86	0.1	0.29	0.928	0.86	1.96
Canthium neilgherrense	1	5	0.81	5	4.28	0.5	1.46	0.818	0.76	3.03
Casearia bourdillonii	2	3	1.61	1.5	1.29	0.3	0.87	0.307	0.28	2.76
Celtis trinervia.	2	2	1.61	1	0.86	0.2	0.58	0.624	0.58	2.77
Cinnamomum sulphuratum.	6	15	4.84	2.5	2.14	1.5	4.37	2.214	2.05	11.3
Cinnamomum verum	1	1	0.81	1	0.86	0.1	0.29	0.115	0.11	1.21
Dysoxylum beddomei	1	1	0.81	1	0.86	0.1	0.29	0.127	0.12	1.22
Elaeocarpus munroni	2	2	1.61	1	0.86	0.2	0.58	1.214	1.13	3.32
Elaeocarpus oblongus	1	1	0.81	1	0.86	0.1	0.29	0.277	0.26	1.36
Elaeocarpus recurvatus	3	10	2.42	3.33	2.85	1	2.92	3.706	3.43	8.77
Eurya nitida	4	8	3.23	2	1.71	0.8	2.33	2.963	2.75	8.31
Ficus hispida	1	1	0.81	1	0.86	0.1	0.29	0.673	0.62	1.72
Garcinia gummi- gutta	5	10	4.03	2	1.71	1	2.92	4.659	4.32	11.3
Garcinia morella	1	1	0.81	1	0.86	0.1	0.29	0.087	0.08	1.18
Garcinia pictoria	1	1	0.81	1	0.86	0.1	0.29	1.766	1.64	2.74

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Glochidion ellipticum	3	4	2.42	1.33	1.14	0.4	1.17	0.687	0.64	4.23
Gnetum ula	1	1	0.81	1	0.86	0.1	0.29	0.250	0.23	1.33
Gordonia obtusa	1	1	0.81	1	0.86	0.1	0.29	0.357	0.33	1.43
Homalium travancoricum	4	6	3.23	1.5	1.29	0.6	1.75	3.170	2.94	7.92
Homalium sp.	1	1	0.81	1	0.86	0.1	0.29	0.127	0.12	1.22
Litsea leavigata	1	1	0.81	1	0.86	0.1	0.29	0.109	0.1	1.2
Litsea stocksii	7	37	5.65	5.29	4.53	3.7	10.79	9.225	8.55	25
Litsea wightiana	2	8	1.61	4	3.43	0.8	2.33	2.673	2.48	6.42
Mappia foetida	1	1	0.81	1	0.86	0.1	0.29	0.092	0.09	1.19
Memecylon sisparense	2	2	1.61	1	0.86	0.2	0.58	0.212	0.2	2.39
Persea americana.	6	14	4.84	2.33	2	1.4	4.08	7.365	6.83	15.8
Microtropis densiflora	3	13	2.42	4.33	3.71	1.3	3.79	3.104	2.88	9.09
Neolitsea scrobiculata	3	6	2.42	2	1.71	0.6	1.75	0.951	0.88	5.05
Olea glandulifera.	7	38	5.65	5.43	4.65	3.8	11.08	22.525	20.87	37.6
Poeciloneuron pauciflorum.	1	1	0.81	1	0.86	0.1	0.29	0.215	0.2	1.3
Rapanea wightiana	2	4	1.61	2	1.71	0.4	1.17	0.571	0.53	3.31
Rhodomyrtus tomentosa	1	2	0.81	2	1.71	0.2	0.58	0.164	0.15	1.54
Saprosma corymbosum	4	4	3.23	1	0.86	0.4	1.17	0.407	0.38	4.78
Saprosma spp (zeylanica ?)	1	1	0.81	1	0.86	0.1	0.29	0.076	0.07	1.17
Schefflera stellata	2	2	1.61	1	0.86	0.2	0.58	0.611	0.57	2.76
Sterculia guttata Roxb.	1	1	0.81	1	0.86	0.1	0.29	0.306	0.28	1.38
Syzygium occidentale	2	4	1.61	2	1.71	0.4	1.17	0.833	0.77	3.55
Syzygium palghatense	3	34	2.42	11.3	9.71	3.4	9.91	5.144	4.77	17.1
Ternstroemia japonica	6	17	4.84	2.83	2.42	1.7	4.96	8.302	7.69	17.5
Turpinia malabarica	5	13	4.03	2.6	2.23	1.3	3.79	2.959	2.74	10.6
Turpinia nepalensis	2	2	1.61	1	0.86	0.2	0.58	0.352	0.33	2.52
Vaccinium leschenaultii	3	6	2.42	2	1.71	0.6	1.75	1.756	1.63	5.8
unidentified	1	1	0.81	1	0.86	0.1	0.29	0.207	0.19	1.29
unidentified 1	1	1	0.81	1	0.86	0.1	0.29	0.097	0.09	1.19

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
unidentified 2	1	1	0.81	1	0.86	0.1	0.29	0.277	0.26	1.36
unidentified 3	1	1	0.81	1	0.86	0.1	0.29	0.223	0.21	1.31
unidentified 4	1	1	0.81	1	0.86	0.1	0.29	0.161	0.15	1.25
unidentified 5	1	1	0.81	1	0.86	0.1	0.29	0.161	0.15	1.25
unidentified 7	1	1	0.81	1	0.86	0.1	0.29	0.796	0.74	1.84

6. SHOLAG

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Apodytes dimidiata.	6	16	5.5	2.67	3.36	1.6	5.76	4.481	5.61	16.87
Calophyllum tomentosum	1	1	0.92	1	1.26	0.1	0.36	0.115	0.14	1.42
Canthium neilgherrense	1	1	0.92	1	1.26	0.1	0.36	0.103	0.13	1.41
Casearia bourdillonii	3	6	2.75	2	2.52	0.6	2.16	1.076	1.35	6.26
Cinnamomum sulphuratum	8	21	7.34	2.63	3.31	2.1	7.55	4.193	5.25	20.14
Elaeocarpus recurvatus	4	12	3.67	3	3.78	1.2	4.32	2.134	2.67	10.66
Eurya nitida	2	3	1.83	1.5	1.89	0.3	1.08	1.238	1.55	4.46
Flacourtia montana	3	5	2.75	1.67	2.1	0.5	1.80	3.346	4.19	8.74
Glochidion ellipticum	1	1	0.92	1	1.26	0.1	0.36	0.082	0.1	1.38
Gordonia obtusa	3	9	2.75	3	3.78	0.9	3.24	4.779	5.99	11.98
Ilex wightiana	1	1	0.92	1	1.26	0.1	0.36	0.176	0.22	1.5
Lasianthus jackianus.	2	2	1.83	1	1.26	0.2	0.72	0.238	0.3	2.85
Litsea stocksii var stocksii	5	28	4.59	5.6	7.05	2.8	10.07	6.837	8.57	23.23
Litsea wightiana	2	2	1.83	1	1.26	0.2	0.72	1.198	1.5	4.05
Memecylon sisparense	3	14	2.75	4.67	5.88	1.4	5.04	2.390	3	10.79
Persea americana	8	36	7.34	4.5	5.67	3.6	12.95	13.067	16.37	36.66
Microtropis densiflora	2	7	1.83	3.5	4.41	0.7	2.52	1.627	2.04	6.39
Olea sp	1	1	0.92	1	1.26	0.1	0.36	0.082	0.1	1.38
Pittosporum neilgherrense	1	1	0.92	1	1.26	0.1	0.36	0.127	0.16	1.44

Species	Frequency	No. of individuals	Relative frequency	Abundance	Relative abundance	Density	Relative density	Basal area	Relative dominance	IVI
Poeciloneuron pauciflorum.	2	2	1.83	1	1.26	0.2	0.72	0.307	0.38	2.93
Rapanea striata	1	1	0.92	1	1.26	0.1	0.36	0.087	0.11	1.39
Rapanea wightiana	4	14	3.67	3.5	4.41	1.4	5.04	2.765	3.47	12.18
Rhododendron arboreum	1	1	0.92	1	1.26	0.1	0.36	0.161	0.2	1.48
Rhodomyrtus tomentosa	3	10	2.75	3.33	4.19	1	3.60	1.433	1.8	8.15
Saprosma corymbosum	5	6	4.59	1.2	1.51	0.6	2.16	0.668	0.84	7.59
Saprosma sp.	1	1	0.92	1	1.26	0.1	0.36	0.109	0.14	1.42
Saprosma spp (zeylanica ?)	1	1	0.92	1	1.26	0.1	0.36	0.076	0.1	1.38
Symplocos macrophylla	1	2	0.92	2	2.52	0.2	0.72	1.070	1.34	2.98
Syzygium occidentale	1	2	0.92	2	2.52	0.2	0.72	0.803	1.01	2.65
Syzygium palghatense	8	39	7.34	4.88	6.15	3.9	14.03	12.695	15.91	37.28
Ternstroemia japonica	5	10	4.59	2	2.52	1	3.60	3.166	3.97	12.16
Turpinia malabarica	4	7	3.67	1.75	2.2	0.7	2.52	2.143	2.69	8.88
Vaccinium leschenaultii	3	3	2.75	1	1.26	0.3	1.08	0.739	0.93	4.76
unidentified 1	1	1	0.92	1	1.26	0.1	0.36	0.097	0.12	1.4
unidentified 10	1	1	0.92	1	1.26	0.1	0.36	1.581	1.98	3.26
unidentified 2	1	1	0.92	1	1.26	0.1	0.36	0.223	0.28	1.56
unidentified 3	1	1	0.92	1	1.26	0.1	0.36	0.147	0.18	1.46
unidentified 4	1	1	0.92	1	1.26	0.1	0.36	0.097	0.12	1.4
unidentified 5	1	1	0.92	1	1.26	0.1	0.36	0.277	0.35	1.63
unidentified 6	2	2	1.83	1	1.26	0.2	0.72	1.547	1.94	4.49
unidentified 7	2	2	1.83	1	1.26	0.2	0.72	1.941	2.43	4.98
unidentified 8	1	1	0.92	1	1.26	0.1	0.36	0.258	0.32	1.6
unidentified 9	1	1	0.92	1	1.26	0.1	0.36	0.121	0.15	1.43

Appendix 4.1. Bird species recorded during the study period including opportunistic observations

S.No	Family	Common name	Scientific name
1	PHASIANIDAE	Jungle Bush Quail	*Perdicula asiatica*
2		Painted Bush Quail	*Perdicula erythrorhyncha*
3		Red Spurfowl	*Galloperdix spadicea*
4		Grey Junglefowl	*Gallus sonneratii*
5	PICIDAE	Speckled Piculet	*Picumnus innominatus*
6		Lesser Yellownape	*Picus chlorolophus*
7		White-bellied Woodpecker	*Dryocopus javensis*
8		Common Flameback	*Dinopium javanense*
9		Heart-spotted Woodpecker	*Hemicircus canente*
10		Black-rumped Flameback	*Dinopium benghalense*
11	CAPITONIDAE	White-cheeked Barbet	*Megalaima viridis*
12		Crimson-fronted Barbet	*Megalaima rubricapilla*
13		Coppersmith Barbet	*Megalaima haemacephala*
14	BUCEROTIDAE	Malabar Grey Hornbill	*Ocyceros griseus*
15		Great Hornbill	*Buceros bicornis*
16	UPUPIDAE	Common Hoopoe	*Upupa epops*
17	TROGONIDAE	Malabar Trogon	*Harpactes fasciatus*
18	ALCEDINIDAE	Blue-eared Kingfisher	*Alcedo meninting*
19		Oriental Dwarf Kingfisher	*Ceyx erithacus*
20	HALCYONIDAE	White-throated Kingfisher	*Halcyon smyrnensis*
21	MEROPIDAE	Green Bee-eater	*Merops orientalis*
22		Chestnut-headed Bee-eater	*Merops leschenaulti*
23	CUCULIDAE	Eurasian Cuckoo	*Cuculus canorus*
24	CENTROPODIDAE	Greater Coucal	*Centropus sinensis*
25	PSITTACIDAE	Vernal Hanging Parrot	*Loriculus vernalis*
26		Malabar Parakeet	*Psittacula columboides*
27	APODIDAE	Indian Swiftlet	*Collocalia unicolor*
28		White-rumped Needletail	*Zoonavena sylvatica*
29		Brown-backed Needletail	*Hirundapus giganteus*
30		Alpine Swift	*Tachymarptis melba*
31		House Swift	*Apus affinis*
32	STRIGIDAE	Spot-billed Eagle Owl	*Bubo nipalensis*
33		Short-eared Owl	*Asio flammeus*
34		Eurasian Eagle Owl	*Buo bubo*
35	CAPRIMULGIDAE	Grey Nightjar	*Caprimulgus indicus*
36		Large-tailed Nightjar	*Caprimulgus macrurus*
37	COLUMBIDAE	Nilgiri Wood Pigeon	*Columba elphinstonii*
38		Pompadour Green Pigeon	*Treron pompadora*
39		Yellow-footed Green Pigeon	*Treron phoenicoptera*
40		Spotted Dove	*Streptopelia chinensis*
41		Emerald Dove	*Chalcophaps indica*
42		Green Imperial Pigeon	*Dacula aenea*

S.No	Family	Common name	Scientific name
43		Mountain Imperial Pigeon	*Ducula badia*
44	ACCIPITRIDAE	Oriental Honey-buzzard	*Pernis ptilorhyncus*
45		Black-shouldered Kite	*Elanus caeruleus*
46		Black Kite	*Milvus migrans*
47		Brahminy Kite	*Haliastur indus*
48		Shikra	*Accipiter badius*
49		Crested Goshawk	*Accipiter trivirgatus*
50		Besra	*Accipiter virgatus*
51		Black Eagle	*Ictinaetus malayensis*
52		Booted Eagle	*Hieraaetus pennatus*
53		Crested Serpent Eagle	*Spilornis cheela*
54	FALCONIDAE	Common Kestrel	*Falco tinnunculus*
55	PHALACROCORACIDAE	Darter	*Anhinga melanogaster*
56		Little Cormorant	*Phalacrocorax niger*
57	ARDEIDAE	Indian Pond Heron	*Ardeola grayii*
58		Malayan Night Heron	*Gorsachius melanolophus*
59	PITTIDAE	Indian Pitta	*Pitta brachyura*
60	IRENIDAE	Asian Fairy Bluebird	*Irena puella*
61		Blue-winged Leafbird	*Chlorospsis cochinchinensis*
62	LANIIDAE	Brown Shrike	*Lanius cristatus*
63	CORVIDAE	Rufous Treepie	*Dendrocitta vagabunda*
64		White-bellied Treepie	*Dendrocitta leucogastra*
65		Large-billed Crow	*Corvus macrorhynchos*
66	ORIOLIDAE	Black-naped Oriole	*Oriolus chinensis*
67		Eurasian Golden Oriole	*Oriolus oriolus*
68		Black-hooded Oriole	*Oriolus xanthornus*
69	CAMPEPHAGIDAE	Scarlet Minivet	*Pericrocotus flammeus*
70		Small Minivet	*Pericrocotus cinnamomeus*
71		Bar-winged Flycatcher-shrike	*Hemipus picatus*
72	DICRURIDAE	Black Drongo	*Dicrurus macrocercus*
73		Ashy Drongo	*Dicrurus leucophaeus*
74		Bronzed Drongo	*Dicrurus aeneus*
75		Greater Racket-tailed Drongo	*Dicrurus paradiseus*
76	MUSCICAPIDAE	Black-naped Monarch	*Hypothymis azurea*
77		Blue Rock Thrush	*Monticola solitarius*
78		Blue-capped Rock Thrush	*Monticola cinclorhynchus*
79		Malabar Whistling Thrush	*Myiophonus horsfieldii*
80		Orange-headed Thrush	*Zoothera citrina*
81		Eurasian Blackbird	*Turdus merula*
82		White-bellied Shortwing	*Brachypteryx major*
83		Brown-breasted Flycatcher	*Muscicapa muttui*
84		Black-and-orange Flycatcher	*Ficedula nigrorufa*
85		Blue-throated Flycatcher	*Cyornis rubeculoides*
86		Tickell's Blue Flycatcher	*Cyornis tickelliae*
87		Rusty-tailed Flycatcher	*Muscicapa ruficauda*

S.No	Family	Common name	Scientific name
88		White-bellied Blue Flycatcher	*Cyornis pallipes*
89		Verditer Flycatcher	*Eumyias thalassina*
90		Dull-blue Flycatcher	*Eumiyas sordida*
91		Nilgiri Flycatcher	*Eumyias albicaudata*
92		Grey-headed Canary Flycatcher	*Culicicapa ceylonensis*
93		Asian Paradise-flycatcher	*Terpsiphone paradisi*
94		Red-throated Flycatcher	*Ficedula parva*
95		Asian Brown Flycatcher	*Muscicapa dauurica*
96		Indian Blue Robin	*Luscinia brunnea*
97		Oriental Magpie Robin	*Copsychus saularis*
98		Pied-Bushchat	*Saxicola caprata*
99	STURNIDAE	Jungle Myna	*Acridotheres fuscus*
100		Hill Myna	*Gracula religiosa*
101	SITTIDAE	Velvet-fronted Nuthatch	*Sitta frontalis*
102	PARIDAE	Great Tit	*Parus major*
103		Yellow-cheeked Tit	*Parus spilonotus*
104		Black-lored Tit	*Parus xanthogenys*
105	HIRUNDINIDAE	Dusky Crag Martin	*Hirundo concolor*
106		Pacific Swallow	*Hirundo tahitica*
107		Barn Swallow	*Hirundo rustica*
108		Red-rumped Swallow	*Hirundo daurica*
109		Streak-throated Swallow	*Hirundo fluvicola*
110	PYCNONOTIDAE	Red-whiskered Bulbul	*Pycnonotus jocosus*
111		Grey-headed Bulbul	*Pycnonotus priocephalus*
112		Yellow-browed Bulbul	*Iole indica*
113		Black Bulbul	*Hypsipetes leucocephalus*
114	ZOSTEROPIDAE	Oriental White-eye	*Zosterops palpebrosus*
115	SYLVIIDAE	Thick-billed Warbler	*Acrocephalus aedon*
116		Blyth's Reed Warbler	*Acrocephalus dumetorum*
117		Tickell's Leaf Warbler	*Phylloscopus affinis*
118		Greenish Warbler	*Phylloscopus trochiloides*
119		Large-billed Leaf Warbler	*Phylloscopus magnirostris*
120		Leaf Warbler	*Phylloscopus sp.*
121		Common Chiffchaff	*Phylloscopus collybita*
122		Wynaad Laughingthrush	*Garrulax delesserti*
123		Nilgiri Laughingthrush#	*Garrulax cachinnans*
124		Puff-throated Babbler	*Pellorneum ruficeps*
125		Dark-fronted Babbler	*Rhopocichla atriceps*
126		Indian Scimitar Babbler	*Pomatorhinus horsfieldii*
127		Rufous Babbler	*Turdoides subrufus*
128		Jungle Babbler	*Turdoides striatus*
129		Brown-cheeked Fulvetta	*Alcippe poioicephala*
130	DICAEIDAE	Thick-billed Flowerpecker	*Diceaum agile*
131		Pale-billed Flowerpecker	*Diceaum erythrorhynchos*

S.No	Family	Common name	Scientific name
132		Plain Flowerpecker	*Dicaeum concolor*
133	NECTARINIIDAE	Purple-rumped Sunbird	*Nectarinia zeylonica*
134		Crimson-backed sunbird	*Nectarinia minima*
135		Purple Sunbird	*Nectarinia asiatica*
136		Loten's Sunbird	*Nectarinia lotenia*
137		Little Spiderhunter	*Arachnothera longirostra*
138	MOTACILLIDAE	Yellow Wagtail	*Motacilla flava*
139		Grey Wagtail	*Motacilla cinerea*
140		Forest Wagtail	*Dendronanthus indicus*
141		Paddyfield Pipit	*Anthus rufulus*
142		Nilgiri Pipit	*Anthus nilghiriensis*
143	FRINGILLIDAE	Common Rosefinch	*Carpodacus erythrinus*
144	PLOCEIDAE	Scaly-breasted Munia	*Lonchura punctulata*
145		Black-throated Munia	*Lonchura kelaarti*

Appendix. 4.2. Bird species density recorded during the study period

Species	rainforest density/ ha	highland density/ ha	Mean	Chi-sq d.f.=1	*P*
Alpine Swift	0.010	0.000	0.005	0.917	0.010
Asian Fairy Blue Bird	0.013	0.000	0.007	0.905	0.013
Ashy Drongo	0.010	0.000	0.005	0.917	0.010
Barn Swallow	0.000	0.027	0.014	0.864	0.027
Bar-winged Flycatcher shrike	0.003	0.000	0.002	0.955	0.003
Besra	0.000	0.027	0.014	0.864	0.027
Black Eagle	0.003	0.000	0.002	0.955	0.003
Black Kite	0.000	0.007	0.004	0.931	0.007
Black-and-orange Flycatcher	0.028	0.128	0.078	0.796	0.064
Black-lored Tit	0.010	0.041	0.026	0.886	0.019
Black-shouldered Kite	0.003	0.027	0.015	0.885	0.019
Black-hooded Oriole	0.008	0.000	0.004	0.926	0.008
Black-naped Monarch	0.003	0.000	0.002	0.955	0.003
Black-throated Munia	0.005	0.000	0.003	0.942	0.005
Blue Rock Thrush	0.031	0.007	0.019	0.898	0.015
Blue-winged Leafbird	0.033	0.000	0.017	0.850	0.033
Blue-throated Flycatcher	0.000	0.027	0.014	0.864	0.027
Blyth's Reed Warbler	0.003	0.000	0.002	0.955	0.003
Booted Hawk Eagle	0.000	0.014	0.007	0.902	0.014
Bronzed Drongo	0.003	0.000	0.002	0.955	0.003
Asian Brown Flycatcher	0.005	0.014	0.010	0.946	0.004
Brown-breasted Flycatcher	0.003	0.000	0.002	0.955	0.003
Chestnut-headed Bee-eater	0.003	0.000	0.002	0.955	0.003
Common Chiffchaff	0.051	0.074	0.063	0.946	0.004
Common Flameback	0.162	0.142	0.152	0.970	0.001
Common Kestrel	0.000	0.007	0.004	0.931	0.007
Common Rosefinch	0.000	0.054	0.027	0.811	0.054
Coppersmith Barbet	0.013	0.000	0.007	0.905	0.013
Crested Goshawk	0.003	0.007	0.005	0.967	0.002
Crested Serpent Eagle	0.005	0.000	0.003	0.942	0.005
Crimson-backed Sunbird	1.831	0.615	1.223	0.557	0.605
Dark-fronted Babbler	0.282	0.169	0.226	0.861	0.028
Dull-blue Flycatcher	0.005	0.000	0.003	0.942	0.005
Emerald Dove	0.054	0.000	0.027	0.811	0.054
Eurasian Blackbird	0.000	0.034	0.017	0.848	0.034
Eurasian Eagle Owl	0.003	0.000	0.002	0.955	0.003
Forest Wagtail	0.000	0.007	0.004	0.931	0.007
Common Flameback	0.003	0.000	0.002	0.955	0.003
Great Hornbill	0.003	0.000	0.002	0.955	0.003
Great Tit	0.000	0.014	0.007	0.902	0.014
Greater Racket-tailed Drongo	0.451	0.020	0.236	0.538	0.394
Greenish Warbler	0.182	0.419	0.301	0.758	0.094
Grey-headed Canary Flycatcher	0.672	0.567	0.620	0.922	0.009

Species	rainforest density/ ha	highland density/ ha	Mean	Chi-sq d.f.=1	*P*
Grey Junglefowl	0.092	0.034	0.063	0.865	0.027
Grey-headed Bulbul	0.046	0.000	0.023	0.825	0.046
Heart-spotted Woodpecker	0.005	0.000	0.003	0.942	0.005
Hill Myna	0.454	0.007	0.231	0.518	0.433
Honey Buzzard	0.003	0.000	0.002	0.955	0.003
House Swift	0.038	0.027	0.033	0.964	0.002
Indian Blue Robin	0.138	0.101	0.120	0.938	0.006
Indian Grey Hornbill	0.015	0.000	0.008	0.898	0.015
Indian Pitta	0.003	0.000	0.002	0.955	0.003
Indian Scimitar Babbler	0.110	0.081	0.096	0.945	0.004
Jungle Babbler	0.036	0.000	0.018	0.844	0.036
Jungle Bush Quail	0.003	0.000	0.002	0.955	0.003
Large-billed Leaf Warbler	0.000	0.108	0.054	0.742	0.108
Little Spiderhunter	0.013	0.000	0.007	0.905	0.013
Loten's Sunbird	0.003	0.000	0.002	0.955	0.003
Vernal Hanging Parakeet	0.010	0.000	0.005	0.917	0.010
Malabar parakeet	0.215	0.000	0.108	0.648	0.215
Small Minivet	0.026	0.000	0.013	0.867	0.026
Malabar Trogon	0.038	0.000	0.019	0.840	0.038
Malabar Whistling Thrush	0.474	0.014	0.244	0.518	0.434
Mountain Imperial Pegion	0.318	0.007	0.163	0.592	0.298
Nilgiri Flycatcher	0.008	0.061	0.035	0.835	0.041
Nilgiri House Swallow	0.000	0.074	0.037	0.782	0.074
Nilgiri Laughingthrush	0.000	1.283	0.642	0.256	1.283
Nilgiri Pipit	0.000	0.257	0.129	0.618	0.257
Nilgiri Wood Pigeon	0.144	0.034	0.089	0.790	0.068
Plain Flowerpecker	0.033	0.000	0.017	0.850	0.033
Orange-headed Thrush	0.005	0.000	0.003	0.942	0.005
Oriental White-eye	0.069	1.452	0.761	0.261	1.258
Paddyfield Pipit	0.000	0.020	0.010	0.883	0.020
Painted Bush Quail	0.003	0.000	0.002	0.955	0.003
Asian Paradise-flycatcher	0.031	0.061	0.046	0.918	0.010
Pied Bushchat	0.000	0.284	0.142	0.601	0.284
Pale-Billed Flowerpecker	0.003	0.000	0.002	0.955	0.003
Pompadour Green Pigeon	0.036	0.128	0.082	0.815	0.052
Puff-throated Babbler	0.013	0.000	0.007	0.905	0.013
Brown-cheeked Fulvetta	0.246	0.000	0.123	0.626	0.246
Red-whiskered Bulbul	0.026	0.000	0.013	0.867	0.026
Red-throated Flycatcher	0.005	0.000	0.003	0.942	0.005
Rufous Babbler	0.003	0.000	0.002	0.955	0.003
Black-throated Munia	0.000	0.014	0.007	0.902	0.014
Rusty-tailed Flycatcher	0.018	0.014	0.016	0.980	0.001
Scarlet Minivet	0.013	0.041	0.027	0.900	0.015

Species	rainforest density/ ha	highland density/ ha	Mean	Chi-sq d.f.=1	*p*
Shikra	0.003	0.000	0.002	0.955	0.003
Greater Coucal	0.000	0.007	0.004	0.931	0.007
Black Bulbul	0.397	0.594	0.496	0.838	0.039
Thick-billed Flowerpecker	0.133	0.142	0.138	0.984	0.000
Thick-billed Warbler	0.015	0.014	0.015	0.991	0.000
Tickell's Blue Flycatcher	0.013	0.027	0.020	0.942	0.005
Tickell's Leaf Warbler	0.172	0.230	0.201	0.924	0.008
Malayan Night Heron	0.003	0.000	0.002	0.955	0.003
Velvet-fronted Nuthatch	0.021	0.027	0.024	0.976	0.001
Verditer Flycatcher	0.003	0.000	0.002	0.955	0.003
White-bellied Blue Flycatcher	0.054	0.243	0.149	0.729	0.120
White-bellied Shortwing	0.005	0.061	0.033	0.822	0.048
White-bellied Treepie	0.123	0.000	0.062	0.726	0.123
White-throated Kingfisher	0.003	0.000	0.002	0.955	0.003
White-bellied Woodpecker	0.003	0.000	0.002	0.955	0.003
White-cheeked Barbet	0.454	0.054	0.254	0.582	0.315
Wynaad Laughing Thrush	0.015	0.000	0.008	0.898	0.015
Yellow-browed Bulbul	1.633	0.169	0.901	0.275	1.189
Yellow-footed Green Pegion	0.003	0.000	0.002	0.955	0.003
Yellow Wagtail	0.003	0.054	0.029	0.826	0.046
Yellow-cheeked Tit	0.003	0.000	0.002	0.955	0.003

Appendix. 4.3. Chi-squared tests to demonstrate the measure of patchiness in species populations in the community.

Species	Mean	Chi-sq, d.f.=5	*P*-value
Aggregated			
Alpine Swift	0.667	20	0.001
Black- lored Tit	1.833	13.55	0.019
Black-and-orange Flycatcher	5.000	19.2	0.002
Black-hooded Oriole	0.500	15	0.010
Black-shouldered Kite	0.833	15.4	0.009
Blue Rock Thrush	2.167	13.31	0.021
Blue-winged Leafbird	2.167	14.23	0.014
Brown-cheeked Fulvetta	16.500	101.2	0.000
Common Flameback	15.333	26.30	0.000
Common Rosefinch	1.333	16	0.007
Crimson-backed Sunbird	139.333	436.69	0.000
Dark-fronted Babbler	24.000	79	0.000
Eurasian Blackbird	1.000	20	0.001
Greater Racket-tailed Drongo	31.500	195.03	0.000
Green Imperial Pigeon	1.500	13	0.023
Grey-headed Canary Flycatcher	60.500	80.92	0.000
Grey Junglefowl	7.667	24.96	0.000
Grey-headed Bulbul	3.333	51.4	0.000
House swift	3.167	57.11	0.000
Indian Blue Robin	12.167	22.42	0.001
Emerald Dove	4.000	15.5	0.009
Indian Scimitar Babbler	10.667	20.56	0.001
Jungle Babbler	2.333	17.71	0.003
Large-billed Leaf Warbler	2.667	32	0.000
Little Spiderhunter	0.833	25	0.000
Malabar Parakeet	14.167	172.58	0.000
Malabar Trogon	2.500	30.2	0.000
Malabar Whistling Thrush	33.333	191.86	0.000
Mountain Imperial Pigeon	24.333	85.78	0.000
Nilgiri Laughingthrush#	31.667	407.85	0.000
Nilgiri Pipit	6.333	83.89	0.000
Nilgiri Wood Pigeon	11.167	41.27	0.000
Oriental White-eye	45.500	254.10	0.000
Pied Bushchat	7.000	91.14	0.000
Pompadour Green Pigeon	5.833	37.51	0.000
Puff-throated Babbler	0.833	15.4	0.009
Red-rumped Swallow	0.833	25	0.000
Red-whiskered Bulbul	1.667	50	0.000
Scarlet Minivet	1.833	15.73	0.008
Hill Myna	32.333	212.70	0.000
Black Bulbul	43.000	24.14	0.000
Thick-billed Flowerpecker	12.667	30.11	0.000
Tickell's Leaf Warbler	18.833	36.58	0.000
Vernal Hanging Parrot	0.667	20	0.001
White-bellied Blue Flycatcher	7.500	50.07	0.000
White-bellied Treepie	8.000	71.25	0.000
White-cheeked Barbet	32.500	130.32	0.000
Wynaad Laughingthrush	1.000	30	0.000
Yellow Wagtail	1.500	14.33	0.014
Yellow-browed Bulbul	114.667	508.83	0.000
Random			
Ashy Drongo	0.667	8	0.155

Species	Mean	Chi-sq, d.f.=5	*P*-value
Asian Brown Flycatcher	0.667	2	0.850
Asian Fairy Bluebird	0.833	10.6	0.059
Asian Paradise-flycatcher	3.500	11.86	0.036
Barn Swallow	0.667	8	0.155
Bar-winged Flycatcher-shrike	0.167	5	0.417
Besra	0.667	8	0.155
Black Eagle	0.167	5	0.417
Black Kite	0.167	5	0.417
Black-naped Monarch	0.167	5	0.417
Common Flamback	0.167	5	0.417
Black-throated Munia	0.333	10	0.074
Blue-throated Flycatcher	0.667	8	0.155
Blyth's Reed Warbler	0.333	4	0.551
Booted Eagle	0.333	10	0.074
Bronzed Drongo	0.167	5	0.417
Brown-breasted Flycatcher	0.167	5	0.417
Chestnut-headed Bee-eater	0.167	5	0.417
Common Chiffchaff	5.333	5.5	0.358
Common Kestrel	0.167	5	0.417
Crested Goshawk	0.333	4	0.551
Crested Serpent Eagle	0.333	4	0.551
Crimson-fronted Barbet	0.833	5.8	0.326
Dull-blue Flycatcher	0.333	4	0.551
Forest Wagtail	0.167	5	0.417
Great Hornbill	1.333	5.5	0.358
Great Tit	0.333	10	0.074
Greater Coucal	0.167	5	0.417
Greenish Warbler	24.667	8.16	0.146
Heart-spotted Woodpecker	0.333	4	0.551
Indian Pitta	0.167	5	0.417
Jungle Bush Quail	0.167	5	0.417
Loten's Sunbird	0.167	5	0.417
Malabar Grey Hornbill	1.333	5.5	0.358
Malayan Night Heron	0.167	5	0.417
Nilgiri Flycatcher	2.333	9.14	0.102
Orange-headed Thrush	0.333	10	0.074
Oriental Honey-buzzard	0.167	5	0.417
Paddyfield Pipit	0.500	7	0.220
Painted Bush Quail	0.167	5	0.417
Pale-billed Flowerpecker	0.167	5	0.417
Plain Flowerpecker	2.500	12.6	0.027
Red-throated Flycatcher	0.333	10	0.074
Rufous Babbler	0.333	10	0.074
Rusty-tailed Flycatcher	2.167	5	0.417
Scaly-breasted Munia	0.333	10	0.074
Shikra	0.167	5	0.417
Small Minivet	0.333	10	0.074
Spot-bellied Eagle Owl	0.167	5	0.417
Tickell's Blue Flycatcher	1.500	7.67	0.174
Tytler's Leaf Warbler	2.167	6.85	0.231
Velvet-fronted Nuthatch	2.000	12	0.035
Verditer Flycatcher	0.333	4	0.551
White-bellied Shortwing	1.833	12.45	0.029
White-bellied Woodpecker	0.167	5	0.417
White-throated Kingfisher	0.167	5	0.417
Yellow-cheeked Tit	0.167	5	0.417
Yellow-footed Green Pigeon	0.167	5	0.417

Appendix 4.4 Number of species and individuals in different trophic categories.

Trophic group	EGGL		EGD		EG		BLHF		SHOLA		SHOLAG	
	Species	Individuals	Species	Individuals	Species	Individuals	Species	Individuals	Species	Individuals	Species	Individuals
Aerial insectivore	2	19	0	0	0	0	0	0	3	11	1	2
Bark insectivore	2	14	2	27	4	34	1	8	2	18	1	7
Canopy insectivore	4	29	7	36	5	37	2	19	5	47	3	48
Carnivore	3	3	3	3	4	4	0	0	3	4	4	9
Frugivore	6	81	7	91	7	99	4	32	5	13	3	34
Frugivore-insectivore	3	249	5	302	6	291	3	50	4	88	3	126
Granivore	2	10	1	7	1	6	1	1	0	0	1	2
Granivore-frugivore	1	5	1	22	1	57	1	1	0	0	0	0
Nectarivore-insectivore	2	213	1	229	2	278	1	31	1	58	1	33
Omnivore	17	207	15	391	17	352	10	90	9	178	5	158
Terrestrial insectivore	4	37	5	62	3	74	2	11	5	28	4	30
Understorey insectivore	12	147	12	183	11	196	7	51	10	98	9	107
Frugivore-nectarivore	0	0	1	4	0	0	0	0	0	0	0	0
Insectivore	0	0	1	0	0	0	0	0	0	0	0	0
Frugivore-granivore	0	0	0	0	0	0	0	0	1	5	1	4
Insectivore-granivore	0	0	0	0	0	0	0	0	1	14	1	24
Insectivore/Omnivore	0	0	0	0	0	0	0	0	1	16	1	26

Appendix 5.1 Number of species and individuals breeding in different months during 2002-2005.

Sl.No.	Species	M 02	A	M	J	J	A	S	O	F03	M	A	M	J	J	A	S	N	D	J04	F	M	A	M	J	J	A	S	J05	F	M	A	Total
1	Black Bulbul	1	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	1	1	-	1	-	-	-	-	-	0	4	6	5	22
2	Ashy Drongo	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
3	Puff-throated Babbler	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
4	Grey-headed Flycatcher	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
5	Hill Myna	1	-	-	-	-	-	1	1	-	-	3	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	3	-	11
6	Malabar Whistling Thrush	-	-	3	5	7	3	1	-	-	-	3	3	3	1	1	1	-	-	-	-	-	1	-	1	4	8	2	-	-	-	-	47
7	Mountain Imperial Pigeon	1	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	1	2	1	-	-	-	-	-	1	3	2	14
8	Nilgiri Wood Pigeon	1	1	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	7
9	Pompadour Green Pigeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
10	Red-whiskered Bulbul	2	3	-	-	-	-	1	-	-	2	5	4	1	-	-	-	1	1	1	-	2	6	-	-	-	-	-	1	4	6	3	43
11	Scimitar Babbler	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1	3	1	-	-	-	-	-	-	-	-	3	3	1	14
12	White-cheeked Barbet	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
13	Crimson-backed Sunbird	2	1	-	-	-	-	-	-	8	5	7	4	3	-	-		4	5	10	8	6		-	-	-	-	-	7	11	5	4	90
14	Oriental White-eye	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	4
15	Yellow-browed Bulbul	2	-	-	-	-	-	-	-	-	2	4	1	2	-	-	-	3	3	10	3	5	11	-	-	-	-	-	3	8	12	9	78
16	Grey Junglefowl	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
17	Pacific Swallow	-	-	-	-	-	-	-	-	5	5	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	1	5	5	24
18	White-bellied Treepie	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

Sl.No.	Species	M 02	A	M	J	J	A	S	O	F03	M	A	M	J	J	A	S	N	D	J04	F	M	A	M	J	J	A	S	J05	F	M	A	Total
19	House Swift	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	4	-	8
20	Greater Racket-tailed Drongo	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
21	Brown-cheeked Fulvetta	-	-	-	-	-	-	-	-	8	1	7	3	1	-	-	-	-	-	12	-	3	2	-	-	-	-	-	5	8	11	7	68
22	Emerald Dove	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	6	-	-	1	-	-	-	-	-	2	3	6	3	23
23	Grey-headed Bulbul #	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3
24	Dark-fronted Babbler	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	5	-	-	-	-	-	3	7	7	4	28
25	Pied Bushchat	-	-	-	-	-	-	-	-	-	3	3	2	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-	-	14
26	Nilgiri Laughingthrush	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	6
27	Nilgiri Pipit	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
28	Little Spiderhunter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
29	Grey Nightjar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1
30	Blackbird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
31	White-bellied Shortwing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
32	Nilgiri Verditer Flycatcher	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Total	10	5	5	5	7	3	3	1	24	26	40	24	11	1	1	1	8	11	44	14	31	35	1	1	-	-	-	21	52	75	43	517

Appendix 5.2. Chi-squared tests to demonstrate the measure of patchiness in the breeding bird species populations in the community in SVNP.

Sl.No.	Species	Mean	Chi-sq d.f.=5	*P*-value
	<u>Aggregated</u>			
1	Malabar Whistling Thrush	4.167	35.720	0.001
2	Red-whiskered Bulbul	7.167	53.419	0.001
3	Indian Scimitar Babbler	2.333	16	0.007
4	Crimson-backed Sunbird	15.000	94.933	0.001
5	Yellow-browed Bulbul	13.000	82.308	0.001
6	Brown-cheeked Fulvetta	11.333	69.824	0.001
7	Emerald Dove	3.833	24.739	0.001
8	Dark-fronted Babbler	4.667	35	0.001
9	Pied Bushchat	2.333	31.429	0.001
10	Pacific Swallow	4.365	33.56	0.001
	<u>Random</u>			
11	Black Bulbul	0.167	5	0.417
12	Ashy Drongo	0.167	5	0.417
13	Puff-throated Babbler	0.167	5	0.417
14	Grey-headed Canary Flycatcher	0.167	5	0.417
15	Hill Myna	1.833	11.364	0.044
16	Mountain Imperial Pigeon	2.333	9.143	0.102
17	Nilgiri Wood Pigeon	1.167	11	0.051
18	White-cheeked Barbet	0.167	5	0.417
19	Oriental White-eye	0.667	11	0.051
20	Grey Junglefowl	0.167	5	0.417
21	White-bellied Treepie	0.167	5	0.417
22	Greater Racket-tailed Drongo	0.167	5	0.417
23	Nilgiri Laughingthrush	1.000	12	0.035
24	Nilgiri Pipit	0.167	5	0.417
25	Little Spiderhunter	0.167	5	0.417
26	Grey Nightjar	0.333	4	0.551
27	Eurasian Blackbird	0.167	5	0.417
28	White-bellied Shortwing	0.167	5	0.417
29	Nilgiri Flycatcher	0.167	5	0.417
30	Paddyfield Pipit	0.167	5	0.417
31	Grey-headed Bulbul	0.167	5	0.417
32	Pompadour Green Pigeon	0.167	5	0.417

Appendix 5.3 The distribution of nests (percentage total for each bird species) among each of the 59 plant species and substrates used as nest substrates by the 12 breeding bird species in SVNP. Nest sample sizes are given in parenthesis.

Sl NO	Scientific name	CBS (90)	ED (23)	NWP (7)	MIP (14)	BCF (68)	DFB (28)	YBB (78)	BB (22)	RWB (43)	ISB (14)	MWT (47)	PS (24)
1	*Agrostistachys borneensis*	-	-	-	-	7.35	17.86	14.1	-	-	-	-	-
2	*Allophyllus cobbe*	-	-	-	-	-	-	1.28	-	-	-	-	-
3	*Ancistrocladus heyneanus*	-	-	-	-	2.94	-	5.13	-	-	-	-	-
4	*Antidesma menasu*	-	-	-	-	5.88	-	3.85	-	-	-	-	-
5	*Bischofia javanica*	-	-	-	7.14	-	-	1.28	-	-	-	-	-
6	*Calamus sp.*	2.22	-	14.3	7.14	-	50	-	-	-	-	-	-
7	*Callicarpa tomentosa*	2.22	-	-	-	-	-	1.28	-	-	-	-	-
8	*Canthium neilgherrense*	1.11	-	-	7.14	-	-	-	-	-	-	4.3	-
9	*Chloranthus brachystachys*	1.11	-	-	-	5.88	-	2.56	-	-	-	-	-
10	*Cinnamomum macrocarpum*	2.22	-	-	-	-	-	-	-	-	-	-	-
11	*Cinnamomum sulphuratum*	-	-	-	-	-	-	2.56	-	-	-	-	-
12	*Clerodendrum viscosum*	-	-	-	-	-	-	-	-	2.33	-	-	-
13	*Croton malabaricus*	-	-	-	-	-	-	-	-	2.33	-	-	-
14	*Cullenia exarillata*	-	13	-	-	5.88	-	6.41	18.18	2.33	-	-	-
15	*Cyathea gigantea*	7.78	-	-	-	-	-	-	-	-	-	-	-
16	*Daphniphyllum neilgherrense*	-	-	-	-	-	-	1.28	-	2.33	-	-	-
17	*Diospyros sylvatica*	-	-	-	-	-	-	1.28	-	-	-	-	-
18	*Diploclisia glaucescens*	-	-	-	-	-	-	-	-	2.33	-	-	-
19	*Elaeocarpus munronii*	-	-	-	-	4.41	-	1.28	-	4.65	-	-	-
20	*Elaeocarpus oblongus*	-	-	-	-	-	-	-	-	-	-	-	-
21	*Elaeocarpus serratus*	-	-	-	-	1.47	-	1.28	-	-	-	-	-
22	*Elaeocarpus tuberculatus*	2.22	-	-	-	-	-	-	-	-	-	-	-
23	*Emblica officinalis*	-	-	-	-	-	-	-	4.545	-	-	4.3	-
24	*Eurya nitida*	-	-	-	-	-	-	2.56	-	-	-	-	-
25	*Flacourtia montana*	-	4.35	14.3	-	-	-	1.28	-	-	-	-	-
26	*Garcinia morella*	-	21.7	14.3	21.4	-	-	-	-	-	-	-	-
27	*Garcinia tinctoria*	-	8.7	14.3	14.3	-	-	-	-	-	-	-	-
28	*Glochidion ellipticum*	3.33	-	-	-	-	-	-	50	25.6	-	-	-
29	*Gomphandra coriacea*	-	4.35	14.3	-	-	-	-	-	-	-	-	-
30	*Hemicyclia elata*	-	-	-	-	-	-	-	-	4.65	-	-	-
31	*Hopea parviflora*	-	-	-	-	-	-	2.56	-	2.33	-	-	-
32	*Knema attenuata*	-	-	-	-	-	-	3.85	-	2.33	-	2.1	-
33	*Lantana camara*	43.3	-	-	-	-	-	-	-	-	-	-	-
34	*Lasianthus ciliatus*	-	-	-	-	11.8	-	19.2	-	6.98	-	-	-
35	*Lasianthus jackianus*	-	-	-	-	-	-	14.1	-	-	-	-	-
36	*Litsea floribunda*	-	-	-	-	-	-	2.56	-	-	-	-	-
37	*Litsea laevigata*	3.33	4.35	-	7.14	-	-	-	-	-	-	-	-
38	*Litsea stocksii*	-	-	-	-	-	-	-	-	4.65	-	-	-
39	*Maesa Indica*	15.6	-	-	-	-	-	-	-	-	-	-	-
40	*Myristica malabarica*	-	4.35	-	-	-	-	1.28	-	-	-	-	-
41	*Mysristica dactyloides*	-	-	-	7.14	-	-	1.28	-	6.98	-	-	-
42	*Neolitsea scrobiculata*	-	4.35	-	-	-	-	1.28	-	-	-	-	-
43	*Neolitsea zeylanica*	-	-	-	-	1.47	-	-	-	-	-	-	-

Sl NO	Scientific name	CBS (90)	IED (23)	NWP (7)	MIP (14)	BCF (68)	DFB (28)	YBB (78)	SBB (22)	RWB (43)	ISB (14)	MWT (47)	PS (24)
44	*Ochlandra travancorica*	-	-	-	21.4	-	10.71	-	-	-	-	-	-
45	*Olea dioica*	-	-	-	-	-	-	5.13	-	6.98	-	-	-
46	*Palaquium ellipticum*	-	4.35	-	-	4.41	-	-	-	-	-	-	-
47	*Phoebe lanceolata*	-	4.35	-	-	4.41	-	-	-	-	-	-	-
48	*Psychotria elongata*	-	-	-	-	-	-	-	-	9.3	-	-	-
49	*Saprosma fragans*	-	17.4	-	-	30.9	-	-	-	11.6	-	-	-
50	*Strobilanthes neilgherrensis*	4.44	-	-	-	1.47	-	-	-	-	-	-	-
51	*Symplocos cochinchinensis*	-	-	-	-	4.41	-	-	-	-	-	-	-
52	*Syzygium cumini*	3.33	4.35	14.3	7.-14	2.94	-	-	-	2.33	-	-	-
53	*Syzygium laetum*	-	4.35	-	-	-	-	-	-	-	-	-	-
54	*Thottea siliquosa*	-	-	-	-	4.41	21.43	-	-	-	14	-	-
55	*Wendlandia notoniana*	3.33	-	-	-	-	-	-	27.27	-	-	-	-
56	*Ziziphus rugosa*	4.44	-	-	-	-	-	-	-	-	-	-	-
57	Rock	-	-	-	-	-	-	-	-	-	-	89	-
58	Ground	-	-	-	-	-	-	-	-	-	-	-	100
59	Mudwall	-	-	-	-	-	-	-	-	-	86	-	-