STUDIES ON THE ECOLOGY OF BIRDS IN MONOCULTURE PLANTATIONS IN GOA, INDIA.

Thesis submitted to the Goa University, Goa.
For the Award of the Degree of

Doctor of Philosophy
in
Zoology

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Dedicated with love and gratitude
to my Mother
for her encouragement and moral support.

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CERTIFICATE

This is to certify that the thesis entitled *"Studies on the ecology of birds in Monoculture plantations in Goa, India"* submitted by Ms Minal Desai, for the award of the Degree of Doctor of Philosophy in Zoology, Goa University, Goa, is a record of research done by her under my supervision and guidance. The thesis or part there of has not previously formed the basis of the award of any degree, diploma, associateship, or any other similar titles.

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Statement

This is to certify that the thesis entitled *"Studies on the ecology of birds in Monoculture plantations in Goa, India"*, is my original contribution and that the same has not been submitted for any other degree or diploma of this University or any other university/Institute.

Date: May, 2005

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PREFACE

Man has been dependent on forests right from precivilisation days. Forests have provided man with his basic needs of food, shelter and water. Forests are known to prevent soil erosion, wind erosion, conserve and recycle water, maintain carbon dioxide balance and also serve as the storehouse for genetic diversity. The forest based industries such as paper and pulp, veneer and plywood, lumber and timber and the industries engaged in distillation of wood to derive many chemicals used as raw materials, in various other industries form the backbone of modern economic development to millions of people all over the world. Forests are not only important for their economic utility but also influence the psychae and social life of mankind.

Man started exploiting forests for economic development at an early stage in human history. As agriculture expanded, forests were considered as rivals for the space needed for crops and flocks and were cleared for agricultural pursuits. So much so the overexploitation of forests are said to have resulted in the extinction of many well-developed and flourishing ancient civilizations. The rolling seas of sands, resulted from soil erosion and aridity owing to extensive deforestation were predicted to have engulfed the colonies of great Indus valley civilisation at Harappa and Mohanjo-Daro. In Greece, Anatolia, Spain and Iraq, the destruction of forest is known to have interfered with their climate and with the moisture content of soil on which, in the ultimate end every nation depends (Singh, 1987). Deforestation has been credited with being one of the principal causes of doom of Roman civilization and prosperous nations associated with it. It may not amount to exaggeration if deforestation is said to have done more damage than any war, destroying great historical empires.

The causes of deforestation are clearance of forests for farming, firewood, industrial and commercial purposes, mining operations and development projects like construction of townships, roads, railway routes, power plants, etc. Deforestation lead to reduction in green cover that used carbon dioxide for photosynthesis. On the other hand release of huge amount of carbon dioxide in atmosphere by human activities resulted in, greenhouse effect/ global warming, melting of ice caps ultimately causing soil erosion, floods, draughts, and destruction of biodiversity. Naturally if man has to escape from this impending environmental crisis then the solution lies in intensive afforestation/plantation programmes.

For a satisfactory ecological balance it is estimated that about 33% of the land need be under the green cover of the forests. Though plantation practices were introduced in pre-independent India, the practice got a boost with the initiation of five-year plans. However as late as 1990 only 21% of the total geographical area of our country was covered by forest (Ray & Mandal, 1990)

Therefore, it is obvious that the large scale growth/ expansion of agroforestry plantations are critically important if not indispensable for meeting the national needs of timber and non-timber forest products, conservation of biodiversity and achieving the national goal of 33% forest cover.

Monoculture plantations are uniform agrosystems that substitute natural ecosystems and their biodiversity, either in degraded zones of natural forest or in grasslands. When natural ecosystems are substituted by large-scale tree plantations, it is believed that they usually result in negative environmental impacts: decrease in water production, modifications in the structure and composition of soils, alteration in the abundance and richness of flora and fauna (Shiva, 1993). Pramod et. al. (1997) based on their studies on Western Ghats concluded that the transformation of forest/grasslands into monoculture plantations lead to most serious loss of biodiversity.

However some studies in the past (Gray, 1974) have suggested that monoculture stands can support better stand for avifauna. Thus extensive controversies surround the monoculture plantations. At the same time conditions vary with geoclimatic zones, thus, making it difficult to arrive at a conclusion as to the efficacy of the various systems on comparative basis. Some of the studies have recommended improvement strategies to ameliorate the negative consequences, in the form of interplanting of few indigenous species to improve the biodiversity in plantations (Gandhi, 1986).

Cruz (1988) opined that understorey shrubs, vines and the upperstorey of few native trees retained enhanced avian use of monoculture stands.

In Goa plantation operation commenced in 1963, by clear felling the suitable areas. Initially teak, eucalyptus and rubber trees were chosen for the and later acacia, cashew and bamboo were also included in monoculture practices. Cashew, teak and acacia are the three important plant species, extensively used for plantation purpose in the state. Cashew, *Anacardium occidentale* alone covers 11,196 ha area, largest among plantations in Goa. It is one of the important fruit-yielding trees earning a large amount of foreign exchange to the state. Teak, *Tectona grandis* covers 9507 ha, second largest area among plantations. Australian acacia, *Acacia auriculiformis* is mostly used to bring about green cover in barren and degraded areas.

Despite arguments and counter arguments regarding monoculture plantation, we cannot give up this practice, because of its need to fulfil the requirement of forest based products and to maintain ecological balance. Therefore, it is necessary that we develop complete information on the comparative effectiveness of various monoculture systems with definite criteria and indicator parameters such that we can choose suitable type of systems when we are compelled to adopt one. The study may help us modify the chosen system appropriately to overcome the problems associated with these plantation practices.

Birds are good indicators of ecological disturbances. The quality of an environment can be measured by its birdlife, and ecological planning as well as impact assessment can be developed through ornithological studies (Ripley, 1978; Parasharya, et. al., 1995). Most of the available work on the ecology of birds in plantations is from tropical Africa, central/south America and temperate Australia or Sweden (Bell, 1979; Carlson, 1986; Cruz, 1988; Hansson, 2000; Fisher, 2001 and Reversat, 2001). To best of my knowledge, reports on this aspect from our country are in single digits (Gray, 1974; Khan, 1978 and Gandhi, 1986). Khan (1978) worked on teak, eucalyptus and acacia plantations in high altitude montane tracks surrounding sholas of Nilgiri Hills and the study was limited to habitat utility by birds without any detailed studies on associated ecological perspectives.

Gandhi (1986) studied birds in cashew, eucalyptus and casuarina plantations in Tamil Nadu. In view of the taller canopies provided by the plantations chosen for study, comparison made by the author with scrub jungles doesn't seem to have provided good controls. Most of the other studies from India on plantations are forestry based, centered around litter – soil nutrient cycles, often on eucalyptus plantations besides others (Pande and Sharma, 1993; Mohsin et. al. 1996; Misra and Nisanka, 1997; Singh et. al. 1993 & 2001; Joshi et. al. 1999; Jha et. al., 2000; Aweto, 2001). These studies are mostly from Uttar Pradesh and North-East falling in subtropical belts of our country. Very often these studies have not maintained appropriate control systems for comparison.

In this background, the present work was designed to study the ecology of birds in three monoculture plantations, teak, acacia & cashew in the tropical precincts of Western Ghats. Primary natural forest was chosen as a control system for comparison. The study was aimed to compare the plantations through a wholistic ecological angle encompassing plant phenology, undergrowth, litterfall, litter decomposition, litter nutrients, soil nutrients, insect population and avifauna and its habitat utilization. The study was expected to throw light on the efficacy and relative merits of different monoculture systems with bird life at the center stage. It was also desired to fill the lacunae in the information on birds of forest in general and monoculture plantations in particular within the state.

Chapter 1:

INTRODUCTION

Forests are some of the most important natural landscapes of the world. Population growth, rapid pace of development and unmindful over exploitation of the natural resources has exerted an immense pressure on the forests and also caused biological impoverishment, leading to disastrous changes in natural ecosystems. The scarcity of raw material and ecological imbalance forced the forest-based industries and forest departments to go in for reforestation drives, especially the monoculture plantations, to meet the need of the day and overcome the imbalances.

In forestry sense, a monoculture forest is dominated by a single species of tree. This is very common feature in forests that grow back after natural disturbances such as fire, floods, landslides or insect attacks. Natural monocultures are common in northern coniferous forests such as the temperate rainforests and boreal forests of North America, Europe and Russia. These forests may be technically monocultures as the word is used in forestry. But they are fully functioning ecosystems containing thousands of species of mosses, ferns, fungi, herbs, insects, reptiles, amphibians and mammals.

While, manmade monoculture plantation forests are farms with monoculture of trees planted in rows, many a times exotic and hybridised. These forests are often established on lands that have already been cleared of its original forest or on grasslands/fallow. Plantations can be of two types namely managed and unmanaged systems. In managed system, management practices such as watering, manuring, weeding, etc are carried out at regular intervals. In unmanaged plantations, management practices are resorted to only during initial 2-3 years and later the trees are allowed to grow on their own with least human indulgence.

The clear understanding of the biology of plant and animal life that manifests the quality of the particular ecosystem is one of the prerequisites for evolving a management programme for any tropical forest biotope (Balasubramanian & Bole, 1993). The general understanding is that the large-scale anthropogenic disturbances contribute to the biological impoverishment of the ecosystems (Laurance and Bierregaard, 1997). Conversely quite a few reports have also indicated that large scale disturbances such as forest fragmentation, deforestation or monoculture plantation have contributed to the high biological diversity found in many tropical ecosystems (Gentry, 1986; Johns, 1986; Salo et. al. 1986 and Bush 1994). Irrespective of the relative merits of these opposing views, ecological sustainability can be assessed by the status of ecosystem components and biodiversity is one of them. Biodiversity is frequently interpreted as an indicator of the ecosystem health (Magurran, 1988). There are some studies that have used birds as indicators to assess the factors influencing changes in biodiversity (Williamson, 1970; Johnsingh & Joshua, 1994; Jayson and Mathew, 2002). Birds depend on plants; plants in turn are dependent on soil fertility, which is affected by litter decomposition and nutrient recycling.

Physiognomy or phenology of the vegetation in the form of leaf fall, sprouting of new leaves, flowering and fruiting schedules are important for evolving management programmes for any forest as it refers to quality of forest ecosystem and its capacity to support fauna (Chhangani, 2004).

Seasonal climatic changes bring about variations in phenological pattern of plants. Birds and insects dependent on plants may also vary accordingly (Balasubramanian & Bole, 1993).

The undergrowth or understorey is one of the integrated components of any natural forest. There are diverse opinions as to the existence of healthy undergrowth in monocultures in terms of the composition as well as the magnitude. Carrere & Lohmann, (1996) opined that plantations lack undergrowth. Contrarily, Lima (1993) reported extensive undergrowth in plantation though it was abandoned or unmanaged one.

Litterfall is an essential component of energy and biogeochemical cycles in any ecosystem, the forests being no exceptions. The integrity of any land ecosystem is maintained by transfer of matter and energy through litterfall. A substantial portion of the accumulated nutrients in the plant biomass is returned to the soil through litterfall (Vidyasagaran, et.al. 2002). Litter production is of great importance for the fertility of forest soils. Litter enters the decomposition subsystem and is broken down by decomposing organisms. The faster the rate of the decomposition, the more is the nutrient availability and consequently, the greater is the forest productivity. Litter of different species differs with respect to their physical texture, chemical composition and rate of decomposition (Pandit et. al. 1993). Hence nutrient content derived from diverse plant species may vary and hence the variations in single species based plantations of exotics/hybrid varieties.

Soil is the loose, natural material that forms the topmost layer of the earth. Water and mineral nutrients that sustain the life processes of plants come from soil. The soil properties are considerably influenced by the interaction of vegetation. Nutrients added to soil through litterfall create zone of enrichment under trees. Vegetation adds organic matter to the soil, decomposition of these release minerals, which maintain fertility of the soil. Favorable soil condition is necessary to the thriving of forest population. Fisher (2001) has attributed poor bird diversity to low nutrient status of the soil that limited productivity. Different topsoil/canopy cover types may affect downward movement of water in the soil in different ways. (Meghan and Salterland, 1962; Nazaror, 1969), hence different plantations may have their different effects on soil nutrients. The heterogeneous distribution in soil properties has been attributed to greater erosion of soil nutrients by the different canopies and the uptake and sequestration of nutrients in accumulated litter or soil organic mater (Jha et. al., 2000). According to some workers plants in monoculture plantation remove particular nutrients from the soil, hence depleting the soil of specific nutrients over a time span. While on the contrary, Singh et.al.(2001) have found that available content of macronutrients such as nitrogen, phosphorus and potassium in the soil under pure stand was found to be higher than soil of the intercropped stands.

Insects, one of the dominant groups of animals exist in nearly all habitats and in most areas of the world. They form an important component of almost all types of ecosystems. As much as they serve as pollinators of plants they also serve the dietary requirements of other animals including the large contingents of insectivorous birds. The views differ as to the relation between insect abundance and richness of plant species. According to Risch et. al. (1983) the loss of plant diversity causes higher insect abundance and lower species diversity. Conversely Haddad et. al.(2001)

opined that higher plant species diversity increased insect diversity as well as abundance.

Birds are considered as good biological indicators due to their ecological specialization, high sensitivity to disturbances and also due to their conspicuous behaviour, rapid and reliable identification, ease of sampling, stable taxonomy and diversity (Scotz, et. al. 1996). Bird communities have been frequently used for conservation assessment and monitoring (Daniels et. al. 1990). The pioneering studies of Mac Arthur et. al. (1962) established the relationship between bird diversity and vegetation structure. According to Jayson and Mathew (2002) bird population density correlated positively with habitat heterogeneity in tropical forest. The distribution of birds in an area is mainly controlled by plant community structure and plant cover at different height levels and availability of the preferred plant species (Mc Clure, 1972). Habitat quality and heterogeneity has also been reported to affect the abundance and diversity of breeding birds in forests (Berg, 1997).

Past studies from tropical rainforest regions (Daniels et. al. 1990; Raman, et. al. 1998, Kunte et. al. 1999) have shown that agroforestry plantations, generally harbour fewer bird species and have altered community composition as compared to primary forests. However, Weins (1983) showed negative relationship between habitat heterogeneity and bird availability.

The spatial and temporal distribution of resources is, to a great extent, determined by seasonal patterns. Thus seasonality is shown to play an important role directly and also with food resource dynamics as intervening variables (Karr, 1980). But according to Karr (1976) seasonal variation in avian community structure decreases with increasing vegetation complexity. The feeding guild is a useful tool for analyzing community structure. Breaking down assemblages of species into feeding guilds (Root, 1967) or functional groups (Cummins, 1973) is one of the main techniques animal ecologists have developed to try to grip community structure and dynamics. A few environmentalists in India and abroad like Vandana Shiva (1993) and Lohmann (2000) are extremely critical about monoculture plantations. They consider some plantations as a threat to ecological stability describing them as the deserts lacking food, shelter and opportunities for reproduction, hence almost devoid of local fauna. According to Pramod et. al. (1997) monocultures support species of widespread occurrence drawn from different habitat types. Bell (1979) and Fisher (2001) in their studies on teak and eucalyptus respectively found that bird diversity was poor in plantations. While Gray (1974) opined that the eucalyptus plantations have enchanced the local avifauna by providing stable vegetation. Some workers are of the view that plantations extend the area of forest canopy available for biodiversity conservation (Thiollay, 1995) and deserve protection (Williams et. al, 1995; Perfecto et. al. 1997; Moguel and Toledo, 1999).

Even though controversies surround the monocultures it may be too early to give up the practice completely in view of the ever-increasing industrial demand and need to bring the barren lands under green cover. Plantation practices are felt to be critically important to fulfill national need of forest products and to achieve 33% of forest cover to maintain ecological balance. Hence it is necessary that we develop complete information base on the comparative effectiveness of various monoculture system with definite criteria and indicator parameters such that we may be able to choose suitable systems if an option is available.

In Goa, monoculture of quite a few species of trees such as teak, acacia, eucalyptus, cashew, rubber and oil palm are being practiced, of which cashew, teak and acacia are most common and extensively cultivated varieties.

The cashew, *Anacardium occidentale*, a native of Brazil is one of the important cash crops of Goa. Among the plantation crops it occupies the largest area of about 56%. Nuts and apples are the two important products of the plant that earns considerable foreign exchange to the state.

The Teak, *Tectona grandis,* a deciduous tree and an important timber species of the world is indigenous to India. It is valuable due to its matchless properties such as lightweight, strength, attractiveness and resistance to termites, fungus and water. Teak wood is a preferred timber in furniture industry. It covers about 9 million ha of area in India and about 9507 ha in

Goa. Teak trees were plentiful in the basins of west coast rivers of India. During British occupation the main aim of the forest working plan was extraction of this timber. The ever rising demand for teak in housing needs and furniture production, and in turn its depletion in nature initiated teak monoculture (Chandran, 1997)

Acacia auriculiformis, native to Australia, has been introduced in India in 1946 by virtue of its fast growth and easy establishment (Amanulla, et. al. 2004). It is known to thrive well on hilly eroded rocky and degraded soils. Acacia is mostly used in raising the green cover in barren areas. It also meets the local demands of fuel, furniture and paper pulp.

In this background the present work was planned to study a comprehensive and comparative profile of the ecology of three monoculture plantations viz. cashew, teak, and acacia, the most common in Goa in comparison with natural forest as a control system for reference. The ecology of avifauna from multifarious angles was kept in the centre stage of study to reflect upon the intricate interdependances to arrive at logical conclusions. The study was to encompass plant phenology cycles, nature and magnitude of undergrowth, quantum of litterfall, rate of litter decomposition, release patterns of litter nutrients, levels of soil nutrients, abundance of insect population, avifaunal dynamics along with habitat utilization. The study was carried out for two complete years from March 2001 to February 2003. The study was intended to throw light on the efficacy and relative merits of different monoculture systems with the bird life at the center stage. The study was also aimed to update the database on the birds of forests in general and monoculture plantations in particular within the state.

Chapter 2:

STUDY AREA

Goa (15^0 48' to14^0 53' N & 74^0 20' 13" to 73^0 40' 33"E) is bounded by the states of Maharashtra on the north and Karnataka on the east and south and by the Arabian Sea on the west. It stretches out to a length of 105 km from north to south and is 60 km wide from east to west, the total area being 3,702 sq km. It is under the influence of two important biomes the marine biome of the Arabian sea and the terrestrial forest biome of the western ghats. Within this geographical canvas are a wide range of ecosystems and habitats, eg. forests, ghats, alluvial plains, coasts, rivers, estuaries, mangroves, wetlands, etc. There are three main physical division or ecozones: the low-lying river basin, and the coastal plains; the middle level plateau in the center and the mountainous region of the sahyadris (part of the Western Ghats) in the east. Forest covers 1424 km^2 of the total 3702 km^2 geographic area of the state.

The present study was carried out in Valpoi range at Sattari Taluka (fig 2.1) of North Goa forest Division. A little more than half (54%) of this second largest taluka of the state is covered by forest that included extensive patches of monoculture plantations of different species. Therefore it was considered to be ideal location for the current study.

Monoculture plantations of cashew (CP), teak (TP) and acacia (AP) and a stretch of natural forest (NF) chosen for the study were all situated at a distance of 4 - 15 km from Valpoi in different directions (Fig. 1c). All these plantations were unmanged types wherein watering, manuring, weeding and lighting fire was not practiced. Details of the trees in natural forest and monoculture plantations are provided in table 2.1.

Natural forest (Fig. 2.2)

A central patch of 5ha in a long stretch of lateritic semi-evergreen forest running for around 4 km located at Bhuipal, was selected as a control system for comparison. It was to the west of Valpoi at a distance of 4 Km. The fully-grown trees of different species numbering 6.8/10 m^2, ranging in height of 5 to 35m and in girth of 7-87cm dbh with a canopy cover of 93% formed the climax vegetation. *Xylia xylocarpa, Terminalia paniculata, and T.*

tomentosa were the common tree species. *Calycopteris floribunda, Ixora coccinea* and *Clerodendron viscosum* constituted the dominant undergrowth species.

Teak plantation (Fig. 2.3)

Teak plantation chosen for the present study was located at Kodal to the North-east of Valpoi at a distance of 12 km. The plantation was 25 years old covering about 4.7 ha area. It was in contiguity with natural forest on 3 sides. On its western side a tar road connecting the villages of Maloli and Kodal and a perennial stream were located. Trees in the plantation were with 11-33 cm dbh and 11-24 m height. Tree density was $9/10m^2$ and canopy cover was 28%. The undergrowth was constituted by *Desmodium cephalotes, Ziziphus rhugosa, Helicteres isora, Ixora coccinea, Calycopteris floribunda*. The other few indigenous trees present in the plantation were *Terminalia paniculata, Careya arborea* and *Holarrhena antidysentrica* with a density of $0.7/10m^2$.

Cashew plantation (Fig. 2.4)

The cashew plantation was located in Maloli, at a distance of 9 km from Valpoi. The plantation covered an area of 5 ha and was 30 years old. Tree density was $8 /10m^2$. The height of trees were 11–19 m tall and dbh was 21-30 cm. The canopy cover was 87%. The plantation on one side merged with another cashew plantation of 3 years of age. The second side was in continuity with an orchard of mango, areacanut and banana plants. The remaining two sides of the plantation gradually merged with stretches of natural forest. The undergrowth was dominated by *Chromolena odorata. Clerodendron viscocum, Lea* sp. and *Calycopteris floribunda* formed the other plant species in undergrowth. The wild trees in plantation were *Terminalia paniculata* and *Careya arborea* with a density of $0.7/10\ m^2$.

Acacia plantation (Fig. 2.5)

The acacia plantation selected for the present investigation was in Gaunem village, 15 km south east of Valpoi. The plantation was 20 years of age covering about 5.4 ha. The trees were 11-25 m tall and with a girth of 9 - 31cm dbh. The tree density was 25/10 m^2 and canopy cover was 89%. Like teak plantation the acacia plantation also was in contiguity with natural forest on 3 sides. On the fourth side, on the west of the plantation Gaunem – Assodem a tar road and a perennial stream were located. Undergrowth was dominated by *Thelepaepale ixiocephala*. *Chromolena odorata* and *Clerodendron viscosum* were the other species of undergrowth. *Terminalia paniculata* were the stray tree species found in the plantation with a density 0.5/10 m^2.

Climate (Table 2.2, Graph 2.1)

The climate of Goa is warm and humid with temperature ranging from 20°C to 36°C and relative humidity ranging from 70-98%. Monsoon is a distinct season of the region extending from June to September, experiencing a total annual precipitation of 2600 mm. Usually during postmonsoon (October and November) stray showers are likely contributing to around 55mm rainfall. The region experiences least temperatures in winter extending from December to February. Summer (March - May) is the hottest season of the region. During summer the region experiences maximum temperature and sunshine hours with moderate humidity.

Temperature

During the present study conducted from March 2001 to February 2003 the maximum temperature was recorded in May 2001 (34°C) and minimum in January 2002 (25.7°C). On a seasonal basis, highest temperature was recorded in summer and least in winter.

Sunshine

The total sunshine hours ranged from 87 hrs in July to 289 hrs in January. On seasonal basis maximum sunshine hours were in summer followed by those in winters.

Rainfall

In 2001, a total of 2119.7mm rainfall was recorded. South –west monsoon precipitation extended from May to November. The year also experienced pre-monsoon showers in April. The maximum rainfall was during July 832.4 mm. During the year 2002, total rainfall was 1941 mm of which 1137mm precipitated in June. The monsoon spell lasted from May to October.

Humidity

Humidity recorded during the study period ranged from 70% in January 2001 to 95% in August 2002. On a seasonal basis humidity was highest in monsoon and lowest in winter.

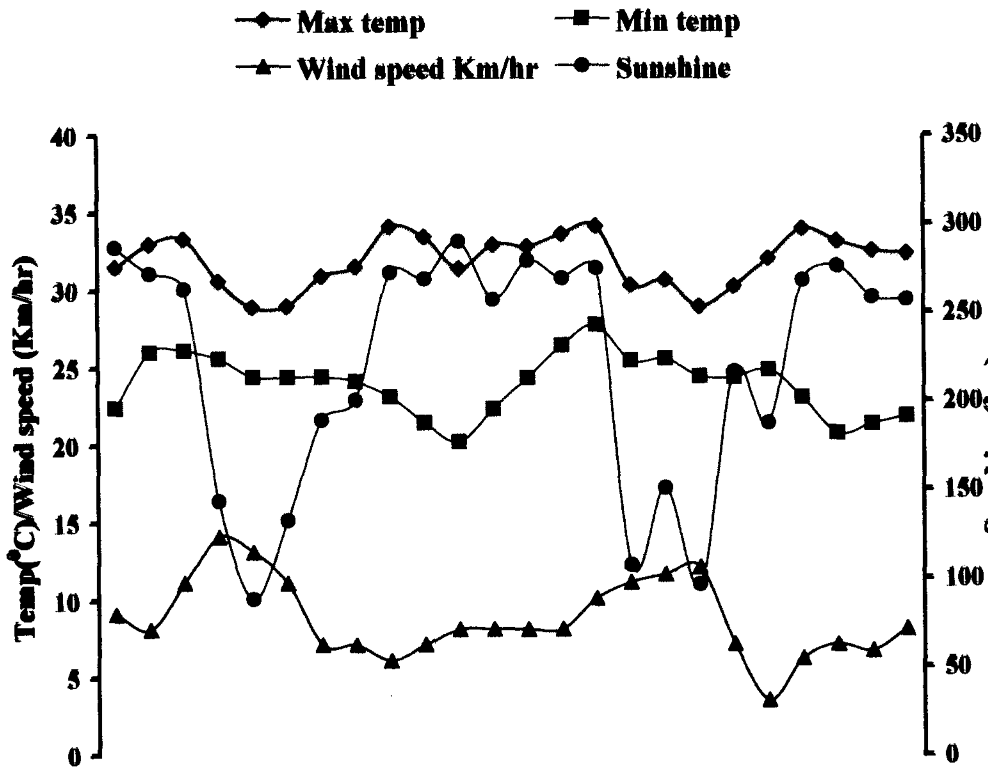
Table 2.1: Details of the trees in natural forest and monoculture plantations studied.

Forest/ Plantations	Age (years)	Height (m)	DBH (cm)	Canopy cover (%)	Density of trees/ 10 m^2	
					Monoculture species	Other trees in plantations
Natural forest	-	22.2±10.37	28.0 ±18.0	93±3.16	6.8	
Teak	25	16.2± 4.60	20.0± 5.50	28±13.0	9	0.7
Cashew	30	12.0 ±3.50	27.8± 3.35	87±8.00	8	0.6
Acacia	20	20.2± 5.00	18.5 ±4.90	89±5.40	25	0.5

Table 2.2: The changes in the climatological parameters in Goa through seasons from March 2001 to February 2003.

Years/seasons	Max Temp. ^{0}C	Min Temp. ^{0}C	Rainfall (mm)	Wind speed Km/hr	Sunshine Hrs	Relative Humidity (%)
2001-02						
Summer	33.0± 0.21	24.7 ± 2.10	57.9 ± 95	9.3 ± 1.5	273.0 ± 11.91	80.0 ± 2.02
Monsoon	29.7 ± 1.04	24.6 ± 0.60	467.2 ± 304.0	11.2 ± 3.09	137.3 ± 41.4	91.5 ± 3.10
Postmonsoon	32.7 ± 1.83	23.5 ± 0.70	37.85 ± 45.6	6.5 ±0 .70	235.4 ± 50.9	86.0 ± 7.07
Winter	32.4 ± 1.04	21.2 ± 1.05	Nil	7.6 ± 0.57	270.5 ± 16.6	76.0 ± 4.10
2002-03						
Summer	33.4 ± 0.65	26.0 ± 1.71	21.3 ± 36.5	8.6 ± 1.15	273.5 ± 5.01	81.3 ± 3.21
Monsoon	29.9 ± 0.75	24.8 ± 0.63	459.4 ± 458.5	10.3 ± 2.28	141.5 ± 54.3	91.2 ± 2.87
Postmonsoon	32.8 ± 1.34	23.8 ± 1.27	48.74 ± 68.7	4.7 ± 1.9	226.4 ± 56.8	85.0 ± 7.07
Winter	32.5 ± 0.41	21.1 ± 0.55	Nil	7.2 ± 0.72	262.5 ± 10.5	83.3 ± 4.50

Graph 2.1:
Monthly variations in climatological parameters in Goa from March 2001 to February 2003.



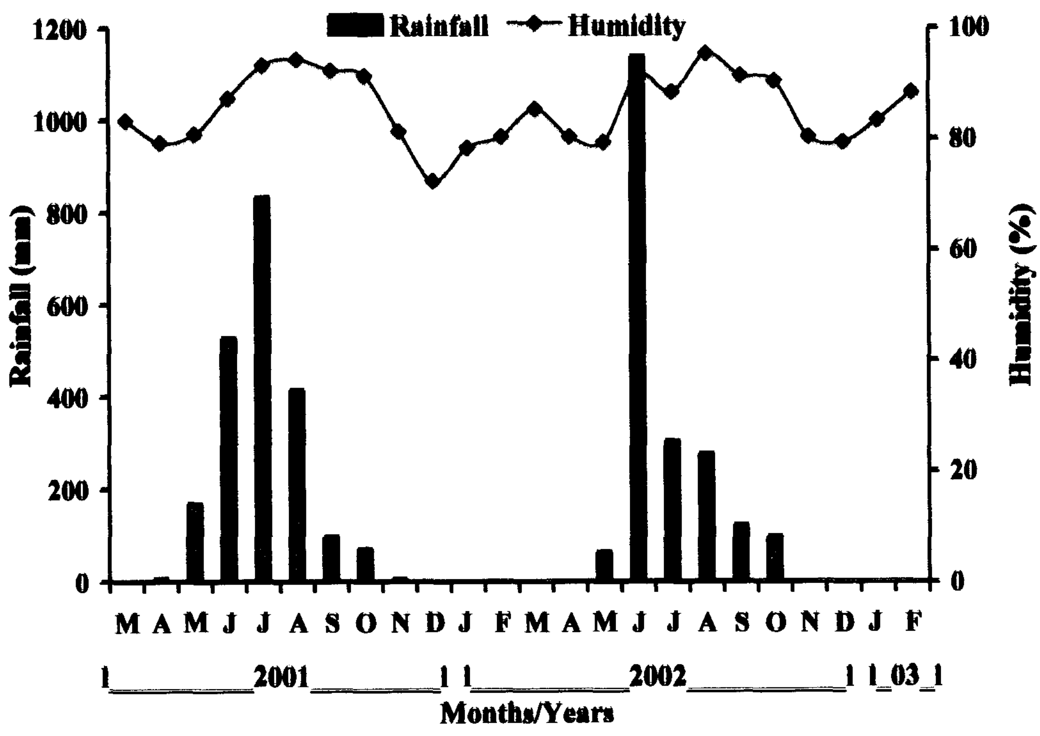


Fig. 2·1: Map of Sattari Taluka showing locations of Natural forest and three plantations studied

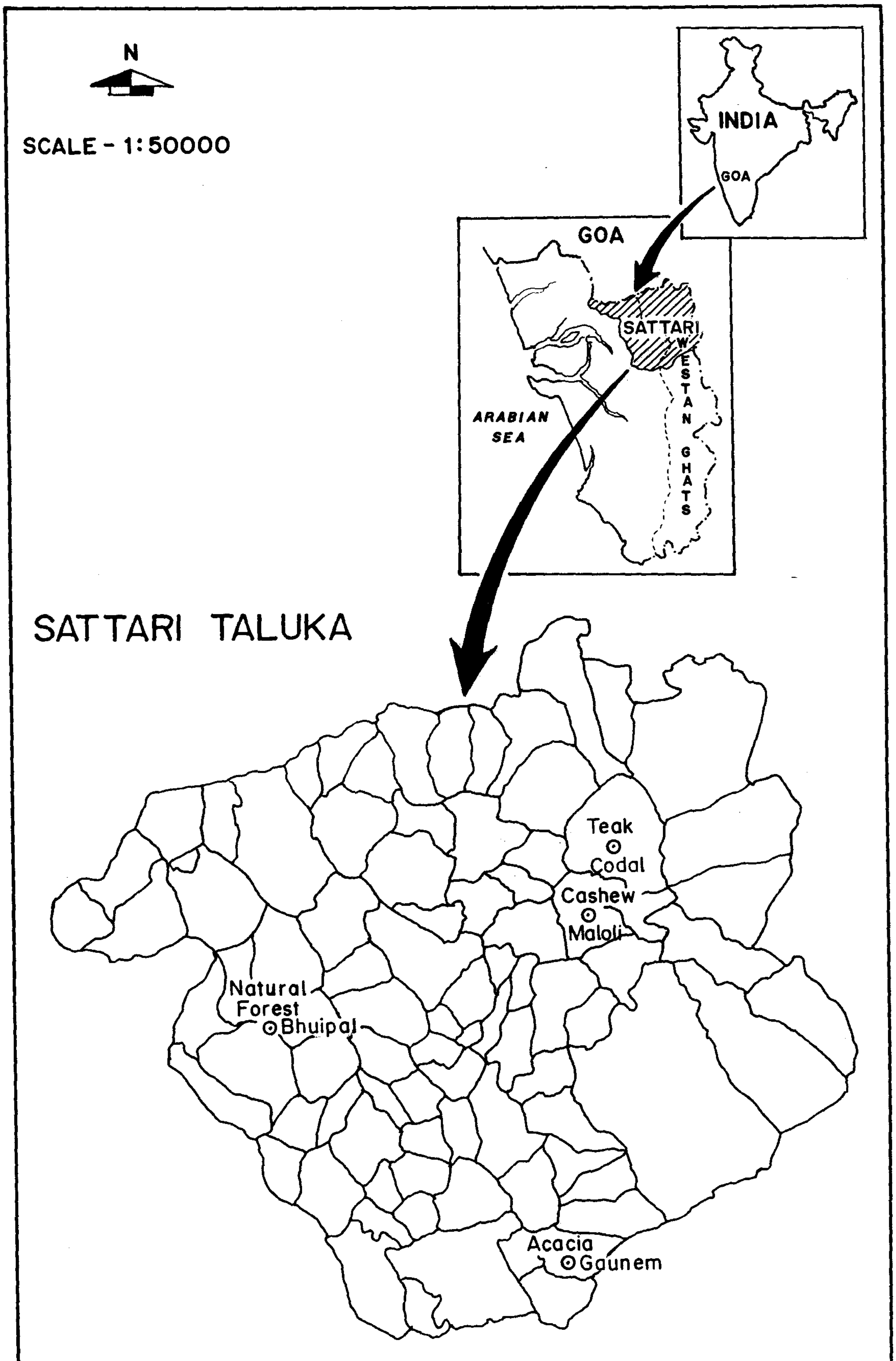


Fig 2.2: A view of natural forest with different tree species, dense canopy and diverse undergrowth.

Fig 2.3: A view of teak Plantation with very sparse canopy and patchy undergrowth.

Fig 2.4: A view of cashew plantation with dense undergrowth in the background.

Fig 2.5: A view of densely packed stands of *Acacia auriculiformis*.

Chapter 3:

MATERIALS & METHODS

The monocultures of such tree species that are extensively used for the purpose in Goa were chosen for the study. The monocultures of teak, cashew and Australian acacia were the natural choices. Preliminary survey was conducted to select appropriate monoculture plantations of chosen tree species. Care was taken such that the selected monoculture sites were approximately of identical sizes in a range of about 5 ha. A stretch of comparable size of a primary forest within the taluka served as control system for comparison.

Initially, the density, height and the girth (diameter at breast height - dbh) of the trees at all the study sites including the primary forest were recorded by analysing all the trees in 5 randomly laid quadrants of 10m x 10m size at each site.

All the subsequent studies pertaining to plant phenology, extent of undergrowth, rate of litter fall, litter decomposition, variations in the nutrient levels in the litter and soil, biodiversity in terms of insects and bird fauna were carried out regularly at monthly intervals. The study was conducted for 2 complete years from March 2001 to February 2003.

Plant phenology

The status and magnitude of phenological events such as leaf fall, sprouting of new leaves, flowering, fruiting, dehiscence, of the trees and the undergrowth plants were studied and recorded at monthly intervals at all the study sites. Qualitative and semiquantitative estimation on a arbitrary 3 point scale as "none', 'few' and 'many' (Frankie et al. 1974; Guy et al. 1979; Opler et al. 1980; and Balsubramanian and Bole, 1993) was employed for the purpose.

Undergrowth

The variations in diversity and densities of undergrowth were studied by using quadrant method described by Trivedy, et. al. (1987). The species of herbaceous plants and shrubs in the height range of 0.5m to 3m and number of individuals of each species were enumerated in five randomly laid quadrants at all the study sites at monthly intervals.

Litterfall

The rate of litterfall was assessed by following the procedure described by Pande & Sharma (1993). Five permanent litter plots of 1m x 1m were randomly demarcated in each of the study sites. Initially the dead organic material from these plots was swept off. Thereafter the fallen plant litter was collected at monthly interval to estimate rate of litterfall. The litter was weighed in the field and representative sample was carried to laboratory for determination of dry weight. The mean of these trap contents converted to g dry wt/ m^2 was taken as the quantum of litterfall for the month. The cumulative total of 12 months of the year was considered as the annual litter production.

Litter decomposition

Rate of litter decomposition was estimated by litter bag technique (Olson, 1963). Litter bags (35x25 cm) were made of nylon mesh (1mm). The sides of these bags were stitched firmly with synthetic thread at intervals of 2 cm consecutively leaving 2 cm gaps in between. In the month of March during both the years freshly fallen leaf litter was collected and 25g litter was placed in each bag. The litterbags were tied with a rope to the base of the trees and laid on the ground. A total of 75 bags were laid in each site. Five litterbags each were recovered at monthly interval from every site. Immediately after recovery, the litterbags were placed individually in polyethylene bags and transported to the laboratory. The recovered material was subjected to careful washing under running tap water to separate soil particles and any other extraneous material. It was dried at 70°C for 24 hours and weighed to find mass lost. The contents were pulverized using electrical mixer, sieved through 0.5mm mesh screen and stored in plastic airtight bottles for further analysis. Percentage of mass lost and decomposition constants were calculated as per the formulae employed by earlier workers (Olson, 1963; Maheshwaran and Gunatilleke, 1988)

% Mass lost=[(M_1-M_2)]/M_1

where, M_1=Initial mass in litterbag

M_2=Final mass in litterbag

Decomposition constant: $X/X_o=e^{-k}$

Where, X_o = Original weight of the litter in the bag

X= weight of the remaining litter at the end of one year.

e= the base of natural log.

k= Constant

Litter nutrients

The total nitrogen, phosphorous, potassium and organic carbon of the litter remnants were analyzed by Kjeldahl method, spectrophotometry, flame photometry and Walkley Black method respectively as per the procedures outlined by Saxena, (1987) and Trivedy et al, (1987).

Nitrogen

To 100g litter sample, 5 ml of concentrated H_2So_4 and 100g digestion catalyst (1:8:1 $CuSO_4$, K_2SO_4 & SIO_2) were added. Digestion was continued till the content turned apple green. The digest was allowed to cool, 75 ml distilled water was added, mixed thoroughly and supernatant was transferred to the kjeldahl flask. The content was mixed with 60 ml of 40 % NaOH and boiled. The condensate was collected in 20 ml boric acid containing methyl red and bromocresol green. On absorption of nitrogen the indicator turned blue. This was titrated against 0.01 N HCl until the colour changed to light brown. Blank was run using the same procedure and % nitrogen was calculated using the formula given below.

$$\% N = \frac{(T_1 - T_2) \times N \text{ of HCl} \times 1.4}{W}$$

Where T_1=vol. of titrant used against sample (ml)

T_2= vol. of titrant used against blank (ml)

N= Normality of titrant

W= weight of litter sample (g)

Phosphorous

For estimation of phosphorous in litter, 100 mg of dried, ground litter sample was taken in a porcelain basin; 5ml of 0.1N magnesium nitrate solution was added. The mixture was heated at low temperature till dryness and later ashed in a muffle furnace at 500 -550°C for 2 hrs. On cooling 5ml of 50% HCl was added to it. This was filtered and was made to 100 ml. To 10 ml of the filtrate, 0.4ml ammonium molybdate and 1 drop of stannous chloride were added, which gave it blue colour. The optical density (OD) was read at 690 nm after 5 minutes and before 12 minutes .OD was compared with the standard curve of phosphorus and % phosphorous was calculated using the following formula.

$$P\% = \frac{\text{mg P/L of ash solution} \times V}{1000 \times S}$$

where V=total volume of ash solution made (100ml)

S =wt of the plant material used (100mg)

Potassium

Potassium in litter was estimated by flamephotometric method. 1g litter powder was ignited at 500°C for 2 hours in muffle furnace. It was allowed to cool and later 5 ml of 50% HCl was added. This was heated at low temperature for 15 minutes, and then 1ml of nitric acid was added and was evaporated till dryness. Heating was continued for 1 hour. Residue was dissolved in 1ml of 50% HCl, some water was added and solution was warmed for complete dissolution. The solution was filtered. The filtrate was collected and the total volume was made-up to 100 ml by addition of distilled water and this was used as sample solution. This sample solution was allowed to aspirate by flamephotometer and optical density was recorded, concentration was determined by using standard curve. Percentage of potassium was calculated using the formula mentioned below.

$$\%K = \frac{\text{mg K/L of ash solution} \times V}{10000 \times S}$$

where, V =Total volume of ash solution (100 ml)

S =wt of litter powder in g (1g)

Carbon

Carbon in leaf litter was estimated using Walkley & Black method. To 100 mg litter sample, 10 ml of potassium dichromate and 20 ml concentrated sulphuric acid were added. This was allowed to stand for 30 minutes and later it was diluted by addition of 200 ml distilled water. Further 10 ml phosphoric acid, 0.2g of sodium flouride and 1ml of dilphenylamine indicator was added to obtain bluish colour, To measure the unutilized potassium dichromate, the solution was titrated against 0.5 N Ferrous ammonium sulphate, so as to obtain brilliant green colour as the end point. Simultaneously a blank was run using the same procedure and % carbon was calculated.

$$\% \text{Carbon} = \frac{6.791}{W \times 1.724} [1 - T_1 / T_2]$$

Where, W = weight of litter (g)

T_1 = vol. of titrant used against sample

T_2 = vol. of titrant used against blank

Soil nutrients

At random five sampling sites were selected in each plantation, soil samples were collected with the help of auger to the depth of 15 cm from the top. The samples were dried at 70°C for 24 hrs, ground with mortar and pestle, sieved through 2 mm screen and preserved in airtight container for analysis of nitrogen, phosphorus, potassium and carbon.

Nitrogen

Kjeldahl method was used for estimation of nitrogen in soil. 25ml distilled water was added to 10 gm soil sample and then 20 g digestion catalyst (containing copper sulphate, mercuric oxide, selenium and sodium sulphate) was mixed. To this mixture 35 ml concentrated sulphuric acid was added, the content was heated at low temperature till frothing stopped, heating was continued at high temperature till contents turned to apple green, digestion was continued further for 1 hr. Digest was allowed to cool, 100 ml distilled water was added, mixed thoroughly and supernatant was added to the Kjeldahl flask. Four to five washings with 50 ml distilled water were carried out and washings were transferred in the same flask, leaving behind as much soil as possible. 130 ml of 40 % NaOH was added to the content. The content was mixed thoroughly and distillation was commenced. 150 ml was collected in 25 ml boric acid and mixed indicator, further the blue colour content was titrated against 0.1 N HCl, until the colour changed to light brown. Percentage nitrogen in soil was calculated using formula given earlier in connection with litter nitrogen.

Phosphorous

Soil phosphorous was estimated using spectrophotometric method. Suspension of 1 mg soil and 200 ml H_2SO_4 (0.02 N) was stirred for ½ hour on magnetic stirrer. The solution was filtered, 10 ml filtrate was collected which was further processed as per the procedure described for phosphorous analysis of litter. Phosphorus percentage was calculated using the formula given below.

$$\%P = \frac{\text{mg P/L in soil solution}}{50}$$

Potassium

Potassium in soil was estimated by using flamephotometer. Soil sample of 50 g of soil was stirred on magnetic stirrer with 40% ethyl alcohol. The suspension was filtered after allowing it to stand for 10 minutes. Further the residue was washed with 40% ethyl alcohol and finally with absolute alcohol. To the residue 100 ml ammonium acetate solution was added and was kept overnight. The filtered supernatant was aspirated on flamephotometer and the O.D was obtained. The concentration of K was estimated using standard curve

$$\% K = \frac{\text{mg K\L of soil extract} \times V}{1000 \times S}$$

where, V =Total volume of solution (100 ml)

S =wt of soil in g

Carbon

The carbon content in the soil sample was estimated by Walkley and Black method described earlier. For this 0.5g soil sample was used instead of 100mg sample in case of litter analysis.

INSECT FAUNA

Ground level and above ground level insects were collected using pitfall traps and net sweeps (Borror et. al. 1981) respectively. Mid of every month, in randomly chosen 5 quadrats of 1x1m, a pitfall trap each was laid at all the four sites. PET bottles of 11 x 6 cm size constituted the pitfall traps. Formaldehyde (4%) was used as the killing agent. Pitfalls of adequate depth were dug and traps containing 50 ml of 4% formaldehyde each were laid and kept for 48 hrs. Captured insects were transferred to plastic vials and were taken to the laboratory. In the laboratory the insects were identified, enumerated and were preserved in 70% isopropyl alcohol.

Sweep net made up of muslin cloth with 40cm diameter rim, and 1m long handle was used to collect the above the ground level insects. At every study site in a predetermined plot of 20mx20m, 100 sweeps were made sweeping the net at constant speed covering the whole area. This was done on monthly basis. The insects collected in the net were pushed to the bottom of the net and the part of the net was inserted in the killing bottle, which was covered until the insects were stunned. Chloroform was used as the killing agent. The pieces of vegetation and other debris were separated. The catch was collected in pvc vials and carried to the laboratory. The insects were identified using standard taxonomic keys (Bingham, 1903; Bolton, 1974 & 1975; Borror et al 1981), enumerated and preserved. For the purpose of comparison the total collection of every month at a site by both the type of efforts was treated as the sample and recorded as individuals per monthly cumulative effort (ind /mce).

Avifauna

Initial survey of birds was made in the plantations. The birds were observed with 12 X 25 binoculars and identified using standard field guides (Ali, 1996; Grimmett et. al. 1998). A preliminary checklist was thus prepared and used for further census work. The new species sighted during the course of study were added to the list. The common (english) names and scientific nomenclature of birds has been adopted from (Manakadan & Pittie, 2000)

The avifaunal diversity and abundance was studied by Encounter Rate Method (Bibby et. al. 1992; Javed and Kaul, 2002). At every study site a peripheral 20m wide belt was demarcated just inside the boundary. Two 1km long, predetermined line transects were laid. One was located in the peripheral area by the edge of every plantation and the other was located inside/centre of plantation. The bird census were conducted by walking on both these fixed transects at a speed of 1 km/hr. The morning hours i.e. 7.00 to 9.00 a.m. were utilised for the purpose. The records of the 2 transects were separately maintained to analyse edge effect if any. The pooled data of both the transects at each site was considered for working out the montly picture at every site. During the year 2001-02 a single set of census data was gathered at every site. With an intention to obtain better accuracy, during the second year of study, i.e. 2002-03, 2 sets of census data were gathered with a gap of 3 days, in every month at each site. The observed birds were enumerated on field log sheets. The details such as residential status, affiliation to feeding guilds, etc. of the sighted birds for the further analysis were derived from standard literature (Ali & Ripley, 1989)

Habitat utilization

During every field visit, whenever a bird or flocks were sighted, records were maintained as to the act in which they were involved at the time of their sightings. Though all major activities of the birds such as resting, roosting foraging and breeding were considered for such a study, emphasis was laid on the latter two activities, they being of primary consideration.

Breeding

During every visit, the study sites were carefully scanned for signs of breeding activities of birds such as courtship calls, territorial defense, pairing, ferrying of the nest building material or food, the active/ abandoned nests, and the fledglings.

Whenever a nest was sighted, the species of host plant, its actual location on the host plant, height of the nest from the ground level, nest architecture etc were recorded.

The breeding bird species was identified with relative ease, if the nest sighted was in active state. In such an instance, involvement of single or both the sexes in parental duties was ascertained. In case of abandoned nests, if identification of breeding bird was not possible based on earlier experience, the nest was collected and shifted to laboratory for further investigation based on the available literature (Ali & Ripley, 1989)

Foraging

If bird(s) were sighted foraging at the study sites, the details such as host plant, foraging location with reference to the forest canopy, feeding guild composition, foraging actions - gleening, probing, aerial capture and the food material were observed and noted.

Statistical Methods

Species indices

The species diversity, evenness and richness for the populations of avifauna were calculated using the formulae given below.

Shannon-Wiener species Diversity Index: (Pielou, 1975)

$$\text{Species Diversity } (H') = -\sum_{i=1}^{s} P_i \ln P_i$$

where P_i is the proportion of individuals belonging to the i^{th} species and S is the total number of species.

Species Evenness or Equatibility Index:(Pielou, 1975)

$$\text{Species Evenness}(J') = \frac{H'}{\log S}$$

where H' is Shannon- Wiener species Diversity index and S is the number of species.

Species Richness Index: (Margalef, 1968)

$$\text{Species Richness } (SR) = \frac{S-1}{\log N}$$

where, S is the number of species in the population containing N number of individuals.

Sorrenson's similarity coefficient: (Southwood, 1978)

The similarities in between the sites in terms of avifauna was calculated as follows:

$$\text{Similarity coefficient } (CS) = \frac{2j}{a+b}$$

where a and b are the number of species at two sites and j is the number of species common to the two sites.

Presentation and Analysis of Data:

Whenever the data was based on replicate samples or more than one reading over a period of time, it is presented as mean of the sample and the range of dispersion in the form of standard error calculated employing the formulae given below.

$$\text{Mean} = \frac{\sum_{i=1}^{n} x_i}{N}$$

Where; x_i= observation for i^{th} character

N=no. of observations taken.

$$\text{Standard Deviation} = \sqrt{\frac{\sum (x-x')^2}{N}}$$

$$\text{Standard error} = \frac{\text{Standard deviation}}{\sqrt{N}}$$

The data was subjected to appropriate statistical tests such as Correlation Coefficient, Unpaired Students t-test, One Way ANOVA, Kruskal Wallis or H test, Mann Whitney U test as per the need.

The correlation between the various parameters within the individual site was analyzed using Correlation coefficient.

The variance in a parameter between the 2 years of study within every site were compared using Unpaired Students t-test.

The variations in different parameters between four sites were analyzed using One Way ANOVA or F test.

The seasonal variance in various parameters was analyzed using the Kruskal Wallis H test.

The variations in the parameter studied, if any, between the identical seasons of the two years were analyzed using Mann Whitney U Test.

The statistical Analysis were carried out using SPSS (version 6.1.3 for windows).

Chapter 4:

OBSERVATIONS

Plant phenology

In NF, dominant tree species such as *Terminalia paniculata* and *T. tomentosa* along with others like *Dillenia pentagyna* and *Ervatamia* sp bloomed during summer and fruited in monsoon. Some of the trees such as *Terminalia bellirica* and *Tectona grandis* were fruiting in post monsoon. While in winter *Terminalia bellirica* continued fruiting along with *Bombax ceiba* (fig 4.4b) and *Hopea vitiane.* In the undergrowth, during summer while plants such as *Ixora coccinea* and *Calycopteris floribunda* flowered (fig 4.4 c), *Lea indica* bore fruits (fig 4.4 d). In postmonsoon *Microcos paniculata* and *Ixora coccinea* were fruiting. Thus in NF through out the year some or the other tree or undergrowth plant species were in bloom or fruition. However, summer was the peak flowering/fruiting season that also witnessed the peak leaf fall.

In TP, the trees bore flowers (fig 4.5a) from early monsoon, (July) to early postmonsoon (October). The fruiting peak was in October, though fruiting continued till early winter (December). In the undergrowth in TP, Microcos paniculata was fruiting by the end of monsoon that continued till postmonsoon. *Helicteres isora* was flowering in postmonsoon. Leaf fall commenced in January, and by March trees were completely devoid of leaves. The sprouting of new leaves started in April.

In CP, flowering (fig 4.5b) commenced in winter and continued till mid summer. Fruiting that started sparsely by end of winter, was at its peak by mid summer. However the trees bore fruits till the end of summer season. *Chromolena odorata*, the dominant undergrowth species in CP was in bloom from November to February. *Clerodendron viscosum* was in bloom in monsoon as in other sites of study. Peak leaf-fall in CP was in winter.

In AP stands as many as 80% of the trees were in bloom (fig 4.5c) by late monsoon (September). Fruiting commenced in postmonsoon and continued till mid winter. Similar phenological pattern was seen during both the years. In undergrowth of AP, *Clerodendron viscosum* and *Helicteres isora* were flowering in monsoon and winter respectively. Peak leaf-fall in AP was in postmonsoon.

Undergrowth

The biennial means and seasonal variations in diversity and density of undergrowth are provided in Tables 4.1- 4.3. The monthly profiles of the same are depicted in Graphs 4.1.

Diversity and density

On biennial basis the undergrowth diversity ranged from 4 sps/m^2 in cashew stand to 12 sps/m^2 in NF and thus it was significantly poorer (F=30.6, df=3, p≤ 0.001) in CP than in other sites. On the other hand in CP the undergrowth was significantly dense (F=79.08, df=3, p≤0.001) with 50 stems/m^2 compared to that in the other 2 plantations and so also the NF, wherein it ranged from 31-34 stems/m^2.

Composition & Seasonality

In NF the diverse undergrowth provided a relatively uniform cover on the floor of the primary forest. It was constituted principally of perennial shrubs, the dominant species being *Calycopteris floribunda, Ixora coccinea* and *Clerodendron viscosum*. During monsoon and post monsoon the undergrowth flora got enriched owing to the addition of herbaceous plants. Figure 4.5 depicts the thick undergrowth cover in natural forest.

High density of undergrowth during monsoon with 50 stems/m^2 persisted through postmonsoon, reduced gradually through winter and reached its lowest level in summer with barely 17 stems/m^2. Thus during both the years of study the undergrowth varied through seasons significantly in terms of diversity (2001- 02: χ^2 =9.57, df=3, p≤ 0.05; 2002-03: χ^2 =7.93, df=3, p≤0.05) and density (2001- 02: χ^2 =9.86, df=3, p≤0.00l; 2002 – 03: χ^2 =8.99, df=3, p≤0.05). Undergrowth density showed positive correlation (r=0.54, p≤0.01) with rainfall.

In TP unlike in NF the undergrowth was patchy dominated by *Calycopteris floribunda*. The diversity of the undergrowth flora was poorer than that of primary forest with 4-8 species/m^2. The undergrowth density that ranged from 19 – 44 stems/m^2 showed similar seasonal pattern as in NF and varied significantly through seasons (2001-02: χ^2 =9.55, df=3, p≤0.05; 2002-03: χ^2 =9.70, df=3, p≤0.05). It also correlated positively with temperature(r=0.45, p≤0.05), rainfall (r=0.70, p≤0.01) and humidity(r=0.72, p≤0.01).

In CP the undergrowth was poor in floral diversity with only 3-5 sps/m^2. The weed *Chromolena odorata* (fig 4.6 a) was the dominant species. The density ranged from 31 –66 stems /m^2. The lowest diversity and highest density of undergrowth in CP were statistically significant compared to those at other sites (F =30.6, df=3, p≤0.001, F =79.08, df=3, p≤0.01). The pattern of seasonal variations in the undergrowth in CP was similar to those registered in other study sites. The variations were statistically significant only during the first year of study in terms of density (χ^2 =10.26, df=3, p≤0.01) as well as diversity (χ^2 =7.67, df=3, p≤0.05). Undergrowth density in CP correlated positively with rainfall (r=0.56, p≤0.05) and humidity (r=0.71, p≤0.01).

In AP the diversity in understorey was in close range of that in TP stands with 3-7 sps/ m^2, but didn't show any perceptible seasonal variations. The shrub, *Thelepaepale ixiocephala* was the dominant species, followed by an indicator species *Clerodendron viscosum* (fig 4.6 b). Significant seasonal variations, were observed during both the years in undergrowth density (χ^2 =9.16 & 9.14, df=3, p≤0.05). Undergrowth density correlated positively with rainfall (r=0.60, p≤0.05) and humidity (r=0.74, p≤0.01).

Litterfall

The biennial monthly mean and the seasonal variations in the quantum of litterfall in the 3 plantations under study and the NF are provided in table 4.1& 4.4 respectively. Graph 4.2 gives the monthly profile of the litterfall at all the study sites.

Maximum litterfall was recorded in AP (44 g/m^2), followed by NF (31 g/m^2) and TP (28 g/m^2). Least litterfall was observed in CP (23 g/m^2). Litterfall in AP was significantly higher (F=12.32, df=3,p≤0.001) compared to that at all other sites. Fig 4.7 depicts sparse litter in teak plantation and thick cover in acacia plantation.

Seasonality

In NF cumulative annual totals of litter in primary forest gathered at monthly intervals were 351 and 393 g/m^2. Peak litterfall (81 & 112 g/m^2) was observed in April of the two years and least (6 g/m^2) was recorded in July 2002. On seasonal basis, the litterfall in NF was maximum (63 &78 g/m^2) in summer and minimum in postmonsoon (9-12 g/m^2). The pattern was similar during both the years. The litterfall in summer was significantly higher (F=7.63, df=6, $p \leq 0.001$) as compared to that in all other seasons. The rate of litterfall correlated positively with atmospheric temperature (r=0.53,$p \leq 0.01$) and negatively with rainfall (r= -0.69, $p \leq 0.01$) undergrowth diversity (r=-0.53, $p \leq 0.01$) and density (r=-0.63, $p \leq 0.01$).

In TP, during the 2 years of study the annual cumulative litterfall was 351 and 321g/m^2. Unlike in primary forest, maximum litterfall (61 &54 g/m^2) was during winter and minimum (13 g/m^2) was in summer.

The litterfall in CP was least amongst the study sites, cumulative annual totals being 268 & 284 g/m^2. The pattern of seasonal variation was similar to the one observed in TP stands, being maximum in winter (42–50 g/m^2) and minimum (18-41 g/ m^2) in monsoon. The variations through seasons were significant during the year 2002 – 03 (χ^2 =8.42, df=3, $p \leq 0.05$). Litterfall correlated positively with sunshine (r=0.42, $p \leq 0.05$).

In AP litterfall on annual basis was highest among the study sites, being 534 & 522 g/m^2 during the 2 years of study. Unlike in NF and TP stands, maximum litterfall in AP was during post monsoon (58-82 g/m^2) and minimum (18-41 g/m^2) was during monsoon. In the year 2001 – 02, litterfall didn't show perceptible variations among the seasons but for monsoon. During the year 2002 – 03 quantum of litterfall varied significantly (χ^2 =8.42, df=3, $p \leq 0.05$) amongst seasons. The monsoons of the 2 years differed significantly (u=0.0, $p \leq 0.05$) in terms of litterfall.

Litter decomposition

The rates of decomposition of litter in three plantations and NF in terms of 'decomposition constants' are provided in graph 4.3. Percentage of mass lost through different seasons are depicted in Tables 4.5 and graph 4.4.

In NF decomposition constant for litter ranged from 1.83 - 2.12. In terms of seasonality, the percentage of mass lost by the litter was highest and in close ranges during monsoon and winter (42 – 53%). It was least during summer (18 – 20%). The percentage of loss of litter mass correlated negatively with temperature ($r=-0.70$, $p\leq0.001$).

For TP decomposition constants of litter were highest (2.5 & 2.52) amongst all the study sites. The loss of litter mass was fastest during monsoon (65 – 69%), closely followed by that of winter (60-63%) and was least in summer (20-22%).

The litter in CP decomposed at a slower rate compared to that in TP or NF, but not that of AP. Mass lost by litter owing to decomposition was highest in winter (46 – 50%) and lowest in summer (4 – 20%). Litter decomposition correlated positively with litterfall ($r=-0.49$, $p\leq0.05$) and negatively with atmospheric temperature ($r=-0.62$, $p\leq0.001$).

The litter in AP decomposed at slowest rate with lowest decomposition constants (1.13 – 1.42) compared to those at all other study sites. Annual percentage of loss of mass was only 72 –76%. The mass lost during winter and monsoon (43 -60%) was more than that in other seasons. Litter decomposition negatively correlated with temperature ($r=-0.65$, $p\leq0.001$).

Litter nutrients

The biennial mean, annual changes and variations through seasons in content of principal nutrients, nitrogen, phosphorus, potassium and carbon in the forest floor litter are provided in Tables 4.6 – 4.11 and Graphs 4.5 &4.6.

On biennial basis, the nitrogen and potassium content of litter in AP being 1.84% and 0.07% were the highest amongst study sites. The phosphorus content (0.055%) in the litter of TP was significantly higher ($F = 9.96$, df =3, $p \leq 0.001$) compared to those in other sites, which were in close range from 0.040 to 0.048%. The carbon content (4.48%) in the litter of NF was significantly higher ($F = 5.32$, df =3, $p \leq 0.01$) than those in all monoculture plantations.

Nutrient release patterns

Litter Nitrogen

A gross increase in nitrogen content of the litter was registered in all the study sites, through decomposition process over a period of a year. The gain was moderate in the litter of NF and TP, being 21% and 21.5 % respectively, while it was substantial in CP and extremely high and AP being 53% and & 72% respectively.

Seasonality

In NF the litter lost nitrogen to the extent of 40 – 49.5% in summer and 9.16 - 35.3% in postmonsoon, while during monsoon and winters it registered gains from 12.5 to 23.3% with reference to the initial level.

In TP the litter lost nitrogen moderately in summer and postmonsoon (10.52 – 31.81%), but gained substantially during winter and monsoon/postmonsoon (8.42 – 85.45%).

In CP litter released its nitrogen content only during summer within a low limit (12 – 29.87%) and gained the same through all the rest of seasons. The gains during monsoon/postmonsoon (72.22 – 100%) were noteworthy.

In AP, except for a negligible loss (1.75 %) during summer of 2002, the decomposing litter acquired nitrogen all through the year ranging from 18.62 – 93.13%.

Litter nitrogen content in all the study sites except in TP correlated negatively with atmospheric temperature (NF: $r = -0.62$, CP: $r = -0.63$ & AP: $r = -0.5$, $p \leq 0.01$).

Litter phosphorous

The initial phosphorus content in the litter in NF, CP and AP was relatively lower, in the range of 0.025 - 0.039%, which increased through the decomposition process over a period of a year. The mean annual increase in phosphorus content in NF and CP was in close range, being 42 and 44% respectively, while that in AP was perceptibly higher being 54%. Unlike in other sites, in TP the litter contained relatively higher quantity of the element being 0.057%. It decreased by 55% with reference to the initial level through the decomposition process over a period of a year

Seasonality:

In NF and AP but for a small loss in summers (5-12.9% & 10.41 – 12.9%) the decomposing litter gained phosphorus through rest of the seasons. The quantum of gains were higher during monsoon/ postmonsoon (90 / 50%) and winters (50/54%) in NF and AP respectively. In NF during the year 2001 – 02 the changes in phosphorus content in the litter through seasons were significant (χ^2=7.97, df=3, p≤0.05). The phosphorus content in the litter in NF correlated positively with litter nitrogen in (r =1.00, p ≤ 0.01) and negatively with atmospheric temperature (r = 0.62, p ≤ 0.01). In AP also it correlated positively with litter nitrogen(r = 0.7, p ≤ 0.01) besides litterfall (r = 0.5, p ≤ 0.05).

In TP except for the monsoons, there was the sustained loss of phosphorus from the decomposing litter, the rates being relatively higher during postmonsoon/winter (32.14/58.62%). It correlated negatively with the litterfall (r = - 0.48, p ≤ 0.01) in TP

In CP The process of litter decomposition lead to a gradual and sustained gain in phosphorus through all the seasons reaching a level of 44.1 – 45.45%. The phosphorus content of the litter in CP were significantly higher during the year 2002 – 03 compared to those in the previous year (t = 2.51, df = 22, p ≤ 0.05). In CP phosphorus content of the litter correlated positively with undergrowth density (r = 0.53, p ≤ 0.01) besides the litter nitrogen (r = 0.51, p ≤ 0.05).

Litter potassium:

On an average 75 – 81% of the potassium content from the litter leached-out annually in different study sites. The maximum release was in TP being 81% to be followed by NF being 79%. It was identical in CP and AP (75%).

Seasonality:

In NF maximum release was registered during summer (42%) and monsoon (32.19%) during the year 2001 – 02. During the subsequent year it was more spread-out with a higher release during postmonsoon (27.5%). The potassium content in the litter in NF correlated with litterfall ($r = 0.5$, $p \leq 0.05$) and showed significant seasonal variations during both the years (χ^2=10.12 & 10.34, df=3, $p \leq 0.05$).

In TP potassium release from the litter was higher during summer and monsoon (39.13 & 8.47% / 18.57 & 47.14%). The potassium content of the litter in TP varied significantly through seasons during both the years of study (χ^2=10.1 & 8.75, df=3, $p \leq 0.05$). It correlated positively with litter phosphorus ($r = 0.41$, $p \leq 0.01$) and negatively with rainfall ($r = - 0.52$, $p \leq 0.01$ as well as litterfall ($r = 0.5$, $p \leq 0.01$).

In CP, quanta of loss of potassium from the litter during summers (26.08 & 45.94%) and monsoons (21.74 &24.33%) were higher, than the following seasons. The variations in the potassium content of the litter in CP through seasons during both the years of study were significant (χ^2=10.34 & 10.12, df=3, $p \leq 0.05$). It correlated negatively with atmospheric temperature ($r = - 0.52$, $p \leq 0.01$), undergrowth diversity ($r = - 0.51$, $p \leq 0.01$) and litter nitrogen ($r = - 0.5$, $p \leq 0.01$).

In AP the potassium from the litter principally got released either in summer (70%), or jointly in summer and monsoon together (29.09 & 49,09%), the changes through the remaining seasons being less significant. The variations through seasons in potassium content of the litter in AP during 2002 – 03 were significant (χ^2= 8.75, df=3, $p \leq 0.05$). It correlated positively with rainfall ($r = 0.56$, $p \leq 0.01$) and negatively with atmospheric temperature ($r = -0.53$, $p \leq 0.01$) and litter nitrogen($r = -0.7$, $p \leq 0.01$).

Litter carbon:

At the four study sites the carbon content to the tune of 31-40 % of the initial level was released during the process of decomposition over a period of a year. The loss was least in NF (31%), followed by that in TP, while the annual losses in CP and AP were identical at the level of 40%.

Seasonality:

In NF, the loss of carbon in decomposing litter was gradual and spread-out with consistently higher rates in summers (15/10.36%). The variations in carbon content of the litter through seasons during the year 2002 – 03 were significant (χ^2= 9.08, df=3, $p \leq 0.05$). The carbon content of the litter positively correlated with litterfall ($r=0.46$, $p \leq 0.05$) and litter potassium ($r=0.74$, $p \leq 0.01$).

In TP, the annual loss of carbon content from the decomposing litter was of intermediate order (33%) between that at NF and other plantations. The loss was principally during summer or monsoon (15.04/19.16%).

In CP the loss of carbon from the litter was pronounced during winter (58.51%), or winter along with monsoon (23.39 &35,09%). The carbon content through seasons varied significantly (χ^2=10.08, df=3, $p \leq 0.05$) during 2002 – 03. Litter carbon correlated positively with litterfall ($r=0.41$, $p \leq 0.05$) and litter potassium ($r=0.54$, $p \leq 0.01$).

In AP, the annual loss of carbon from decomposing litter varied from 32 – 49%, the biennial mean being 40%. The loss during summers was consistently higher (5.26/20.5%) along with that in winter (9.67%) in one year, and monsoon (27.33%) during the other. The carbon content in the litter varied significantly through the seasons during both the years (χ^2 = 7.82 &10.45, df=3, $p \leq 0.01$). Litter carbon correlated positively with litter potassium ($r=0.41$, $p \leq 0.05$).

Soil nutrients

The monthly mean of soil nutrients, nitrogen, phosphorus, potassium and carbon on biennial basis in NF and the 3 plantations is provided in table 4.12 and graph 4.7. The variations in the soil nutrients through seasons at all the 4 sites are given in tables 4.13 - 4.16 and graph 4.8.

Soil Nitrogen

On biennial basis nitrogen content of the soil in AP was maximum being 0.25%, while that at NF was closely on the heels of it, being 0.22%. It was minimum in TP (0.10%) and of intermediate order in CP (0.15%)
Thus the lower levels of nitrogen content of the soil in TP compared to all other sites and lower levels of the same in CP compared to those of NF and AP were statistically significant ($F=93.72$, $df=3$, $p\leq0.001$).

Seasonality:

In NF soil nitrogen levels were significantly lower ($t=2.18$ $df=22$, $p\leq0.05$) during the year 2002-03 compared to those of the previous year. Nitrogen content of the soil at the site showed a mild seasonality. Relatively higher levels in summer (03/0.21%) dropped in monsoon (0.25/0.17%) and recovered marginally in postmonsoon (0.27/0.20%). Variations in soil nitrogen content through seasons during the year 2001-02 were significant ($\chi^2=9.81$, $df=3$, $p\leq0.05$). The soil nitrogen content differed significantly during the monsoons ($u=0.0$, $p\leq0.05$) of 2 years. Soil nitrogen correlated positively with soil carbon ($r=0.5$, $p\leq0.05$).

In TP the soil nitrogen varied within a narrow range of 0.8 to 0.11%, except for the monsoon of 2002, wherein it was fairly higher being 0.14%. The changes neither through the years nor through seasons were statistically significant.

In CP, the nitrogen content in the soil was intermediate between those at NF and TP. In general, it oscillated within a narrow limit from 0.13 to 0.16% except for the higher level of 0.19% registered in summer 2002. Soil nitrogen in CP correlated negatively with rainfall ($r=-0.65$, $p\leq0.01$), litter nitrogen ($r=-0.47$, $p\leq0.05$), and positively with temperature ($r=0.5$, $p\leq0.05$).

Soil nitrogen in AP was highest among the study sites and fairly uniform through the seasons oscillating between 0.22 to 0.3. In CP, as in case of NF soil nitrogen correlated positively with soil carbon ($r=0.57$, $p\leq0.01$).

Soil phosphorous

Soil phosphorous concentration on biennial basis in NF and CP were identical (0.03%) and significantly higher ($F=6.90, df=3$, $p\leq0.001$) than that at TP and AP.

Seasonality

In NF soil phosphorous content varied from 0.02 to 0.05% through seasons. The levels which were relatively lower in monsoons (0.02/0.03%) increased in postmonsoons (0.03/0.05%). The variations through seasons during the year 2001-02 were significant ($\chi^2=8.45$, $df=3$, $p\leq0.05$) unlike during the subsequent year. Phosphorous content of the soil in NF during the 2 summers differed significantly ($u=0.0$; $p\leq0.05$). It negatively correlated with litter potassium ($r=-0.50$, $p\leq0.05$).

In TP, the lower limits of the phosphorous content of the soil in monsoons (0.01/0.02%) increased sharply during postmonsoon or winter (0.08/0.05%). It varied between the 2 years significantly ($t = -2.73$, $df = 22$, $p \leq 0.05$). In TP the phosphorous content of the soil in 2 winters also differed significantly ($u=0.0$, $p\leq0.05$). Soil phosphorous correlated positively with soil carbon ($r=0.5$, $p\leq0.05$) and negatively with soil potassium ($r=-0.41$, $p\leq0.05$).

In CP the soil phosphorous that ranged from 0.02 to 0.04% showed consistently higher levels in postmonsoons (0.037/ 0.04%) and lower levels in summers (0.02%). Soil phosphorous content correlated positively with that of potassium ($r=0.51$, $p\leq0.05$).

In AP, phosphorous content of the soil varied from 0.01 to 0.04 %. It was consistently higher during summer (0.02/0.03%) and lower during postmonsoons or winters (0.01-0.02%). The variations in soil phosphorous content, through the seasons during the year 2001-02 were significant ($\chi^2=9.46$, $df=3$, $p\leq0.05$).

In AP the phosphorous content of the soil differed significantly between the identical seasons of the 2 years except for postmonsoons (Summers: u=0.0, p≤0.05; Monsoons: u=1.0, p≤0.05; and Winters u=0.0, p≤0.05). Soil phosphorous correlated negatively with litterfall (r=-0.56, p≤0.01) and litter phosphorous (r=-0.60, p≤0.01)

Soil potassium

On a biennial basis soil potassium content was least in TP being 0.09%, while that at NF (0.14%) was also lower than those at AP (0.19%) and CP (0.18%). All the differences were statistically significant (F = 47.20, df = 3, p ≤ 0.001).

Seasonality:

In NF, the potassium content of the soil ranged from 0.131% to 0.145%. No perceptible changes were observed during different seasons of the 2 years.

In TP, the potassium content of the soil ranged from 0.05 to 0.13%. It was significantly lower (t = 2.43, df=22, p≤0.05) during 2002-03 than that of the previous year. The potassium content of the soil that was nearly uniform during summers (0.07/0.08%) increased during monsoons (0.09 –0.13%). The levels of the element in the soil at TP during the monsoons of the 2 years varied significantly (u=0.5, p≤0.05). The potassium content of the soil correlated negatively with soil carbon (r = - 0.40, p ≤ 0.05), soil phosphorous (r = - 0.41, p ≤ 0.05) and litter carbon (r= -0.441, p ≤ 0.05).

In CP, the moderate levels of potassium in the soil during summers (0.17%) continued to be the same or dropped marginally during monsoons (0.155%) and rose reasonably (0.19%) or steeply (0.256%) during postmonsoons. The variations through seasons during the year 2001-02 were significant (χ^2=8.33, df=3, p≤0.05). The highest potassium content of the soil in the plantation in winter of 2001-02 was significantly different than that during the succeeding winter (u=0.0, p≤0.05). The content of the potassium in soil correlated positively (r=0.50, p≤0.05) with that of phosphorous in soil and negatively (r=-0.41, $p \leq 0.05$) with that of potassium in the litter.

In AP, the potassium content of the soil varied in a narrow range from 0.17 to 0.21% except for the perceptibly high levels in summer of 2001-02, and hence the variations through seasons during the year were significant (χ^2=8.92, df=3, $p \leq 0.05$). In general, the potassium content of the soil in AP were significantly lower (t = 2.45, df=3, $p \leq 0.01$) during the year 2002-03 than those of the previous year. Soil potassium content correlated negatively with undergrowth diversity (r=-0.5, $p \leq 0.05$) and positively with litter carbon (r=0.43, $p \leq 0.05$).

Soil carbon

On biennial basis, the concentration of soil carbon was highest in AP (3.47%) but in close range with that at NF (3.37%). The soil carbon content in TP was least (1.52%) amongst the sites, and that in CP was significantly lower than that at NF and AP (F=47.90, df=3, $p \leq 0.001$).

Seasonality:

In NF carbon content remained broadly in the range of 3.03 to 3.8% through most of the seasons, except for the inconsistencies in winters (2.51 vs 3.8%) and post monsoons (3.03 v/s 4.15%). The variations through seasons during the year 2002-03 were significant (χ^2=7.83, df =3, $p \leq 0.05$). Soil carbon contents correlated positively with those of soil nitrogen (r=0.5, $p \leq 0.05$).

The carbon content in soil in TP ranged from 0.98 to 2.3% through seasons. It was significantly higher (t = -3.24, df =22, $p \leq 0.01$) during the year 2002-03 than that of the previous year. The soil carbon content in TP during winters of 2 years differed significantly (u=0.0, p=0.05). The carbon content of the soil correlated negatively with that of litter (r = -0.63, $p \leq 0.01$), potassium (r = -0.41, $p \leq 0.05$) and phosphorous (r = -0.41, $p \leq 0.05$) content in the soil.

In CP, carbon content in the soil ranged from 1.51 to 3.3% through the seasons and was significantly higher during the year 2002-03 (t = - 4.03, df =22, $p \leq 0.01$). Here the soil carbon during monsoons and postmonsoons was consistent, but it varied significantly between the summers (u=0.0, $p \leq 0.05$) and winters (u=0.0, $P \leq 0.05$) of the 2 years. The carbon content of the soil in CP correlated negatively with that of litter (r=-0.52, $p \leq 0.01$).

In AP carbon content of the soil varied from 2.93 to 4.25% through the seasons. But for monsoons, the levels of carbon in the soil were inconsistent between the identical seasons of 2 years. The variations between summers (u=0.0, $p \leq 0.05$) and winters (u=0.0, $p \leq 0.05$) of the 2 years were significant. Soil carbon content in the plantation correlated positively (r=6.0, $p \leq 0.01$) with that of soil nitrogen.

Insect Fauna

The checklist of insect families represented in natural forest and monoculture plantations is given in table 4.17. The comparative composition of the insect fauna in study sites and insect abundance on biennial basis are provided in graphs 4.9 and 4.10 respectively. The variations in insect abundance in study sites through seasons are given in table 4.18 and graph 4.11.

Composition of insect fauna

The insects that occurred at all the study sites put together, belonged to 8 orders and 43 families. The total number of families represented in different study sites varied within a narrow range from 35 to 38. The insect families Cicadellidae and Chrysomelidae were prominent by their absence only at NF. Likewise, Cleridae, Stratiomyiidae; Phlocidae, Salticidae, Rophalidae, Apidae and Icheumonidae; and Tetragnathidae, Scarabaeidae; and Tenebrionidae were prominent by their selective absence from TP, CP and AP respectively. But the Haliplids and Scolytids were encountered only in TP while Eucnemids occured only in CP.

Dominance

The Hymenoptera containing 28.5 – 48.6% of the population was the dominant insect order in all the study sites except in AP, where Orthopterans with 46.1% population occupied the first rank pushing the former to the second position. In NF and CP Orthopterans acquired second position with 22 and 24% representation respectively. Only in TP Coleopterans were second to Hymenopterans.

In terms of population of different species, the Orthopteran *Gryllus* sp. dominated all the study sites but for TP wherein it was pushed to 2nd rank by an ant species *Anoplolepsis litoris*.

Abundance

On biennial basis, the insect abundance in NF was minimum with 36.12 ind./mce, while it was higher in TP, CP and AP with 49.37, 38.04 and 45.5 ind/mce respectively.

Seasonality in abundance

In NF the insect abundance during the year 2002-03 was significantly lower ($t = 22$, $df = 22$, $p \leq 0.05$) than that during the previous year. The abundance was consistently higher in monsoons (46 and 36ind/mce) and lower in post monsoons (26 and 23 ind/mce). It was not consistent during summers and winters.

In TP, as in NF the insect population was abundant in monsoons (48.25 & 50.75 ind/mce) and was poorer in postmonsoons (38.5 & 36.5 ind/mce). Once again it was erratic in summers and winters with wide fluctuations. The seasonal variations during the year 2002 – 03 were significant (χ^2=8.83, df =3, $p \leq 0.05$).

In CP the insect abundance was higher in summer or monsoon (49.3 or 54.75 ind/mce), lower in postmonsoons and least in winters(26.6 & 21 ind/mce). The variations through seasons were significant during both the years (χ^2=8.88, & 9.14, df =3, $p \leq 0.05$). The insect abundance in the plantation correlated positively with rainfall($r = 0.56$ $p \leq 0.001$) and negatively with litterfall($r = -0.50$ $p \leq 0.001$).

In AP insect abundance was better in monsoon (102.75 &72.25 ind/mce) and poorer in postmonsoon or winter (13.5 &13.3 ind/mce). The changes through seasons were significant during both the years (χ^2=8.88, & 9.14, df =3, $p \leq 0.05$). In AP also insect abundance correlated positively with rainfall ($r = 0.60$, $p \leq 0.001$) besides undergrowth density ($r = 0.57$, $p \leq 0.001$).

Avifauna

A complete checklist of birds in general, sighted at all the sites during the present study along with their residential status, feeding habits, and sight based ranks of dominance is provided in table 4.19. The numerical position on biennial basis of general composition of bird community is given in the table 4.20.

Community structure

Diversity

On the whole 129 species of birds were sighted that included 7 species of distant migrants and 15 species of local migrants. CP harbored 78 species of birds that were in close range of that housed by NF (80 species). The diversity in TP was marginally higher with 83 species while AP supported reasonably low diversity with only 69 species.

In terms of affiliation, the birds in TP as well as CP belonged to 9 orders and 27 families. Those in NF were more diverse belonging to 12 orders and 30 families. On the other hand the birds in AP had affiliation to only 7 orders and 27 families.

Dominant species

Three insectivorous species, Black Drongo, Greater Racket tailed-Drongo (fig.4.8a) and Chestnut bellied Nuthatch were the dominant species in the NF. The Black Drongo also occupied the first rank in TP, while the omnivore, Jungle Crow, and the nectarivore, Purple Sunbird (fig 4.8 b) followed in rankings in the site. In CP the omnivores – Red-whiskered Bulbul and Jungle Babbler (fig 4.8 c) dominated, while the Purple Sunbird occupied the 3rd rank. In AP, The Greater Racket tailed Drongo, and Red-whiskered Bulbul acquired the first 2 ranks and the phytophage, Black-headed Oriole (fig 4.8 d) occupied the third place.

Exclusives and Endemics

Of the 129 bird species sighted during the study period, only 29 species were common to all the study sites. Considering the 2 year long regular study at monthly intervals, some species of the birds were encountered exclusively in one of the 4 study sites. Most of these were rare sightings in single digits in cumulative total, encountered only during one of the census rounds. But some of them were encountered in 2-9 census visits, reaching a figure of 10 to 53 on the cumulative count.

The Chestnut-bellied Nuthatch, *Sitta castanea*, White-hooded Babbler, *Gampsorhynchus rufulus*, and Marshall's Iora, *Aegithina nigrolutea* were predominant among the 11 species sighted exclusively in NF.

Amongst the another 11 species encountered only in TP, Asian Palm-swift, *Cypsiurus balasiensis*, Dusky Crag-Martin, *Hirundo concolor* and Chestnut-headed Bee-eater, *Merops leschnaulti* were more common.

The species with exclusivity in CP were marginally higher numbering 14, of which Franklin's Prinia, *Prinia hodgsonii*, Jungle Myna, *Acridotheres fuscus* and Ashy Prinia, *Prinia socialis* were noteworthy.

AP was relatively poor in this regard with only 3 species of birds – Emerald Dove, *Chalcophaps indica*; Black-lored Yellow Tit, *Parus xanthogenys* and Streaked spider hunter, *Arachnothera magna*. All these sightings were in singles or twos only in a single encounter each.

During the current study 4 species of birds endemic to the Western Ghats were spotted in the study sites. The nectarivore, Small Sunbird, *Nectarinia minima* was sighted in NF as well as all the plantations. Likewise the Malabar Grey Hornbill, *Ocyceros griseus* was found in all the study sites except in TP. The Grey-headed Bulbul, *Pycnonotus priocephalus* was noticed in AP and CP while Indian Rufous Babbler, *Turdoides subrufus* was sighted only in CP.

New sightings

Thirteen species of birds hitherto unreported for the region of Goa were sighted during the 2 year long intensive study in different sites as given in the Table 4.21.

The Indian Grey Hornbill, easily differentiable from Malabar Grey Hornbill was sighted in NF and all the plantations on 5 occasions from late monsoon to mid summer, cumulatively totaling to 9 individuals. White-hooded Babbler (fig 4.9 a), Pied Tit and Indian Blue Robin were exclusively found in NF. On the whole 25 individuals of White-hooded Babblers were seen in 5 sightings in summer, monsoon and postmonsoon, confined to canopy or sub canopy and never on ground or in undergrowth. Totally 8 individuals of the vulnerable species, Pied Tit were encountered in 3 sightings from first half of monsoon to winter. A lone individual of Indian Blue Robin, unmistakable owing to its prominent blue colour was sighted in subcanopy of the NF in Nov '02.

Two minivet species, Long-tailed- and White-bellied were newly sighted in the region along with other minivets. On 6 occasions, 21 individuals of the former were encountered in NF, TP and CP in monsoon of '01 and '02, while on 4 occasions, 12 individuals of latter were noticed in all the 3 plantations in Nov. & April '01 and Jan. & July '02.

On 4 occasions, a total of 14 individuals of another vulnerable species, Yellow throated Bulbul were sighted in NF, TP and AP in later half of monsoon of '01.

Orphean Warbler, a migrant species was noticed on 5 occasions in TP and AP during Sept. and Oct., '01; Apr. and Sept., '02 and Jan., '03.

A total of 3 individuals of Lineated Barbet were encountered in CP and AP in mixed hunting parties with Racket-tailed Drongo and Tree Pie in 2 sightings during Aug. and Oct. '02.

During one of the census in May '01, five individuals of Large Grey Babbler were sighted on the edge of the CP.

Three individuals each of Lesser Grey Shrike and White-throated Munia were encountered in TP and CP, and only in TP respectively.

A lone Streaked Spider Hunter was sighted in June'01 on the edge of AP.

Abundance

The bird abundance on biennial basis, in terms of encounter rate varied within extremely narrow range of 42.2 – 44.58 ind./ Km in all the 3 plantations, that was in turn close to that of the primary forest, being 44.75 ind. /Km.

Seasonality in abundance and diversity

The variations in abundance and diversity of birds through seasons is given in table 4.22 and graphs 4.12-4.13.

In the NF the bird abundance showed a subtle seasonal pattern during both the years. The reasonable abundance prevailing during summer (39.5 & 69 ind /Km) dipped to lower level during monsoon (30.75 & 44 ind/Km), regained and stabilized during postmonsoon (44.5&46.5 ind/Km) and winter (45.25 & 40 ind/Km). In NF the bird abundance negatively correlated with the rainfall ($r=-0.53$, $p \leq 0.01$)

The bird abundance in TP during both the years was highest during summer (61 & 48.75 ind/Km) and lowest during monsoon and postmonsoon (32 or 32.5 ind/Km). Similarly, in CP the lowest bird abundance prevailing during monsoon (26 & 38.5 ind/Km) reached highest levels in winter (72.66 ind/Km) or summer (58.6 ind/Km). In TP as well as CP bird abundance correlated positively with sunshine ($r = 0.55$, $p \leq 0.05$ & $r = 0.42$, $p \leq 0.05$). In TP the bird abundance correlated negatively with humidity ($r = -0.50$, $p \leq 0.05$).

AP was an isolated instance, wherein seasonality didn't seem to be uniform. The abundance was moderate during summer (39 or 40.6/Km). During the year 2001-02 it rose gradually through monsoon and reached a sharp peak in postmonsoon (72.5/Km). During the year 2002-03 summer density persisted through monsoon and dipped precipitously through post monsoon reaching a lowest level in winter (18/Km).

Broadly the profiles of bird diversities at all the study sites ran parallel to those of abundance.

In NF the bird diversities through the seasons varied within a very narrow range of 23 to 33 species and fairly went hand in hand with the variations in abundance, but for the monsoon of the year 2001. During both the years the bird diversity was relatively high during monsoon (30 and 33 sps.) and moderate during winter (27 and 28 sps.). The diversities showed broader oscillations during the summer (25 and 33 sps.) and postmonsoon (23 and 29 sps.).

The bird diversity through seasons in all the 3 plantations under study varied on relatively a broader scale compared to that at NF. In TP, but for the lowest bird diversity during post monsoon (15 and 20 sps.) it ranged within 27 to 33 species in other seasons. The bird diversities in TP correlated positively with sunshine ($r = 0.61$, $p \leq 0.01$) and negatively with humidity ($r = -0.41$, $p \leq 0.05$).

The bird diversity in CP though varied from 16 to 30 species a season, through most of the study it was in a narrow range (26 –30 sps.), but for the isolated instances of monsoon (22 sps.) and postmonsoon (16 sps.) during the year 2001.

In AP the bird diversity ranged from 16 to 28 sps. a season. However during most of the study period it varied within a narrow limit (23 – 28 sps.), but for isolated instances of summer (16 sps.) of 2001 and winter (12 sps.) of 2003. None of the variations in diversity or density of birds through seasons were statistically significant.

Species indices

The species indices on biennial basis are provided in table 4.20, while their seasonal profiles are provided in table 4.23.

On biennial basis the species diversity index (H'), species richness index (SR) and species evenness index (J) were highest for NF being 2.24, 3.5 and 0.85 respectively. H' for CP and AP were on par being 2.00 and 2.01 respectively, while it was marginally higher for TP being 2.03. J for CP and AP was same being 0.83, while it was least for TP with a value of 0.82. SR for TP being 3.08 was in close range of that of NF, while it was least for CP being 2.83.

Seasonality in species indices

Throughout the study period in all the plantations the H' and SR of birds grossly remained marginally lower than those in NF.

H' in NF was in stable range (2.27 to 2.44) in monsoon and postmonsoon, but showed larger variations during summers (1.8 / 2.36) as well as winters (1.96 / 2.58) of both the years.

The lower limits of H' in TP during monsoons (1.78 / 1.9) and postmonsoons (1.98 / 1.9) gained in winters (2.16 / 2.09) and remained higher in summers (2.2 / 2.29).

In CP lower range of H' in summers (1.79 / 1.97) picked up in monsoon and remained stable through the following seasons within a narrow range (2.1 – 2.18), but for an exceptional dip during the monsoon of 2001.

In AP, H' remained in a very narrow range from 2.02 to 2.32 with slight peaks during monsoon (2.32/2.05) and post monsoon (2.19/2.15).

The species richness (SR) in NF was higher in postmonsoons (3.94/4.27) compared to those of monsoons (3.27 /3.41) and winters (3.48/3.37). Summer didn't show a repetitive trend.

In TP, the higher limits of SR during summer (3.73/3.42) depleted during monsoons and postmonsoons only to regain in winters (3.57/3.3).

In CP, the SR followed almost a similar trend as that in TP, but for an unusual peak during postmonsoon of 2002. Generally, the SR showed better values during summers (2.89/2.70) and winters (2.87/3.31).

But for the mild peaks during postmonsoons of both the years (3.14/3.85) the SR in AP oscillated within narrow limits of 2.21 to 3.29. Only during winter of 2003 there was a precipitous drop (1.86) in SR.

Species evenness (J) in NF was moderately higher and consistent during monsoons (0.9/ 0.85) and postmonsoons (0.87/0.84) while it was inconsistent during remaining seasons of the two years oscillating from 0.73 to 0.99.

In TP the J showed a trend very similar to that at NF with balanced levels during monsoons (0.81/0.84) and postmonsoons (0.83/0.81), fluctuating during remaining seasons of the 2 years with wider margins from 0.79 to 0.87.

In CP also J was consistently higher in monsoons (0.94/0.88), with drift of a wider range during remaining seasons of the 2 years from 0.73 to 0.87.

In AP, the J was relatively stable (0.80-0.84) all through the study period of 2 years but for an exceptional peak during the monsoon (0.94) of 2001.

Clustering: Fig.4.1

Species diversity, species evenness and species richness were high in NF compared to those at all three plantations. Among plantations, species diversity and species richness were high in TP, while species evenness was almost on par in the three plantations.

The species similarity indices led to close clustering of TP and AP with coefficient of 0.66. While CP and NF clustered at the level of 0.62 and 0.615 respectively.

Guild compositions

The composition of avifauna on biennial basis in terms of residential status, passer-non passer grouping and the principal dietary guilds in the study sites is provided in table 4.24.

Residents and Migrants

Comparative picture of their initial sightings and duration of stay in the study area on biennial basis, principally on presence or absence criteria are given in fig 4.2. The relative picture of abundance and diversities of residents and migrants on cumulative basis and their variations through seasons are provided in graphs 4.14 and table 4.25 respectively.

During the study period, 22 migrant species were sighted that included 7 distant migrants, mostly warblers such as Blyth's Reed-warbler, Eurasian Great Reed-warbler, Booted Warbler, Orphean Warbler, Greater Whitethroat, Forest Wagtail, and Black-headed Rock-Thrush. A local migrant, Greenish Leaf Warbler occupied 1st rank in NF as well as AP and CP, but had a 2nd place in TP. Another local migrant, Eurasian Golden Oriole occupied the 1st rank amongst the migrants in TP. The distant migrants such as Blyth's Reed-warbler, Booted Warbler, Greater White throat and the local migrants such as Ashy Drongo, Asian Paradise-flycatcher were the other prominent migrant species that figured within 3rd place in different study sites.

None of the migratory species were exclusive to NF, AP and CP. However, Rosy Minivet, Brown breasted Flycatcher Ultramarine Flycatcher, Verditer Flycatcher, Black Red start, Blue throated Flycatcher and Black-headed Rock-Thrush were the seven migrant species encountered exclusively in TP.

The abundance of resident population constituted major portion of the avifauna at all the study sites ranging from 85% in NF to 90.9% in CP and hence differed significantly from that of migrants (NF: $t = 8.21$, TP: $t = 9.18$, CP: $t = 8.52$, AP: $t = 8.19$, $p \leq 0.001$). The diversity of resident population too totally surpassed that of migrants in all the study sites forming 80.5% of total population at TP to 83% in AP with a statistically significant difference (NF: $t = 11.9$, TP: $t = 10.6$, CP: $t = 9.31$, AP: $t = 12.42$, $p \leq 0.001$). The residents in terms of diversity at all the sites (NF: $r = 0.91$, TP: $r = 0.89$, CP: $r = 0.90$, AP: $r = 0.89$, $P \leq 0.01$) and density at all the sites except at CP correlated significantly with respective attributes of total bird fauna (NF: $r = 0.89$, TP: $r = 0.94$, CP: $r = 0.108$, AP: $r = 0.92$, $p \leq 0.01$). The abundance of resident birds in CP was significantly higher compared to that at all other sites ($F = 56.26$, $df = 3$, $p \leq 0.001$).

Only in NF, migrants constituting 15% of the total bird fauna, correlated with the latter significantly in diversity ($r = 0.64$, $p \leq 0.01$) as well as abundance ($r = 0.53$, $p \leq 0.05$).

Seasonality in residents and migrants

The 22 species of migrant birds differed substantially in their appearance and disappearance schedule in the study area. The species like Greenish Leaf-Warbler and Brown-breasted Flycatcher appeared in the area as early as second half of monsoon (August) and left the area by mid or late summer (April/May). The others like Orphean Warbler, Asian Paradise-Flycatcher and Ashy Drongo appeared on the scene either by late monsoon or early post monsoon (September/October) and stayed in the area little farther till late summer or early monsoon (April/June). These migrants which stayed longer in the area were also relatively in greater density accounting to 16 to 127 on biennial cumulative total. Some species such as Lesser White Throat, Long-tailed Minivet, Eurasian Golden Oriole and Rufous-backed Shrike appeared on the scene by second half of monsoon (August/September), lingered around till late summer (May) with an intervening period of absence for 2-4 months and had a biennial cumulative strength of 16 – 44. Blyth's Reed-Warbler, though found only during 3 months of winter totalled 58 on biennial count. Seven of the migrant species were encountered hardly for a month during post monsoon or winter numbering in single digits of 1 –5. No migrant species was sighted during peak monsoon (July), and only 4 of them were encountered during initiation phase of the season (June).

In NF, the abundance of residents during the years broadly remained in the range of 29.25/Km to 38.5/Km through most of the seasons, but for slightly higher levels of 56 and 45.25/Km respectively during summer and monsoon of the year 2002. The diversity of the residents was in identical ranges during the 2 monsoons (31/29 sps.) and winters (25/23 sps.) and showed wider oscillations during the remaining seasons of the 2 years.

In TP, abundance of residents, from relatively higher levels during summers (55 & 45.66 ind/Km) dropped precipitously during monsoons (40 &

30 ind/Km) and post monsoons (26.7 and 31.5 ind/Km). The diversity of the guild during postmonsoon was lowest (14 sps.) compared to higher ranges (18 – 29 sps.) during the rest of the seasons.

In CP, the abundance of residents from reasonably higher levels during summer (53.66 or 54 ind/Km) dropped to substantially lower limits during monsoons (24.5 or 37.25 ind/ Km) and postmonsoons (22 or 44.5 ind/Km). The diversity of the guild in the plantation remained relatively stable (23 –28sps.) except for lower levels during monsoon and post monsoon (19 and 11 sps.) of the year 2001.

In AP, the abundance of residents broadly remained within a narrow range of 30 –40 ind/Km except for a high (65.5 ind/Km) during postmonsoon 2001 and low (17.33 ind/Km) during winter 2003. The diversity of the guild also was relatively stable (21-25sps.) except for summer 2001 (14sps.) and winter (12 sps.) 2003.

In NF, the abundance of migrants from higher levels during summers 4.3 and 13 ind/Km) dropped during monsoons (1.5 and 1.25 ind/Km) to regain gradually through succeeding seasons. The diversity represented by hardly 1-2 species during monsoon rose to 3-4 species during postmonsoon and winter.

In TP, the abundance of migrants, from lower limits of summers (6 & 3 ind/Km) and monsoons (5 &2.25 ind/Km) rose gradually or sharply in winters (9.33 and 6 ind/Km) through post monsoon.

In CP, the abundance of migrants, compared to the lower ranges of summer , winter and monsoon (1.2 –5.03 ind/Km), showed sharp peaks during postmonsoons (9.5 and 11 ind/Km). Their diversities also were relatively higher during postmonsoon and summer (4-5 sps.) compared to those of other seasons (2-3 sps.).

In AP, the abundance of migrants oscillated between two extremes in monsoons (2.2 –10 ind/Km) and winters (0.6-12.6 ind/Km). The diversities of the guild ranged from single to seven species through the seasons, it being true for identical seasons, the winters.

Passerines and nonpasserines

The composition of total bird fauna in terms of passerines and nonpasserines in different sites is given in table 4.24 and graph 4.15. The variations through seasons in their densities and diversities are provided in graphs 4.16.

In all the study sites the passerines were significantly higher than non-passerines in terms of abundance (NF: $t = -10$, TP: $t = -8.72$, CP: $t = -12.04$, AP: $t = -9.83$, $p \leq 0.001$) as well as the diversity (NF: $t = -10.02$, TP: $t = -885$, CP: $t = -13.94$, AP: $t = - 10.23$, $p \leq 0.001$). Hence the total avifauna correlated significantly with passerines in terms of density (NF: $r = 0.75$, TP: $r = 0.97$, CP: $r = 0.89$, AP: $r = 0.97$, $P \leq 0.01$) as well as diversity (NF: $r = 0.59$, TP: $r = 0.92$, CP: $r = 0.97$, AP: $r = 0.95$, $P \leq 0.01$). The nonpasserines in AP correlated significantly with those of total avifauna in the site in both abundance ($r = 0.5$, $P \leq 0.05$) and diversity ($r = 0.69$, $P \leq 0.01$). The abundance and diversities of nonpasserines correlated significantly with the respective parameters of total avifauna in TP ($r = 0.5$, $P \leq 0.05$) and CP($r = 0.55$, $P \leq 0.05$) respectively.

The passerines in terms of abundance formed 86.9% of the bird fauna in NF, but was higher in plantations ranging from 89 to 91.6%. In terms of diversity, passerines constituted only 67% of the bird fauna in NF, but the guild was with higher representation in plantations ranging from 74.7- 77.5%. The proportion of nonpasserines naturally was in reverse order, being higher in NF in abundance (13.1%) as well as in diversity (33%) compared to those of plantations.

Seasonality in passers and nonpassers

The passerines at all the sites showed seasonality very similar to those shown by the total avifauna.

In NF the abundance of nonpassers through seasons varied within a narrow limit from 3.66 to 5.5 ind /Km except in summer of 2001 wherein it was 15 ind/Km. The diversity of the guild was in a narrow range of 4-5 sps. a season, but for marginally higher levels of 7 and 9 sps. a season in summer and monsoon of 2001, respectively.

In TP, the abundance of nonpassers was consistently higher in summers (7.25 and 8.75 inds./Km) and lower in post monsoons (0.5 and 3.5inds/Km). The diversities of nonpassers in the plantation were also consistently higher in summers(6 & 8 sps./season) and lower in postmonsoons (1 and 2 sps./season).

In CP, the nonpasserine abundance was consistently higher in winters (3 and 15 ind/Km) and lower in postmonsoons (0-2 ind/Km). Diversities of the group at the site were better during winters and summers (4-7 sps. a season).

In AP, the nonpasserines in terms of abundance were marginally better in monsoons and post monsoons (2.5 –10.5 ind/Km) and poorer in winters (0.33 ind/Km). The diversities of the group in the plantation were also higher during monsoons and postmonsoons (4-7 sps./season).

Feeding guilds

The composition of bird fauna in terms of feeding guilds at the study sites on biennial basis is provided in table 4.24 and graph 4.17.

Of the 4 main feeding guilds, insectivores and phytophages dominated all the study sites in abundance as well as diversities. Both of them together constituted 79.4-96.7% and 80-91.5% of the total bird fauna in abundance and diversity respectively and hence correlated significantly with it (Table 4.29). The insectivore abundance constituted 59.9% of the birds in NF, while it was lower in all the plantations, the difference being significant in CP (F =7.29, df=3, p≤0.001). The diversity of the guild in NF was 53.6%. It was higher in TP, marginally higher in AP, but significantly lower in CP (F =4.33, df =3, p≤0.01).

The other 2 guilds, omnivores and carnivores together got limited to 20% share of the avifauna in all the study sites. The omnivores in NF were represented by 10 species with mean abundance of 8.5 ind/ Km. The guild at all the study sites was lower than that at CP, the difference being statistically significant in terms of abundance (F =6.47, df =3, P≤0.001) as well as diversity (F =5.61, df =3, P≤0.001).

Intrasite variations and seasonality in feeding guilds

The variations in abundance and diversity of feeding guilds in different study sites are provided in Graphs 4.18. The statistically significant correlations between the guild abundance and diversity of the feeding guilds and the bird community as a whole at the four study sites is provided in table 4.26

Natural Forest:

The insectivores, constituting 59.9% of the bird population was the dominant guild that followed the seasonal pattern similar to that followed by the latter. The guild dominated in all the seasons in abundance as well as diversity, summer and monsoon of 2001 being exceptions for abundance and diversity respectively, wherein phytophages dominated. Insectivorous abundance varied significantly between 2 years ($t=-2.10$, $df=22$, $F<0.05$).

Phytophages were the second dominant guild with 36.8% share that showed consistently higher abundance during summers (21.2 and 20.7 ind/Km). The omnivores and carnivores formed a small portion of the bird fauna without any discreet seasonality, but overall diversity of the later (9sps.) was highest in NF compared to that at all other sites.

Teak plantation:

As in NF, the insectivores with 53 species formed the most dominant guild in TP holding a share of 46% and 61% in abundance and diversity respectively. From seasonal angle the densities of the guild were consistently higher during summers (24.7 & 21.2 ind/Km) while diversities remained higher during summer as well as monsoons (14-17 sps.). Phytophages were the next dominant group, often surpassing the insectivores in abundance. Their density was consistently higher in summer and monsoons (14.2 –27.2 ind/Km) so also the diversity (11- 15 sps.). The diversity of the guild was poor during postmonsoons (4 & 7 sps.). Omnivores were represented by 1-2 species, their abundance ranging from 0.5 to 9.7 ind/Km. Carnivores were the most inconsistent guild represented hardly by 1 or 2 species.

Cashew plantation:

Phytophages in CP compared to those in NF and other plantations, were with maximum abundance (21ind./Km, 47%) and diversity (28sps.,35%). Similarly, the omnivores in CP also outnumbered the group in other study sites in abundance (8.5 ind/Km, 19%) and diversity (10 sps.,12.5%). In CP, unlike in NF and TP, phytophages surpassed insectivores in terms of density through most of the seasons. The insectivore abundance was consistently higher in summers (10 &16ind/Km) and lower in monsoons (4.7 & 8 ind/Km). The phytophage population was consistently higher in summers (26 & 30 ind/Km; 11-12sps.) and lower in postmonsoons (14 &16 ind/Km, 6 & 9 sps.). The omnivores in CP, unlike in other study sites, formed a larger contingent with consistently higher representation almost all through the year (3.2-13.7 ind/Km, 2-5 sps.).

Acacia plantation:

On overall consideration, the phytophages were highest in abundance (19.7 ind/Km, 45.2%) and diversity (26 sps., 36.6%) in AP compared to those at NF as well as other plantations. In AP phytophages surpassed insectivores in their abundance, but the latter maintained its supremacy in terms of diversity (39sps.,54.9%). Insectivore abundance were significantly lower in AP during 2002-03 compared to those of previous year ($F=11.19$, $df=1$, $p\leq 0.001$). The carnivores in AP were with the lowest representation (0.37 ind/Km, 0.8% & 3 sps., 4.2%) compared to the guild in all other study sites.

Through most of the study period phytophages marginally outnumbered insectivores in their abundance, except during monsoon and postmonsoon of 2001. The omnivores represented by 1-3 species were consistently higher in summers (10.6 & 8.2 ind/Km) and postmonsoons (3.5 & 14.5 ind/Km) and lower in monsoons (3.7 & 1.7/Km) and winters (1.2 & 2 ind/Km).

Variations in avifauna at the edge and the centre of plantations: Graph 4.19 & Fig 4.3.

Of the 83 species of birds encountered in TP, little more than half (45 sps.) were common to the periphery as well as the central region, while 26 species were sighted only in the central region and 16 were exclusively found in the periphery of the plantations. Bird abundance as well as diversity was higher in the central region (32ind/Km and 67 sps.) of the plantation compared to those at the edge (20.5 ind/Km and 59 sps.), in all the seasons except monsoon of the year 2002.

In CP, of the 78 species of birds encountered during the 2 years of study, little less than half (38 sps.) were common to the core and the border areas of the plantation. Almost identical numbers of species (37) were exclusively sighted on the edges. Only 5 species exclusive to central region were Lineated Barbet, Lesser Grey Shrike, Black-headed Munia, Jungle Myna and Indian Great reed-warbler. In CP, unlike in TP the bird population on the edges (29.75 ind/Km; 73 sps.) significantly surpassed ($t = 2.89$, $df = 44$, $p \leq 0.01$ & $t = 4.49$, $df = 44$, $p \leq 0.001$) that at the centre (18 ind/ Km, 43 sps.).

Of the total 69 species encountered in AP, more than half (40 sps.) were common to core as well as peripheral regions of the plantation and 26 species were exclusive to the edge. Emerald Dove, Heart-spotted Woodpecker, Large Cuckoo-Shrike, Spotted Babbler and Plain Prinia were the only 5 species exclusively sighted in the central region. In AP as in CP the bird population in the edge (27.5 ind/Km; 65 sps.) significantly exceeded that in the centre (17.41ind/ Km; 45 sps.) ($t = 2.72$, $df = 46$, $p \leq 0.01$ & $t = 3.59$, $df = 46$, $p \leq 0.001$). The post monsoon of the year 2001 was an exception.

Breeding birds

The list of bird species that showed direct or indirect signs of the breeding activity during the study period in different study sites are given in Table 4.27.

During the 2 years of study extending from March 2001 to February 2003, either breeding per se or indirect signs of breeding of 15 species of birds in the study sites were registered. Six species were found breeding in NF and 5 species each were sighted breeding in all the 3 plantations under study.

Red whiskered bulbul (fig 4.9 c) was found breeding in all the plantations, but not in NF. The Small Sunbird, *Nectarinia minima* an endemic species was observed to breed in TP. The site based details are as under.

Natural forest

Six species of birds listed below were found to breed in NF, 4 of which were exclusive to the site.

1. Lesser Spotted Eagle

Two platform nests of Lesser Spotted Eagle were found on *Terminalia paniculata* in March 2002. One of them was active. The birds were found incubating the eggs. Both the sexes were found sharing the parental duties such as incubation and guarding the nest.

The nest, a massive platform made up of sticks and lined by leaves. Nest was placed on the topmost branch of a tree. The height of the host tree was 40 m and the nest was located 35 m above the ground. The dbh of the tree was 30.2 cm. Other trees in the close vicinity of the host tree were of the same species besides those of *Terminalia tomentosa* and *Xylia xylocarpa.* They were of similar height.

2. Lesser golden backed Woodpecker

An active cavity nest of Lesser Golden-backed Woodpecker was sighted in September 2002 in NF on a dry, dead trunk of *Terminalia* *tomentosa*. A fledgling lurking out of the nest and parent bird in feeding action were noticed.

Only one out of total 4 cavities on the same tree was used for nesting. The nest was at a height of 12m from the ground. The entrance to the nest was oval shaped measuring about 17cm in length and 8cm in width.

3. Yellow-browed Bulbul

A nest of Yellow-browed Bulbul was found in NF in May 2002 on a *Terminalia paniculata* sapling by the side of a ephemeral stream. The bird was sighted ferrying fibre for building the nest.

The nest was a hanging cup made up of soft fibers. It was placed in a fork of twigs. The host tree was about 3m tall and the nest was located at a height of 2m from the ground.

4. Orange-headed Thrush

Three deserted nests of Orange headed Thrush were observed in NF. Two nests were on *Xylia xylocarpa* trees while 1 was on a sapling of *Makaranga paltata* (fig 4.10 a).

Nests were located in the fork of twigs at an average height of 4.7m, even if the host trees were taller. The nests were thick pads with base made up of bamboo and teak leaves and upper part with mid ribs of leaves and rootlets. Mud was used for plastering the nest

5. White-rumped Munia

In October 2002 a nest of White-rumped Munia, was found in NF. The nest was globular shaped with a lateral hole located at 10m ht. It was fabricated using leaves of bamboo, *Calycopteris floribunda* and the grass, *Themeda triandra*. Outer part of nest was formed of shoots of grass while inner region was lined by fruiting ears and fern fibers. The fibers used for the outer wall were coarser than those used for the inner wall. The nest contained fresh droppings.

6. Black-napped Monarch-Flycatcher

In July 2002, 2 fledglings of Black-naped Monarch-Flycatcher were observed in NF. The nest was not found.

Teak plantation

1. Jungle crow

In TP a pair of Jungle Crows was found breeding. Initial activity of ferrying the nesting material and nest building commenced in March 2002. A nest with a platform and a cup-shaped depression was built on a teak tree at a height of 11m. In April the bird was sighted incubating. By 1st May, parents were sighted feeding the young one. Both the parents were found attending the nest.

2. Great Racket-tailed Drongo

During April 2001 a single breeding pair was encountered in TP. Teak tree with approximate height of 20m and dbh 19 cm was used as a host plant. A hanging cup / hammock shaped nest (fig 4.10 b) was positioned between the twigs, 25m above ground level. Parent bird was found guarding the nest.

3. Orange-headed Thrush

Four nests of Orange-headed Thrush were sighted in September 2002 in TP. A nest each was on 3 different teak trees in an area of around 25 m^2. Another nest was found on a *Terminalia paniculata* tree within the plantation. The host trees were with mean height of 15.2 m and dbh of 18.7cm. The nests were located at a height of 3-5 m from the ground.

4. Red whiskered Bulbul

Two nests of Red whiskered Bulbul were sighted on teak trees in TP, one each in April 2001 and March 2002. Nests (fig 4.10) were cup shaped made up of fine twigs and grass and were located at a height of about 20m.

5. Small Sunbird

In June a deserted purse shaped nest made up of soft fiber was found on the ground in TP, probably dislodged from the neighbouring host tree.

Cashew plantation

1. Jungle Babbler

In March 2002, a nest of Jungle Babbler (fig 4.10 c) was sighted on a sapling of *Careya arborea,* on the edge of CP. Three hatchlings were found in the nest. On slightest disturbance the hatchlings were raising their heads and opening their mouth probably in anticipation of food. Both the parents were seen feeding the young ones.

Nest was cup shaped with16 cm diameter. It was made up of herb *Rangia ripens,* growing below the tree. It was located at a height of 6.2 ft on a 7.5 ft tall sapling.

2. Red-whiskered Bulbul

Totally 7 deserted nests of Red-whiskered Bulbul were sighted in CP. Four of them were found in March 2001 and 3 in March 2002 located at a height of 2-3 m, one each on different cashew trees. The host trees were located approximately 20m apart from one another.

3. Red vented Bulbul

In March 2002 a nest of Red vented Bulbul was sighted in CP. Nest was cup shaped placed in a fork of twigs on a cashew tree at a height of 6m.

4. Oriental Magpie Robin

In CP, on 30th June 2002, 3 fledglings of Oriental Magpie-Robin were sighted on a cashew tree along with both the parents. The nest of the bird was not sighted.

5. Red Spur fowl

Four young ones of Red Spur fowl were sighted, following their mother in month of April in CP.

Acacia plantation

1. Great Racket-tailed Drongo

A nest of Great Racket-tailed Drongo was found in AP in May 2001. Parent bird was found feeding the young ones. The hanging cup shaped nest was located at 10m height on *Terminalia paniculata* tree on the edge of plantation.

2. Bronzed Drongo

In May 2002, a hanging nest of Bronze Drongo was sighted in AP. The nest was on a tree of *Ervatamia* sp. by the edge of plantation. One of the parents was always found guarding the nest, not allowing any other bird to enter his territory.

3. Red-whiskered Bulbul

In AP a single deserted nest of Red whiskered Bulbul was found in March 2002.

4. Black- naped Monarch-Flycatcher

In AP, in September 2001, 3 fledglings of Black-naped Monarch-Flycatcher were seen. Parent bird was sighted bringing food and feeding the fledglings demanding the food.

5. Ashy Drongo

Two fledglings of Ashy Drongo along with their parents were found in AP in May 2001. However the nest was not sighted.

Table 4.1: The biennial profiles of undergrowth and litterfall in natural forest and monoculture plantations.

	Natural forest	Plantations		
		Teak	Cashew	Acacia
Diversity species/m²	12±0.36	7±0.38	4±0.89	6±0.14
Density plants/m²	34±2.93	31±2.11	50±10.22	33±2.39
Litter g/ m²	31 ± 5.56	28 ± 4.49	23 ± 3.46	44 ± 5.24

Table 4.2: Seasonal variations in undergrowth density (stems/m^2) in natural forest and monoculture plantations.

Years/Seasons	Natural forest	Plantations		
		Teak	Cashew	Acacia
2001-02				
Summer	17±1.00	20±0.32	31±1.32	22±0.32
Monsoon	47±1.19	42±0.95	60±0.64	42±0.45
Post monsoon	41±5.01	32±2.00	49±4.51	39±4.51
Winter	22±0.32	22±0.32	39±0.87	23±0.32
2002-03				
Summer	19±0.87	19±0.33	38±1.45	21±0.66
Monsoon	50±1.41	44±3.27	66±2.09	47±3.14
Post monsoon	50±1.00	38±1.00	49±3.17	46±6.01
Winter	26±4.70	29±2.02	49±17.0	25±2.18

Table 4.3: The seasonal variations in undergrowth diversity (species/m^2) in natural forest and monoculture plantations.

Years/Seasons	Natural forest	Plantations		
		Teak	Cashew	Acacia
2001-02				
Summer	8.6±0.57	4.0±0.57	3.3±0.57	5.0±0.57
Monsoon	12.0±1.40	8.0±0.47	5.0±0.47	6.0±0.25
Post monsoon	12.0±0.49	7.5±0.70	5.0±0.49	5.5±0.7
Winter	9.6±0.57	5.0±0.32	4.0±0.32	3.3±0.57
2002-03				
Summer	10.6±0.57	4.0±0.32	3.0±0.32	6.0±0.32
Monsoon	13.0±0.50	8.0±0.62	5.0±0.25	7.0±0.25
Post monsoon	13.0±1.41	8.0±0.49	4.3±0.57	6.0±0.49
Winter	10.6±1.15	7.0±0.70	3.3±0.57	5.6±0.57

Table 4.4: Seasonal variations in litterfall (g/m^2) in natural forest and monoculture plantations

Years/Seasons	Natural Forest	Plantations		
		Teak	Cashew	Acacia
2001-2002				
Summer	63±9.65	13±6.44	21±0.02	46±0.05
Monsoon	24±6.92	14±2.48	13±3.59	41±10.75
Post monsoon	12±0.49	32±13.03	16±2.00	58±6.51
Winter	24±7.45	61±18.50	42±13.39	43±8.65
2002-2003				
Summer	78±17.1	13±4.26	16±2.08	37±1.76
Monsoon	14± 4.23	14±2.89	10±2.60	18±1.41
Post monsoon	9±1.00	31±8.52	23±8.52	82±56.16
Winter	15±1.76	54±4.35	50±9.72	59±0.86

Table 4.5: Seasonal profile of % mass lost from litterbags in natural forest and monoculture plantations with reference to the mass of the litter in the beginning of respective season.

		Plantations		
Years/Seasons	Natural forest	Teak	Cashew	Acacia
2001-2002				
Summer	20	20	4	8
Monsoon	50	65	33	43
Post monsoon	30	28	37	15
Winter	50	60	50	60
2002-03				
Summer	18	22	20	16
Monsoon	53	69	45	52
Post monsoon	26	21	36	15
Winter	42	63	46	27

Table 4.6: Biennial profile of the litter nutrients (%) in monoculture plantations and natural forest.

Nutrients	Natural forest	Plantations		
		Teak	Cashew	Acacia
Nitrogen	1.28±0.060	1.06±0.060	0.86± 0.070	1.84±0.140
Phosphorus	0.041±0.003	0.055±0.003	0.048±0.002	0.04±0.003
Potassium	0.05±0.005	0.05±0.006	0.05±0.006	0.07±0.010
Carbon	4.48±0.140	3.40±0.130	3.38±0.270	4.00±0.280

Table 4.7: The changes (%loss/gain) in the nutrient concentration of the litter at annual intervals on the floor of natural forest and plantations.

Nutrients	Natural forest			Plantations								
				Teak			Cashew			Acacia		
	Before	After	% Change	Before	After	% Change	Before	After	% Change	Before	After	% Change
Nitrogen	1.48	1.79	21↑	1.02	1.24	21.5↑	0.65	1.00	53↑	1.08	1.86	72↑
Phosphorus	0.025	0.037	42↑	0.057	0.031	55↓	0.039	0.056	44↑	0.027	0.030	54↑
Potassium	0.102	0.021	79↓	0.11	0.021	81↓	0.12	0.029	76↓	0.21	0.032	75↓
Carbon	5.49	3.64	31↓	4.26	2.60	33↓	4.55	2.69	40↓	5.04	3.64	40↓

Table 4.8: Seasonal variations in the nitrogen (%) in the litter of natural forest and monoculture plantations.

Years/ Seasons	Natural forest	Plantations		
		Teak	Cashew	Acacia
2001-2002				
Summer	1.34±0.24	0.08±0.04	0.63±0.06	1.15±0.06
Monsoon	1.46±0.27	1.32±0.27	1.33±0.28	2.48±0.45
Post monsoon	1.14±0.00	0.76±0.01	0.99±0.07	1.83±0.06
Winter	1.44±0.12	1.05±0.12	0.95±0.03	2.24±0.41
2002-2003				
Summer	0.92±0.13	1.09±0.19	0.50±0.01	1.12±0.00
Monsoon	1.33+0.07	0.91±0.07	0.78±0.13	1.59±0.20
Post monsoon	1.28±0.19	1.16±0.09	0.87±0.05	2.12±0.27
Winter	1.19±0.02	1.02±0.09	0.78±0.05	2.20±0.39

Table 4.9: Seasonal variations in the phosphorus (%) in the litter of natural forest and monoculture plantations.

Years/Seasons	Natural forest	Plantations		
		Teak	Cashew	Acacia
2001-02				
Summer	0.03±0.001	0.05±0.001	0.04±0.001	0.03±0.001
Monsoon	0.05±0.007	0.03±0.150	0.05±0.005	0.05±0.005
Post monsoon	0.07+0.007	0.05±0.007	0.06±0.007	0.06±0.010
Winter	0.03±0.004	0.03±0.005	0.04±0.002	0.03±0.004
2002-03				
Summer	0.01±0.002	0.06±0.002	0.04±0.005	0.01±0.050
Monsoon	0.02±0.005	0.05±0.004	0.04±0.002	0.02±0.005
Post monsoon	0.05±0.019	0.03+0.000	0.04±0.007	0.05±0.010
Winter	0.04±0.005	0.05±0.005	0.03±0.004	0.04±0.005

Table 4.10: Seasonal variations in the potassium (%) in the litter of natural forest and monoculture plantations.

Years/Seasons	Natural Forest	Plantations		
		Teak	Cashew	Acacia
2001-2002				
Summer	0.10±0.010	0.06±0.005	0.07±0.005	0.15±0.040
Monsoon	0.03±0.002	0.04±0.003	0.05±0.002	0.05±0.003
Post monsoon	0.02±0.001	0.03±0.000	0.03±0.003	0.04±0.001
Winter	0.02±0.001	0.02±0.004	0.02±0.001	0.03±0.005
2002-03				
Summer	0.07±0.002	0.12±0.005	0.11±0.010	0.18±0.010
Monsoon	0.06±0.001	0.04±0.001	0.05±0.000	0.05±0.005
Post monsoon	0.04±0.004	0.04±0.001	0.04±0.000	0.03±0.000
Winter	0.02±0.003	0.03±0.005	0.03±0.002	0.02±0.003

Table 4.11: Seasonal variations in the carbon (%) in the litter of natural forest and monoculture plantations

Years/Seasons	Natural Forest	Plantations		
		Teak	Cashew	Acacia
2001-02				
Summer	4.74±0.23	4.40 ± 0.20	5.02±0.05	5.53±0.08
Monsoon	4.31±0.08	3.74±0.40	4.75±0.09	5.24±0.08
Post monsoon	4.09±0.15	3.61±0.01	4.39±0.05	5.15±0.03
Winter	4.19±0.14	3.47±0.08	2.50±0.08	5.05±0.03
2002-03				
Summer	5.52±0.17	3.69±0.05	3.75±0.11	3.95±0.26
Monsoon	5.18±0.14	3.20±0.10	2.84±0.33	2.78±0.23
Post monsoon	4.09±0.09	2.69±0.02	1.99±0.00	2.17±0.07
Winter	3.49±0.09	2.21±0.16	1.42±0.11	1.90±0.00

Table 4.12:Biennial profile of the soil nutrients (%) in natural forest and monoculture plantations.

% Soil Nutrient	Natural Forest	Plantations		
		Teak	Cashew	Acacia
Nitrogen	0.22±0.010	0.10±0.040	0.15±0.004	0.25±0.006
Phosphorous	0.03±0.002	0.02±0.002	0.03±0.002	0.02±0.002
Potassium	0.14±0.004	0.09±0.006	0.18±0.008	0.19±0.006
Carbon	3.37±0.120	1.52±0.130	2.10±0.150	3.47±0.140

Table 4.13: Seasonal variations in nitrogen content of the soil (%) in natural forest and monoculture plantations

Years /Seasons	Natural forest	Plantations		
		Teak	Cashew	Acacia
2001-2002				
Summer	0.30±0.005	0.10±0.005	0.14±0.010	0.30±0.030
Monsoon	0.25±0.017	0.11±0.007	0.14±0.010	0.25±0.010
Post monsoon	0.27±0.004	0.11±0.010	0.16±0.007	0.22±0.014
Winter	0.16±0.006	0.11±0.010	0.13±0.002	0.24±0.010
2002-2003				
Summer	0.21±0.020	0.08±0.010	0.19±0.014	0.26±0.010
Monsoon	0.17±0.010	0.14±0.020	0.15±0.004	0.24±0.010
Post monsoon	0.20±0.010	0.08±0.020	0.14±0.004	0.25±0.007
Winter	0.22±0.010	0.09±0.005	0.16±0.023	0.24±0.010

Table 4.14: Seasonal variations in phosphorus content of the soil (%) in natural forest and monoculture plantations.

Years/ Seasons	Natural Forest	Plantations		
		Teak	Cashew	Acacia
2001-2002				
Summer	0.02±0.001	0.02±0.000	0.02±0.002	0.02±0.010
Monsoon	0.03±0.004	0.01±0.003	0.03±0.003	0.01±0.002
Post monsoon	0.05±0.006	0.08±0.001	0.03±0.006	0.01±0.001
Winter	0.04±0.004	0.01±0.003	0.03±0.004	0.01±0.001
2002-03				
Summer	0.04±0.001	0.02±0.005	0.02±0.010	0.03±0.002
Monsoon	0.02±0.006	0.02±0.004	0.02±0.005	0.05±0.010
Post monsoon	0.03±0.004	0.03±0.020	0.04±0.007	0.02±0.009
Winter	0.02±0.002	0.05±0.010	0.02±0.005	0.02±0.002

Table 4.15: Seasonal variations in potassium content of the soil (%) in natural forest and monoculture plantations.

Years/Seasons	Natural forest	Plantations		
		Teak	Cashew	Acacia
<u>2001-2002</u>				
Summer	0.14±0.005	0.07±0.010	0.17±0.010	0.26±0.010
Monsoon	0.14±0.140	0.13±0.005	0.15±0.010	0.21±0.005
Post monsoon	0.14±0.020	0.13±0.009	0.25±0.007	0.19±0.007
Winter	0.13±0.002	0.10±0.030	0.27±0.010	0.17±0.005
<u>2002-03</u>				
Summer	0.13±0.020	0.08±0.003	0.17±0.023	0.17±0.020
Monsoon	0.14±0.010	0.09±0.011	0.17±0.005	0.18±0.015
Post monsoon	0.13±0.007	0.06±0.010	0.19±0.014	0.18±0.010
Winter	0.13±0.002	0.05±0.010	0.15±0.014	0.17±0.005

Table 4.16: Seasonal variations in the carbon content of the soil (%) in natural forest and monoculture plantations.

Years/ Seasons	Natural Forest	Plantations		
		Teak	Cashew	Acacia
2001-2002				
Summer	3.69±0.16	1.25±0.31	1.51±0.14	4.25±0.34
Monsoon	3.51±0.35	1.19±0.15	1.76±0.16	3.44±0.35
Post monsoon	3.03±0.18	0.98±0.19	1.69±0.11	3.06±0.14
Winter	2.51±0.08	1.12±0.03	1.65±0.07	2.93±0.13
2002-03				
Summer	3.35±0.49	1.07±0.18	2.38±0.09	2.67±0.23
Monsoon	3.10±0.01	2.04±0.40	1.90±0.16	3.53±0.24
Post monsoon	4.15±0.14	2.30±0.19	3.30±1.69	4.10±0.27
Winter	3.80±0.37	2.20±0.14	3.06±0.40	3.89±0.43

Table 4.17: Representation of insect orders/ families in the natural forest and monoculture plantations

Order/Family	Natural	Teak	Cashew	Acacia
Araneae				
Amaurobiidae	*	*	*	*
Dysderidae	*	*	*	*
Lycosidae	*	*	*	*
Oxyopidae	*	*	*	*
Pholcidae	*	*		*
Salticidae	*	*		*
Tetragnathidae	*	*	*	
Thomisidae	*	*	*	*
Opiliones				
Phalangidae	*	*	*	*
Orthoptera				
Gryllidae	*	*	*	*
Blatellidae	*	*	*	*
Hemiptera				
Rhopalidae	*	*		*
Homoptera				
Cicadellidae		*	*	*

Membracidae	*	*	*	*
Coleoptera				
Buprestidae	*	*	*	*
Carabidae	*	*	*	*
Cerambycidae	*	*	*	*
Chrysomelidae		*	*	*
Languriidae	*	*	*	*
Cleridae	*		*	*
Coccinellidae	*	*	*	*
Curculionidae	*	*	*	*
Eucnemidae			*	
Haliplidae		*		
Nitidulidae	*	*	*	*
Scarabaeidae	*	*	*	
Scolytidae		*		
Tenebrionidae	*	*	*	
Ostomatidae	*	*	*	*
Diptera				
Stratiomyiidae	*		*	*
Asilidae		*	*	*
Cecidomyiidae	*	*	*	*
Chironomidae	*	*		
Drosophilidae	*			*
Mycetophilidae	*	*	*	*
Tabanidae	*	*	*	*

Tachnidae	*	*	*	
Tipulidae	*	*	*	*
Hymenoptera				
Apidae	*	*		*
Agridae	*	*	*	*
Chalcididae	*	*	*	*
Formicidae	*	*	*	*
Icheumonidae	*	*		*

Table 4.18: Seasonal profile of insect abundance (Ind/ mce) in natural forest and monoculture plantations.

Years/ Seasons	Natural forest	Plantations		
		Teak	Cashew	Acacia
2001-02				
Summer	50.0± 13.5	40.6±10.17	49.3 ±18.04	55.6 ±12.90
Monsoon	46.7± 6.54	48.2±3.09	47.0±10.57	102.7 ±27.70
Postmonsoon	26.0± 8.07	38.5±9.59	28.0 ±2.00	13.5±0.50
Winter	39.6±3.84	84.3±44.3	26.6 ±3.33	21.5±4.35
2002-03				
Summer	29.0± 4.93	66.3±12.0	36.3±11.90	22.3±3.28
Monsoon	36.0±9.65	50.7±3.19	54.7±13.45	72.2±13.07
Postmonsoon	23.0±8.02	36.5±4.50	25.0±1.00	14.0±2.01
Winter	27.3±3.28	21.6±0.87	21.0±4.35	13.3 ±1.76

Table 4.19: Checklist of birds sighted in natural forest and plantations studied with their resident status, feeding habits and site based ranks of dominance.

Sr.No	Scientific Name	Common Name	(Rank of dominance)				Migratory Status	Feeding guild
			Natural (1-34)	Teak (1-28)	Acacia (1-38)	Cashew (1-39)		
	Falconiformes/ Accipitridae							
1	*Pernis ptilorhynchus*	Oriental Honey-Buzzard	34				R	C
2	*Elanus caeruleus*	Black-shouldered Kite						
3	*Haliastur indus*	Brahminy Kite	34				R	C
4	*Spilornis cheela*	Crested Serpent-Eagle	34				R	C
5	*Accipiter badius*	Shikra		28	28		R	C
6	*Accipiter nisus*	Eurasian Sparrowhawk	31	24		29	R	C
7	*Aquila pomarina*	Lesser Spotted Eagle	33	28	34		R	C
	Galliformes/ Phasianidae							
8	*Galloperdix spadicea*	Red Spur fowl				26	R	O
9	*Pavo cristatus*	Indian Peafowl	30			28	R	O
	Gruiformes/ Ralliadae							
10	*Amaurornis phoenicurus*	White-breasted Waterhen	33		34		R	O
	Columbiformes/ Columbidae							
11	*Streptopelia orientalis*	Oriental Turtle-Dove	33		34		LM	P
12	*Sterptopelia chinensis*	Spotted Dove	28	27	22	27	R	P
13	*Streptopelia decaocta*	Eurasian Collared-Dove				29	R	P
14	*Chalcophaps indica*	Emerald Dove			33		R	P
	Psittaciformes/ Psittacidae							
15	*Loriculus vernalis*	Indian Hanging-Parrot	32	10	31	26	R	P

16	*Psittacula krameri*	Rose-ringed Parakeet		24		26	R	P
	Cuculiformes/ Cuculidae							
17	*Hierococcyx varius*	Brainfever Bird	33	28			R	I
18	*Eudynamys scolopacea*	Asian Koel	32	28			R	P
19	*Phaenicophaeus viridirostris*	Small Green-billed Malkoha	34	28			R	C
20	*Centropus sinensis*	Greater Coucal				23	R	C
	Strigiformes/ Strigidae							
21	*Athene brama*	Spotted Owlet	34				R	C
	Apodiformes/ Apodidae							
22	*Cypsiurus balasiensis*	Asian Palm-Swift		15			R	I
23	*Apus affinis*	House Swift	33	18		8	R	I
	Trogoniformes/ Trogonidae							
24	*Harpactes fasciatus*	Malabar Trogon	31	23	31		R	I
	Coraciiformis/ Alcedinidae							
25	*Halcyon symrnensis*	White-breasted Kingfisher	33		34	22	R	C
	Meropidae							
26	*Merops orientalis*	Small Bee-eater		32		25	R	I
27	*Merops philippinus*	Blue-tailed Bee-eater					R	I
28	*Merops leschenaulti*	Chestnut-headed Bee-eater		24			R	I
	Bucerotidae							
29	*Ocyceros griseus*	Malabar Grey Hornbill	24		31	26	R	P
30	*Ocyceros birostris*	Indian Grey Hornbill	31	27	33	28	R	P
31	*Anthracoceros coronatus*	Malabar Pied Hornbill	17	19		26	R	P
	Piciformes/Capitonidae							
32	*Megalaima zeylanica*	Brown -headed Barbet	34	28	34	33	R	P
33	*Megalaima lineata*	Lineated Barbet			34	28	R	P
	Indicatoridae							
34	*Dendrocops nanus*	Brown-capped Pygmy woodpecker	34	28			R	I

35	*Picoides tridactylus*	Three-toed Woodpecker	23	27	27	28	R	I
36	*Celeus brachyurus*	Rufous Woodpecker	33	28	27		R	I
37	*Dryocopus javensis*	Great Black Woodpecker	31	26			R	I
38	*Dinopium benghalense*	Lesser Golden-backed Woodpecker	18	21	8	27	R	I
39	*Hemicircus canente*	Heart-spotted Woodpecker	33	24	31		R	I
	Passeriformes/ Hirundinidae							
40	*Hirundo concolor*	Dusky Crag-Martin		22			R	I
41	*Hirundo rustica*	Common Swallow	30	23	31	24	R	I
42	*Hirundo smithii*	Wire-tailed Swallow			34	28	R	I
43	*Hurindo daurica*	Red-rumped Swallow				25	R	I
	Motacillidae							
44	*Dendronanthus indicus*	Forest Wagtail	33	26			DM	I
45	*Campephagidae*							
46	*Coracina macei*	Large Cuckoo-Shrike	34	25	34		R	I
47	*Coracina melanoptera*	Black-headed Cuckoo-Shrike		27	31	28	R	I
48	*Pericrocotus roseus*	Rosy Minivet		27			LM	I
49	*Pericrocotus Cinnamomeus*	Small Minivet	15	9	29	25	R	I
50	*Pericrocotus erythropygius*	White-bellied Minivet		25	33	24	R	I
51	*Perircrocotus ethologus*	Long-tailed Minivet	22	24	33	26	LM	I
52	*Pericrocotus flammeus*	Scarlet Minivet	9	5	27	15	R	I
53	*Tephrodornis pondicerianus*	Common Woodshrike	34				R	I
	Pycnonotidae							
54	*Pycnonotus priocephalus*	Grey-headed Bulbul		22	29	22	R	P
55	*Pycnonotus melanicterus*	Black-crested Bulbul	4	15	23	27	R	P
56	*Pycnonotus jocosus*	Red-whiskered Bulbul	30	10	2	1	R	P
57	*Pycnonotus cafer*	Red-vented Bulbul			21	8	R	P
58	*Pycnonotus xantholaemus*	Yellow-throated Bulbul	33	27	38		R	P
59	*Pycnonotus luteolus*	White-browed Bulbul	28	25	33	25	R	P

60	*Iole indica*	Yellow-browed Bulbul	7	1	8		R	P
61	*Hypsipetes leucocephalus*	Black Bulbul	25	11	33		R	P
	Irenidae							
62	*Aegithina tiphia*	Common Iora	27	26	31	20	R	I
63	*Aegithina nigrolutea*	Marshall's Iora	33				R	I
64	*Chloropsis cochinchinensis*	Jerdon's Chloropsis	8	7	30	25	R	I
65	*Chloropsis aurifrons*	Gold-fronted Chloropsis	23	23	29	25	R	I
	Laniidae							
66	*Lanius vittatus*	Bay-backed Shrike				29	R	C
67	*Lanius schach*	Rufous-backed Shrike	27			22	LM	C
68	*Lanius minor*	Lesser Grey Shrike		28		28	R	C
	Turdinae							
69	*Monticola cinclorhychus*	Blue-headed Rock-Thrush		27				
70	*Myiophonus horsfieldii*	Malabar Whistling-Thrush	29	23			R	I
71	*Zoothera citrina*	Orange-headed Thrush	26	27	9	17	R	P
72	*Luscinia brunnea*	Indian Blue Robin	34			25	LM	I
73	*Copsychus saularis*	Oriental Magpie-Robin		23	29	17	R	I
74	*Copsychus malabaricus*	White-rumped Shama	31		30	25	R	I
75	*Phoenicurus ochruros*	Black Redstart		27			LM	I
	Timaliinae							
76	*Pellorneum ruficeps*	Spotted Babbler	33	27	30	14	R	I
77	*Turdoides malcolmi*	Large Grey Babbler				25	R	O
78	*Turdoides Subrufus*	Indian Rufous Babbler				21	R	O
79	*Turdoides striatus*	Jungle Babbler			7	2	R	O
80	*Gampsorhynchus rufulus*	White-hooded Babbler	14				R	I
81	*Alcippe poioicephala*	Quaker Tit-Babbler				28	R	O
	Sylviinae							
82	*Prinia hodgsonii*	Franklin's Prinia				15	R	I
83	*Prinia socialis*	Ashy Prinia				10	R	I

84	*Prinia Inornata*	Plain prinia	27	27	34		R	I
85	*Acrocephalus dumetorum*	Blyth`s Reed-Warbler	23	22	29	10	DM	I
86	*Acrocephalus stentoreus*	Indian great reed warbler	33			29	DM	I
87	*Acrocephalus aedon*	Thick-billed Warbler					DM	I
88	*Hippolais caligata*	Booted Warbler	20	22	33	15	DM	I
89	*Orthotomus sutorius*	Common Tailorbird	24			28	R	I
90	*Phylloscopus trochiloides*	Greenish leaf warabler	11	11	10	8	LM	I
91	*Phylloscopus magnirostris*	Large-billed Leaf-Warbler			33	23	LM	I
92	*Sylvia curruca*	Lesser Whitethroat	27	21	31	17	DM	I
93	*Sylvia hortensis*	Orphean Warbler	30	20		28	DM	I
94	*Muscicapa muttui*	Brown-breasted Flycatcher		20	33	26	LM	I
95	*Ficedula superciliaris*	Ultramarine Flycatcher		25			LM	I
96	*Eumyias talassina*	Verditer Flycatcher		28			LM	I
97	*Cyronis pallipes*	White-bellied Blue-Flycatcher		27			R	I
98	*Cyornis rubeculoides*	Blue-throated Flycatcher		27			LM	I
99	*Cyornis ticktelliae*	Tickell`s Blue-Flycatcher	21	22	33	27	R	I
	Monarchinae							
100	*Terpsiphone paradisi*	Asian Paradise-Flycatcher	13	17	24	27	LM	I
101	*Hypothymis azurea*	Black-naped Monarch-Flycatcher	16	23	10	29	R	I
	Rhipidurinae/ Paridae							
102	*Parus major*	Great Tit		28	34		R	I
103	*Parus nuchalis*	Pied Tit	27				R	I
104	*Parus xanthogenys*	Black-lored Yellow Tit			34		R	I
	Sittidae							
105	*Sitta castanea*	Chestnut-bellied Nuthatch	4				R	I
106	*Sitta frontalis*	Velvet-fronted Nuthatch	6	23	29		R	I
	Dicaeidae							
107	*Dicaeum erythrorhynchos*	Tickell's Flowerpecker	29			28	R	P

108	*Dicaeum concolor*	Plain Flowerpecker	18	16		24	R	P
	Nectariniidae							
109	*Nectarinia zeylonica*	Purple-rumped Sunbird	5	7	23	5	R	P
110	*Nectarnia minima*	Small Bird	19	6	19	6	R	P
111	*Nectarinia asiatica*	Purple sunbird	2	4	18	4	R	P
112	*Nectarina lotenia*	Loten`s Sunbird	33	14		13	R	P
113	*Arachnothera magna*	Streaked Spiderhunter			34		R	I
	Estrildidae							
114	*Lonchura malabarica*	White -throated Munia		26			R	P
115	*Lonchura straita*	White-rumped Munia			33	28	R	P
116	*Lonchura malacca*	Black-headed Munia				28	R	P
	Plocinae							
117	*Ploceus philippinus*	Baya Weaver				23	R	P
	Sturnidae							
118	*Acridotheres fuscus*	Jungle Myna				16	R	O
	Oriolidae							
119	*Oriolus oriolus*	Eurasian Golden Oriole	33	8	34	19	M	P
120	*Oriolus chinensis*	Black-headed Oriole	10	7	4	11	R	P
	Dicruridae							
121	*Dicrurus macrocerus*	Black Drongo	1	1	5	20	R	I
122	*Dicrurus leucophaeus*	Ashy Drongo	30	12	21	25	LM	I
123	*Dicrurus caerulescens*	White -bellied Drongo	29	25	31		R	I
124	*Dicrurus aeneus*	Bronzed Drongo	10	12	2		R	I
125	*Dicrurus hottentottus*	Spangled Drongo		26	26		R	I
126	*Dicrurus paradiseus*	Greater Racket-tailed Drongo	2	7	1	20	R	I
	Corvidae							
127	*Dendrocitta vagabunda*	Indian Treepie	32	27	17		R	P
128	*Corvus splendens*	House Crow				24	R	O
129	*Corvus corone*	Jungle Crow	25	2	5	5	R	O

Table 4.20 : Biennial picture of general composition of bird community and species indices in natural forest and monoculture plantations.

	Natural forest	Plantations		
		Teak	Cashew	Acacia
Abundance ind/ km	44.75 ± 3.59	43.58 ± 4.15	44.58 ± 4.13	42.2 ±3.99
Affiliation				
Orders/ Families	12/30	9/27	9/27	7/23
Total no. of species	80	83	78	69
Exclusives	11	11	14	3
Endemics	2	1	4	3
Breeding	6	5	5	5
Species indices				
Species diversity(H')	2.24	2.03	2.00	2.01
Species eveness (J)	0.85	0.82	0.83	0.83
Species richness (SR)	3.5	3.08	2.83	2.91

Table 4.21: The details of bird species newly sighted in Goa region during 2001-2003.

Sno.	Bird species	NOS	CT	Sites				Zone	Months/ Years
				NF	TP	CP	AP		
1	.White hooded Babbler	5	25	+				C,Sc	Mar, Apr, May, Jul, Oct 2002
2	Long tailed Minivet	6	21	+	+	+		C	June & Aug 2001 & 2002
3	White bellied Minivet	4	12		+	+	+	C	Apr, Nov 2001 Jan, Jul 2002
4	Yellow throated Bulbul	4	14	+	+		+	Sc, Ug	Aug, Sep 2001
5	Orphean Warbler	5	14		+		+	C	Sep, Oct, 2001; Apr, Sep 2002 Jan 2003
6	Indian grey Hornbill	5	9	+	+	+	+	SC	Dec 2001 Feb, Apr, Sep 2002
7	Pied Tit	3	8	+				C	July, Oct 2001, Feb 2003
8	Large grey Babbler	1	5			+		Ug	May 2001
9	Southern grey Shrike	2	3		+	+		Sc, Ug	Nov 2001
10	Lineated Barbet	2	3			+	+	C,,Sc	Aug, Oct 2002
11	White throated Munia	1	3		+			Sc	Sept 2001
12	Indian blue Robin	1	1	+				Sc	Nov 2002
13	Streaked spider Hunter	1	1				+	Sc	June 2001

Note: NOS- no. of sigthings

Zone – C-canopy, Sc- subcanopy, Ug- undergrowth

Table 4.22: Seasonal profile of bird population in natural forest and monoculture plantations. (The numbers in parenthesis indicate number of species sighted in the respective seasons.)

Years/Seasons	Natural forest	Plantations		
		Teak	Cashew	Acacia
2001-02				
Summer	39.5±4.69(25)	61.0± 6.63(30)	47.7±15.78 (28)	39.0±13.60 (16)
Monsoon	30.7± 6.97(33)	43.0± 14.97(28)	26.0± 2.73(22)	53.0± 14.49(28)
Postmonsoon	44.5± 3.49(23)	32.0± 9.00(20)	32.0±18.04 (16)	72.5±0.49 (23)
Winter	45.2± 10.20(28)	57.7± 8.19(32)	72.6±8.32 (30)	51.6±9.39 (28)
2002-03				
Summer	69.0± 16.06(33)	48.7± 9.91(28)	58.6±9.21(28)	40.6±10.17(26)
Monsoon	44.0± 7.52(30)	32.5± 13.45(33)	38.5± 3.92(30)	37.7± 8.72(28)
Postmonsoon	46.5± 17.49(29)	33.5± 0.49(15)	56.5±12.50 (29)	32.5±3.50(26)
Winter	40.0± 8.08(27)	33.6 ± 1.32(27)	40.3±10.17 (26)	18.0± 5.00(12)

Table 4.23: Seasonal variations in species indices of birds in natural forest and monoculture plantations.

Years	2001-02				2002-03			
Sites/ Indices	Summer	Monsoon	Postmonsoon	Winter	Summer	Monsoon	Postmonsoon	Winter
Natural H	1.80	2.27	2.44	1.96	2.36	2.23	2.44	2.58
J	0.73	0.90	0.87	0.73	0.86	0.85	0.84	0.99
SR	2.95	3.27	3.94	3.48	3.76	3.41	4.27	3.37
Teak H	2.20	1.78	1.98	2.16	2.29	1.9	1.90	2.09
J	0.79	0.81	0.83	0.79	0.87	0.84	0.81	0.84
SR	3.73	2.28	2.99	3.57	3.42	2.83	2.7	3.30
Cashew H	1.79	1.96	1.74	2.15	1.97	2.09	2.18	2.1
J	0.73	0.94	0.87	0.80	0.79	0.88	0.76	0.83
SR	2.89	2.14	1.90	2.87	2.70	2.79	4.01	3.31
Acacia H	1.80	2.32	2.19	2.02	2.03	2.05	2.15	1.55
J	0.82	0.94	0.82	0.80	0.81	0.82	0.81	0.84
SR	2.21	2.81	3.14	2.96	3.17	3.29	3.85	1.86

Table 4.24: Guild compositions of the bird community in natural forest and monoculture plantations.

Guilds	Abundance (ER – Ind/km & percentage)				Diversity (Total no. of species & percentage)			
	Natural	Teak	Cashew	Acacia	Natural	Teak	Cashew	Acacia
Resident	38.0 ± 3.12 (85%)	39.0 ± 3.86 (88.7%)	42.0 ± 3.87 (90.9%)	36.7 ± 3.69 (87.6%)	67 (81.7%)	70 (80.5%)	66 (82.5%)	59 (83%)
Migrant	6.7 ± 1.47 (15%)	5.0 ± 1.01 (11.4%)	4.2 ± 0.99 (9.1%)	5.2 ± 1.32 (12.4%)	15 (18.3%)	17 (19.5%)	14 (18.5%)	12 (16.9%)
Passerine	37.8 ± 4.09 (86.9%)	39.0 ± 3.86 (89%)	40.2±3.73 (91%)	39.1 ± 3.93 (91.6%)	55 (67%)	65 (74.7%)	62 (77.5%)	55 (77.5%)
Nonpasserine	5.7 ± 1.16 (13.1%)	4.83 ± 1.03 (11%)	4.0 ± 1.58 (9%)	3.6 ± 0.92 (8.4%)	27 (33%)	22 (25.3%)	18 (22.5%)	16 (22.5%)
Insectivores	27.0 ± 3.22 (59.9%)	20.0 ± 2.19 (46%)	14.5± 2.45 (32.4%)	1.8 ± 2.24 (42.4%)	44 (53.6%)	53 (61%)	36 (45%)	39 (54.9%)
Phytophages	16.6 ± 1.82 (36.8%)	18.8 ± 2.57 (43.3%)	21.0 ± 2.64 (47%)	19.7 ± 2.2 (45.2%)	26 (31.7%)	26 (29.8%)	28 (35%)	26 (36.6%)
Omnivores	0.7 ± 0.24 (1.6%)	4.2 ± 0.90 (9.7%)	8.5 ± 1.27 (19%)	5.1 ± 1.12 (11.7%)	3 (3.6%)	2 (2.3%)	10 (12.5%)	3 (4.2%)
Carnivores	0.8 ± 0.34 (1.8%)	0.4 ± 0.15 (0.9%)	0.75 ± 0.24 (1.7%)	0.37 ± 0.14 (0.8%)	9 (11%)	6 (6.9%)	6 (7.5%)	3 (4.2%)

Table 4.25: Seasonal variations in resident/ migrant bird population in natural forest and plantations. (The number in parenthesis indicates the diversities in terms of total no. of species.)

	Natural forest		Teak plantation		Cashew plantation		Acacia plantation	
	Resident	Migrant	Resident	Migrant	Resident	Migrant	Resident	Migrant
2001-02 Summer	35.3±6.63 (22)	4.3±2.84 (3)	55±6.56 (27)	6±2.08 (4)	53.66±12.3 (23)	5±3.21 (5)	33±9.17 (14)	1.66±1.2 (2)
Monsoon	29.25±4.73 (31)	1.5±1.5 (2)	40±11.92 (27)	5±4.35 (1)	24.5±2.28 (19)	2.75± 0.94 (3)	40±8.25 (25)	10± 5.77 (3)
Post Monsoon	36.5±3.49 (20)	8± 0 (3)	26± 3.5 (14)	7± 4.0 (6)	22± 20 (11)	11±3 (5)	65.5±26.5 (21)	7±5.01 (2)
Winter	33.33±7.54 (25)	12±5.29 (3)	50±14.2 (29)	9.33±2.95 (3)	68.66±8.88 (26)	4.66±1.2 (4)	39±8.04 (21)	12.6±3.56 (7)
2002-03 Summer	56±16.18 (29)	13±8.15 (3)	45.66±9.39 (27)	3± 1.73 (1)	54±7.81 (23)	5.03±2.9 (5)	35.66±9.13 (25)	5±1.73 (3)
Monsoon	45.25±6.87 (29)	1.25±0.94 (1)	30±11.09 (29)	2.25±1.43 (4)	37.25±4.17 (28)	1.2± 1.25 (2)	38±8.64 (25)	2.2± 1.03 (3)
Post Monsoon	38.5±13.53 (29)	8±4 (4)	31.5± 2.51 (14)	2± 2 (1)	44.5±0.49 (25)	9.5± 9.02 (4)	30.5±1.5 (21)	2±2 (5)
Winter	30.0±6.0 (23)	10±2.31 (4)	27.66±10.23 (18)	6±3.46 (9)	33.33±4.33 (24)	1.33± 0.66 (2)	17.33±5.36 (12)	0.6±0.6 (1)

Table 4.26: The correlations between the abundance and diversities between the different feeding guilds with those of total bird community in different study sites (Only the guilds showing statistical significance are shown).

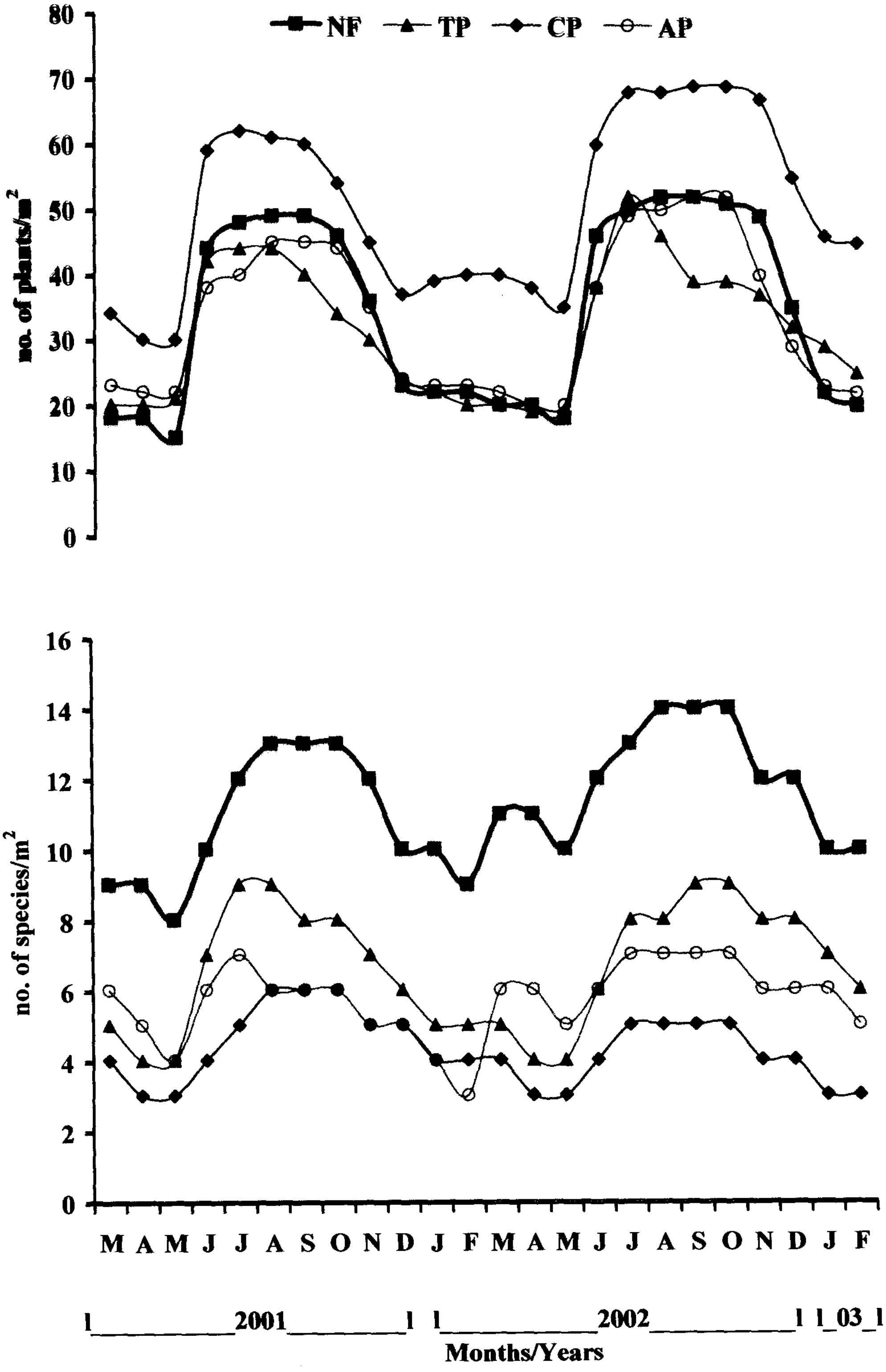
Feeding guilds	Natural forest		Plantations					
			Teak		Cashew		Acacia	
	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity
Insectivores density	0.78**	0.66**	0.80**	0.77**	0.67**	0.46*	0.74**	0.62**
Insectivores diversity	0.80**	0.87**	0.69**	0.87**	0.64**	0.78**	0.63**	0.78**
Phytophages density	0.58**	0.66**	0.79**	0.64**	0.68**	0.61**	0.70**	0.55**
Phytophages diversity	0.48*	0.60**	0.71**	0.76**	0.52*	0.71**	0.58**	0.68**

significance level * 0.05
** 0.01

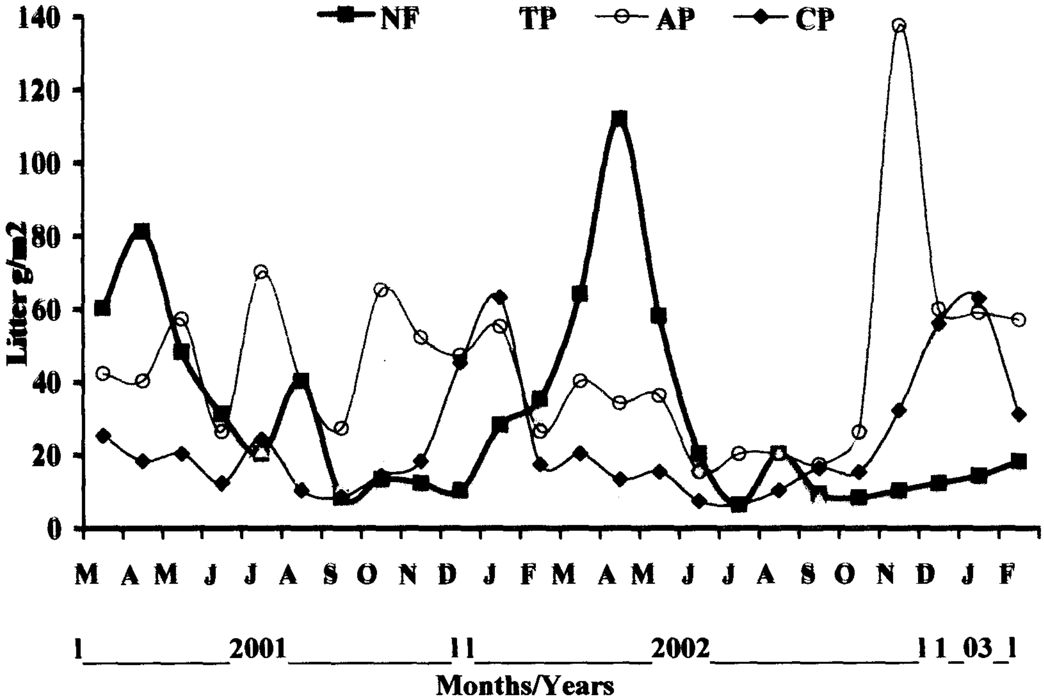
Table 4.27: Checklist of breeding birds sighted in natural forest and monoculture plantations.

Species	Natural	Teak	Acacia	Cashew
Greater spotted eagle	+	-	-	-
Indian spur fowl	-	-	-	+
Lesser golden backed woodpecker	+	-	-	-
Red whiskered bulbul	-	+	+	+
Red vented Bulbul				
Yellow browed bulbul	+	-	-	-
Orange headed thrush	-	+	-	-
Oriental magpie robin	+	-	-	+
Jungle babbler	-	-	-	+
Black napped flycatcher	+	-	+	-
Small sunbird	-	+	-	-
White rumped munia	+	-	-	-
Ashy drongo	-	-	+	-
Bronzed drongo	-	-	+	-
Great racket tailed Drongo	-	+	+	-
Jungle crow	-	+	-	-

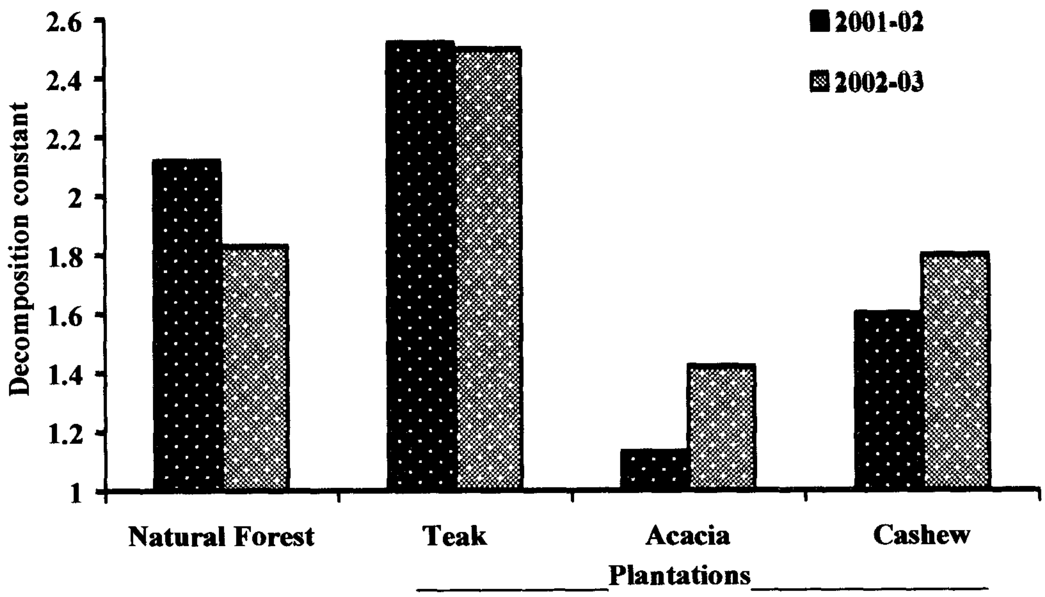
Graph 4.1:
Monthly variations in the density and diversity of undergrowth in natural forest and monoculture plantations.



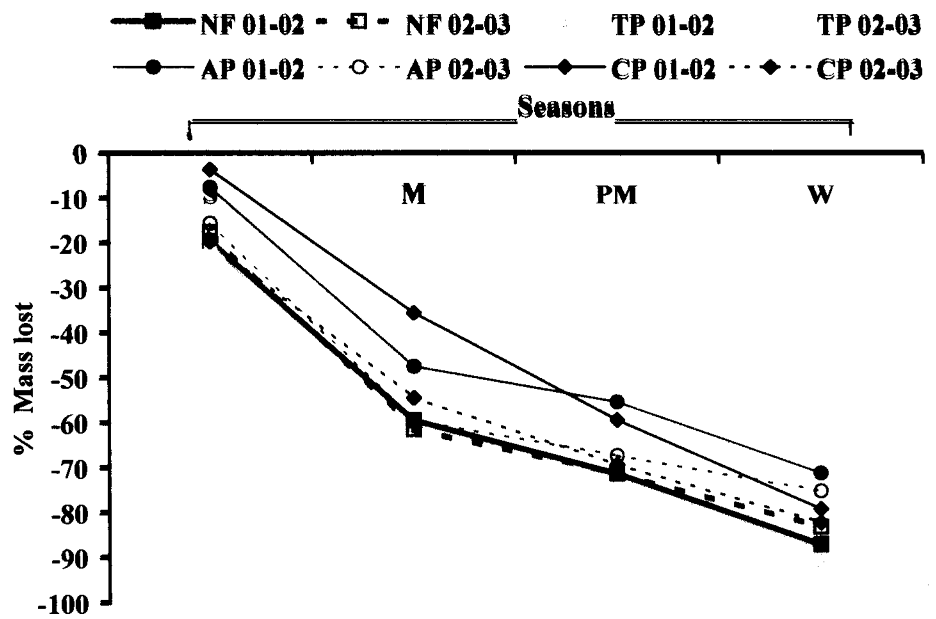
Graph 4.2:
Monthly variations in litterfall in natural forest and monoculture plantations.



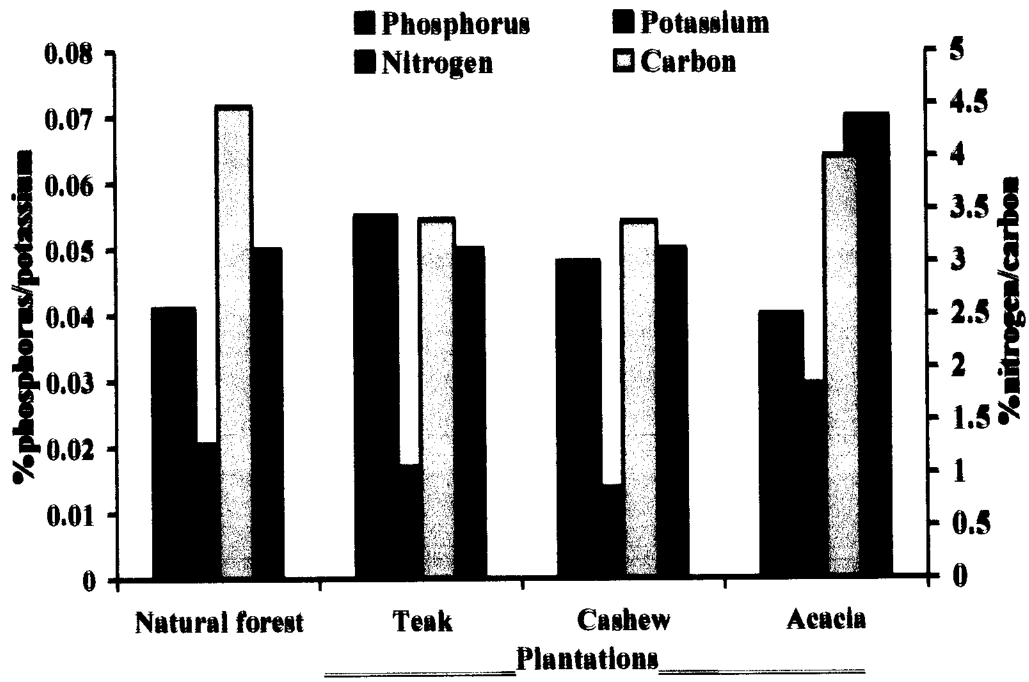
Graph 4.3:
Decomposition constants of the litter at natural forest and monoculture plantations.



Graph 4.4:
Seasonal variations in the mass lost by the decomposing litter in natural forest and plantations during the two years of study.



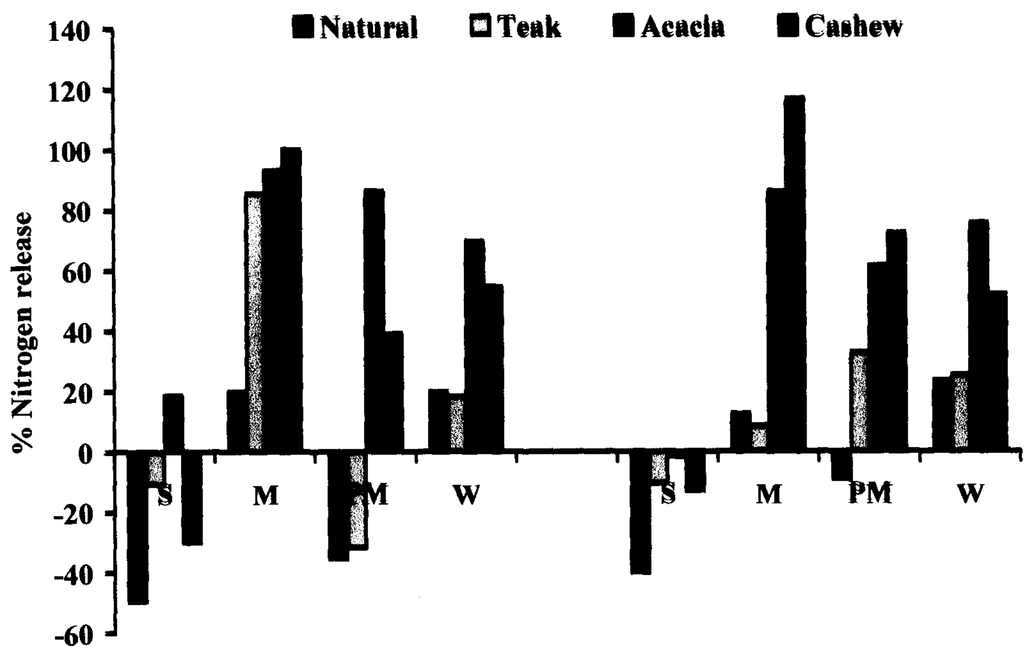
Graph 4.5:
Comparative picture of nutrient content (%) of litter in natural forest and monoculture plantations on biennial basis.



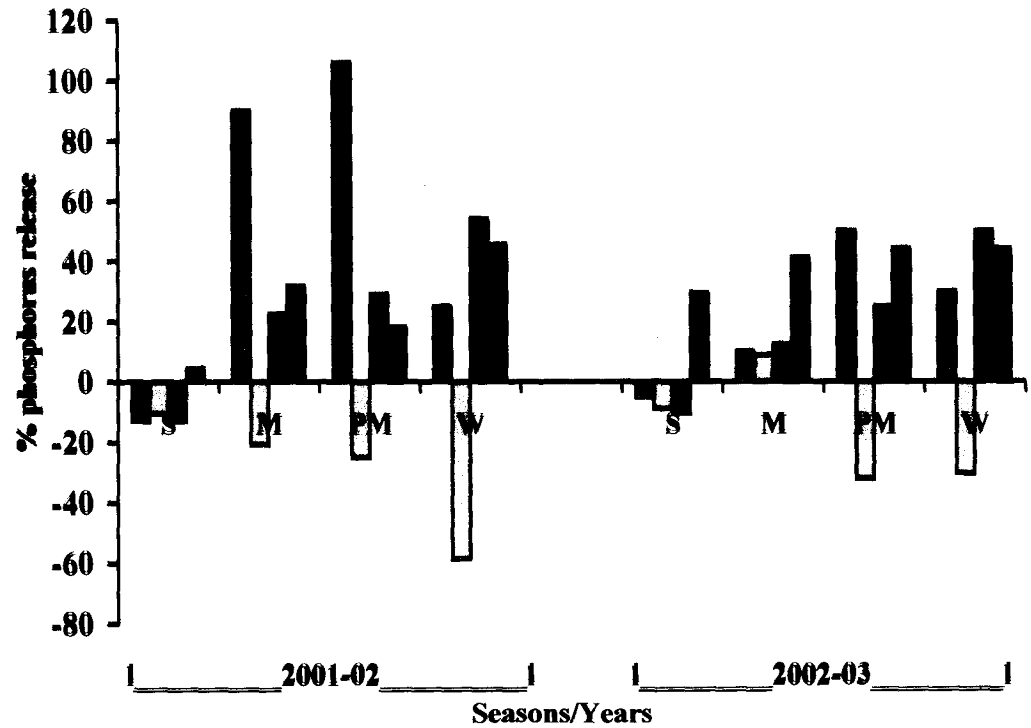
Graph 4.6

The seasonal changes in the nutrient content of the decomposing litter (cumulative %) with reference to the initial levels.

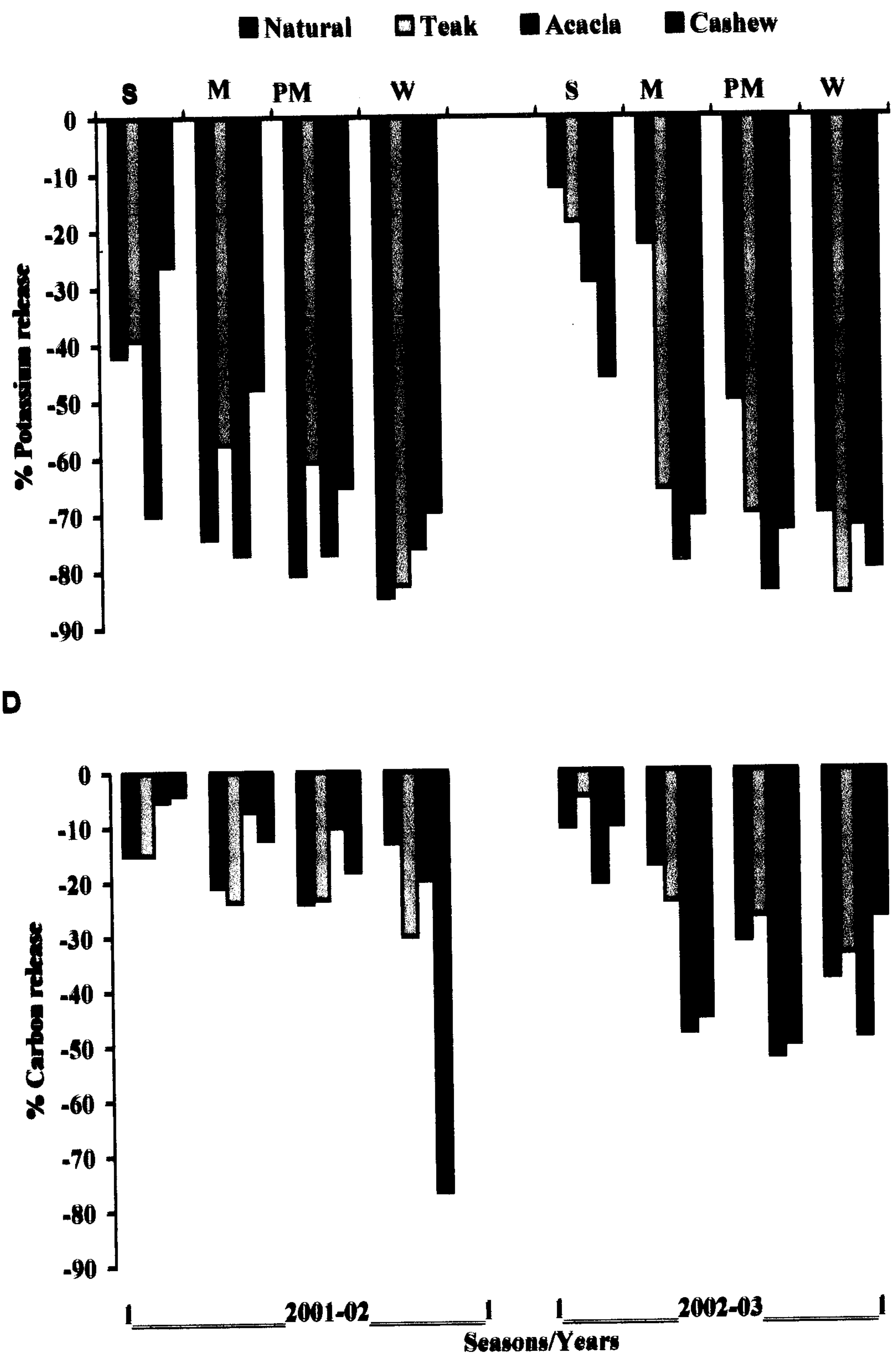
A



B

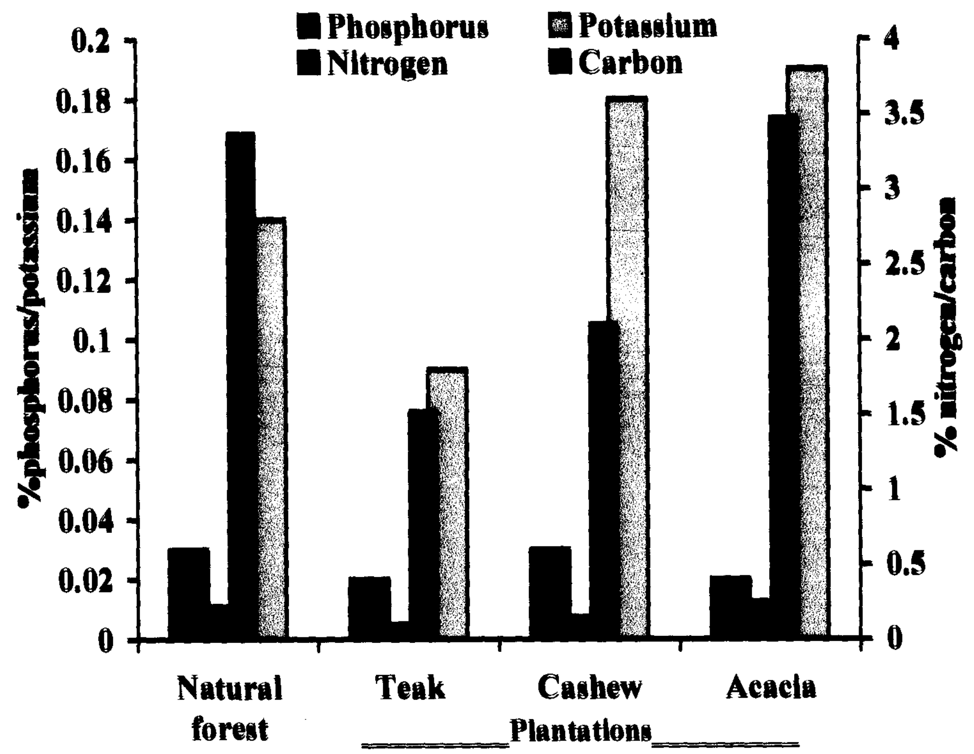


C

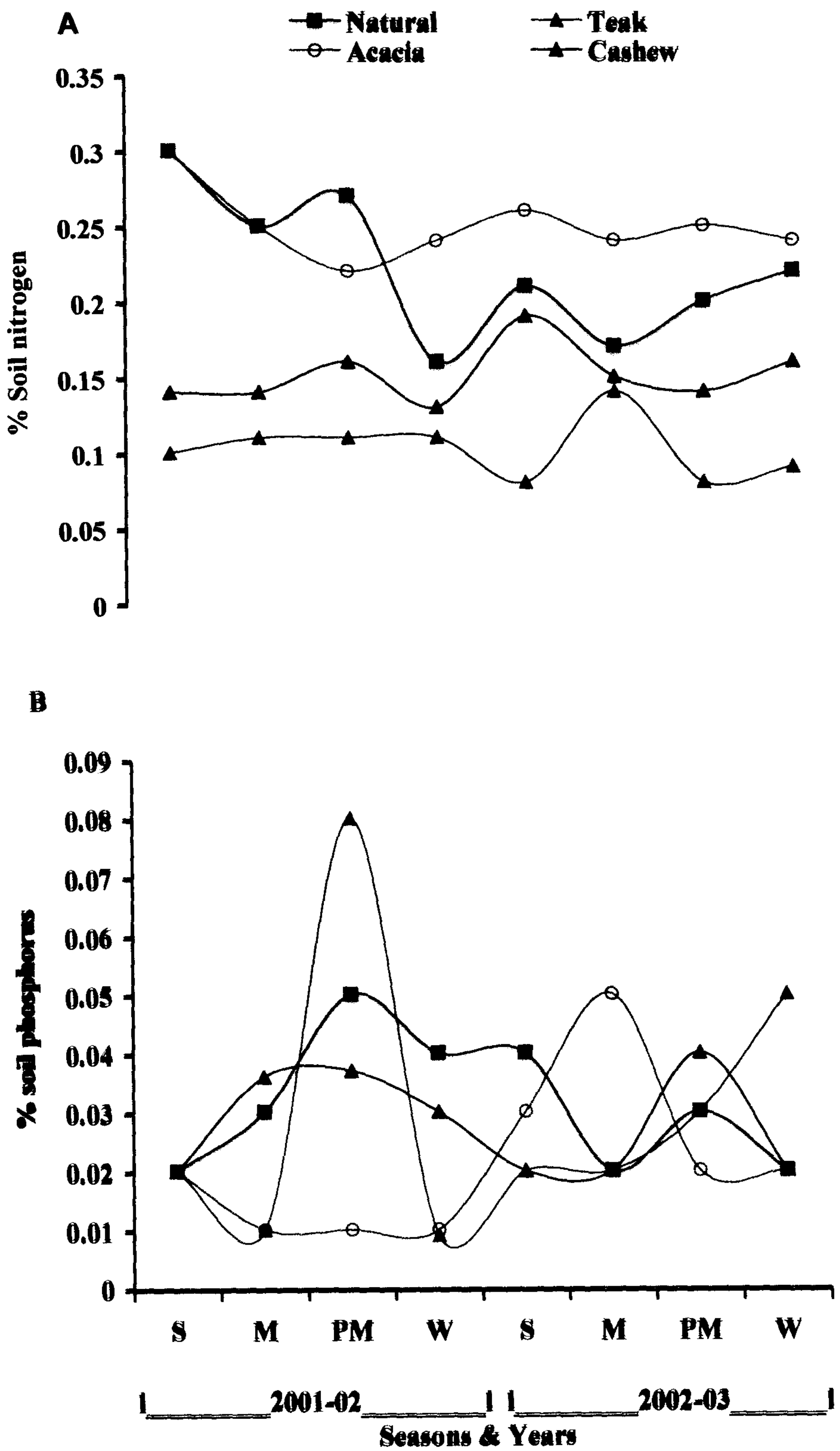


Natural
Teak
Acacia
Cashew
S
M
PM
W
% Potassium release
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
D
% Carbon release
2001-02
2002-03
Seasons/Years

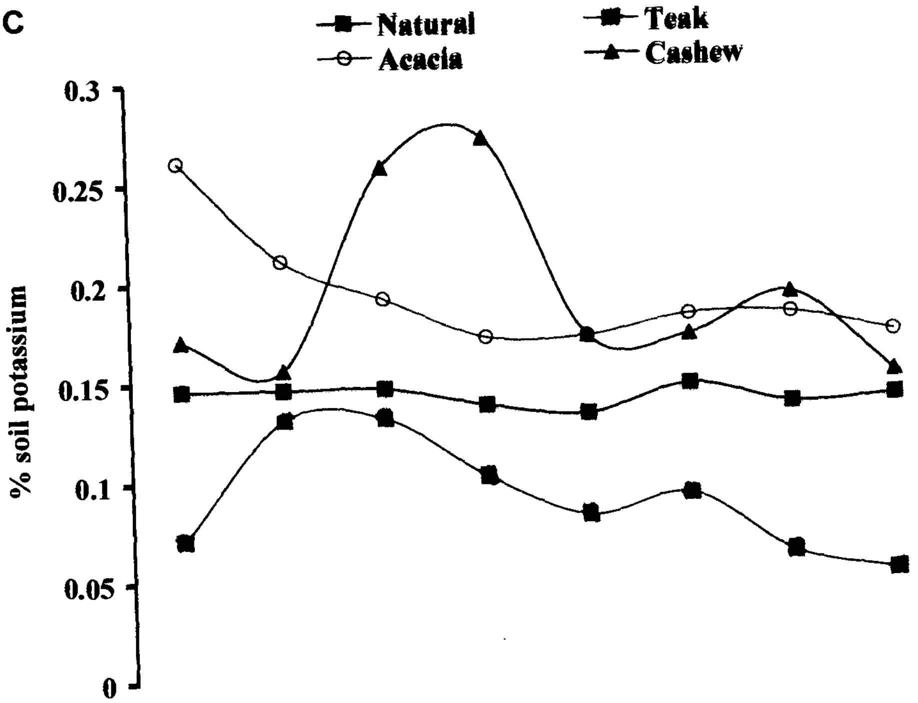
Graph 4.7:
Nutrient content of the soil (%) in natural forest and monoculture plantations on biennial basis.



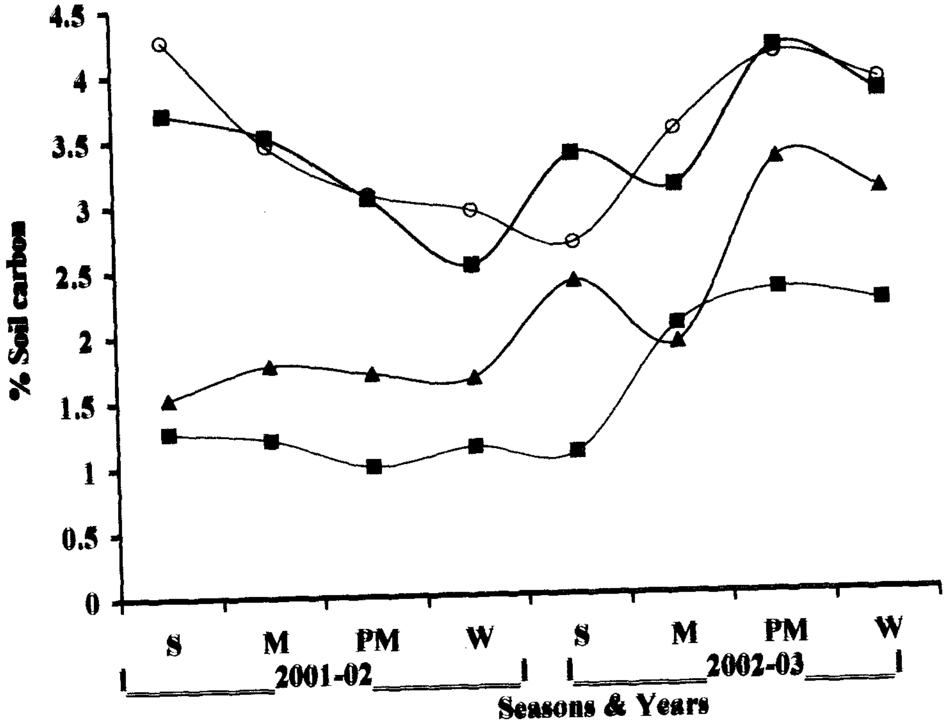
Graph 4.8:
The seasonal variations in nutrient content of the soil in natural forest and plantations.



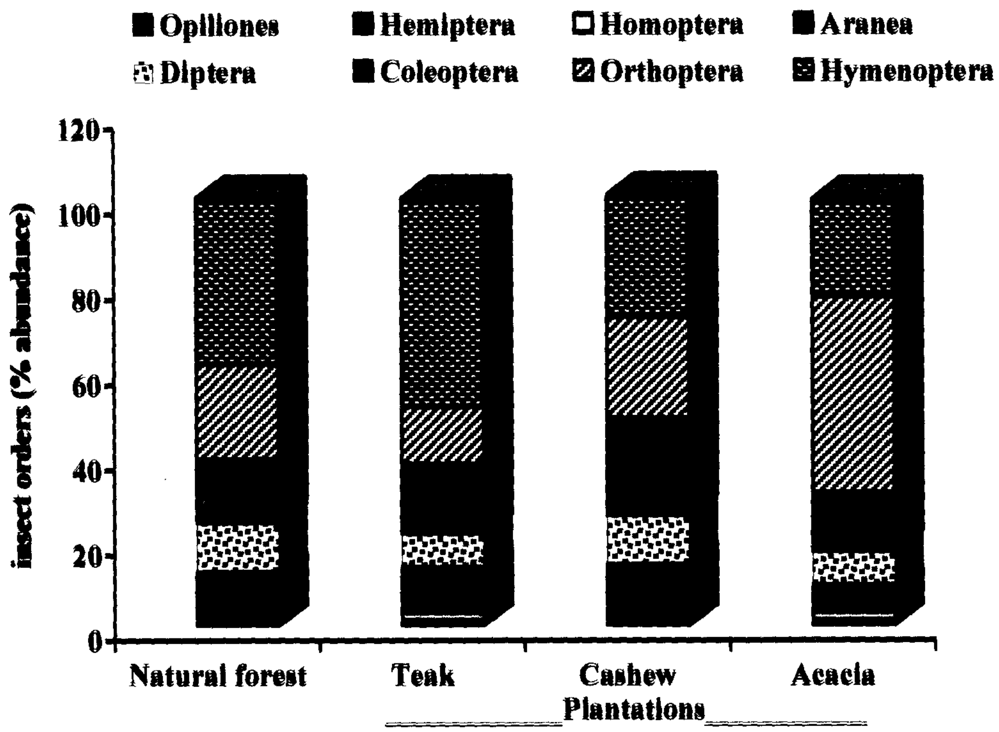
C


Natural
Acacia
Teak
Cashew
0.3
0.25
0.2
0.15
0.1
0.05
0
% soil potassium

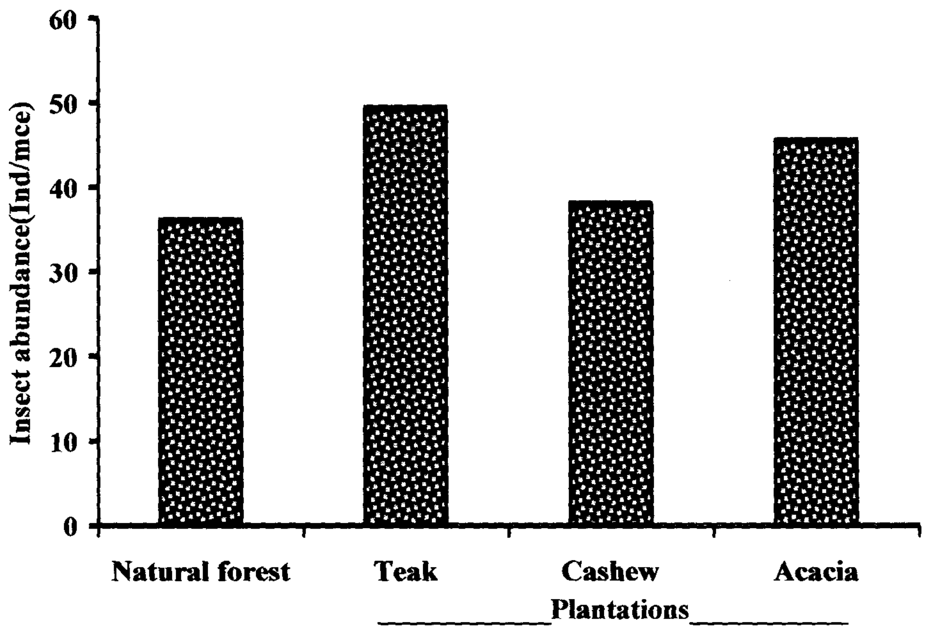
D


4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
% Soil carbon
S
M
PM
W
S
M
PM
W
2001-02
2002-03
Seasons & Years

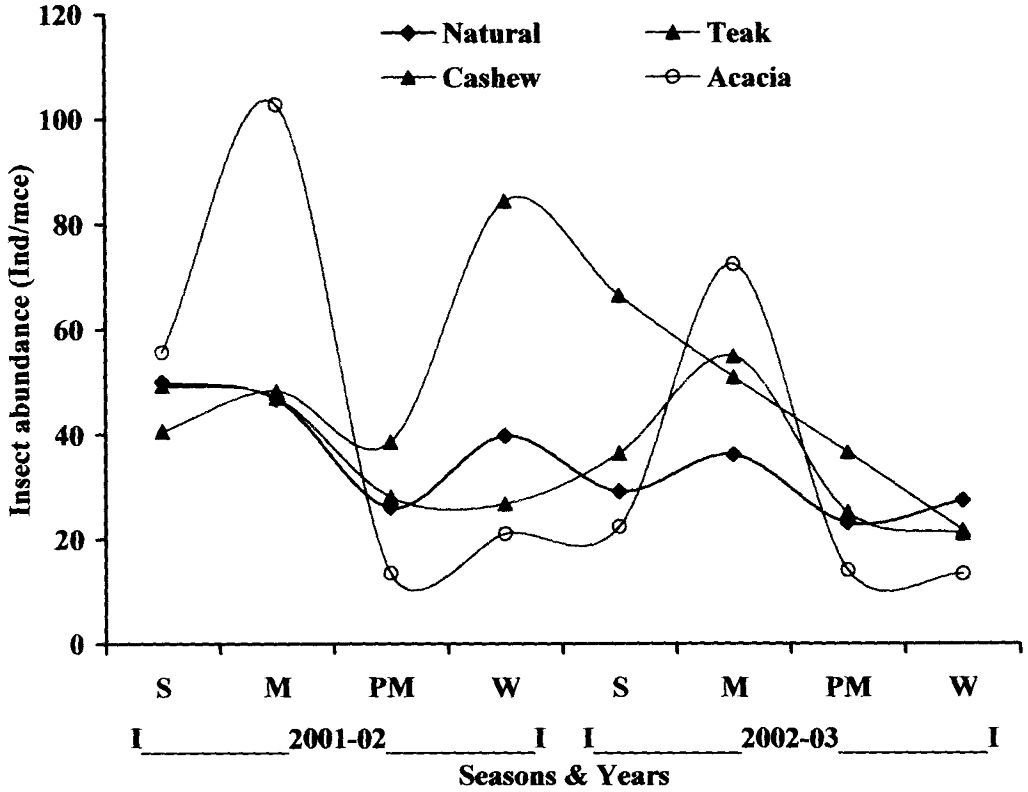
Graph 4.9:
Comparative composition of the insect fauna in four study sites on the basis of family based abundance.



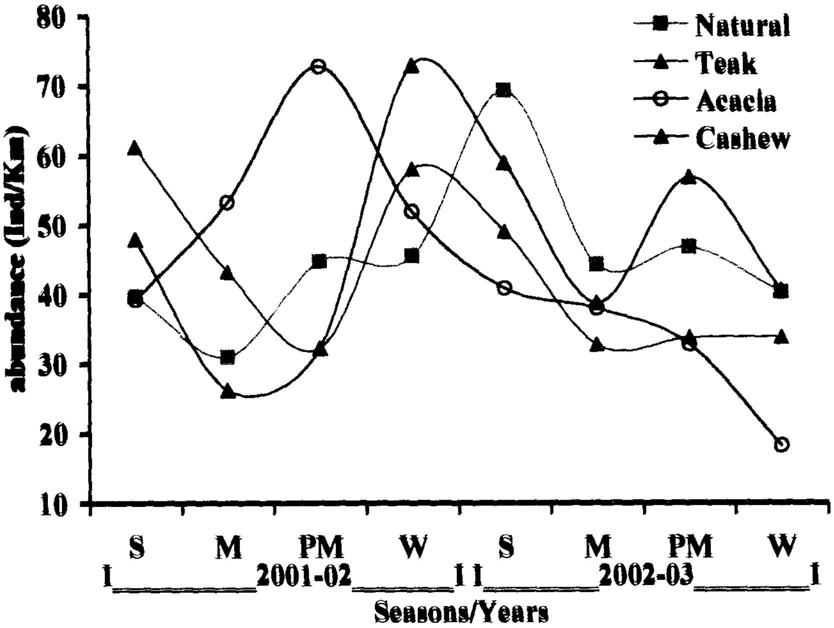
Graph 4.10: Insect abundance in four study sites based on biennial cumulative total.



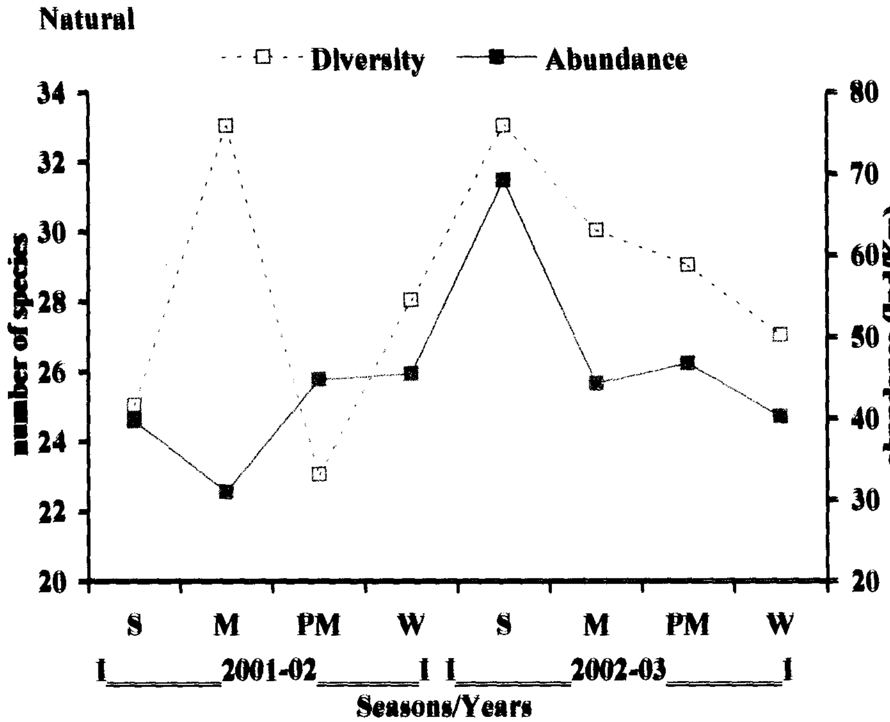
Graph 4.11: Seasonal variations in insect abundance in natural forest and monoculture plantations.



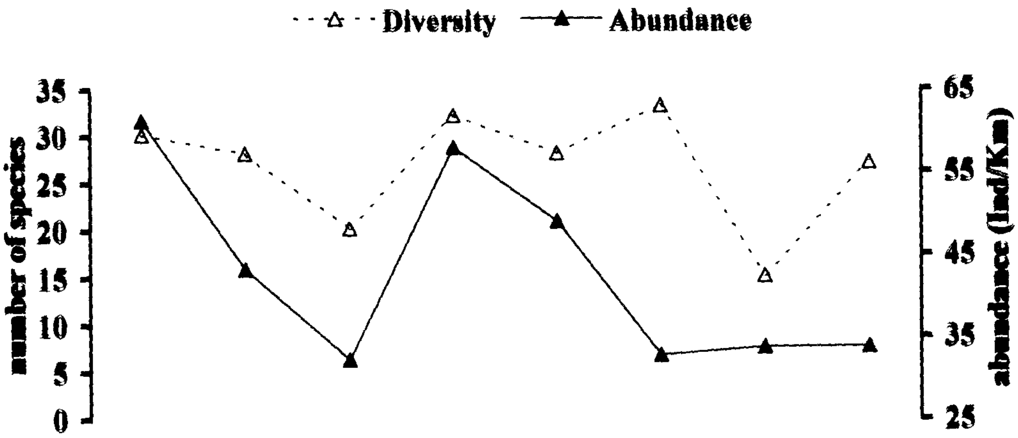
Graph 4.12:
Seasonal variations in bird abundance in natural forest and monoculture plantations.



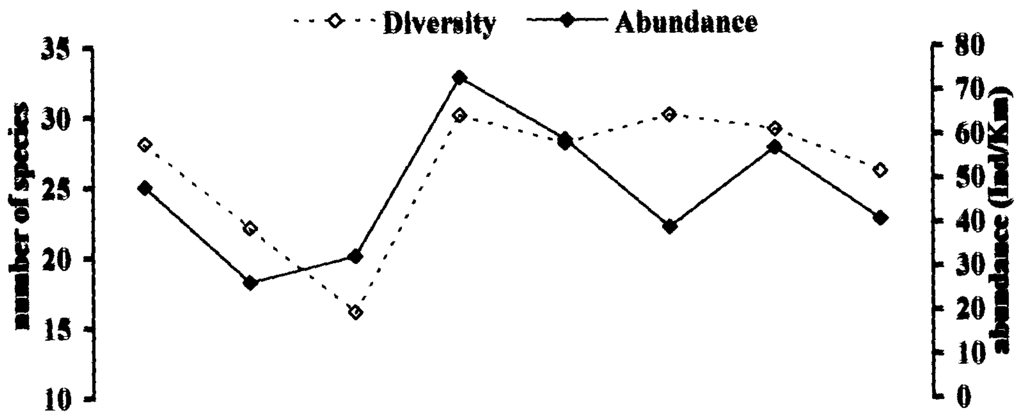
Graph 4.13:
The seasonal profiles of bird abundance compared with those of bird diversity at the four study sites.



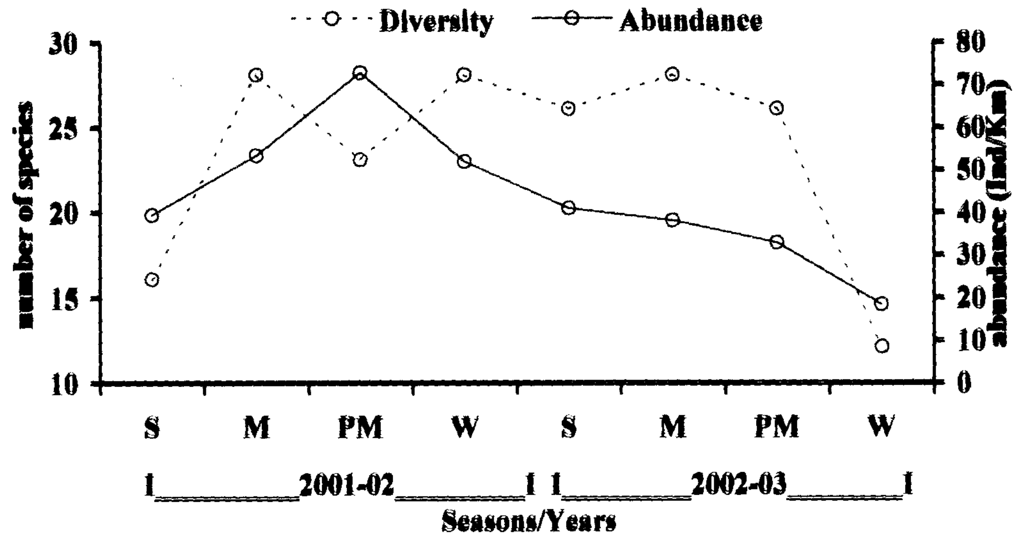
Teak plantation



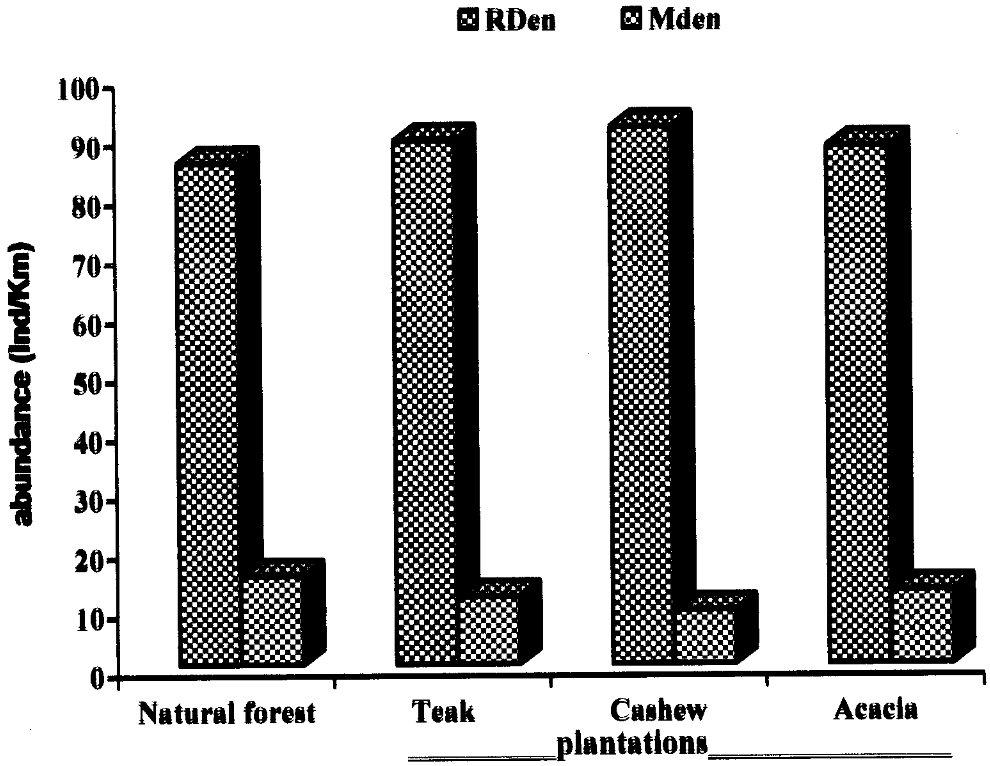
Cashew plantation

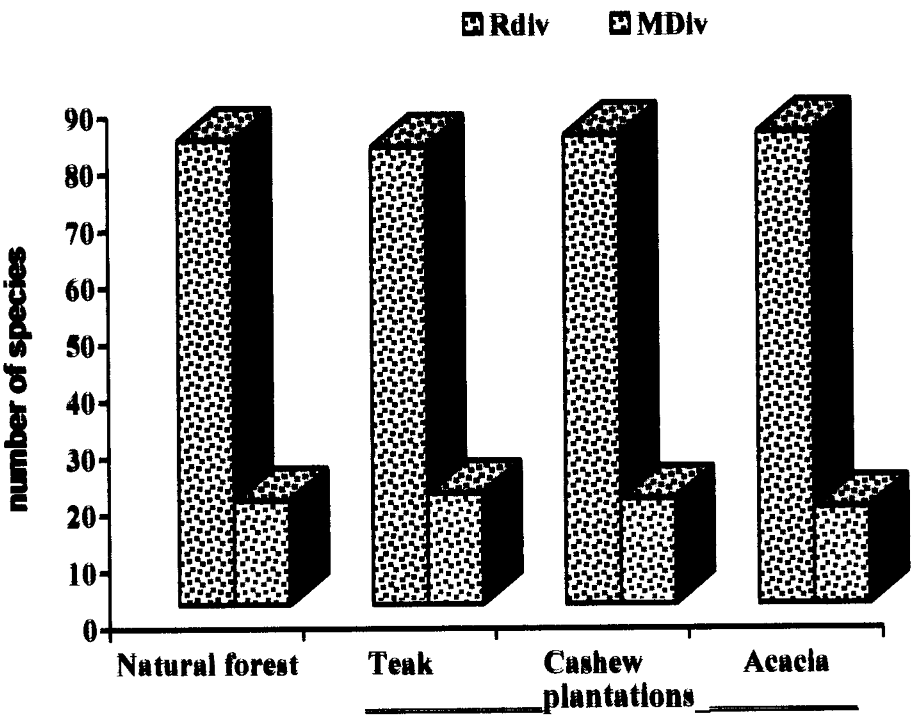


Acacia plantation

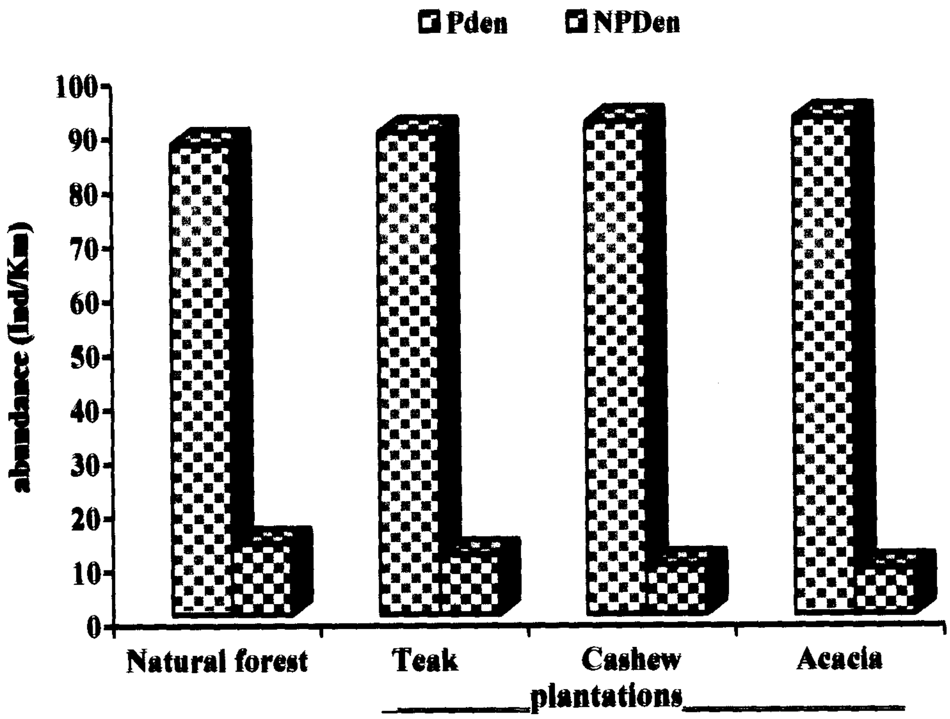


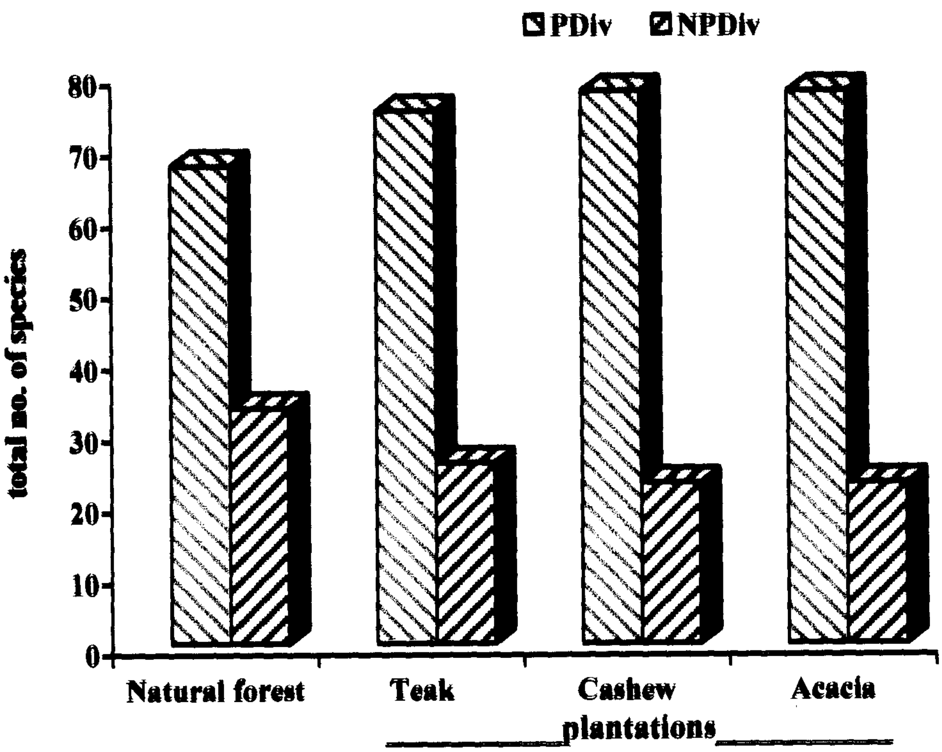
Graph 4.14:
Biennial profiles of resident and migrant bird populations in natural forests and monoculture plantations.





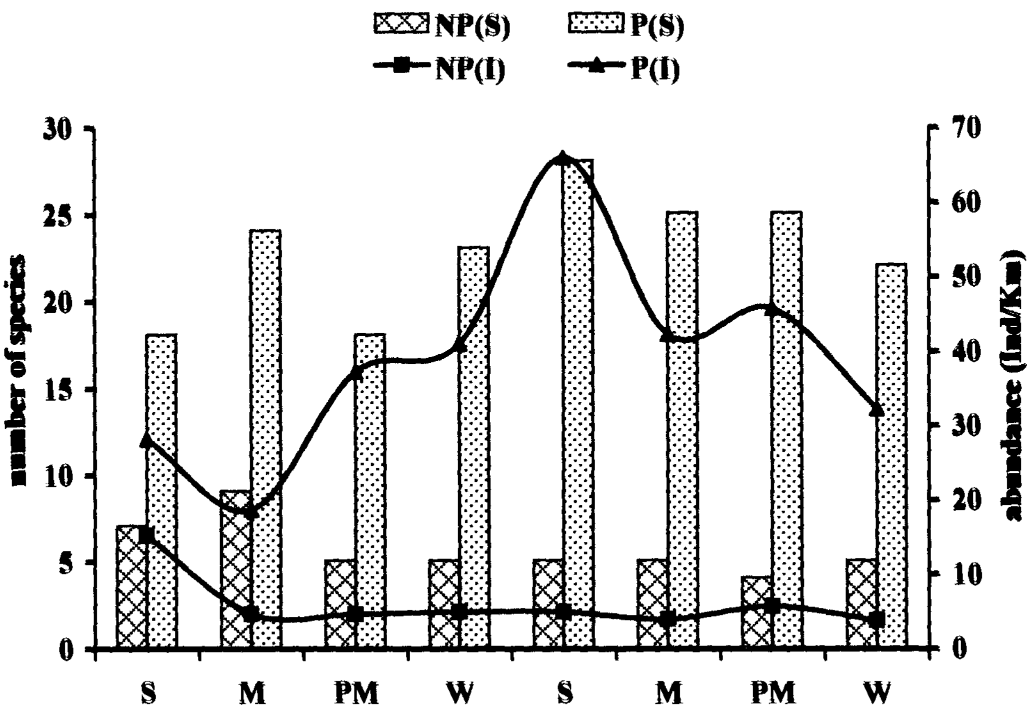
Graph 4.15:
Biennial profiles of passerine and non-passerine birds in the 4 study sites.



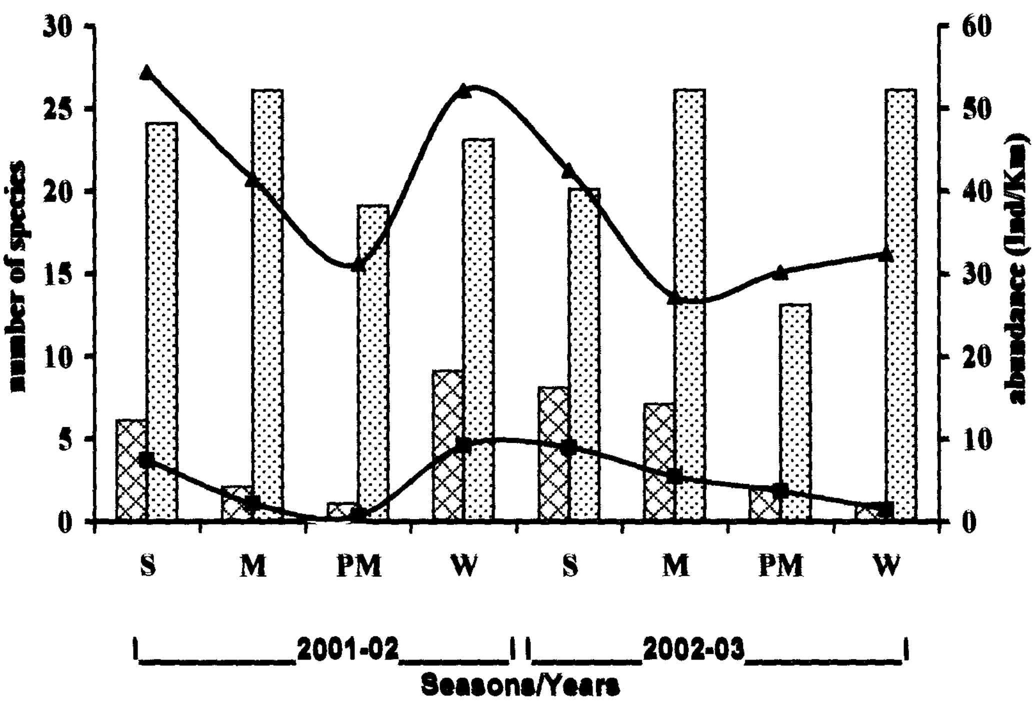


Graph 4.16:
Seasonal variations in nonpasserines and passerines in natural forest and monoculture plantations.

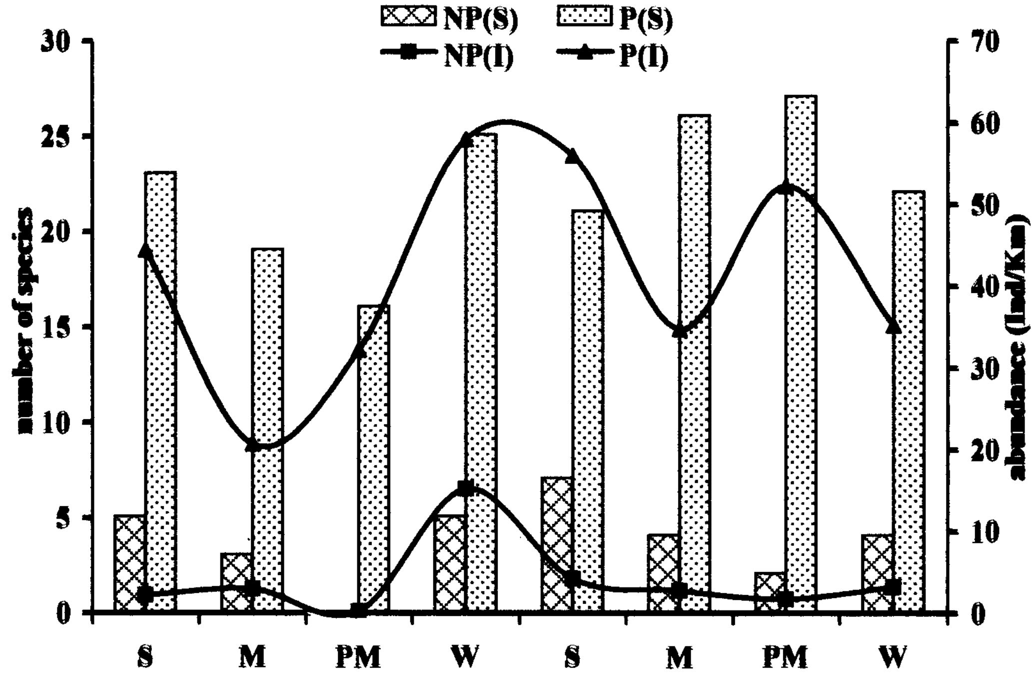
Natural forest



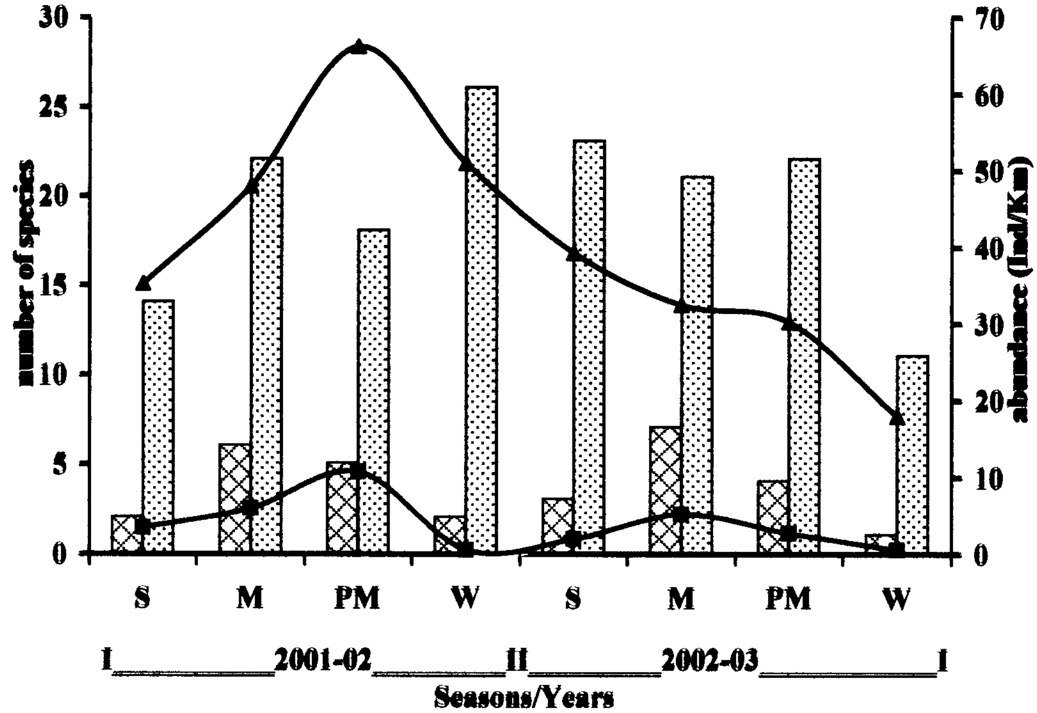
Teak Plantation



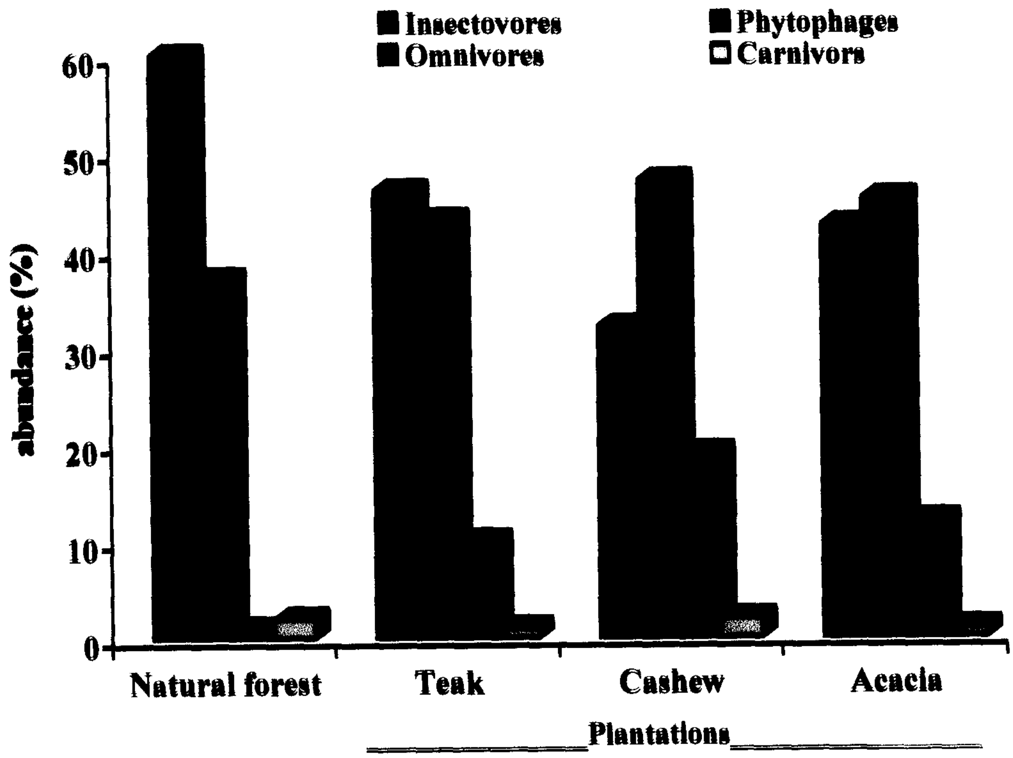
Cashew Plantation

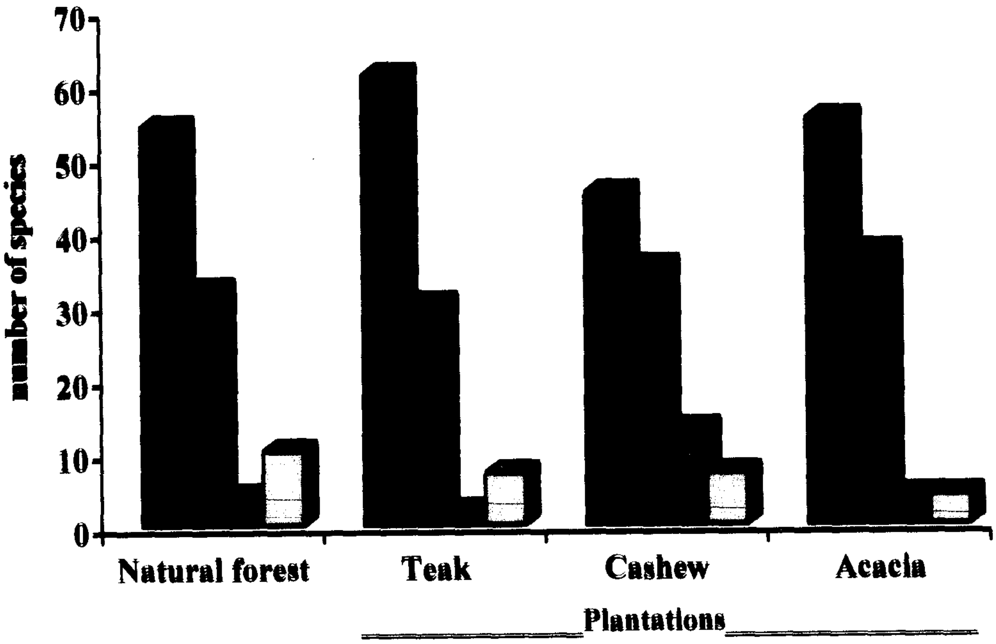


Acacia Plantation



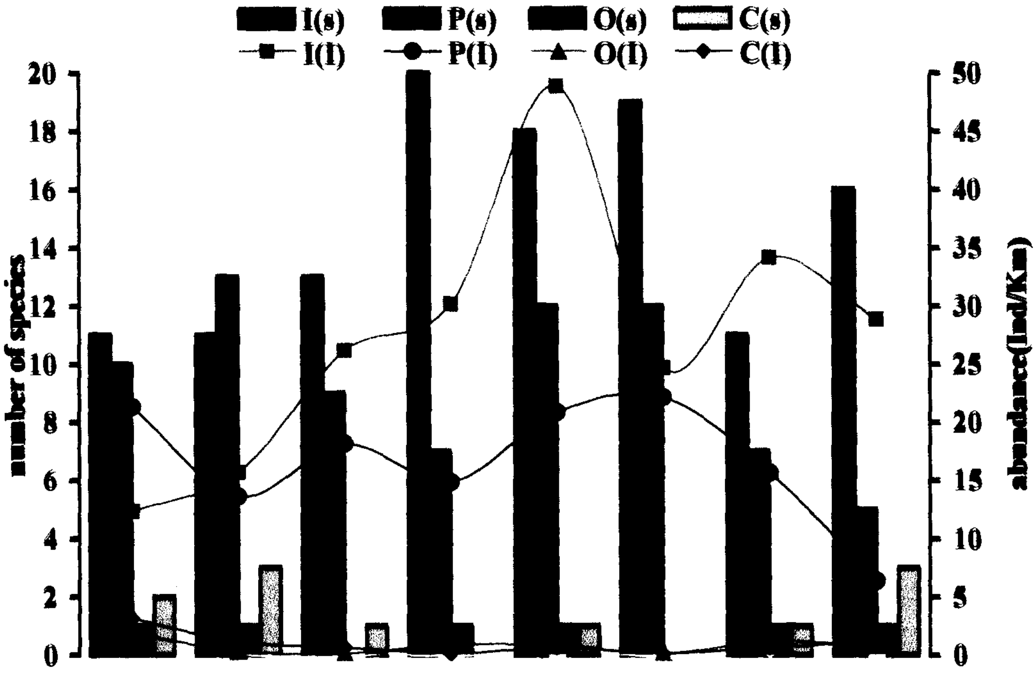
Graph 4.17:
Feeding guild based composition of avifauna at the study sites.



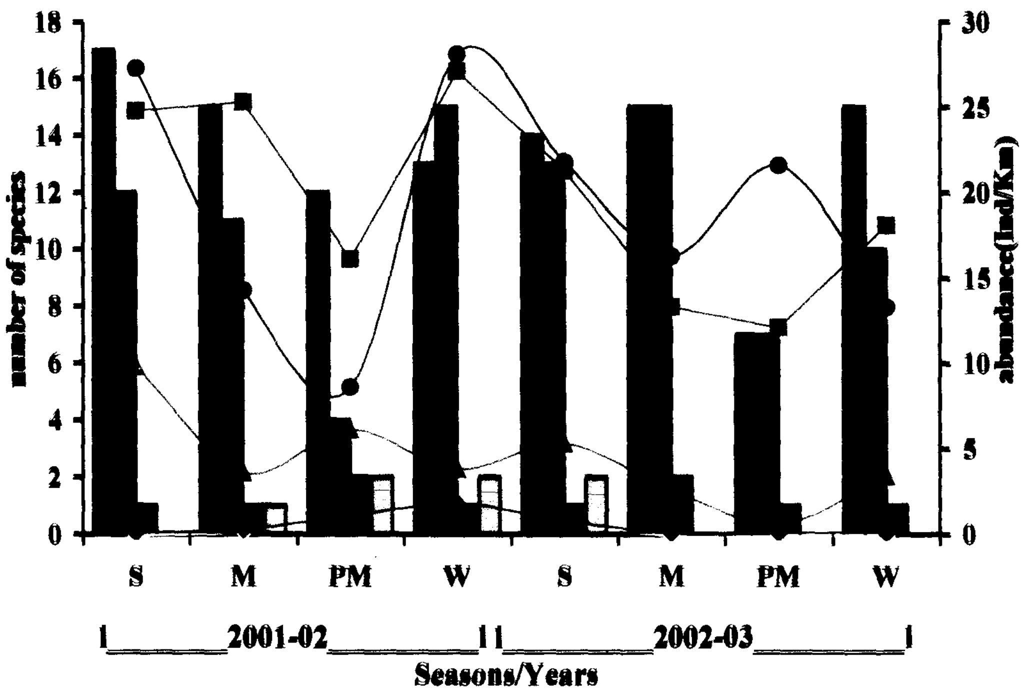


Graph 4.18:
Seasonal variations in the diversity and abundance of birds belonging to different feeding guilds.

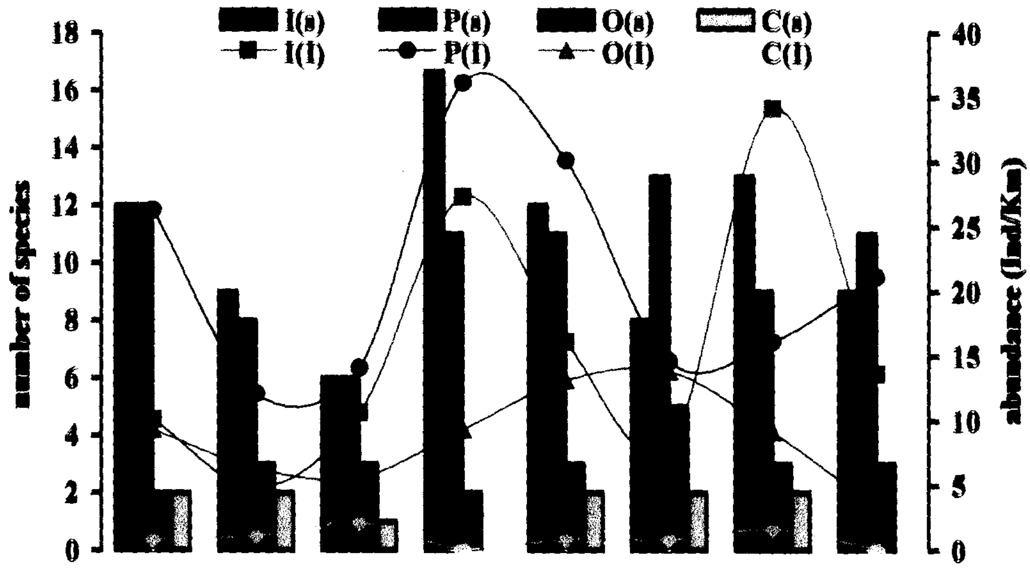
Natural forest



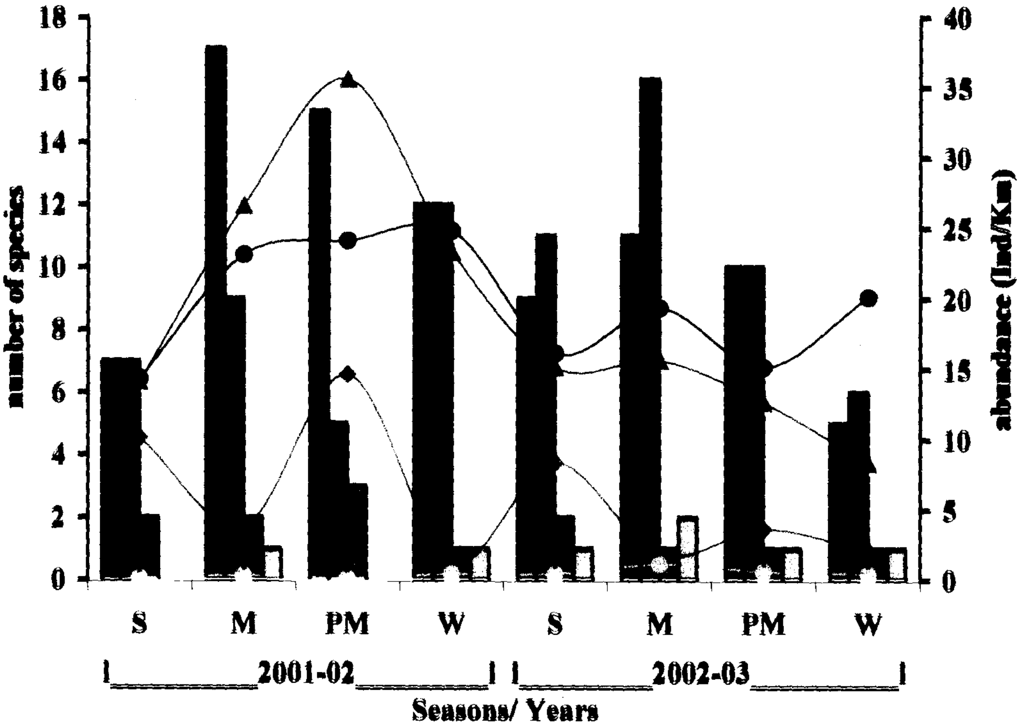
Teak plantation



Cashew plantation



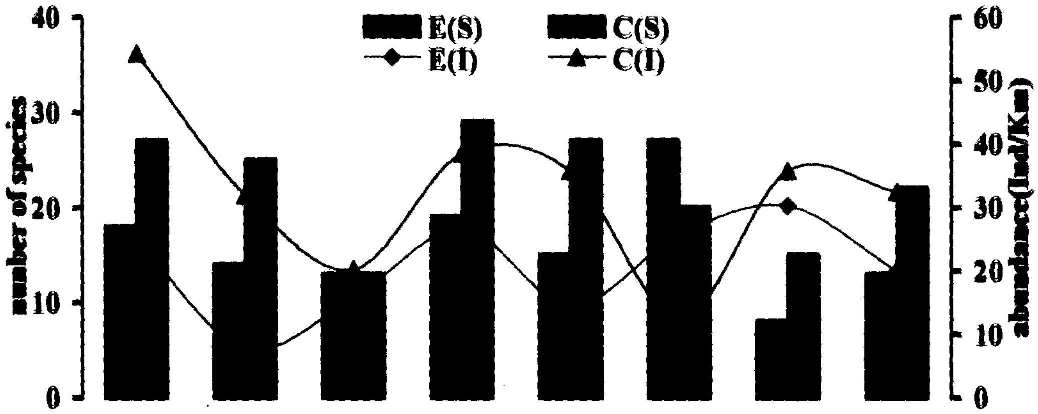
Acacia Plantation



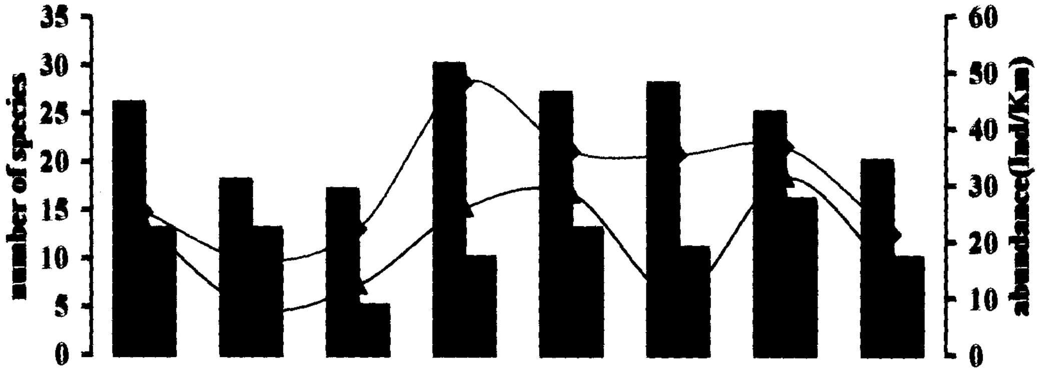
Graph 4.19:

Seasonal variations in the diversity and abundance of birds on the edge and centre of the three monoculture plantations.

Teak plantation



Cashew Plantation



Acacia plantation

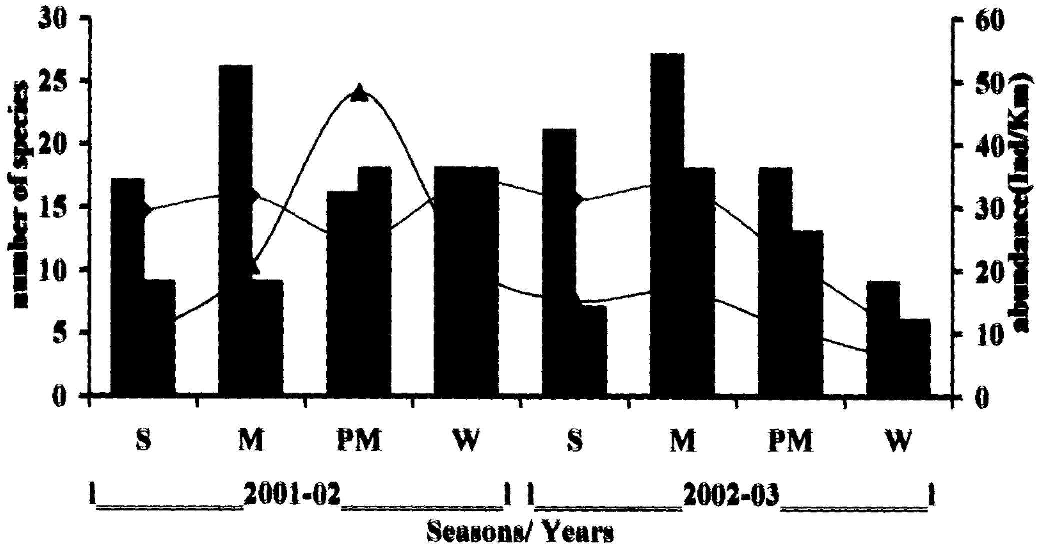


Fig. 4.1:
Dendogram illustrating the relationship between the plantations and natural forest in terms of bird species similarity indices.

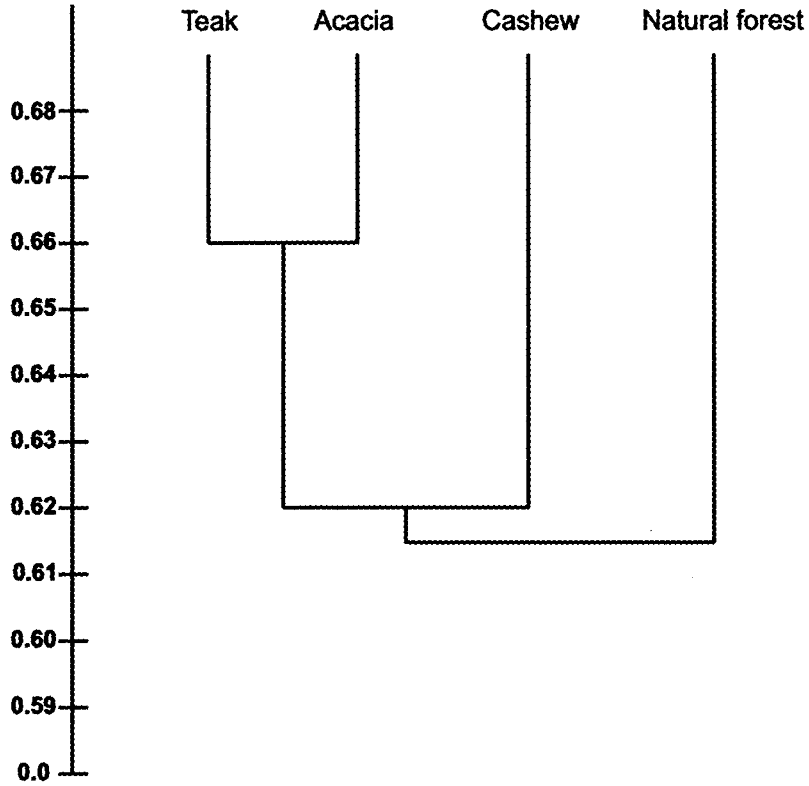


Fig.4.2:

Months of occurance of migratory birds in the study region onthe basis of year long study

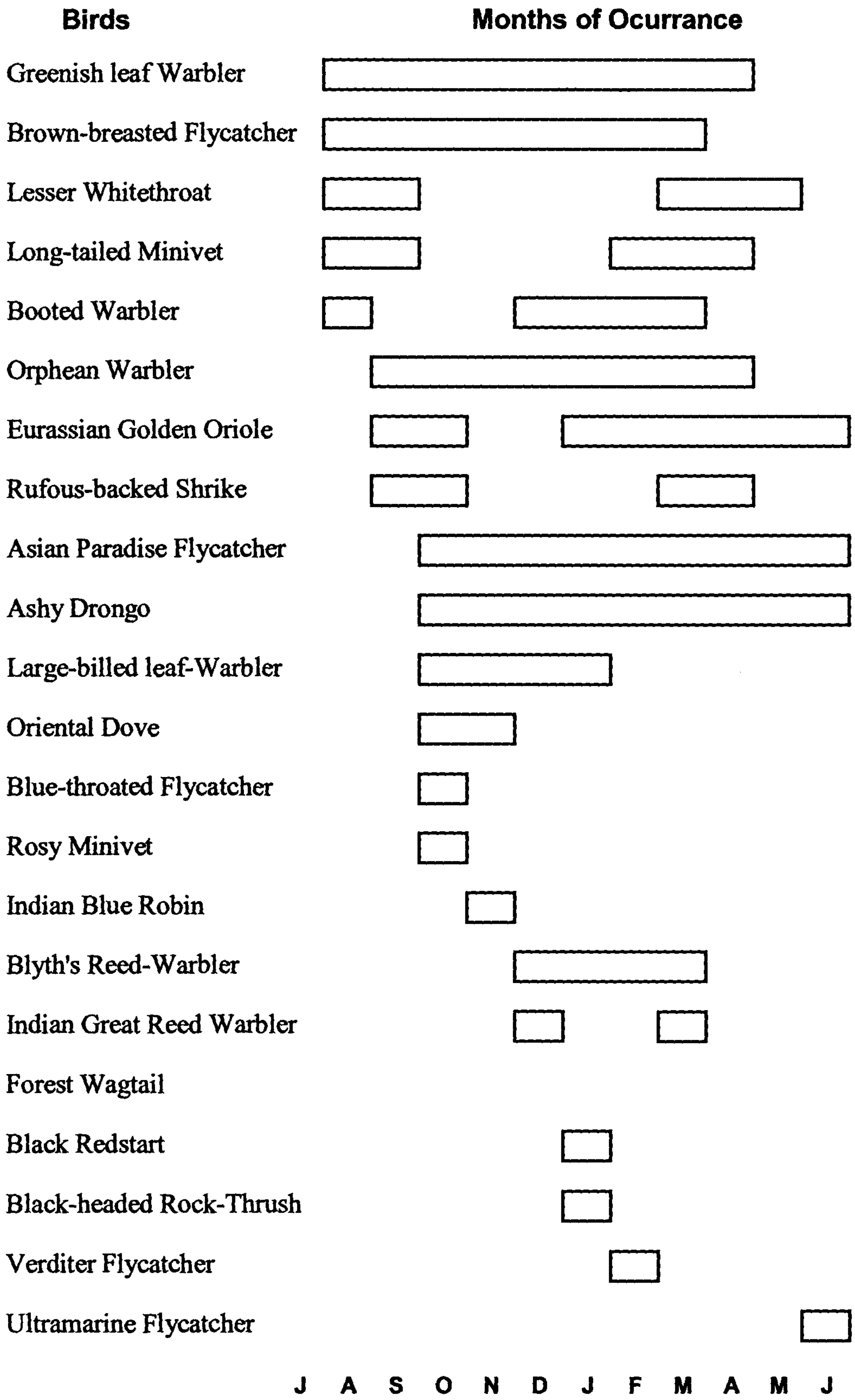
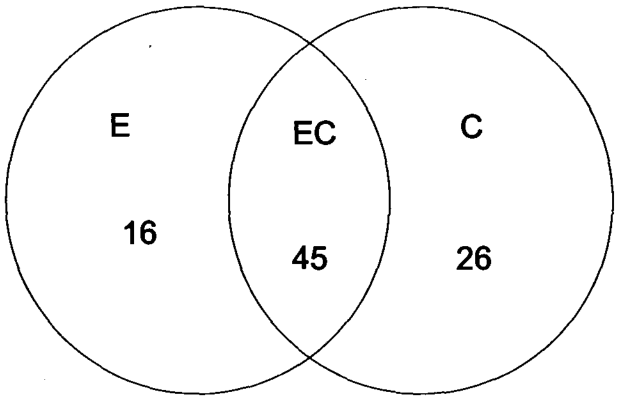
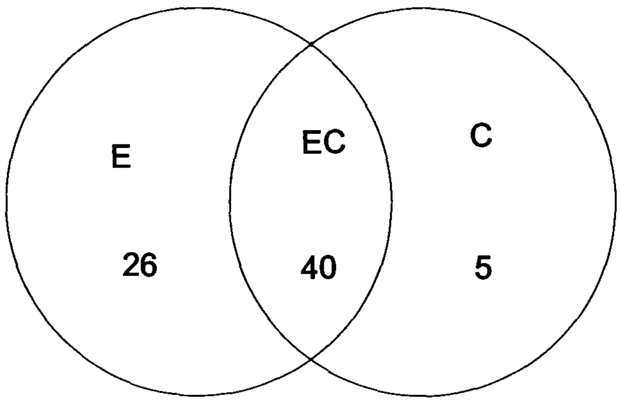


Fig.4.3:
Figures showing the number of bird species occurring at the edge, in the centre and common to both the regions in the monoculture plantations.

Teak plantation



Acacia plantation



Cashew plantation

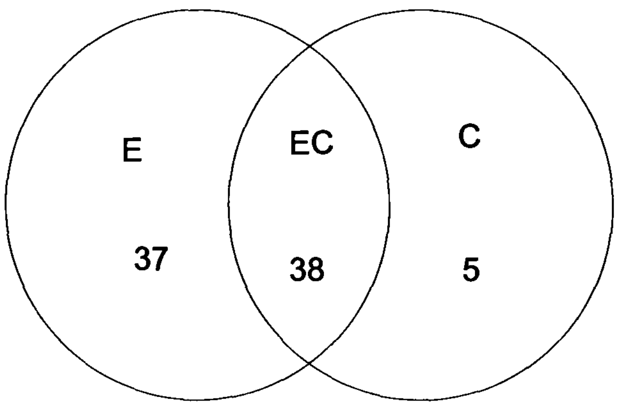
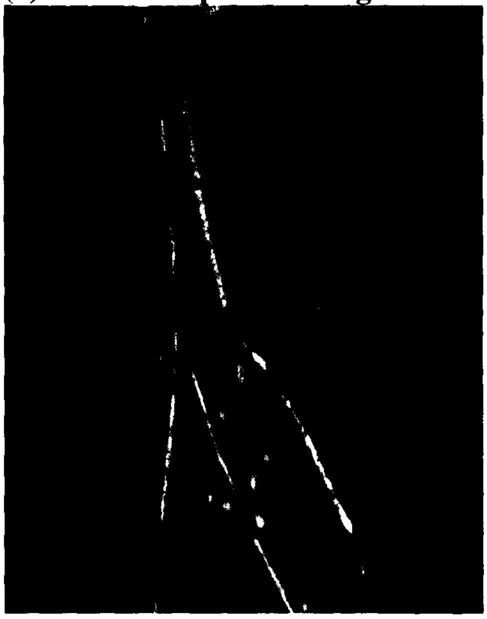
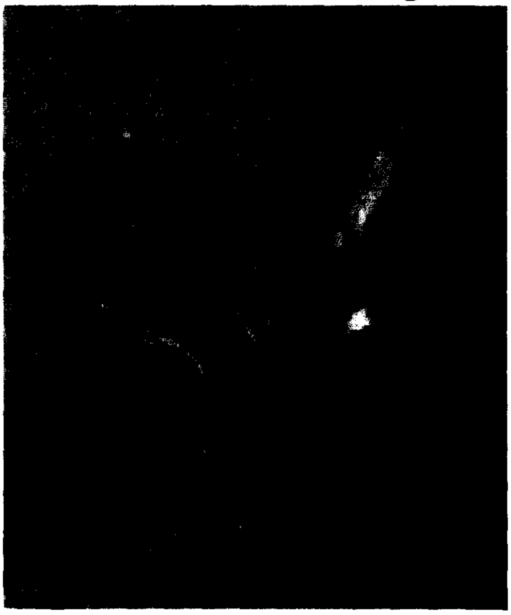


Fig 4.4: Some plant species in natural forest depicting flowering and fruiting states.

(a) *Aporusa* sp. in fruiting



(b) *Bombax ceiba* in flowering

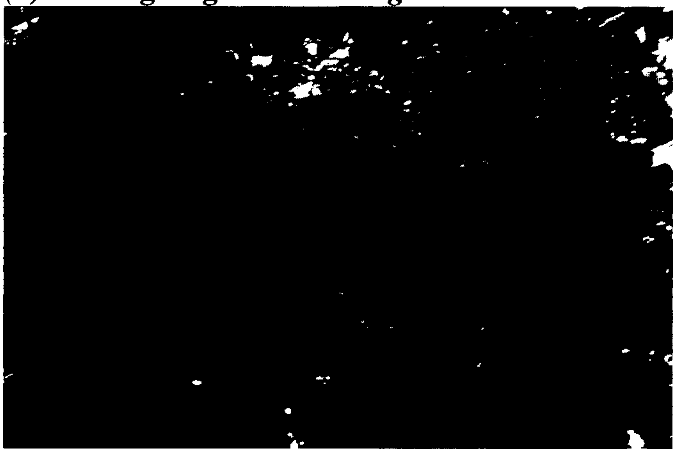


(c) *Calycopteris floribunda* in flowering

(d) *Lea* sp. in fruiting

Fig 4.5: Selected phenological states in plantation species.

*(a)*Fruiting stage of *Tectona grandis*



(b)Flowers and fruits of *Anacardium occidentale*

*(c)*Initial flowering in *Acacia auriculiformis*

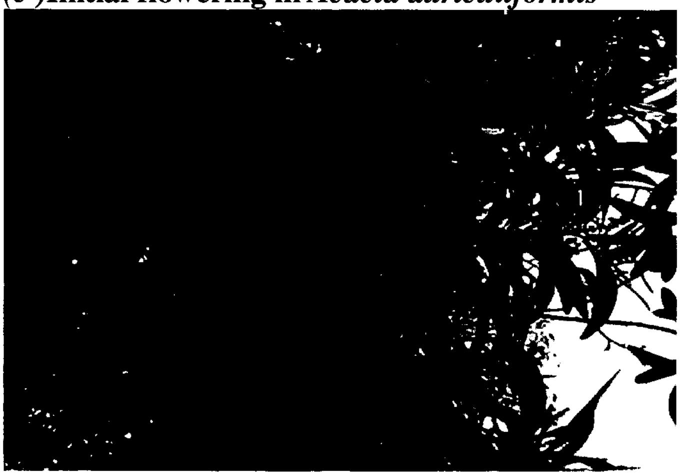


Fig 4.6: Undergrowth in plantations

(a) Thick understorey dominated by the weed *Chromolena odorata* in CP

(b) Clerodendron viscosum, an indicator species for better soil fertility dominantly occurring in the understorey of AP.

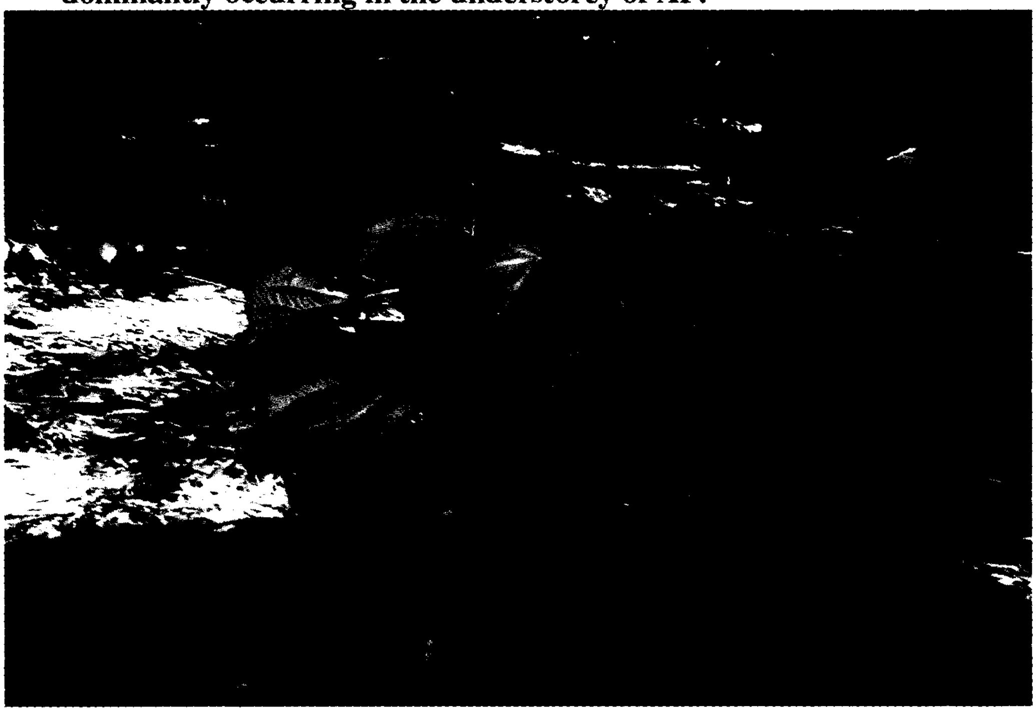


Fig 4.7: Magnitude of litter in Plantations

(a) Scanty litter in teak plantation

(b)Dense leaf litter forming a thick mat on the floor of AP.

Fig 4.8: Dominant birds species

(a) Greater Racket-tailed Drongo, the 2nd most dominant bird species found in NF.

(b) Purple Sunbird, one of the dominant bird species in TP and CP.

(c) Jungle Babbler, the 2nd most dominant bird species in CP

(d) Black-headed Oriole, a dominant bird species inhabiting the AP.

Fig 4.9:

(a) White-hooded Babbler- a new sighting for the region, exclusive to NF.

(b) Rufous-backed Shrike, a local migrant sighted in NF and CP.

Bird species common to all the study sites

(c) Red-whiskered Bulbul

(d) Tickell's Blue-Flycatcher

Fig 4.10: Nests of birds found breeding in the study sites.

(a) Orange-headed Thrush in NF

(b) Racket-tailed Drongo in TP

(c)Jungle Babbler in CP

(d) Red-whiskered Bulbul in all plantations.

Chapter 5:

DISCUSSION

Plant Phenology

Phenology indicates quality of forest system and serves as an important attribute for evolving management programme for any forest (Balsubramanian & Bole, 1993; Chhangani, 2004)

Newton (1988) based on his studies on dry deciduous forest in the highlands of central India, concluded that peak flowering coincides with hot weather or summer, despite some flowers and fruits being available throughout the year. The present study revealed that in primary lateritic semi evergreen forest also, peak flowering and leaf shed is during summer. But some or other canopy and undergrowth flora is in bloom or fruition throughout the year.

The observations during the current study as to the phenological parameters of teak plantation, flowering extending the most of the monsoon, fruiting during post monsoon and leaf fall in winter are in conformity with the earlier studies in other parts of the country (Singh et. al. 2001).

Cashew in its native is known to bear flowers in March and April, and the fruits maturing approximately 3 months after, turning to bright yellow or red (www.desert-tropicals .com). In the course of present study, in Goa flowering in cashew was noticed to commence fairly early by December reaching a peak in March and bore fruits till the end of summer i.e. May.

Acacia is said to have flowers throughout the year, with timing of peak bloom varying with locality (Booth & Turnbull, 1994). During the present study it was found that acacia in the region has a definite flowering season from September to February.

Undergrowth

The undergrowth in any natural forest is a normal component of the ecosystem contributing immensely for its healthy floral and faunal diversity. There are differences in opinions regarding the normalcy of undergrowth in plantations. Some workers are of the view that plantations prevent understorey vegetation, thus resulting in decreased biodiversity and increased soil erosion, ultimately resulting in loss of fertility (Poore and Fires, 1985; Abbasi and Vinithan, 1997; Reversat, 2001). On the contrary others

(Gledenhnys, 1997; Harrington and Ewel, 1997) found that plantations helped in establishment of undergrowth plants from surrounding forests, thus regenerating the biodiversity, increasing fertility and animal population (Brosset, 1997; Mboukou-Kimbatsa et al. 1998).

In the present study also it was observed that undergrowth in NF was more diverse than that at all the monoculture plantations, though not significantly different. The finding is in consonance with those of earlier workers (Poore and Fires, 1985; Abbasi and Vinithan, 1997; Bouvet, 1998). It is relevant to note that even in secondary natural forest, the undergrowth has been observed to be more diverse than in plantations (Reversat, 2001).

On the other hand, in terms of density the undergrowth in TP as well as AP was as good as in NF. It could be due to fairly advanced age of these plantations over 20 years, and also their close proximity to the primary forest. An improvement in the undergrowth with the increase in age of plantation is said to be a common phenomenon (Parrotta,1999; Abbasi and Vinithan, 1999). Further, the positive influence of proximity of natural forest on undergrowth has already been suggested (Parrotta, 1993).

The undergrowth in CP was completely different from other sites owing to its significantly lower diversity and higher density. This appears to be principally because of the dominance of the weed, *Chromolena odorata* in the undergrowth and its extensive vigor. The weed is known to be allelopathic not allowing any other vegetation to establish in its surroundings (Muniappan, 1994).

Undergrowth densities as well as diversities in all the study sites showed seasonal variations, with abundance in monsoons and post monsoons. It also correlated positively with rainfall. It is only but natural, as annual herbs dominated the undergrowth in all the study sites. Secondly the rainfall appears to be one of the important limiting factors regulating the undergrowth in NF as well as plantations in subtropical belt.

Plant indicators are known to be of great value in finding out the potentiality and capability of lands. They have been used extensively as an aid in determining the suitability of lands for various land use purposes (Devaraj, 1999). The plant, *Clerodendron viscosum* is identified to be an indicator highlighting favorable soil condition while others such as *Holarrhena* *antidysentrica* and *Helicteres isora* are supposed to indicate unfavorable soil states (Lal, 1992). On the basis of these criteria, the occurrence of the former species in the undergrowth at NF, CP and AP; and occurrence of the latter species in undergrowth at TP amount to indicate that soil in TP is poorer than that in other study sites.

Litter

A substantial portion of the accumulated nutrients in the plant biomass is returned to the soil through litterfall (Vidyasagaran, 2002). Therefore, the litter with the associated events such as litterfall, litter decomposition and nutrient release is an important component of biogeochemical cycles. Nitrogen fixing plants are known to have higher litterfall (Parrotta, 1999). The findings in the course of present study that the litterfall in AP was significantly higher compared to NF and other plantations is substantiating the observation, as Acacia has nitrogen fixing potential, being a leguminous plant. The regulation of litterfall has been attributed to various environmental factors such as water stress, light intensity, photoperiod, mineral deficiency and mechanical effect of rain (Bray and Gorham, 1964). Quite a few studies have shown that peak litterfall during summer is a common feature in many forest types and plantations (Baker, 1983; Pande and Sharma, 1986; Sanchez & Alvarez Sanchez, 1995) and water stress has been identified to be an important regulating factor. In the present study the seasons with maximum litterfall were noted to be different for NF and the plantations. The leaf fall was more in summer in NF, while it was at its peak in TP and CP in winter and in AP during postmonsoon. Therefore it appears that besides environmental factors, genetically preprogrammed physiognomy of plant species might also be regulating the phenomenon, and hence the variations in the peak seasons of litterfall in monoculture plantations. However the response of heterogenous flora of NF might collectively be falling in line with majority of the forest systems with peak litterfall in summer in tune with water stress.

A negative correlation between litterfall and rainfall has been reported in forests of subtropical belt (Sharma & Ambasht 1987; Pant & Tiwari, 1992), which was also true with NF in the present study. According to Misra &

Nisanka (1997), no relation exists between temperature and litterfall, which is substantiated by the current observations in different plantations.

Singh et. al. (1993) in the course of their studies on litter decomposition in plantations of teak, sal , poplar and eucalyptus in the Central Himalayan subtropical belt observed higher decomposition rate in teak, which they attributed to a series of factors such as physical and chemical properties of leaf, fast disappearance of nitrogen and calcium content, and perhaps to the presence of high termite population at the site. Similar findings on teak litter during the present study indicate that the decomposition of the litter of teak is faster in tropical region also.

Singh et. al. (1993) also opined that litter of the species having highest nitrogen content showed the fastest rate of decomposition and that with lowest nitrogen content decomposed very slowly. The slowest decomposition of acacia litter having highest nitrogen content observed in the present study is diagonally contrary to the said view. Hence, something other than nitrogen content might also be determining the rate of decomposition of leaf litter of different plant species. Leathery texture and high levels of polyphenols might be responsible for the retarded rate of decomposition in acacia litter as reported earlier in semi-humid tropics of Togo (Drechsel et. al. 1991).
Joshi et. al. (1999) observed a positive correlation between the loss of weight in decomposing litter of five different tree species and atmospheric temperature in subtropical tarai of UttarPradesh. Contrarily a negative correlation was found between the parameters in the current study at all the sites, but for TP. The variations in subtropical and tropical conditions could be responsible for the differences.

Austin (2002) noted that low rainfall lead to lower production of litter and also its decomposition in tropical Hawaii. Many other workers in the field (Pant and Tiwari, 1992; Singh et. al. 1993; Joshi et. al. 1999), who observed higher rate of litter decomposition in monsoon credited it to suitable atmospheric temperature and moisture for microbial activities and also to leeching of water soluble substances from the bio-mass. Thus the findings of the present study that litter decomposition rates in NF as well as other plantations were higher in monsoon than those of other seasons are in concurrence with the earlier studies cited above.

Maheshwaran and Gunatilake (1988) observed an increase in concentrations of N and P content in the decomposing litter of some common forest trees in Sri Lanka with the increase in duration. Misra and Nisanka (1997) arrived at similar conclusions based on their studies on the litter of *Casuarina* in subtropical region. The identical results obtained in the present work as to the behaviour of N and P in the decomposing litter of the NF and other plantations but for TP, confirm it to be a general phenomenon, but for few isolated exceptions. Microbial immobilization, translocation, inputs through precipitation, addition through insect frass, leaching from fresh litter are listed to be the series of factors responsible for the phenomenon in isolation or combination (Bocock, 1964; Gosz et. al. 1973; de Catanzaro & Kimmins, 1985). The teak litter also can't be considered as clear exception to the general trend; taking in to account the marginal rises in P content in it through intervening phases. The totally different annual picture could be owing to the fastest rate of decomposition of teak litter because of its paper-thin texture.

Immobilization of potassium is also reported by some workers in different parts of globe (Lousier & Parkinson, 1978; de Catanzaro & Kimmins, 1985 and Upadhyay & Singh, 1989). But the precipitous or gradual release of the element from the decomposing litter in all the sites in the present study is in agreement with the findings by some of the earlier works (Maheshwaran and Gunatilake,1988; Misra & Nisanka, 1997).

Soil nutrients

The soil system depends largely on organic materials for the nitrogen content because it is not constituent of rocks (Singh and Mudgal, 2002). The high C: N ratio in the tree leaf litter has the potentiality to enrich the soil by liberating the nutrients for the growing vegetation. Nutrients added through litterfall maintain fertility of the soil. Higher accumulation of litter on soil surface under the plantations are known to enhance soil carbon (Jha et. al. 2000) and nitrogen (Singh et. al. 2001). Likewise the likelihood of higher nutrient store in soils with higher organic matter is an established fact because it provides more exchangeable site available to hold nutrient against leaching losses besides acting as a nutrient reservoir (Santos, 1997). In view of the above sighted facts the highest levels of carbon, nitrogen and potassium in the soil in AP paralleling with significantly higher litterfall at the site is but natural. It may also be noted that Santos (1997) recorded higher potassium content in the soil at Eucalyptus plantations coinciding with higher organic matter.

In this background, the lowest levels of all the nutrients in the soil of TP compared to those at NF as well as other plantations observed in the present work are self explanatory. The lowest litter production and least accumulation of the same owing to its fast decomposition must be the contributory factors for the observed results. The lower nitrogen levels in the soil of TP noticed in the present work are in agreement with similar findings by Singh et. al. (2001) in subtropical belt of Arunachal Pradesh. But it is difficult to comprehend the higher carbon contents obtained by the same authors in the soil in TP compared to that in NF in contrast with our findings. The authors have neither provided the profile of litter fall in NF in the region nor the extent of undergrowth in teak plantation studied by them. Therefore one plausible explanation is that, more dense multistoryed flora in NF in the high rainfall (3500 –5000mm/Yr) belt of Arunachal Pradesh might be exerting greater demand on the nutrients of soil which in turn might be responsible for lower levels of carbon in natural forest compared to teak plantation.

Organic carbon and nitrogen are considered to be the main factors responsible for soil fertility and hence to ascertain the soil condition (Jha et. al. 2000). The root systems of Acacia are also known to contain nitrogen-fixing bacteria, which can help in rejuvenation of the poor soils (Khanna,1994). The higher levels of nitrogen and carbon in acacia plantation recorded in the present study besides the occurrence of the indicator plant species *Clerodendron viscosum* confirm beyond doubt the soil fertility improvement potential of the plantation species.

In deciduous species, the immediate demand of the resumption of entire foliage mass every year, necessitate the recovery of nutrients by translocation from the dying foliage, because acquisition of nutrients through active absorption from the soil is costlier (Pande and Sharma, 1993). In this regard the teak is considered to be much more efficient in nutrient conservation, returning less amount of nutrients through leaf fall to the floor (Pande and Sharma, 1993). In view of the above facts, the poor quality of litter and soil in TP observed in the present study is self explanatory.

Insects

There are differences of opinions as to the relation between richness of plant species and insect abundance. According to Risch et. al. (1983) the loss of plant diversity causes lower insect richness and higher abundance. Conversely Haddad (2001) through his field experiments carried out at Minnesota opined that higher plant species richness increased insect species richness as well as abundance. In the present study higher insect abundance was noticed in all plantations compared to the natural forest, but no perceptible change in diversity was noticeable, thereby partially confirming the view of Risch et. al. (1983)

In Malaysian tropical Dipterocarpus forest the ants (Formicidae) constituted the largest portion of insect fauna, the beetles being second largest and orthopterans with smallest representation (Wong, 1986). Present study confirms the observation and goes a step further ascribing the dominant status to the Formacid ants of Hymenoptera, not only in natural forests but also in the plantations with the exception of Acacia, wherein they acquired 2nd place. Though the orthopterans were a small group in Malaysian forest, in the present study they were found to occupy first place in AP and 2nd or 3rd place in other sites, prescribing the supremacy of the order amongst insects in this part of the world. The orthopterans were predominantly represented by *Gryllus* sp. in NF as well as all the plantations probably owing to its omnivorous food habits (Veeresh and Rajagopal, 1983; Ganihar, 1990) coleopterans gained 2nd or 3rd rank in the present study sites. Thus proving beyond doubt that the 3 orders Hymenoptera, Orthoptera and Coleoptera dominated the insect world in natural forests as well as many plantations in tropical belts.

Long-term studies in tropical forests have demonstrated that insect populations exhibit pronounced seasonal fluctuations (Levings & Windsor,1982; Wolda & Wong, 1988; Develey and Peres, 2000). Further, they are reported to be abundant in tropical forests during rainy season (Fogden, 1972; Charles-Dominique, 1971). In the present study, in all the study sites the insect abundance was observed to be consistently higher in monsoons. It also showed positive correlation with rainfall in acacia and cashew plantations. High food availability in the form of newly germinating herbs and sprouting shoots for herbivores; decomposing organic matter to detritivores; and these herbivores and detritivores serving as prey to predators might have collectively contributed to the phenomenon. Besides, the flowering in teak and acacia in mid and late monsoon respectively might also have added to nectarivores in the season. The higher diversity and abundance of insects in TP compared to all other study sites observed in the present study is in agreement of the view that broad leaved deciduous forests support more insects (Haartman,1971).

Birds

Buffering of the plantation effect

Bird communities have been frequently used for assessing the conservation programmes, monitoring the wildlife habitats (Daniels, 1989; Raman & Sukumar,2002) and also planing their management aspects (Williamson, 1970).

The diversity of bird species is said to increase with increasing diversity of vegetation (Ripley, 1978). The food resources such as fruits and flowers are said to influence distribution patterns of many forest birds. Some of the capture based studies from Central and Southern America showed that bird population showed positive correlation with the availability of food resources spatially as well as temporally (Levey 1988; Loiselle and Blake,1991 and 1993). Further structurally complex vegetation types are known to provide greater stability to resource availability (Janzen, 1967) thereby increasing the diversity of the fauna exploiting the resource (Smythe, 1974). In this background, the marginally better abundance of birds, and their reasonably higher diversity observed in natural forest in the current study is but natural in view of the flowering and fruiting, spread across the year owing to its diverse tree population and the undergrowth.

In the present study the plantations, particularly those of teak and cashew were observed to be closely on the heels of the NF in terms of bird abundance and diversity despite the marginal edge of NF over plantations. It may be because of one or more of the following factors. All the plantations studied had natural forests in close proximity on one or more sides.

Secondly certain amount of floristic heterogeneity existed within the plantations because of a few indigenous / native forest trees.

Thirdly plantation floors had undisturbed substantially diverse or dense undergrowth.

These findings may have to be viewed in the backdrop of some of the earlier reports. Bell (1979) observed lower bird diversity in teak plantation compared to that in rainforest of New Guinea, and went a step ahead to suggest the preservation of rainforest areas adjacent to the plantations to improve the situation. Studies on pine plantations in Central Chile (Estades and Temple, 1999) showed that vegetation adjacent to plantations or forest fragments had significant positive impact on the birds inhabiting them. An enhanced avian use of pine stands in Puerto Rico was reported because of heterogeneity provided by understorey shrubs, vines and few retained upper storey trees (Cruz, 1988).

Khan (1978) based on his studies in Nilgiri Hills reported that Acacia supported least number of bird species 'as food is almost absent' in the plantation. However, in the course of present work though acacia was found to harbour substantially lower bird diversity, in terms of abundance it was only marginally lower than natural forest and the other plantations. It may be noted that even though Acacia doesn't produce plenty of nectar or edible fruits, their plentiful seeds are considered to be valuable food resource for the birds, particularly in dry places (Khanna. 1999). Even in the present study the Red vented- and Red whiskered- Bulbuls were seen to feed on the seeds of Acacia. Secondly Acacia plantation supported abundant insect fauna more than that of natural forest and the cashew plantation, naturally catering the needs of insectivorous birds. Therefore it is obvious that AP supported fairly abundant bird fauna, though least compared to those at other sites studied.

Undergrowth & the birds

In drier countries due to absence of undergrowth few birds are reported to occur in plantations (Smith, 1974). On the other hand plantation areas with high rainfall such as Congo were shown to permit development of undergrowth thereby favouring the occurrence of birds (Loumelo and Huttel, 1997). Reversat (2001) opined that abundance of undergrowth determined the diversity and density of birds in plantations. On the contrary, Duncan and Chapman (1999) were of the view that the abundance of birds in old plots might contribute to the dispersal of the seeds of undergrowth vegetation, resulting in the maintenance and the increase in its diversity and density. In the present study undergrowth in TP and AP was on par with that in natural forest in density; while though lower was not significantly different in diversity. The condition might be owing to the high precipitation in the region besides the higher age of over 20 years of stabilized plantations. It may be noted that the undergrowth in all the study sites correlated positively with rainfall. In CP significantly poor undergrowth diversity might be due to its significantly high density, made possible by overpowering weed *Chromolena odorata*. Thus fairly better undergrowth in all the plantations might also have contributed to the abundance and diversity of birds in them being identical or near identical with those of natural forests.

Impact of environment and physiognomy

The negative correlation registered between bird abundance and rainfall in lateritic semievergreen forest currently studied, is in concurrence with similar observation by Jayson and Mathew (2000 a & b and 2002) in evergreen forest of southern Western Ghats. But such a correlation was not seen in plantations of moist deciduous teak or evergreen species like cashew and acacia. On the contrary, AP had highest bird diversity in monsoon /postmonsoon and lowest in summer. In view of the peak flowering in the plantation in monsoon and also concomitant rise in insect abundance at the site and the total absence of flowers or fruits in summer seem to be the obvious reasons for the observed phenomenon. The bird abundance in TP was in summer and it also showed positive correlation with sunshine and negative correlation with humidity. It seems to be the reflection of greater patronage of insectivores for the plantation, and leafless state of deciduous teak trees in winter/early summer facilitating better view and free sallying of insectivorous birds. It is note worthy that Robin and Davidar (2002) were also of the opinion that leafless branches of deciduous trees might be offering unobstructed view for searching the prey. In CP bird abundance correlated with sunshine positively, being highest in winter or summer coinciding with flowering and fruiting seasons respectively. Thus the sum total of physiognomy of plants and associated events rather than environmental factors *per se* have a greater influence on bird population in natural forest or plantations.

Forest generalists Vs Forest specialists

The alterations in the habitats are known to affect bird population considerably. Different species may respond differently. While most species decrease in their densities, a few may decrease substantially or disappear from the site altogether. In contrast a few species also could increase in abundance in altered habitats. In this whole gamut of changes the common species are known to benefit from habitat disturbances at the cost of rare specialized restricted range species (Leck, 1979; Raman, 2001; Raman & Sukumar, 2002). Carlson (1986) through his studies on pine plantations in Kenya showed that more forest generalist species than forest specialist species were encountered in plantations.

In the present study Red whiskered Bulbul, an omnivore was sighted rarely in natural forest and there were no encounters with the signs of its breeding activity at the site during this 2 year long study. But it was not only frequently observed in plantations occupying 1^{st} & 2^{nd} rank of in dominance in cashew and acacia plantations respectively but also found breeding in all the plantations. Likewise another omnivore, Jungle crow ranking 5^{th} in both cashew and acacia plantations and 10^{th} in teak plantation was absent from natural forest. Oriental magpie Robin was the another generalist bird that was absent from natural forest occurred in all the plantations. It may be noted that Red whiskered bulbul was detected only in spice plantations of cardamom and not in primary rain forest of Niligiri sholas (Raman and Sukumar,2002). Similarly, Reiko and Robert (2003) found that jungle crows were more abundant in small/disturbed forest than in large forests in Japan.

On the other hand the Chestnut-bellied Nuthatch, a foliage gleaner, ranking third in terms of dominance in natural forest was exclusive to this site. The foliage gleaners like nuthatch are known to forage well in moderate to dense foliage, as open areas with few leaves offer reduced insect densities while large size leaves hinder their mobility (Pearson, 1975). Similarly the diet guild based analysis in the present study also showed that the natural forest harbored more carnivores and nonpasserines than all the plantations. Thus the present study concurs and authenticates the concept that only the natural forest with extensive array of microhabitats, diverse and sustained food resource can support forest specialists generally occupying higher trophic levels, while the forest generalists such as omnivores can find refuge in plantations.

Differential treatment of feeding guilds

The foraging environment ultimately determines which bird species can successfully exploit and survive in a particular habitat, and as a consequence influences community structure and species diversity of birds (Robinson & Holmes, 1984). Therefore, habitat structure is expected to strongly influence avian guild structure (Vale et. al. 1982). Thus the number of individuals in a guild reflect the availability of the resource supporting it, whereas the number of species included suggest how finally these resources are shared (Wong, 1986). Naturally the similarity in guild structure suggests that similar resource types are available in similar proportions (Wong, 1986; Mac Nally, 1994). Likewise, the dissimilar guild structure suggests that the resource utilization pattern of birds in the varied vegetation types is different (Johnsingh & Joshua, 1994). Besides, difference in food availability the foliage structure of vegetation also influences habitat use by birds (Cruz, 1988).

In the present study the insectivorous birds constituted the dominant guild in natural forest as well as all the monoculture plantations. The findings are in agreement with similar results obtained by earlier workers (Boletta et.

al.,1995 and Giannini,1999) in Argentinean subtropical forests. Amongst the plantations the insectivores were more in TP on both counts, ie. abundance as well as diversity. As discussed earlier, the highest abundance of insects in TP compared to other plantations and exposed perches provided by tall teak trees with open canopy, more so in winter/summer owing to their deciduous nature might have been the collective causes for the same. The findings are in consonance with the earlier comparative studies on deciduous and coniferous forest wherein it was shown that former habitat had higher species richness than the latter (Salt, 1957; Winternitz, 1976; Beedy, 1981; Hansson, 2000). It may also be pertinent to note here that ants and beetles were the most frequently found insect groups in bird stomachs in tropical Dipterocarp forests of Malaysia (Wong, 1986). Incidentally these were also the dominant groups of insects in all the study sites in the present study.

While phytophage representation in the plantations neither differed from that at natural forest nor amongst themselves. On the other hand omnivores not only were more in all the plantations compared to those in natural forest, but also were significantly higher in their abundance as well as diversity in the Cashew plantation. The findings are clear reflections of the fact that all the plantations under study met the needs of phytophages on par with the natural forest, while omnivores could show better adaptability to plantations in general and cashew plantation in particular. In this context the observation by May (1982) that the omnivores are expected to do better in disturbed habitats is noteworthy.

Carnivores, though with a smaller representation at all the sites in comparison with other guilds, was better in diversity as well as abundance in natural forest compared to monoculture plantations. This could be because, large bodied carnivores with higher trophic level status might need complex vegetation of a natural forest to meet their niche requirements including the food resources. Thus it is amply clear that like natural forest, different plantations under study catered the needs of feeding guilds differentially.

Residents vs Migrants

As far as wetlands are concerned, wintering waterfowl, especially some of the anatids are known to arrive in huge flocks of large numbers across southern hemisphere including the Goan region (Lopez and Mundkur,1997; Walia and Shanbhag,1999; Shanbhag et. al. 2001; and Borges,2002). They also outnumbered the resident bird population pushing the species evenness (J') to the other extreme in winter/ early summer (Walia, 2000 and Borges, 2002). Unlike the phenomenon, even though as large as 22 migrant species including 7 long distance migrants were sighted in study area during the 2 year long study, the resident bird population always dominated over the migrants in abundance as well as diversity at all the sites. The findings are in agreement with similar reports by earlier workers in the secondary forests of Hong-Kong (KwoK, 1996; and KwoK & Corlett ,1999). The occurrence of migratory species in plantations was not much different from that in natural forest, indicating their efforts to exploit the new environment to the fullest extent without much discrimination. However, the maximum migratory species were recorded in teak plantation and seven of them that were exclusive to the site were insectivores. This once again authenticated the better insect resource at the site, besides the insectivore friendly habitat provided by the deciduous plantation. A local migrant, Greenish Leaf Warbler occurred in all the sites with the higher dominance ranks. The species has been reported to winter in high densities in Anaimalai Hill section of Western Ghats also (Kannan, 1998). Like the waterfowl, most of the migratory birds sighted arrived between late -monsoon to early- winter and stayed up to mid–summer.

Edge effects

Ecotone is characterized by rapidly changing species composition. Ecotone has high species diversity, for the reason that they have species from the 2 merging communities. They may also have some additional animal species, which require resources from both kinds of habitats. The increased diversity in ecotones is commonly referred as edge effect. Increasing edge effect is a powerful tool in wildlife management (Lal, 1992). However according to Kruger and Lawes (1997) there was no significant quantitative differences in bird species diversity between the forest edge and interior. In the present study bird population on edge was significantly higher than that in centre in CP & AP. While in TP the situation was reverse, but the difference was not statistically significant. Though, Hansson (2000) also had found that the number of species was higher in deciduous woodland centres than at edges, the reasons for diagonally opposite picture of normal edge effect by deciduous forests or plantations are not very clear.

Breeding birds

Of the 6 species of birds sighted to breed in NF, 5 such as Lesser Spotted Eagle, Lesser Golden-backed Woodpecker, Yellow-browed Bulbul, White-rumped Munia exclusively bred at the site. The only Orange-headed Thrush that bred at NF also bred In TP. This amount to the fact that some species needing specific requirements provided by NF for their breeding probably can't get easily adopted to altered environments.

The number of species that were found to breed in the 3 plantations was not much different from that in NF, being 5 each. Interestingly, while Small Sunbird and Jungle Crow bred exclusively in TP, 2 other species, Ashy Drongo and Bronzed Drongo were sighted to breed only in AP. Four out of 5 species that bred in CP, i.e. Red Spur fowl, Oriental Magpie-Robin, Jungle Babbler and Red-vented Bulbul were encountered in breeding state only in the plantation. Further Red-whiskered Bulbul was found to breed in all the plantations but not in natural forest. These observations amount to indicate that selective advantages provided by these plantations such as intensive insect resource in teak, highly dense undergrowth in cashew and tall nesting platforms in acacia besides lack of indulgence by carnivorous/raptorial birds might have lured these birds to breed in them. At this juncture it may be noted that Khan (1978) stated that "So far as food, shelter, and breeding places are concerned eucalyptus and acacia plantations provide poor environment as is evidenced by paucity of breeding birds" in the course of his studies at Nilgiri hills. In the very publication he recorded the breeding of flycatchers in acacia plantation and also good number of other breeding species such as Jungle Crow, Black-and orange-Flycatcher, Nilgiri Verditer Flycatcher, Tickell's Blue

Flycatcher, White-spotted Fantail Flycatcher, Pied Flycatcher-Shrike, Black Bulbul, Nilgiri Pipit and white eye etc. in eucalyptus plantation.

New bird sightings for the region

As far as avifauna of Goa is concerned, initially 154 species were recorded for the region (Grubh and Ali, 1976). Since then the list gradually increased to 208 species (Saha and Dasgupta, 1992). However, thus far most of these studies were short duration opportunistic surveys. A quantum jump was made in this direction by the extremely long duration but once again an opportunistic survey by Lainer (1999 a & b) taking the total to 382 species. Borges and Shanbhag (In press) based on their 2 year long planned survey of esuarine wetlands of Mandovi River added 8 more species and also authenticated an unconfirmed one.

During the course of 2 year long present study across the natural forest and monoculture plantations 13 new sightings have been made. Of these, the occurrence of Indian Blue Robin and Streaked Spider-hunter may have to be confirmed because one individual each was sighted in single encounters. Remaining 11 species are confirmed occurrences as 3-25 individuals of these species were sighted in 3-6 sightings, many of them being repeat sightings across the 2 years of study. Seven of the species were sighted in TP while 5 each were sighted in CP and AP as against 6 in NF, once again kindling a thought as to whether plantations under certain circumstances could be as good habitats as natural forests, if not better.

Endemism

Endemism describes species that are native to a particular geographic area or continent. It usually occurs in areas that are isolated in some way. Therefore, as much as it can occur between the continents it can occur within them too. India, because of its position in tropical subtropical latitudes enjoys a status of megabiodiversity country and has 969 species of birds of which 69 are endemic (Gadgil, 1996). The Western Ghats, one of the 25 biodiversity hotspots is known to have 12 endemic birds (Kannan, 1998). In the course of present study, 4 species of birds endemic to Western Ghats were sighted in the study area, of which the Small Sunbird was found in all the three plantations besides natural forest. All the 4 species were encountered in CP, and Malabar Grey Hornbill was sighted in all the study sites except TP. These facts probably hold a pointer to the fact that monoculture plantations studied, especially CP probably did meet the requirements of some of the endemic birds of the Western Ghats.

Summary
Conclusions & Reccomendations

Though the monoculture forest plantations are muddled with controversies (Pramod et. al. 1973; Gray, 1974; Shiva, 1993; Hansson 2000, and Reverstat, 2001) they don't seem to be dispensable under the ever increasing demand for green cover and forest based products by the consumer oriented west and the burgeoning human population of the east. Most of the work pertaining to monocultures has come from tropical central/south America, Africa and partly from North America and Europe (Winkler and Dana, 1957; Cruz, 1988; Estades and Temple, 1999; Hansson, 2000). The work from India is more on litter-soil nutrient cycling mostly in selected plantations of eucalyptus, pine, poplar, sissoo, teak and acacia from subtropical north (Singh et. al. 1993; Misra and Nisanka, 1997; Joshi, et. al.1999). Despite the fact that the birds are considered to be good biological indicators of the health of ecosystem, to best of my knowledge there are only few reports regarding the bird fauna in forest plantations in India (Gray, 1974; Khan, 1978 and Gandhi, 1986). In this background, the present work was contemplated to study the ecology from totalitarian perspective of 3 most common forest plantations in Goa, viz. cashew, *Anacardium occidentale*; teak, *Tectona grandis*; and Australian acacia, *Acacia auriculiformes*. The study included plant phenology, nature of undergrowth, quantum of litterfall, rate of litter decomposition, release of macronutrients, soil fertility levels, abundance of insect fauna and habitat utility by avifaunal population. A stretch of primary natural forest served as the control site for comparison. The study sites were located in Valpoi range in Sattari Taluka of Goa. All the plantations were fringed with natural forests in close proximity. All observations/analysis were carried out at monthly intervals for a period of two years from March 2001 to February 2003. The highlights of the study and the interpretations/explanations are given below.

It was observed that monocultures of teak and acacia if unmanaged, can sustain undergrowth in close range of that observed in natural forest in terms of density. The significantly poor diversity and higher density of undergrowth observed in cashew plantation could be because of infestation of weed *Chromolena odorata* and its allelopathic nature.

High concentration of nitrogen, potassium and carbon in soil and the higher content of the former 2 macronutrients in the litter of acacia seem to be in favour of the plantation towards improving fertility fallow lands or degraded soils. This view is strenghthened by the higher quantum of litter fall, and presence of *Clerodendron viscosum,* an indicator of better soil fertility in the undergrowth.

In all the plantations as also the natural forest, nitrogen and phosphorus content in decomposing litter increased by the end of a year except P content of teak litter. This indicated the immobilisation / enhancement of N and P in decomposing litters of most of the plant species in one or other season. Potassium and carbon from the litter got released precipitously or gradually throughout the year without any immobilisations. Compared to natural forest all the monoculture plantations studied had higher insect abundance.

A total of 129 forest bird species were recorded during the study. These included 13 new sightings records for the region / state.

At all the sites the resident birds were significantly more than the migrants throughout the year. A total of 22 migrants were sighted and Greenish leaf warbler, *Phylloscopus trochiloides* was the dominant migrant in all the sites. Eight species of migrants were common to all the sites while 6 of them were exclusive to teak plantation. Interestingly all of them exclusive to teak plantation were insectivores. The highest insect abundance in the teak plantation amongst the monocultures studied could be the causative factor.

Four endemics species Malabar Grey Hornbill, Ocyceros griseus; Grey- headed Bulbul, *Pycnonotus priocephalus*; Indian Rufous Babbler, *Turdoides subrufus* and Small Sunbird, *Nectarinia minima* were recorded during the study. Of this Small Sunbird was seen in all the plantations as well as in natural forest throughout the year.

During the 2 year long study 16 bird species were found breeding in the study area that covered 5 and 9 species exclusive to natural forest and plantations respectively. Only 2 species, Orange headed Thrush and Black-naped Monarch-Flycatcher were common to both the ecosystems.

Teak and cashew plantations supported avifaunal diversity almost in close range of that supported by natural forest. Even though the bird diversity at acacia plantation was the least, the difference was not statistically significant.

Plantations and natural forests had their own individuality in terms of differential support provided by them to different feeding guilds. The patronage of forest specialists such as nonpasserines and carnivores to natural forest, may be because of their higher trophic status taken care off by the complex food web of pristine forest. Chestnut-bellied nuthatch ranking third in terms of rank of dominance in natural forest was exclusive to this site. The bird being a insect gleaner is better suited to vegetation with small leaves and moderate canopy cover of the natural forest.

Insectivores were more in teak plantation owing to its higher insect abundance and better launching perches along with an open view provided by teak trees to sallying insectivores during deciduous phase. More than 80% of the birds exclusive to the teak plantation were insectivores.

The omnivores were more in cashew plantation while phytophages dominated the acacia plantation.

The cashew and acacia plantations depicted the text book example of edge effect with significantly higher density and diversity of birds on thier edges than the centres. The situation was reverse in teak plantation, reasons for, which is not obvious.

In final analysis the monoculture forest plantations per se may not be as bad as picturised by self styled environmentalists, as in unmanaged state and with mature age they also can be good habitats for undergrowth, insects and bird life.

CONCLUSIONS AND RECOMMENDATIONS

There can't be a suitable replacement for natural primary forests as high trophic level forest specialists birds such as non passerines, carnivores, gleaners more often patronise them exclusively.

Among plantations teak, an indigenous species with better quality undergrowth, insect and bird diversity besides its higher commercial value can be the first choice. In view of the low nutrient quality fast decomposing litter and also the plantation floor soil, besides its efficiency in conservation of nutrients owing to its deciduous nature, it may be a plantation of choice to nutrient poor quality areas.

Cashew plantation can be of second choice as it supports good bird and insect diversity possibly because of extensive blooms and fleshy thalami, besides its commercial value to the region.

Acacia plantation, though relatively poor in terms of bird diversity, is any time better than no forest, as it is a hardy xerophyte mostly planted to cover the barren or degraded lands. Because of its higher quantum of litter, slow degradation, nitrogen fixing ability and capacity to improve the soil fertility, it is more suited to fallow lands and can be treated as transient plantation to make room for better indigenous plantations to follow after selective felling.

The most plausible reasons for getting the encouraging results in this study on plantations could be

Close proximity of all the plantations under study with the natural forests.

Unmanaged practice leading to establishment of undegrowth increasing the floral diversity.

Some stray trees of indigenous varieties that might have remained as left over wild saplings in plantation stage or established later owing to seed dispersal from neighbouring forests. These might have had the positive impact on buffering of poor floral diversity in plantations.

Thus unmanaged system of plantations, besides introducing a few stray saplings of indigenous trees, establishing the plantations in close proximity of primary forests or establishing definite movement corridors between the two may go a long way in ameliorating the likely undue impact of plantations on faunal diversity.

Though Forest Department in Goa is practicing unmanaged monocultures, fringed by natural forest, there are private parties that practice managed and isolated plantations. Extension of the study to such sites may throw additional light on the vexed problem.

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