भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Certificate

This is to certify that Mr. Sahas S. Barve has carried out an original piece of research in partial fulfilment of Master's Degree in Wildlife Science of the Saurashtra University, Rajkot. The topic of his dissertation is "Responses shown by bird communities to teak plantations in Sagar Forest Division, Karnataka". The investigations were carried out under our supervision from November 2008 to June 2009. We hereby certify that this work has not been submitted for any degree to any university.

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Responses shown by bird communities to teak plantations in Sagar Forest Division,Karnataka

Dissertation Submitted to

University of Saurashtra, Rajkot

In partial fulfilment of

Master's Degree in Wildlife Science

By

SAHAS S. BARVE

Under the Supervision of

Dr. Dhananjai Mohan and Mr. Qamar Qureshi

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Summary

This study was aimed at discerning the responses shown by bird communities to teak plantations of various age classes in Sagar Forest Division, Karnataka within Latitude 13° 36' and 14° 38' North 74° Longitude 38' and 75° 32'East Latitude. Birds were sampled using line transects in three habitat strata, natural plantations, mature teak plantations and young teak plantations. Density, diversity and community similarity were the chief ecological responses that were quantified to bring out differences in the usage of forest plantations by native bird fauna. Habitat (vegetation) correlates, both structural and floristic were quantified to establish the reasons for differences. The sampling period was from December 2008 to April 2009. This period was divided into two seasons, winter and summer. A total of 9 transects were laid, marked and sampled at least 4 times per season.

Birds were divided into three feeding guilds and three habitat guilds for analysis. The overall density of birds across the three strata was found to be higher in summer than in winter. However a guild level analysis showed that in winter while insectivorous birds were most abundant in natural forest with decreasing density towards young plantations ($F_{(6.241)}$, $p< 0.05$). There was no difference in their density in summer. Phytophagous birds showed the exact reverse trend. Density of this guild was higher in young plantations than natural forests and mature plantations in winter and summer ($F_{(5.689)}$, $p< 0.05$), ($F_{(14.302)}$, $p< 0.01$) respectively. Overall diversity of birds showed a trend of decreasing species richness from natural forests to young plantations in both seasons. However this difference was almost non existent in summer at the guild level. The abundance of birds belonging to evergreen and moist deciduous forests shows a consistent rise in abundance from winter to summer in all the three strata. There is also evidence that there is ingression of individuals of species that were

common to both seasons possibly for nesting. The overall community similarity is quite high between the three strata and it increases from winter to summer. Bird diversity was found to be affected by the vertical spread of vegetation and tree height heterogeneity ($R=0.871$, $p<0.01$). It was also correlated to canopy cover ($R=0.807$ $p<0.05$) and continuity ($R= 0.737$ $p< 0.01$). Insectivorous guild was affected by correlates of forest maturity ($R= 0.805$ $p< 0.01$). The high density of phytophagous birds was found to be correlated to the abundance of parasitic epiphytes which were most numerous in young plantations ($R= 0.766$, $p< 0.05$ in winter and $R= 0.796$, $p < 0.01$ in summer). Although resident bird composition showed association with tree species composition in winter ($R= 0.49$, $p< 0.001$), no such association was observed in summer.

1. Introduction

As rates of deforestation continue to rise in many parts of the world, the international conservation community is faced with the challenge of finding approaches which can reduce deforestation and provide rural livelihoods in addition to conserving biodiversity. However, much of modern day conservation is motivated by a desire to conserve 'pristine nature' in protected areas (Bhagwat et al 2008). The burgeoning human population has already removed somewhere between 8 and 12 million square kilometres (between 35% and 50%) of the original closed canopy tropical forests around the world (Wright and Miller-Landau 2006). The loss of natural forest is most profound in the tropics where annually 0.8% of the remaining forests are cleared and converted into cultivated land. Growing human populations and accelerating demand for forest resources such as wood resulted in increasing areas of degraded forests and forest plantations. New forests are regenerating on former agricultural land, and forest plantations are being established for commercial and restoration purposes (Nagendra 2007, Chazdon 2008). During the past thirty years an evident decline in natural forest resources in a number of countries and the difficulties in accessing increasingly remote areas of natural forest available for wood supply, has resulted in intensification in the focus on plantation forests. Plantations provide a potential means for alleviating potential future wood shortages and providing continuity of supply for existing industrial enterprises or household fuel wood needs (FAO 2002). Apart from fuel and timber biomass, plantation forests are also known to provide services like carbon sequestration and soil conservation.

Role in biodiversity conservation: Although networks of protected areas in the tropics provide habitat for many rare and endemic species that prefer old-growth forest, these networks alone fail to protect all tropical biodiversity due to their small land area (Montagnini et al 2005). Plantation systems can buffer existing reserves and provide corridors for persistence and movement of species across landscapes (Daily et al 2001). Such systems are useful with pristine forests for combating species loss as a result of tropical forest fragmentation.

1.1 Review of Literature

Birds in plantations: Birds are one of the most well studied groups of organisms. With their varying levels habitat specificity, birds make excellent indicators of ecosystem health and habitat quality. Hence, birds can be used to assess the quality of habitats the growing plantations offer and use them as a surrogate for biodiversity. Biodiversity conservation is thought to be an inherent service provided by the plantations of the world. But it is important to understand what aspect of biodiversity is being conserved. An increasing number of studies suggest that the differences in bird communities in the plantations versus natural forests are quite stark. Generally not more than 50-60% of the original bird fauna is supported (Bhagwat et al 2008). Petit et al (1999) reported a mere 43%-54% forest bird species present in rustic coffee plantations. Similar results have been shown from Costa Rica (Daily et al 2001), India (Raman 2001), Kenya (Sekercioglu 2002) and many other studies. Research indicates that in the plantations forest specialist birds are most commonly replaced by more generalist, open habitat species that may not be of significant conservation importance (Kwok and Corlett 2000, Daily et al 2001, Rotenburg 2007).

1.1.1 Choice of species for plantations: In a study from Kenya Farwig et al (2008) illustrated that plantations of indigenous trees support more bird diversity than those of exotic ones. Plantations of a mixture of native species more closely resembled natural forests with respect to bird species composition than monocultures of a single species. The bird conservation significance of using native tree species has also been reported from studies on rustic (native) shade tree coffee plantations in the Americas (Greenberg et al 1998, Moguel and Toledo 1999, Jende et al 2005, Tezeda-cruz and Sutherland 2006,) and India (Anand et al 2008). The choice of species for plantation is known to be extremely important for certain guilds of birds like frugivores and cavity nesting birds (Clout and Gaze 1984).

1.1.2 Age of stand/plantation: The age of the plantation is also important in determining the usage by local bird communities. This trend has been seen with *Tectona grandis* plantations in India, in which the older plantations always seem to have a greater diversity of birds and a more stable community structure than the younger monocultures (Daniels 1989, Mehta 1998, Trivedi 2006). Because plantations are generally man-made habitats, it takes many years for a stable bird community to establish. Hence it is recognized that plantations of tree species with long rotation cycles provide time for the system to stabilize and provide the habitat complexity needed for higher bird diversity.

1.1.3 Landscape matrix: There is an increasing body of literature on the importance of the landscape matrix in determining bird diversity of plantations. A landscape has been defined as an area with an interaction of its elements (e.g. ecosystems) relevant to some phenomenon under consideration (Mazerolle and Villard 1999). Many bird species react to small scale (patch level) and landscape level changes in habitats including the ones which extend beyond their home ranges (Taylor and Krawchuk 2005). Plantations alone might not support a large diversity but where they are located in close proximity to natural forest, they can give good cover for many species and hence can act as good buffers for these habitats especially for dispersing individuals.

1.1.4 Proximity or connectivity to natural forest: Raman (2006) reports that the species diversity and richness of some native tree plantations located adjacent to forest fragments were comparable to wet evergreen forest habitats. But as the distance of the plantation increased away from the natural forest vegetation, the number of true forest species declined. Lawes and Wethered (2005) in their study of the plantation forest matrix in Afromontane ecosystem describe the importance of canopy connectivity. The importance of canopy connectivity has also been realized in forest fragments- agro-ecosystem network in Panama (Petit et al 1999), and the Israeli scrub desert (Shochat et al 2001) also. Hence it is evident that not only the existence but also the pattern of juxtaposition of forest plantations and natural forest areas is important in conserving forest bird communities.

1.1.5 Plantations as bird habitats: The composition of avian assemblages and how they are influenced by habitat features has been one of the most pervasive themes of investigation in community ecology (Jayapal et al 2009). Habitat structure (physiognomy) and floristics (composition) have been recognized as the key components affecting land bird assemblages in general. It is important to assess plantations using these two attributes for their value as bird habitats.

Physiognomy: Birds are known to respond to two broad aspects of habitat structure, vertical heterogeneity and horizontal or spatial heterogeneity. While Foliage Height Diversity and Tree Height Diversity are important attributes of vertical heterogeneity, canopy cover and spread, tree density, number of snags, basal area, shrub density and volume are determinants of spatial heterogeneity (MacArthur and MacArthur 1961).

Plantations because they are planted in a uniform fashion and very seldom regenerated naturally offer very little structural heterogeneity. Tree density is generally known to be higher in plantations than in natural forests (Saha 2003, Daniels 1992). Sekercioglu (2002) reported that there was definite distinctness between the bird communities found in unlogged or little logged forests and heavily logged forests. This pattern, he explained due to the loss of horizontal heterogeneity. Hansen et al (1995) and Wilson (1974) reported the relationship between the density of snags and dead poles and their effect on the abundance of cavity nesting birds. The loss of these nesting sites seriously affected this guild and there was a marked recovery when snags were retained. Marsden et al (2001) reported that Eucalyptus plantations lacked substantial bird fauna as there was little or no under storey vegetation in these plantations.

Floristics (composition): This aspect of habitat heterogeneity is known to play a significant role when comparing sites in the same overall habitat type (Lee and Rottenburry 2005). Bell (1979) reported very little native plant and bird diversity from teak plantations in Papua New Guinea. Arnold (2003) showed that Australian agro-forestry areas showed that the difference in under storey diversity translated into a difference in both diversity and abundance of bird species.

1.1.6 `Teak plantations- Brief history and studies on their role in biodiversity conservation.

Teak (*Tectona grandis*) is a hardwood species is indigenous to India. Teak has been grown in other countries including Costa Rica and Papua New Guinea, Central and South America and Africa where it is an exotic making it the most widely planted high quality timber species covering about 2.3 million ha (Enters 2000,F.A.O., 2002). Teak plantations exist in many parts of India and often replace natural evergreen forests and also moist and dry deciduous forests. Today it has the second biggest share in the national growing stock contributing 6.31% of the stems and 4.33% of the volume of trees in forests (SFR 2005).

Bell (2000) reported that in Papua New Guinea, Teak had little lateral branching, few epiphytes or climbers and little undergrowth. There were far fewer species of birds and mammals than in the rain forest, owing mainly to the loss of small insectivorous passerines, nectarivores and ground feeders. Teak plantations of different age classes especially young plantations if intermixed with natural forest provide good habitat to large mammals in the Western Ghats of India.(Nair and Jayson 1989, Harikrishnan et al 2007).

Few studies have been done on birds found in teak plantations in India. Prachi Mehta (1998) in her study of birds in different age classes and silvicultural systems of teak in Bori Wildlife Sanctuary, found that the diversity differed little after a teak plantation had reached 20 years. The density of birds however showed considerable variation in clear felled areas and teak plantations. Daniels (1989) worked on birds of Uttara Kannada and demonstrated that the teak plantations were very homogenous habitats and supported a considerable proportion of the local avian species fauna. Trivedi (2006) reported that species richness of birds increased from young monocultures of teak to moist deciduous forests in the Dangs. Hence teak plantations usually follow the same trends in diversity as most other plantation crops.

The present study compares density and diversity of birds in teak plantations of two age classes with the bird community in the surrounding natural forests. It examines bird abundance and diversity at a guild level across the three strata. A vegetation profile of the three strata is carried out to highlight differences in structural and floristic attributes and describing the vegetation of the study area. Finally the study investigated habitat attributes that explain bird community responses to teak plantations.

1.2 **Objectives**

1) To estimate density and diversity of birds in teak plantations in Sagar Forest Division, Karnataka and the surrounding natural forests.
2) To evaluate the extent of similarity in bird community structure and composition of teak plantations and surrounding natural forests.
3) To find habitat correlates which explain the differences in density and diversity of birds in these strata.

These objectives are used to answer the following research questions-

1) What are differences in overall density of birds in natural forests, mature teak plantations and young teak plantations in winter and summer?
2) What are differences in density of birds at the guild level across the three strata in winter and summer?
3) What are the differences in species richness as a measure of diversity among the three strata across two seasons?

4) What are the bird attributes that explain the seasonal difference in density and diversity?

5) What is the level of similarity/dissimilarity in the bird community of the three strata?

6) What are the differences in the structural and floristic attributes of the vegetation of the three strata?

7) What are the habitat variables that explain the differences in the bird density and diversity in the three strata in the two seasons?

2. Study Area

The study was carried out in the Sagar Forest Division situated in the Shimoga district in the state of Karnataka. The division is named after the Sagar town that houses the headquarters of the division. The division is divided further into ten ranges (Murthy, S.F.D. Working plan 2001).The current study was carried out in the ranges of Sagar, Anandpuram and Soraba.

2.1 Location

Sagar Forest Division is situated within 13° 36' and 14° 38' North 74° 38' and 75° 32'East .The total area of the division is 14,782 km^2. The area is very hilly and undulating. The highest point in the division is Kodchadri with an elevation of 1341m with the average elevation is 670 m M.S.L. The significant rivers flowing through the division are the Sharavathy, Kumudwathi, Varada, Varahi and Chakra. Water availability generally does not fluctuate seasonally (Murthy, S.F.D. Working plan 2001).

2.2 Climate and Rainfall

The climate of the area is moderate with temperatures varying between 13°C and 37°C. The Southwest monsoon brings most of the rain, commencing usually in the early part of June with very short interruptions. Heavy and continuous rainfall is received until September with an average annual rainfall of 2400m. Pre- monsoon showers arrive in May. November, December and January are the coolest months. Summers are severe with March-May being the hottest months of the year.

The world famous Jog Falls on the course of the Sharavathy River are present in the division. Two Protected Areas, Gudavi and Sharavathy Wildlife Sanctuaries also fall within the limits of the division (Murthy, S.F.D. Working plan 2001).

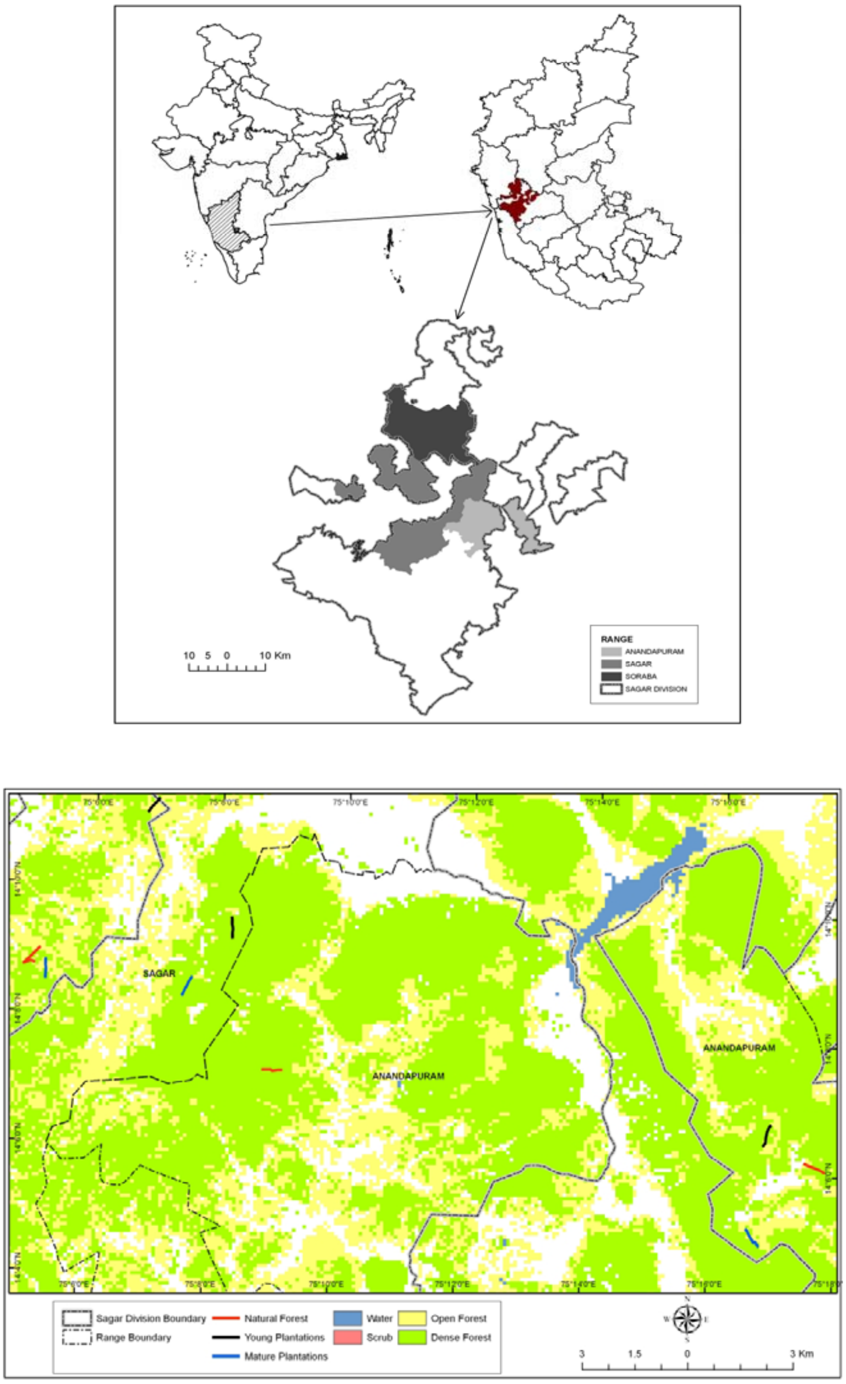

Figure 2.1 Maps of Study Area- The highlighted ranges is the intensive study area and location of transects within those ranges.

2.4 History of Forestry

This area has a rich history of forestry dating back to the late nineteenth century. Although the division came into existence for the first time in 1916, but it has maintained a permanent division status only since 1932. The oldest reserved forests of the area were given protection in the year 1888. The area has been a source of massive extractions of many commercially important timber species such as *Tectona grandis*, *Pterocarpous marsupium*, *Terminalia alata, Terminalia paniculata, Lagerstromia lanceolata, Haldina cordifolia* and *Xylia xylocarpa*. Minor Forest Produce of the area includes bamboo and sandal wood.

2.5 Biodiversity

Vegetation

The forests of the area can be divided into four main categories (Champion and Seth 1968). These are as follows-

1) Southern Tropical Wet Evergreen Forest
2) Southern Tropical Semi-Evergreen Forest
3) Southern Tropical Moist Deciduous Forest
4) Southern Tropical Dry Deciduous Forest

The wet-evergreen forests are limited to the Hosnagara, Kargal and Nagar ranges. Due to deterioration by biotic pressures, the forests of the area show a tendency to change from wet-evergreen forests to semi-evergreen forests and from semi-evergreen to moist deciduous forests.

The present study was carried out in the moist-deciduous forests of the Sagar, Anandpuram and Soraba ranges. The semi-evergreen and moist-deciduous forests of the area are not very dense. Although an intimate mixture of species is observed, only a few species make up the canopy. The chief feature of these forests of the area is that they do not shed leaves until well into the dry season, which is late February or March. Interestingly, they come into new leaf long before the monsoon starts. The important species of this zone include *Tectona grandis*, *Pterocarpous marsupium*, *Terminalia alata, Terminalia paniculata, Lagerstromia lanceolata, Haldina cordifolia, Xylia xylocarpa, Anogeissus latifolia, Dalbergia latifolia, Bombax ceiba, Mangifera indica* (Murthy, S.F.D Working Plan 2001)

***Fauna*-**

Mammals- The reserved forests do not have a high density of large mammals, chital (*Axis axis*), wild pig (*Sus scrofa*) and sambar (*Cervus unicolor*) are occasionally encountered. Bonnet macaques (*Macaca radiata*), black napped hare (*Lepus negricollis*) hanuman langur (*Seminopithecus entellus*), jackal (*Canis aureus*) and Indian giant squirrel (*Ratufa indica*) are more common(Pers. Observ.)

***Birds*-** The division is rich in bird life. Although the study was aimed at forest birds and was limited to communities in moist deciduous forests where a total of 119 species were observed, visits to other localities and habitats in the division yielded a total of 247 species.

2.7 Anthropogenic Pressures on Wildlife Habitats: The area is not thickly populated and hence the human impact on the forests is not very high (Murthy A., S.F.D. Working Plan 2001). Nonetheless a large amount of biomass is extracted in the form of firewood and leaf litter. Firewood is used in most homes and hotels particularly in Sagar town, hence generating a large demand on the forest. Leaf litter collection is done in the summer season using sweeping techniques leaving the ground almost bare. The collected litter is mixed with cattle dung as an organic fertilizer in the areca nut (*Areca catechu*) plantations that occupy most of the low-lying areas in the region. Hunting is not a significant problem in the area, although the sparse density of mammals hints at a probable past of hunting in the area.

2.8 History of Teak Plantation Forestry in the Division:

Sagar division has 7815.6 ha of teak plantations. A teak conversion working circle manages the teak plantations within the division. The main objective of the circle is to exploit the marketable timber and conversion of existing growing stock into valuable teak plantations. Ten felling series were formed, with a rotation period of eighty years and an exploitable girth of 4.5 feet. Though some thinnings were carried out in the past they depended mainly on the availability of funds. Due to irregular and unsystematic workings in the past, Laurey's thinning formula for teak plantations has been adopted. The main objectives of management are-

1) To convert existing teak plantations into valuable growing stock by following proper thinning schedule.
2) To enrich plantations with concentrated artificial regeneration of teak if they are damaged due to biotic pressures.
3) To meet the teak pole requirement of the local and distant stakeholder.
4) To convert plantations into mixed nature if teak has failed on account of some locality factors.
5) To remove Eucalyptus coppice and convert areas into pure teak stands.

According to the existing silvicultural practices there are six thinnings in one rotation cycle and the number of stems retained per hectare changes from 1250 per hectare to 198 per hectare after the sixth thinning in the 48th year. (Murthy, Working Plan S.F.D. 2001).

2.9 Study Design:

There were three strata namely- Natural forests, Mature plantations and Young plantations. Each stratum had three transects in each.

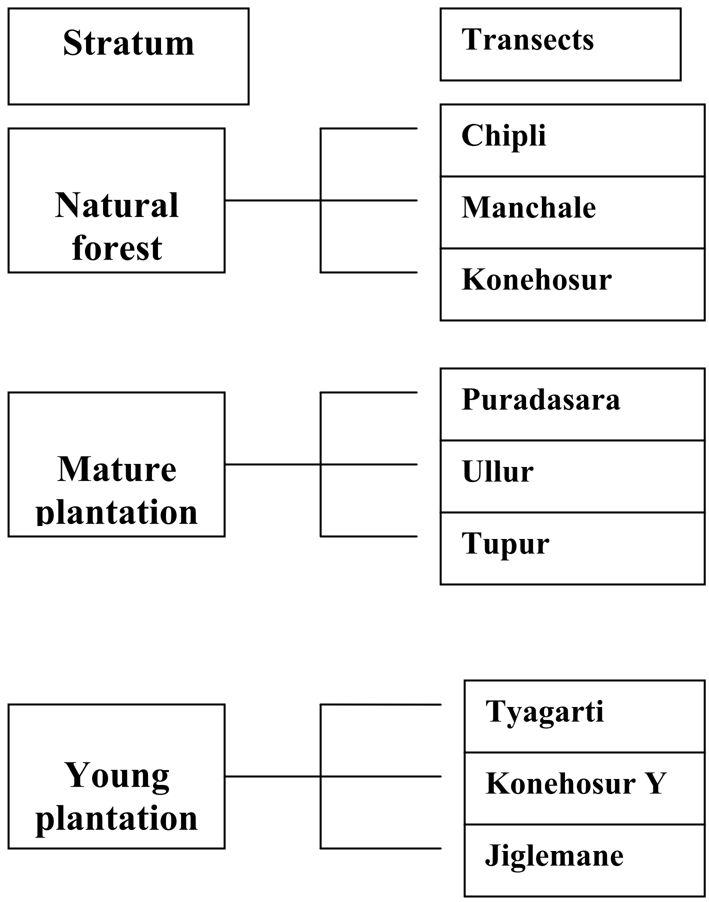

Figure 2.2 Study Design

2.10 Plantations chosen for the study: The plantations for the study were selected after a weeklong survey of the area. They were chosen based on whether transects could be laid in the plantations while maintaining a buffer of atleast 150 m from each side and that fell in the desired age class category. Care was also taken that the plantations were primarily surrounded by moist deciduous forests to control for effects of surrounding habitats on the bird community within the plantations.

Table 1.1- List of mature plantations selected for bird sampling

Name of Plantation	Year of establishment	Area (ha)
Ullur	1965	41
Konehosur	1962	140
Malali	1962	50

Table 1.2- List of Young plantations selected for bird sampling

Name of Plantation	Year of establishment	Area (ha)
Teliganmane	1989	40
Bilisiri	1987	50
Konehosur	1987	65

Hence the average age of mature plantations is 47 years and that of young plantations is 23 years.

Natural Forest:

Three natural forest patches were also selected for sampling. These patches were chosen on the basis of their quality as bird habitats and distance to the selected teak plantations (≤ 3 km). The quality of these patches was assessed by carrying out reconnaissance surveys in the early mornings and making multiple bird species richness lists. The patches were also chosen in a fashion so as to control for distance of teak plantation to closest natural forest.

3 Methodology

3.1 Bird Sampling-

Distance sampling (line transects)

Birds were sampled using variable width line transects (Rosenstock et al 2002, Thomas et al 2002). Line transects were chosen as they give maximum detections/ unit time in field and hence effectively cover more area in the same time as compared to point counts (Verner 1985). The basic assumption of line transects is that all objects on the line are detected and the probability of detection goes on decreasing as distance from the line increases. Hence a detection function is fitted on the observations so as to arrive at the required abundance estimates.

Three transects each were laid out in three strata mature plantations, young plantations, and natural forests. All transects were between 500m-700m in length. The transects were laid in a way so that there was a buffer of at least 150m from all sides to negate 'edge effects'. All plantations that were chosen for sampling all had semi evergreen and moist deciduous forest on at least three sides so as to control for 'neighbourhood effect' (Wethered and Laws 2005)

All transects were walked at a steady pace (approximately 1.25 km/hour) between 6:30 a.m. and 9:30 a.m. At each detection of a bird species the following variables were recorded- 1) Species 2) Group size 3) Angle between the observer and the bird using a standard hand held compass 4) Distance between the observer and the bird using a laser rangefinder 5) The height class at which the bird was seen. The birds were recorded as being in one of 4 height classes. If they occurred in the first 0-5 m above ground then they were recorded in height class 'a'. If between 5m-10m then in height class 'b'. If between 10m-15m then in height class 'c' and if between 15m and above then in height class'd'. These height categories were selected after reconnaissance walks in the plantations and developing a visual perception of the heights at which vegetation was stratified. Similarly rough height classes were chosen at heights where the birds were observed. Only birds actually perching in the habitat were recorded. Birds were also detected and recorded using aural cues. On detection by the call of the bird, the angle and distance to the tree or bush the call originated from, was recorded.

Sampling was divided into two seasons- winter and summer. Each transect was walked a minimum of 4 times (pseudo-replicates) in winter and a minimum of 5 times in summer, with a total of 49 walks in winter and 57 walks in summer combined in all strata.

3.2 Vegetation Sampling

The following habitat attributes were quantified as covariates to explain bird community responses to teak plantations. The variables were classified into two main categories-

1) Structural Covariates: These quantify the structural attributes of the habitat.
2) Floristic Covariate: These quantify the floristic attributes.

Structural Attributes

1. **Tree density**: Number of live trees was counted. A tree is defined as any woody plant > 2m in height (Jayapal 2007).
2. **Girth at breast height (G.B.H.)**: G.B.H of all trees in the plot was recorded.
3. **Tree height diversity**: The lowest and the apical height of branches of the trees was recorded and the Shannon Weiner Index was derived **$-\Sigma$ [Pi* ln(Pi)]** where Pi= proportion of trees in the i^{th} height class (Jayapal et al 2007, Mohan 2007)

4. **Canopy cover and spread**: Percentage canopy cover as measured by a spherical densiometer. Mean of four directional readings were taken from the centre of the plot.

5. **Shrub abundance**: Number of shrubs was counted in each plot. For the purpose of this study, a shrub is defined as any woody plant < 2m in height.

6. **Shrub volume**: Mean shrub volume as the product of height X breadth X width was recorded for each shrub wherever possible.

7. **Ground cover**: Ocular estimation of % grass cover, % litter cover and % bare soil in each plot was recorded.

8. **Parasites**: Number of plant parasites present on trees in the 10m circular plots was recorded.

9. **Bamboo clumps**: A total count of bamboo clumps was done in a belt of 60m on both sides of the transect.

Floristic attributes

1) **Tree species richness**: Number of tree species encountered in each plot was recorded.

2) **Tree species diversity**: This was calculated by using the Shannon's Index as **$-\Sigma$ [Pi* ln(Pi)]** where Pi= proportion of trees belonging to species 'i'.

3) **Shrub species richness**: Number of species of shrubs encountered in each plot was recorded.

4) **Shrub species diversity**: This was calculated by using the Shannon's Index as **$-\Sigma$ [Pi* ln(Pi)]** where Pi= proportion of shrubs belonging to species 'i'.

3.3 Analysis

Density of birds

We checked for a size bias in the distance sampling of small sized birds. This was done by dividing the birds into 4 size classes. Birds up to 15 cm in size were classified into size class ‘1’. Species that measure between 15 cm -20 cm in length were classified as group ‘2’. Species up to 25 cm in length were classified as group ‘3’. All bird species larger than 25 cm were placed in group ‘4’ (Ali and Ripley 1973).

Winter **Summer**

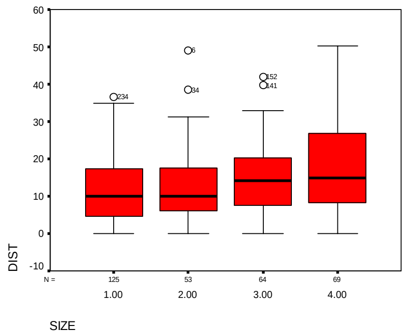

Fig 3.1a Winter Natural

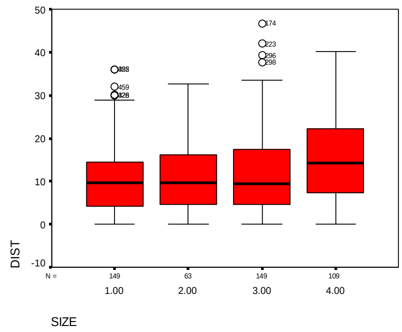

Fig 3.2 a Summer Natural

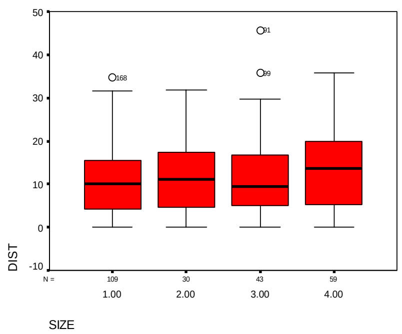

Fig 3.1 b Winter Mature

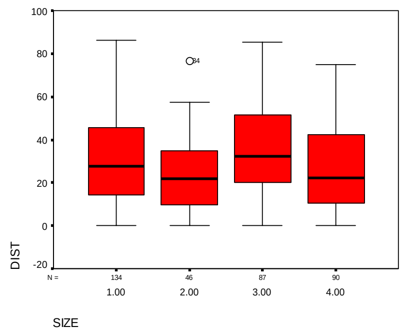

Fig 3.2 b Summer Mature

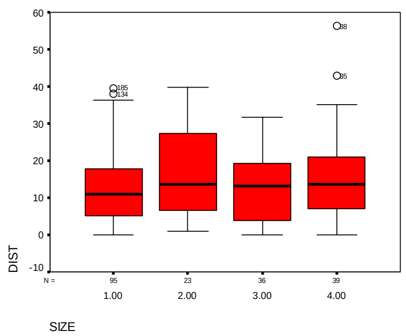

Fig 3.1 c - Winter Young

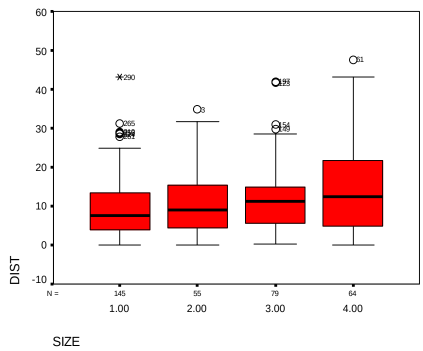

Fig 3.2 c- Summer Young

Figure 3.1 and 3.2 Box plots showing median distance for detections of the 4 size classes analyzed in winter and summer respectively (a) Natural forests (b) Mature plantations and (c) Young plantations

When no size based bias was observed then all the bird detections were used to carry out density estimations.

Density of birds was estimated using the programme DISTANCE 5 (Thomas et al. 2006). The programme allows for global estimates (of the entire data set) of density and also allows stratification according to sampling design and also 'post stratification' for known subsets of data. In DISTANCE models datasets for clustered observations are modelled separately than those for single object observations (Rosenstock et al. 2002). Transect datasets were analyzed in the following manner-

Season

Winter	Summer

Habitat Strata

Natural	Mature	Young

Bird Feeding Guild

Insectivorous Guild	Phytophagous Guild	Others Guild

Figure 3.3 Hierarchical classification of data used in analysis.

Birds were assigned to three basic feeding guilds- 1) Insectivorous 2) Phytophagous and 3) Others, based on the species' feeding habits (Ali and Ripley 1973, Jayapal et al 2009). Density estimates were calculated separately for whole strata and the feeding guilds separately. Birds were also classified into 'habitat guilds'. Each species was classified into three categories 1) Evergreen and Moist Deciduous forest 2) Woodland and 3) Generalist (Ali and Ripley, 1973). Densities were compared using t- tests and one way Analysis of Variance (Zar 1999).

Diversity of birds: The Shannon-Weiner Index was calculated for bird diversity separately for each transect, for both the seasons separately. This index assigns unequal weights to each species based on its frequency of occurrence and is increasingly considered to be the most reliable diversity index (Jost 2007). Hence they served as surrogates for diversity in the habitat attribute analysis.

Software ESTIMATE S 8.0 (Colwell 2006) was used to estimate bird species richness in the same data hierarchy as used in density estimates. The JACK 1 estimator was used in all estimations as it performed consistently with all datasets.

Community similarity

The Morisita- Horn Index and the Sorenson Index were calculated as a measure of community similarity between the three strata in the two strata using software ESTIMATE S 8.0 (Colwell 2006).

Vegetation profile

Structural attributes of the vegetation were calculated using the data from the circular plots.

The following variables were calculated for each transects and then used in the analysis.

1) Tree height heterogeneity
2) Average girth breast height and its distribution.
3) Average canopy cover (quantified for summer and winter separately)
4) Tree density
5) Epiphytic parasitic abundance/ plot
6) Mean N. D. V. I. was extracted from a buffer of 20 m along transects using Arc GIS 9.2 (E.S.R.I. 2003). This was used a measure of canopy continuity.

7) Vertical spread of canopy which was calculated as the standard deviation of the difference between the top height and first branch heights of trees.

Floristic attributes

The Shannon Weiner Index was calculated for tree and shrub species for each transect.

Bird- Habitat Interactions

Principal Component Analysis (P.C.A.) (Zar 1999) was carried out for the structural and floristic attributes measured for the three strata along the transect.

Pearson correlations (Zar 1999) were calculated between bird density and diversity measures and habitat variables. Bird species diversity matrices were regressed against vegetation structural variables matrix and a tree species diversity matrix (Mantel test). The repeated randomization model was used with 1000 runs in all the pairs of matrices used (McCune and Grace 2002). All statistical analyses were done using Statistical Package for Social Sciences (SPSS) version 11.5 (SPSS Inc).

4. Results

One hundred and nineteen species of birds were observed while sampling (Appendix A) and 247 species were seen in the whole duration of the study in the study area. (Appendix B). Winter sampling recorded 89 bird species while 102 species were recorded in summer. This includes 746 detections of birds in winter sampling and 1,171 detections of birds in summer sampling.

4.1 Density of birds

The density of birds was consistently higher in natural forests than in mature or young teak plantations.

Table 4.1 Overall (strata level) density estimates (birds/ha), the values in parentheses denote % coefficient of variance.

Strata	Winter	Summer
Natural Forest	14.95 (9.66%)	22.38 (11.9%)
Mature Plantation	9.94 (10.51%)	15.17 (9.66%)
Young Plantation	10.01 (13.79%)	18.74 (10.88%)

Table 4.2 and 4.3 Guild level density estimates (Birds/ha) for each season - the values in parentheses denote % coefficient of variance

Winter	**Natural**	**Mature**	**Young**
Insectivorous(I) Guild	9.36 (10.41 %)	5.65 (14.12%)	3.90 (18.38%)
Phytophagous (P) Guild	4.20 (28.76%)	3.42 (31.19%)	6.60 (25%)
Others Guild	0.84 (29%)	2.03 (29.44%)	0.83 (24.28%)

Summer	**Natural**	**Mature**	**Young**
Insectivorous (I) Guild	12.06 (10.50%)	6.82 (14.8%)	8.43 (16.58%)
Phytophagous (P) Guild	4.52 (26.7%)	7.65 (28.39%)	10.14 (26.9%)
Others Guild	2.37(32.39%)	2.37 (32.39%)	1.38 (30.68%)

4.1.1 Overall densities

Overall densities at the stratum level were higher in summer than in winter.

Natural forest summer > Natural forest winter ($t_{(0.05, 4,2)}$=2.4517)

Mature plantation summer > Mature plantation winter ($t_{(0.05, 4,2)}$= 2.8313)

Young plantation summer > Young plantation winter ($t_{(0.05,4,2)}$=3.5427)

4.1.2 Guild level densities amongst strata in the same season-

Insectivorous guild

Winter: Tukey's Post hoc test revealed that natural forests had higher density of birds than young plantations in winter ($F_{(6.241)}$, $p< 0.05$). Densities of birds in the plantation strata in winter were not significantly different.

Summer- There was no significant difference in insectivorous bird density across the three strata in summer.

Phytophagous guild

Winter- Tukey's Post Hoc test revealed that in winter, Phytophagous guild density in young plantations was higher than mature plantation but not significantly higher than natural forest ($F_{(5.689)}$, $p< 0.05$).

Summer- Density of phytophagous birds was higher in young plantations than in natural forests and mature plantations ($F_{(14.302)}$, $p< 0.01$).

Others guild

Winter-Tukey's Post Hoc test showed that the densities of this guild in winter were not significantly different in the three strata.

Summer- The density of this guild in natural forest was significantly different from that in young plantations, but the plantation strata did not differ significantly in their Others guild densities ($F_{(56.61)}$ $p < 0.05$)

4.1.3 Guild level densities across seasons

Insectivorous guild: Insectivorous bird density in natural forests was significantly higher in summer than in winter ($t_{(0.05,4,2)} = 2.94$). Mature plantations did not differ in their densities and the densities in young plantations in summer were higher than the density in winter ($t_{(0.05,4,2)} = 4.9897$).

Phytophagous guild: The density of birds belonging to this guild was higher in mature plantations in summer ($t_{(0.05,4,2)} = 3.0205$). The other two strata did not differ in their Phytophagous guild densities across seasons.

Others guild: The density of this guild was significantly higher in summer than in winter ($t_{(0.05,4,2)} = 5.9294$). The plantation strata did not differ significantly in the density of this guild across seasons.

Proportion of detections in each guild across seasons: The rise in overall density estimates fails to explain the contribution of each guild, an idea can be derived as to the biggest contributor to the rise in density in each stratum by looking at the proportion of densities of each guild across seasons in the same stratum.

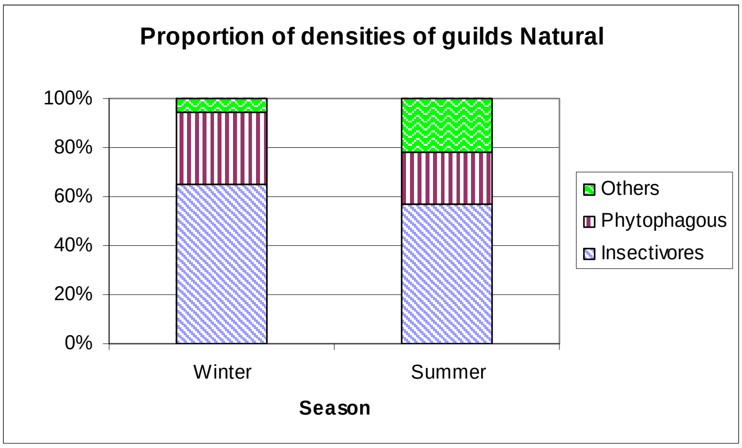

Fig 4.1

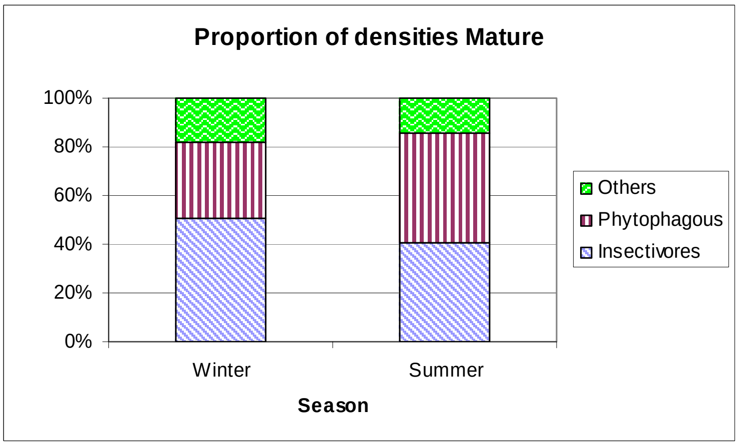

Fig 4.2

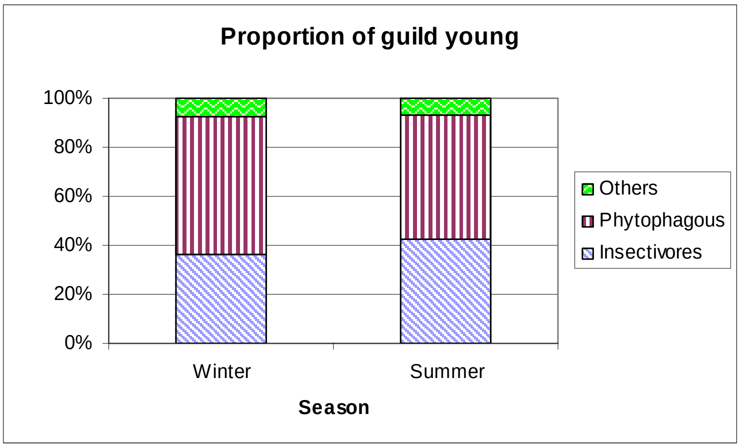

Fig 4.3

Figures 4.1- 4.3 The proportion of each guild in total density in each stratum across seasons.

4.1.4 Comparison of abundances according to habitat guilds across seasons

A comparison of the proportion of detections of each habitat guild in the three strata is a good representation of the change in their abundance. This is because a rise in their density might be an artefact of the overall rise in densities in summer. EvMD shows increase in all three strata with greatest gain in young plantations. While woodland birds do not show a marked change, the overall detections of generalist birds decreases in plantation strata. All detections considered were the ones falling in the first 15m on either side of the transect as detection probability for all size classes at this distance was close to, or equal to 1.

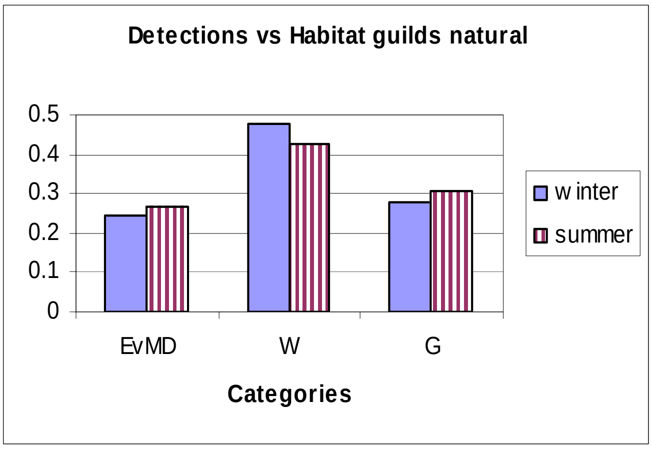

Figure 4.4

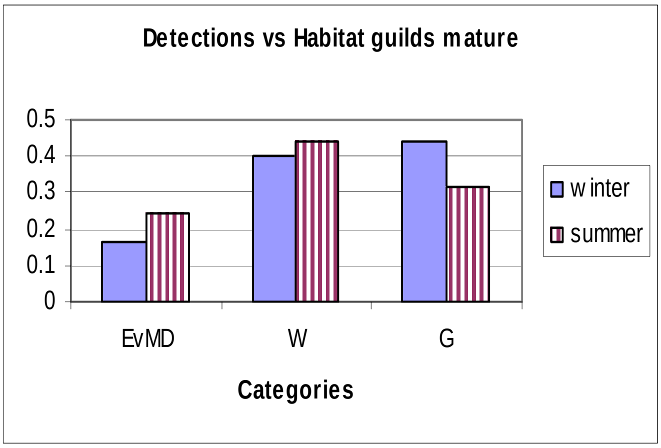

Figure 4.5

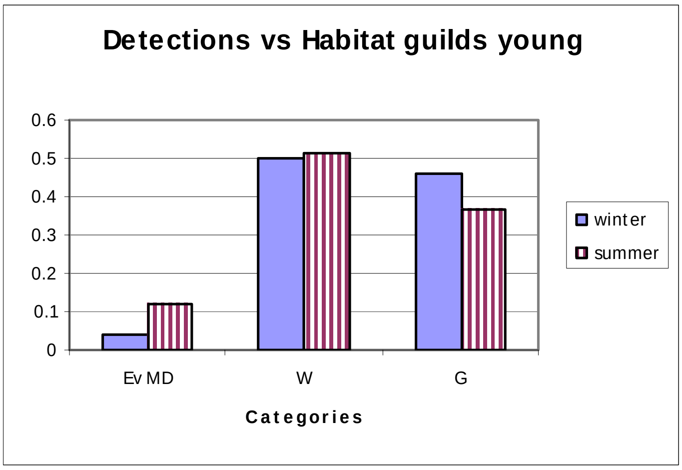

Figure 4.6

Figures 4.4- 4.6 Graphs showing the proportion of detection of each habitat guild in 15m belt in transects.

4.2 Diversity of birds in natural forests and teak plantations

Estimated species richness of birds showed an increase from winter to summer especially in the plantation strata. The biggest gain in richness occurred in the insectivorous guild in summer.

4.2.1 Winter

Overall estimated bird species richness was highest in natural forests followed by mature plantations and young plantations. At the guild level, insectivorous bird species richness was similar in mature and young plantation strata but less than the natural forests. The phytophagous guild showed a trend of decreasing richness similar to that of overall species richness.

Estimated species richness winter

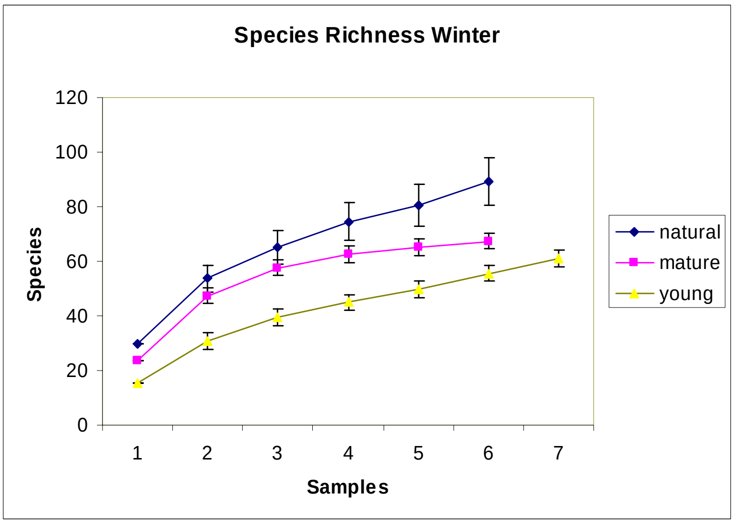

Figure 4.7 Overall estimated species richness in winter (error bars denote standard deviation)

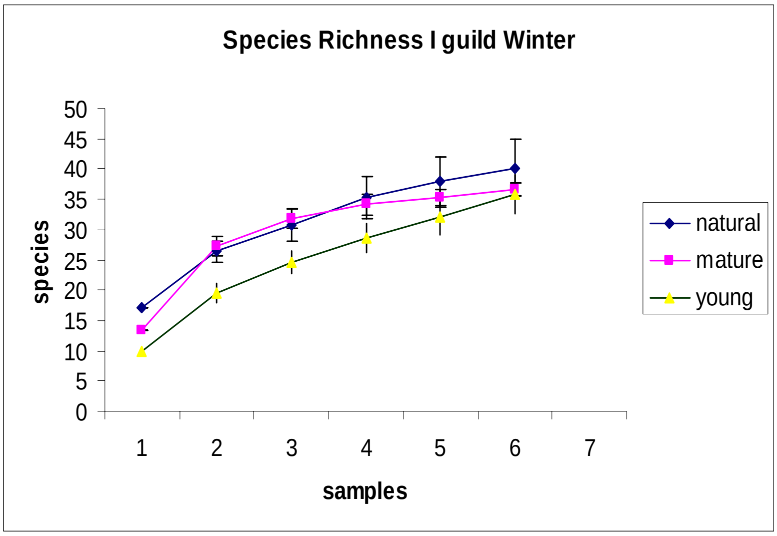

Figure 4.8 Estimated species richness of the insectivorous guild winter (error bars denote standard deviation)

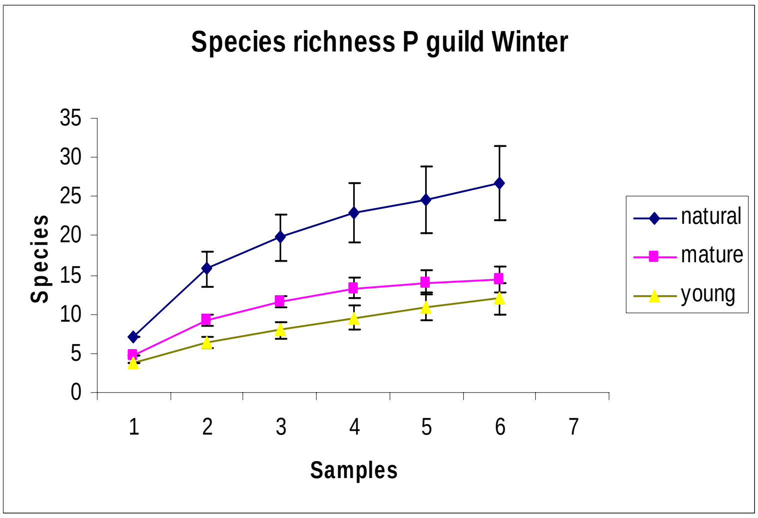

Figure 4.9 Estimated species richness for phytophagous guild winter (error bars denote standard deviation)

Table 4.4 Estimated species richness in winter using JACK 1 estimator –

	Natural	Mature	Young
Overall	89.33	67.33	55.61
Insectivorous guild	40.17	36.67	35.92
Phytophagous guild	26.67	14.33	11.99

4.2.2 Summer

The overall estimated species richness was highest for natural forest while the two plantation strata showed little difference in richness. At the guild level, the insectivorous guild showed a higher richness in the plantation strata than the natural forest. The phytophagous guild had highest richness in natural forests followed by young plantations and mature plantations.

Estimated Species Richness Summer-

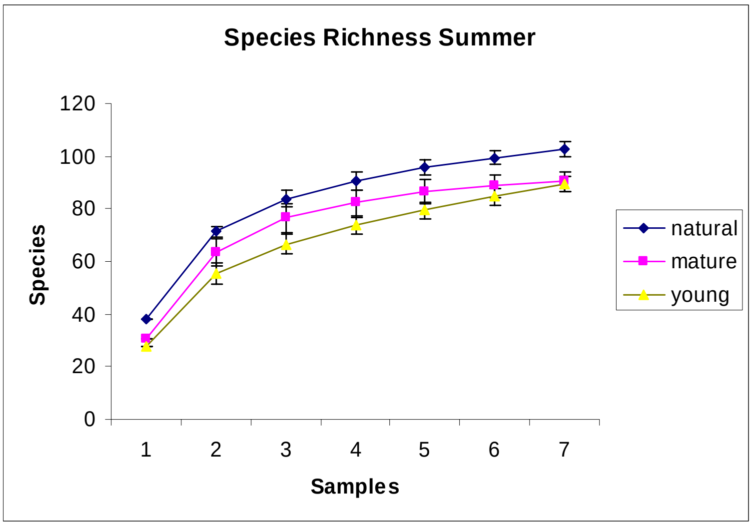

Figure 4.10 The overall estimated species richness in summer (error bars denote standard deviation)

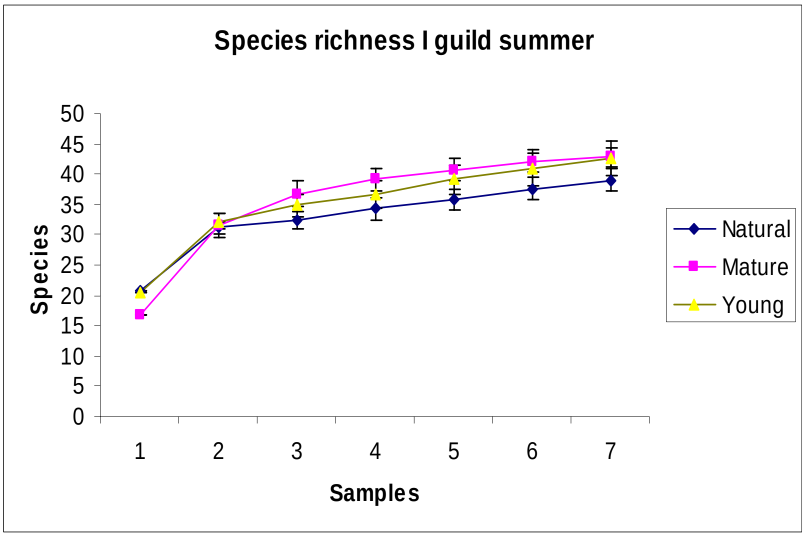

Figure 4.11 The estimated species richness of the insectivorous guild summer (error bars denote standard deviation)

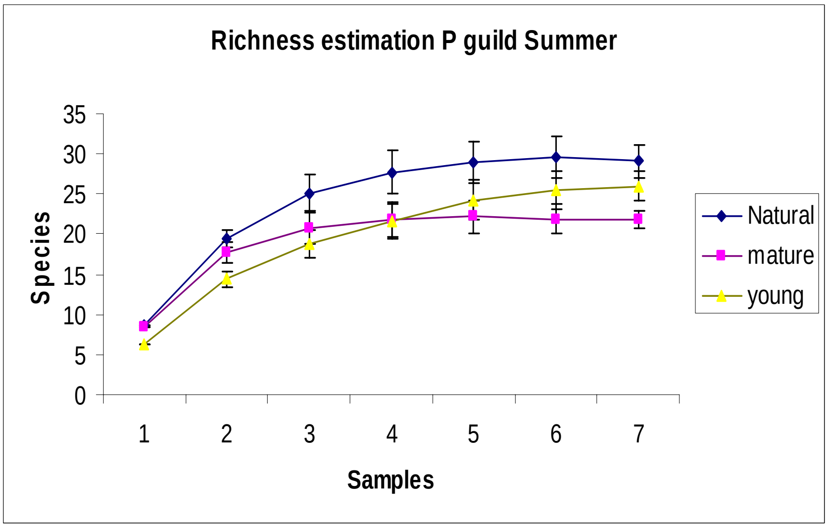

Figure 4.12 The estimated species richness for phytophagous guild summer (error bars denote standard deviation)

Table 4.5 Estimated species richness in summer using the JACK 1 estimator

	Natural	Mature	Young
Overall	102.71	90.29	89.43
Insectivorous	39	42.86	42.71
Phytophagous	29.14	21.87	26

4.2.3 Diversity of birds- Shannon's index calculated at the transect level produced the following index values-

Table 4.6 The Shannon's Index values for each transect in the two seasons

Strata	Transect	Shannon's Index Winter	Shannon's Index Summer
Natural	Chipli	2.91	3.58
Natural	Manchale	2.88	3.41
Natural	Konehosur	3.30	3.44
Mature	Ullur	2.58	3.04
Mature	Puradasara	2.83	3.58
Mature	Tupur	3.33	3.12
Young	Tyagarti	2.39	2.67
Young	Jiglemane	2.31	2.34
Young	Konehosur(Y)	2.53	2.89

4.3 Community Similarity

4.3.1 Winter-

Table 4.7 Community similarity using the Morisita Horn Index for winter. Values in parentheses denote number of species shared between the two strata.

Strata	Unique Species			Morisita Horn Index
	Natural	Mature	Young	
Natural-Mature (44)	18	9	-	0.734
Natural-Young (31)	29	-	11	0.624
Mature-Young (31)	-	22	11	0.805

Summer-

Table 4.8 Community similarity using the Morisita Horn Index for summer. Values in parentheses denote number of species shared between the two strata.

Strata	Unique Species			Morisita Horn Index
	Natural	Mature	Young	
Natural-Mature (61)	18	11	-	0.867
Natural -Young (51)	28	-	14	0.797
Mature -Young (53)	-	19	12	0.829

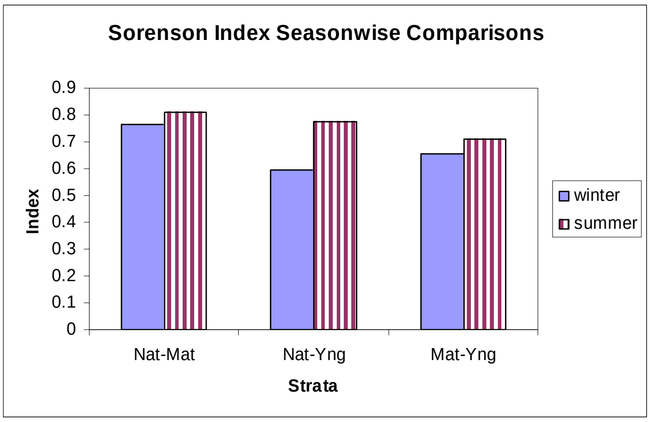

Figure 4.13 Community similarity between sets of strata across seasons (Sorenson's Index)

The three strata show a high degree of bird community similarity. The two plantation strata show highest degree of similarity in winter. In summer however, natural forest and mature plantations show the highest degree of similarity. The overall similarity between the strata increases from winter to summer (high overlap) although the two plantations do not show an increase in similarity. This trend is mirrored in the Sorenson index demonstrating that it is not biased due to many singletons in the plantation strata.

4.4 Vegetation

4.4.1 Structural Attributes

Vertical heterogeneity of a habitat has been recognized as an important factor affecting bird diversity. Foliage height diversity has been quantified as an important vertical heterogeneity variable (Macarthur and Macarthur 1961). The foliage height diversity (F.H.D) of the three strata showed three distinct trends.

Young plantations had a skewed distribution in the lower height categories with most of the foliage located 5-9 m above ground. Mature plantations had a more even foliage distribution with distinct strata forming at 2-5m, 7-9m, and 12-16m above ground. Natural forests had strata at 2-4m and 10-15m above ground.

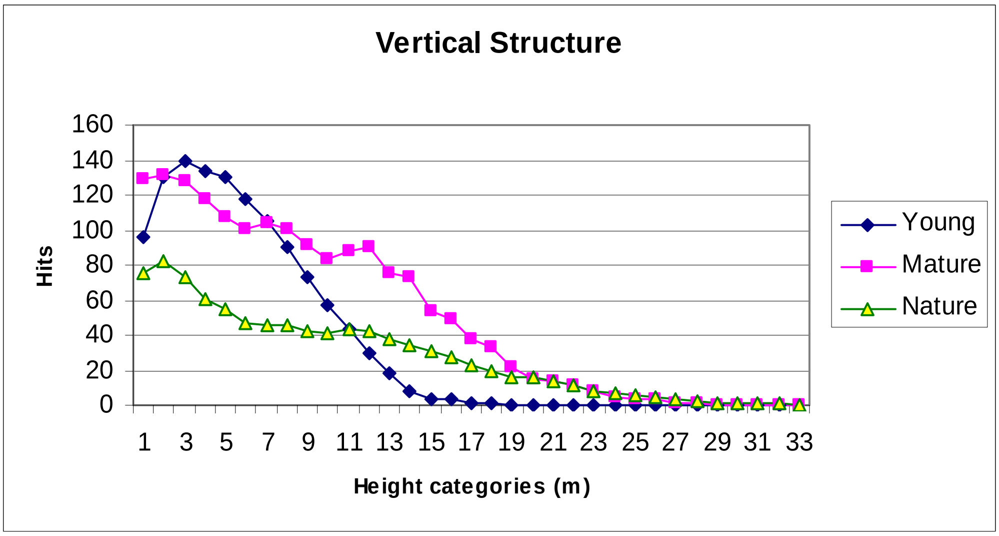

Figure 4.14 Distribution of foliage in a vertical spread of vegetation

Top Height Heterogeneity

The natural forest had a lot of heterogeneity in top height while the two plantation strata showed more consistent homogenous distribution of tree top height. This was used in further analysis as a measure of the vertical spread and distribution of foliage.

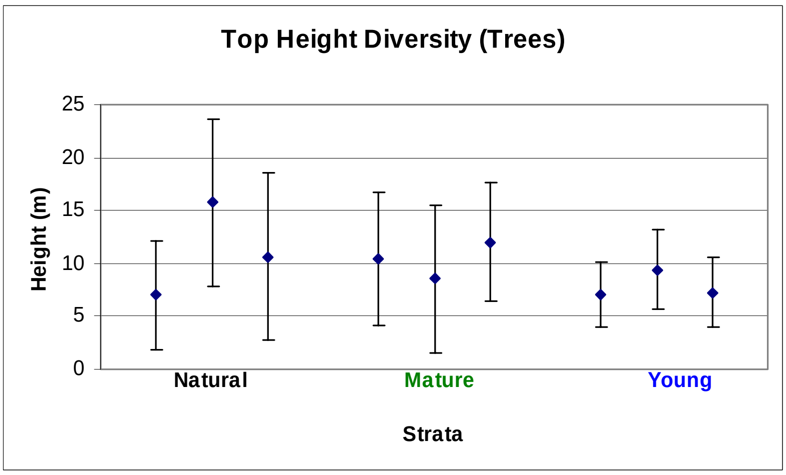

Figure 4.15 Variability among the crown height of trees in each transect. (error bars denote standard deviation)

Vertical spread of vegetation

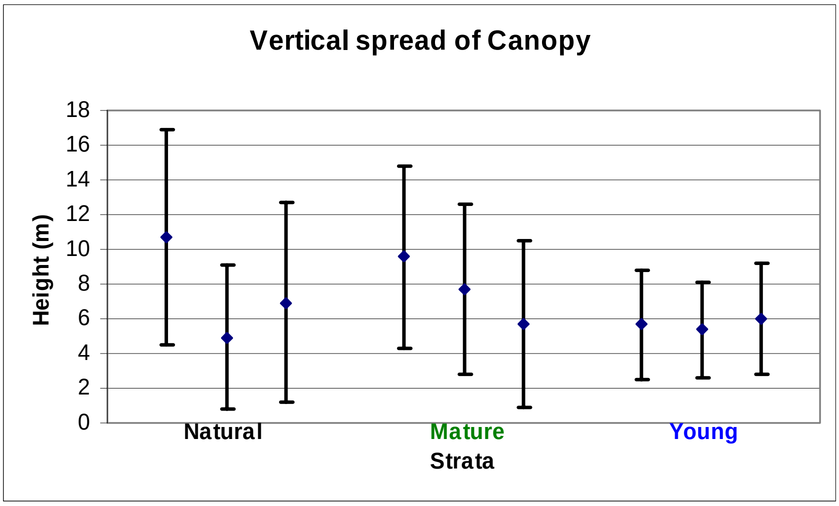

Figure 4.16 Difference in the vertical spread of foliage in the three strata. (error bars denote standard deviation)

The vertical spread of vegetation was most heterogeneous in natural forests and quite uniform in the plantation strata.

G.B.H: Average G.B.H decreased in the order from natural forests to mature plantations to young plantations. While plantation strata had an even G.B.H. distribution natural forests had a high heterogeneity in its GBH distribution.

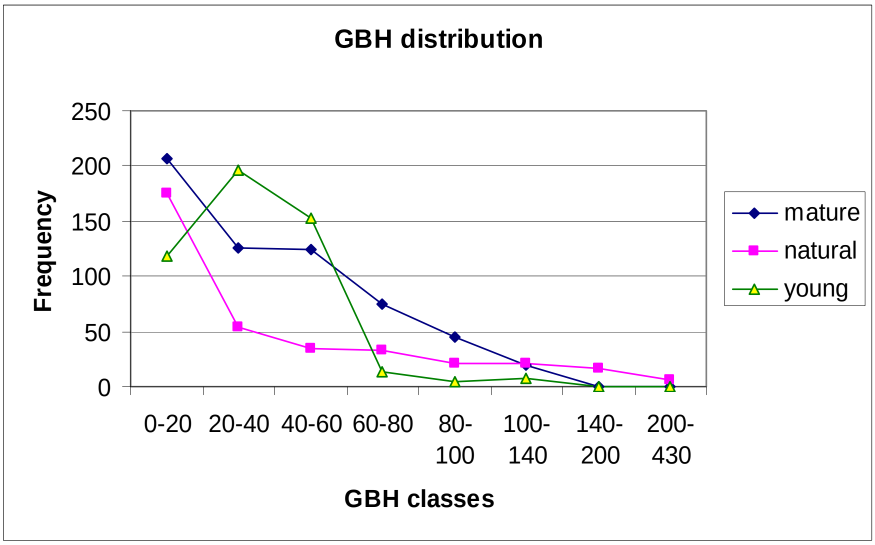

Figure 4.17 Distribution of Girth at Breast Height in trees in the three strata.

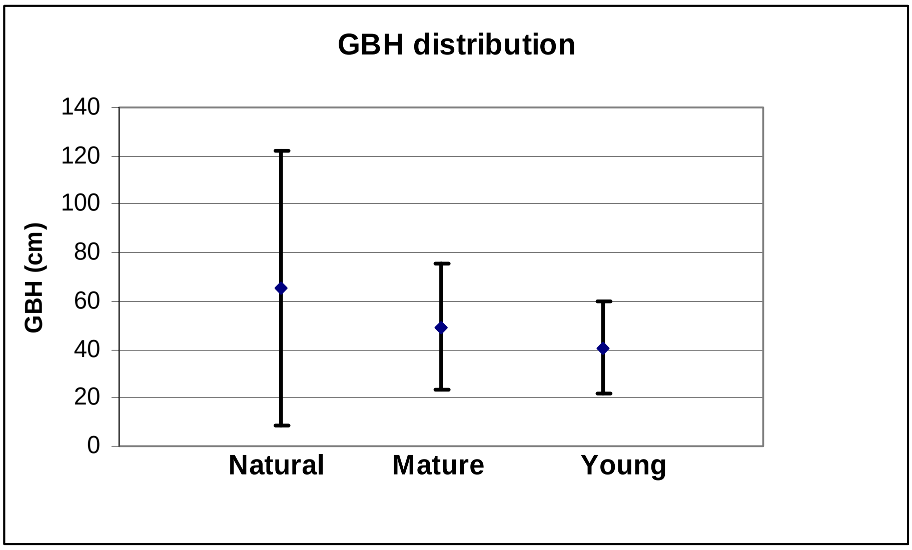

Figure 4.18 Variability in the GBH in trees of the three strata. (error bars denote standard deviation)

Tree Density

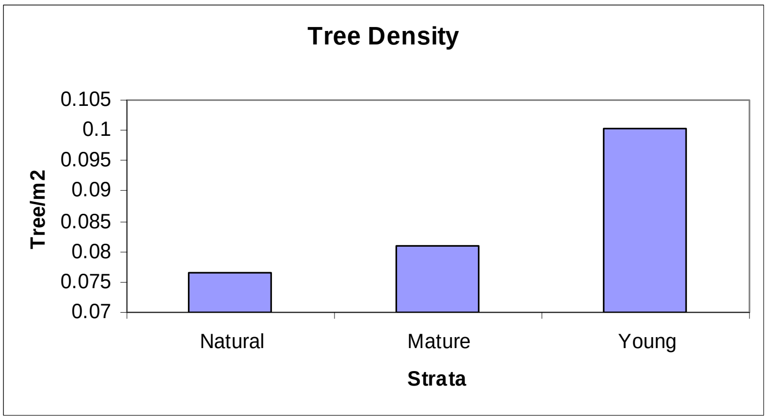

Figure 4.19 Trees/m^2 in the three strata.

Tree density followed a trend opposite to that of GBH. Tree density was highest in young plantations followed by mature plantations and natural forests (only trees above 15 cm G.B.H were considered)

Epiphytic parasites

Parasites were must abundant in the young plantations as they are known to be partial to areas with high incident sunlight and canopy openings.

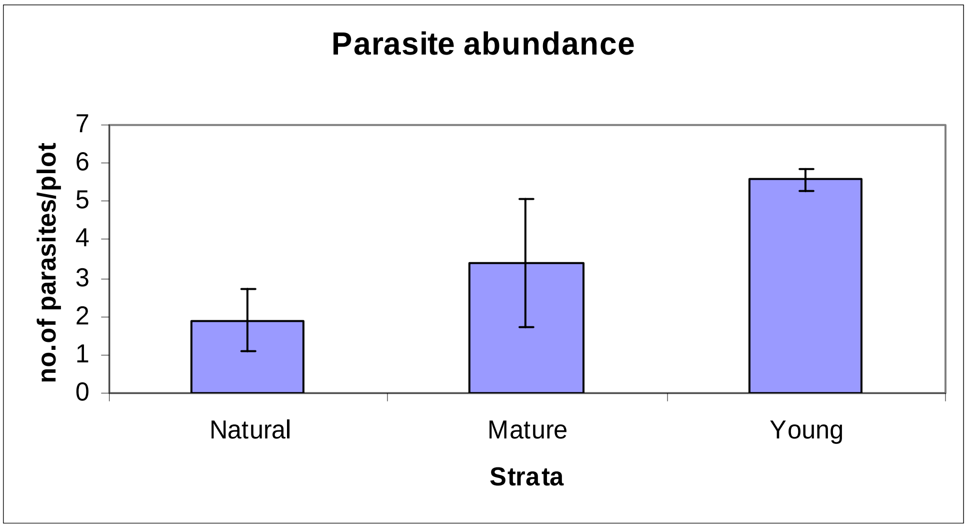

Figure 4.20 Number of parasites/ vegetation sampling plot (error bars denote standard deviation)

Canopy cover: Natural forests had almost complete canopy cover in winter, but most of the trees shed their leaves with the onset of summer, the teak had dried leaves in winter and almost no leaves in summer.

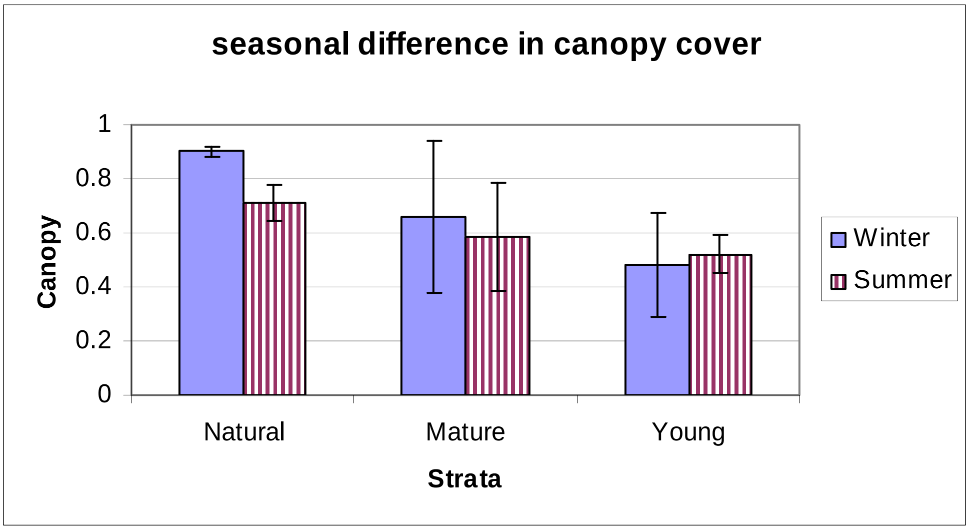

Figure 4.21 Seasonal differences in canopy cover in the three strata (error bars denote standard deviation)

4.4.2 Floristic attributes of the three strata

4.4.2.1 Tree diversity: Estimated tree species richness was highest in natural forests followed by mature plantations and young plantations.

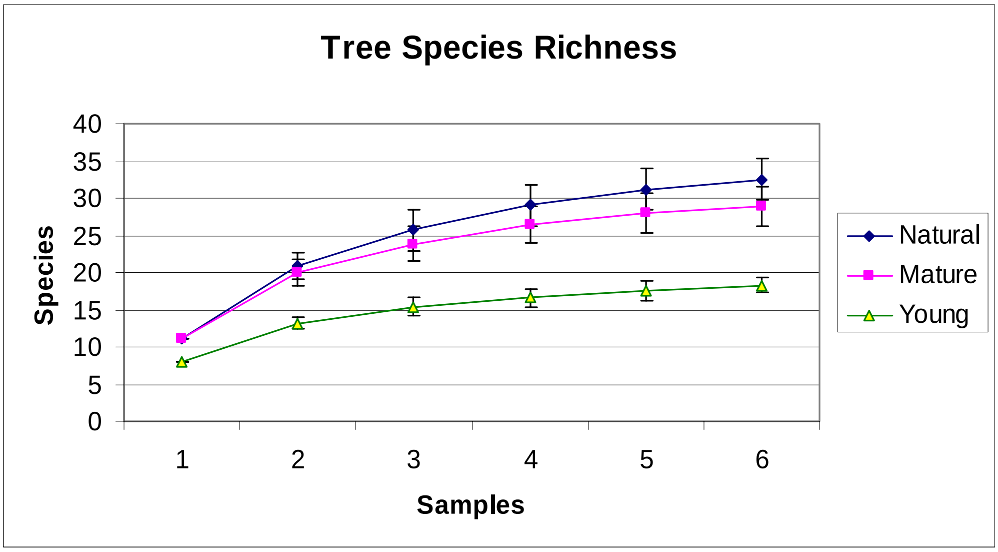

Figure 4.22 Estimated tree species richness using the JACK 1 estimator (error bars denote standard deviation)

4.4.2.2 Tree and shrub species diversity at the transect level

Table 4.9 The Shannon's index for tree and shrub diversity for transects

	Transect	Tree	Shrub
Natural	Chipli	1.09	1.72
	Manchale	1.88	1.05
	Konehosur	2	1.08
Mature	Ullur	1.39	0.09
	Puradasara	1.8	0.03
	Tupur	1.39	0.07
Young	Tygarti	0.96	1.84
	Jiglemane	1.17	1.97
	Konehosur Young	1.08	0.96

Natural forests: These are habitats with low tree density, a highly heterogeneous GBH distribution, highest heterogeneity in tree height diversity ($F_{(10.801)}$ $p< 0.05$) and vertical spread of foliage ($F_{(7.345)}$ $p <0.05$). It had high tree and shrub diversity with a high and continuous canopy cover and few epiphytic parasites.

Mature plantations: As these are actively managed habitats they have homogenous GBH distribution, tree density is slightly higher than natural forests and a homogenous tree height distribution. Canopy cover was highly variable as teak is a deciduous species. Epiphytic parasites were a little more abundant than in natural forests. There is an abundant regeneration of trees like *Xylia xylocarpa, Terminalia paniculata and Syzigium cumini.* Tree species diversity is only a little below that of natural forests. But they were very poor in shrub species diversity.

Young plantations: These habitats have a high tree density, and highly homogenous GBH distribution with most trees between 20cm -50cm in girth and homogeneity in tree height. They have highly variable and discontinuous canopy cover. Teak trees in young plantations lost their leaves earlier and grew new leaves earlier than the mature plantations (pers. observation). They had the highest density of epiphytic parasites ($F_{(8.691)}$ $p < 0.05$). Tree diversity was not very high but they had the highest shrub species diversity ($F_{(13.029)}$ $p < 0.05$).

4.5 Habitat correlates explaining bird diversity

The Principal Component Analysis decomposed the data into three principal factors together explaining 90.28 % of the variance in the dataset.

Table 4.10 Contribution of each variable to the extracted factors

Component Matrix

	Component		
% Variance explained	(1) 48.92	(2) 25.49	(3) 15.87
Canopy Cover (Summer)	.419	.491	.735*
GBH	.824*	-.418	.201
Std.dev of Top Height Diversity	.969*	-.044	-.190
Tree Species Diversity	.599	.728*	.103
Shrub Species Diversity	-.267	-.601	.678
Tree Density	-.676	.686*	.080
Shrub Density	.862*	.056	-.134

Extraction Method: Principal Component Analysis.
a 3 components extracted.
(*) indicate significant correlation between Factor Score and Variable.

Component 1 was related to "forest maturity" as GBH, Top Height Diversity and Shrub Density were all contributing to this factor. Component 2 was related to tree density and diversity, while Component 3 was related to canopy cover.

4.5.2 Habitat variables explaining trends in bird density and diversity

Winter

Overall bird diversity was explained by N.D.V.I. and canopy cover ($R= 0.737$ $p< 0.01$ and $R=0.807$ $p<0.05$ respectively). This shows that birds favour areas with high canopy cover and respond positively to canopy connectivity and continuity. It also shows a strong positive correlation to the tree height heterogeneity ($R= 0.871$, p<

0.01). Hence bird diversity increases with increasing heterogeneity in vertical spread of foliage. The insectivorous guild density also responded to tree height heterogeneity (R= 0.793 $p < 0.01$). Phytophagous birds showed a positive correlation to mean number of epiphytic parasites/ plot (R= 0.766, $p< 0.05$). These parasites were flowering in winter and might have attracted a large number of nectarivores. They also showed a negative correlation to tree height heterogeneity (R= 0.815, $p < 0.01$) which could be an artefact of them being most abundant in young plantations.

Overall resident bird composition and tree species composition showed a strong relationship (R= 0.49, $p< 0.001$). Resident insectivorous and phytophagous guilds also showed significant relationships (R= 0.36 $p< 0.001$, R= 0.49, $p < 0.001$ respectively) (Mantel tests). This shows that tree composition plays a significant role in determining the resident bird community.

Summer-

In summer overall bird diversity was highly positively correlated to Principal Component 1 which represented forest maturity (R= 0.852, $p < 0.01$). Overall diversity also shows a strong correlation to the tree height heterogeneity (R= 0.820, $p < 0.01$). Insectivorous guild density was negatively correlated to tree density (R= -0.824, $p< 0.01$) and positively correlated to G.B.H (R= 0.864, $p < 0.05$) suggesting that this guild responded well to forest maturity. Phytophagous bird density was positively correlated to number of epiphytic parasites (R= 0.796, $p < 0.01$) and negatively to tree density and diversity (R= -0.885, $p< 0.01$) due to highest densities of this guild occurring in young plantations. This guild is negatively correlated to the tree height heterogeneity (R= -0.815, $p < 0.01$). This is because young plantations had the least vertical heterogeneity in habitat and had highest densities of this guild.

There was no significant correlation between bird composition and structural habitat variables and tree species composition (Mantel tests).

5. Discussion

Most studies have shown that forest plantations support less avifaunal diversity than natural forests. However the differences in seasonal use of plantations have not been discussed widely. This study demonstrates that a well known trend of decreasing bird diversity and abundance from natural forests to mature plantations to young plantations exists in teak plantations also. However the results indicate a distinct change in both bird density and diversity with change in season.

5.1 Differences in Habitat Characteristics (Vegetation structure)

Teak plantations of Sagar Forest Division show some obvious structural and floristic differences from natural forests. As they are actively managed forests, teak plantations show an increased tree density and lowered tree species diversity. Floristically it is difficult to tease out differences in tree and shrub diversity, as they do not show a high regeneration of teak saplings. *Xylia xylocarpa Terminalia paniculata and Diospyros melanoxylon* are the dominant regenerating species in all the strata. This fact may contribute to the similarity in the shrub diversity. Teak plantations also have a discontinuous canopy because teak trees as a physiognomic trait do not have a high horizontal canopy spread. They also show a high degree of seasonal change in canopy cover as almost all the trees shed leaves simultaneously resulting in a considerable amount of insolation (incident sunlight). This has resulted in young teak plantations having the highest shrub diversity due to abundant light reaching the forest floor. An important feature of young plantations is the increased abundance of epiphytic parasites on the teak trees. Additionally all teak plantations have an increased abundance of the climber *Calycopteris floribunda*, a dry deciduous plant utilizing the abundant sunlight. However, the most important structural attribute that sets natural forests apart from the actively managed teak plantations is the heterogeneity in the top heights of trees and the vertical spread of foliage rendering the natural forests much more structurally complex than the plantation strata.

5.2 Density of birds

The increase in over all densities from winter to summer is a phenomenon seen often with birds in forest environments (Karr 1976). This season is the breeding season for most birds and they might be consequentially converging into forest habitats for nesting. Findings of this study show that there is ingression of individuals of species that were common to both seasons into forest habitats in summer. Number of detections of species common to both seasons increase in summer. Subtraction of winter values from those in summer give positive values (an increase in abundance) for around 65 % species in all strata. The species showing negative values are primarily migratory birds like Greenisg Warbler (*Phylloscopus trochiloides*) and Western Crowned Warbler (*Phylloscopus occipitalis*).

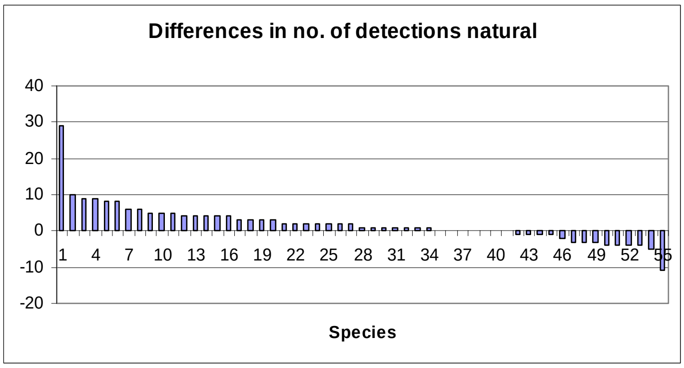

Figure 5.1 Increase in abundance of birds common to both seasons in natural forests. A positive value bar denotes an increase in abundance in summer.

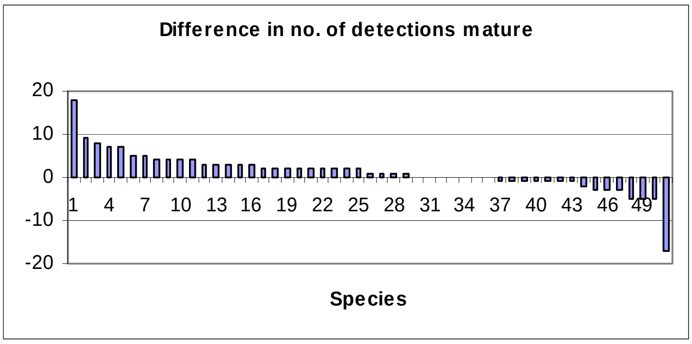

Figure 5.2 Increase in abundance of birds common to both seasons in mature plantations. A positive value bar denotes an increase in abundance in summer.

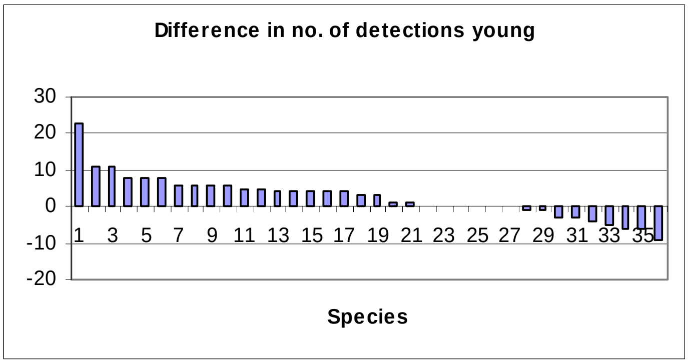

Figure 5.3 Increase in abundance of birds common to both seasons in young plantations. A positive value bar denotes an increase in abundance in summer.

A look at the ecology of the species increasing in abundance throws some light on the possible reasons for the same. The species that shows the highest increase across the three strata is the White rumped shama (*Copsychus malabaricus*) which is a cavity nesting bird (Ali and Ripley 1973). Even the other species increasing in abundance are mostly birds that are cavity nesters like the Greater flameback (*Chrysocolaptes lucidus*) Black rumped flameback (*Dinopium bengalense*) and Brown headed barbet (*Megalaima zelanica*). They also include birds that need a good shrub layer as they nest close to the ground like Yellow browed bulbul (*Iole indica*), Red whiskered bulbul (*Pycnonotus jocosus*), Brown cheeked fulvetta (*Alcippe poioicephala*), Indian scimitar babbler (*Pomatorhynus horsefieldii*) and Tickell's blue flycatcher

(*Muscicapa tickellii*) (Ali and Ripley 1973). There is a strong possibility that the birds use plantations as nesting habitats, also possibly due to these habitats have minimal disturbance due to enforced protection.

Overall density of birds was highest in natural forests. Prachi Mehta (1998) in her study in the Bori Wildlife Sanctaury reports that the density of birds increases from young teak plantations to mature teak plantations with maximum density in natural forests, a trend published for other plantations as well (Trivedi, 2006 Rumble and Gobeille,1998). A similar trend is also reflected in the current study also and this is attributed generally to the stabilization of habitat structure a more stable microclimate regime and plant communities. Guild level densities of birds however showed some peculiar results. The plantation strata show a high variability in bird abundance.

While the density of insectivorous birds did not change in natural forests across seasons, plantations showed a marked increase in insectivore density in summer. This might be a response to the increased arthropod abundance that occurs in most forest environments in summer (Karr 1976) and also an apparent tracking of arthropod abundance after the teak starts getting new leaves.

Phytophagous birds show a reverse trend in density. In both seasons young plantations supported the highest densities of phytophagous birds. This appears to be primarily explained by the the high abundance of Common rosefinch (*Carpodacus erythrinus*). These birds were found in large flocks in the young plantations. Bamboo (*Dendrocalamus strictus*) was flowering and holding seed in most of the study area. As open forest granivorous birds, Common rosefinches probably preferred young plantations to the closed moist-deciduous and semi-evergreen natural forests even though they did not have the highest bamboo density. Common rosefinches make up a large portion of the Phytophagous guild detections. They are followed in abundance by sunbirds and flowerpeckers. These birds were probably attracted to the epiphytic parasites that were found in highest densities in this stratum. These parasites were flowering during winter and fruiting during summer, a constant food source explaining the inflated abundance of these birds. Young plantations supported no true frugivores in winter and very few in summer.

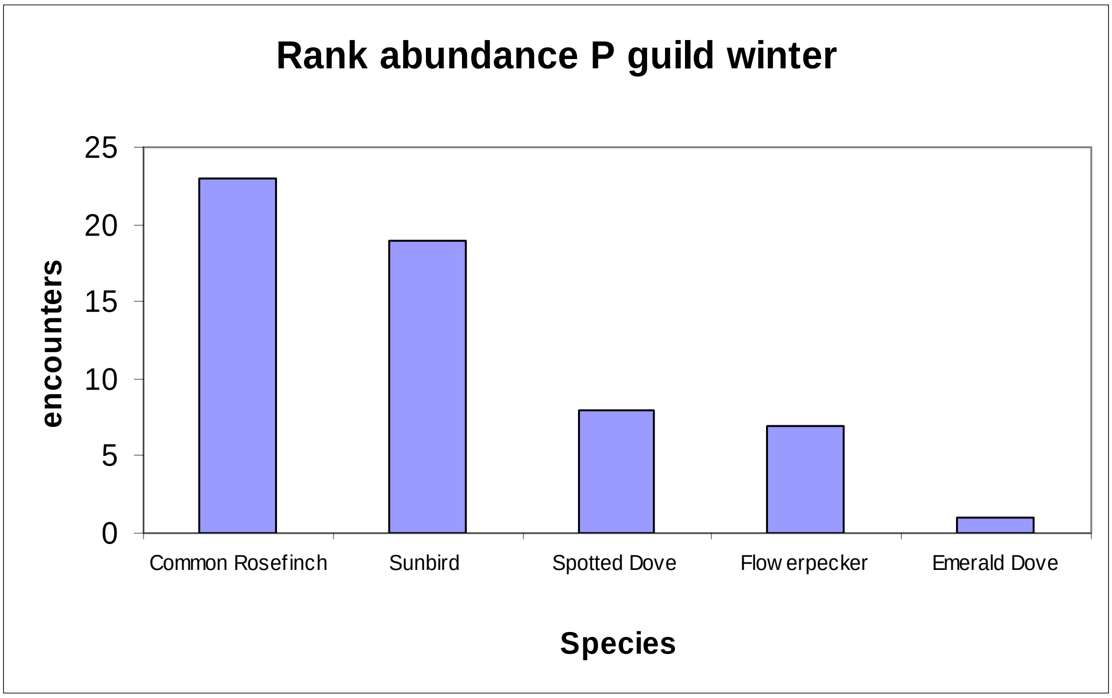

Figure 5.4 Rank abundance of phytophagous birds in young plantations in winter.

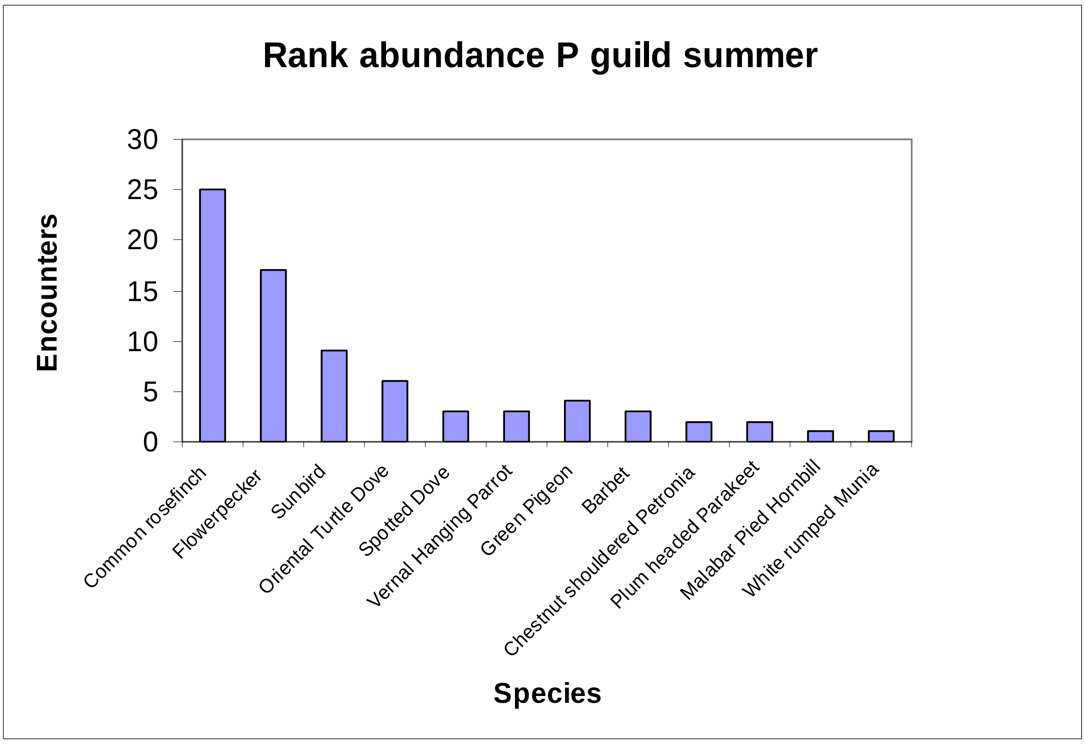

Figure 5.5 Rank abundance of phytophagous birds in young plantations in summer.

Hence the high density of phytophagous birds was mostly due to the inflated abundance of nectarivores and rosefinches. This abundance of nectarivores might have an explanation in the resource concentration hypothesis. This phenomenon has been observed with other taxa like insects in monocultures (Connors et al 2000). This finding is in contrast to that of Bell (2000) who reported a loss of granivores and nectarivores from teak plantations in New Guinea where it is an exotic and the local epiphytic plants are probably not adapted to exploit teak.

5.3 Diversity

The diversity of birds also followed a similar trend as that of density with natural forests showing highest diversity followed by mature plantations and then by young plantations in winter. However this difference is not apparent in summer. Bhagwat et al (2008) report that on an average only 50 - 60% of original bird fauna is represented in forest plantations. Generally the birds that are missing from plantations are primarily the obligate frugivores and birds of primary closed canopy forest (Petit et al 1999, Raman 2001, Daily et al 2001). Hence plantations of native species, even though they support comparable species richness, generally do not contain species of conservation importance (Kwok and Corlett 2000, Rotenburg 2007). The present study looks at seasonal variation in diversity and variation in the community.

The increased bird diversity in all three strata in summer can be attributed to the influx of species for nesting (pers. observ.) or for feeding opportunities. Interestingly the species richness of even young plantations increases considerably and is as high as the mature plantations. The greatest rise in estimated species richness which is amongst phytophagous birds is the effect of many species like Oriental turtle doves (*Streptopelia orientalis*), Vernal hanging parrots (*Loriculus vernalis*), White rumped munias (*Lonchura striata*) and Chestnut shouldered petronia (*Petronia xanthocollis*) using the plantations to feed on the fruits of *Calycopteris floribunda* a common climber which has a large fruit crop.

In part, a common influence on the increase in density and diversity is the apparent seasonal use of the plantation habitats by evergreen and moist deciduous forest (EvMD) birds. The birds belonging to this habitat guild show a consistent rise across all strata, with the highest gain in young plantations. These birds include species like Yellow browed bulbul (*Iole indica*), White bellied woodpecker (*Dryocopus javensis*), Brown-cheeked fulvetta (*Alcippe poioicephala*), Large woodshrike (*Tephrodornis gularis*), Malabar Trogon (*Harpactes fasciatus*), Dark fronted babbler (*Rhopocichla atriceps*) and Pompadour green pigeons (*Treron pompadora*). The reason for this seasonal influx might be for nesting (pers. observation) or to exploit feeding opportunities. In their study of birds of Uttara Kannada Daniels et al (1992) said that birds in teak plantations have species in common with dry deciduous forests. The present study also supports this hypothesis due to the high proportion of woodland and generalist species, but also reports a possibility of interplay of seasonality and use of these plantations by evergreen forest elements in summer.

5.4 Community Structure

The bird community of the region shows a high degree of overlap. The similarity increases in summer likely due to the influx of closed forest birds into the plantation strata. This is supported by both the Morisita Horn Index and the Sorenson Index indicating that the high degree of similarity is not an artefact of individual species abundances.

Overall trends in bird abundance and diversity

<u>Winter</u>

Density

Overall	Natural forests > Mature plantations ≈ Young plantations
Insectivore guild	Natural forests > Mature plantations ≈ Young plantations
Phytophagous guild	Natural forests < Mature plantations < Young plantations

Diversity

Overall	Natural forests > Mature plantations > Young plantations
Insectivore guild	Natural forests > Mature plantations > Young plantations
Phytophagous guild	Natural forests > Mature plantations > Young plantations

<u>Summer</u>

Density

Overall	Natural forests > Young plantations > Mature plantations
Insectivore guild	Natural forests > Young plantations > Mature plantations
Phytophagous guild	Natural forests < Mature plantations < Young plantations

Diversity

Overall	Natural forests > Mature plantations ≈ Young plantations
Insectivore guild	Natural forests ≈ Mature plantations ≈ Young plantations
Phytophagous guild	Natural forests ≈ Mature plantations ≈ Young plantations

Alpha, beta and gamma diversity are amongst the fundamental descriptive variables of ecology, but their quantitative definition has been controversial. The dependence of the value of beta on alpha has been seen as a cause of concern, as it makes the diversity index behave in ways that are not always intuitively correct. The numbers equivalent of all standard diversity indices however behave in this intuitive manner. This has led to the modification of Shannon Weiner Index to give the numbers equivalent of the formula as [exp {-Σ pi * log(pi)}]. By this new modification, the landscape level diversity is $\exp(H_\gamma) = \exp(H_\alpha) + \exp(H_\beta)$ i.e. $\exp(H_\beta) = \exp(H_\gamma) - \exp(H_\alpha)$.

If the numbers equivalent answer for this equation is ≥2 then it is safe to say that the samples are drawn from two mutually exclusive and distinct communities (Jost 2007). Gamma level diversity was calculated for the whole dataset for the two seasons separately. Then, using the diversity of the natural forest strata as the alpha diversity (as it had the highest species richness) the beta diversity was calculated. It was 1.12 for winter and 1.21 for summer. Hence it seems that the bird community of the teak plantations of the area is derived from the original Semi Evergreen- Moist Deciduous forest bird community.

5.5 Habitat Attributes

Forest structure (physiognomy) and composition (floristics) have been known to be the two most important albeit broad, factors governing the avian community of a given area. Also there is evidence that these factors play important roles at different levels in the landscape. While floristics play a role at the site level, forest structure often plays a role at the regional level (Lee and Rotenberrry 2005). Hence vegetation structure plays a role across habitats and vegetation composition plays a role within a habitat. Similar trends have been seen in the present study. As comparisons were done across three main habitats, vegetation structure proved to be the most important factor explaining differences in bird density and diversity.

5.5.1 Patterns in bird responses common to both seasons

An important factor determining bird density and diversity was the vertical structural heterogeneity (tree height heterogeneity). This attribute renders vertical structural complexity which provides for more niches to develop and hence results in higher bird densities (MacArthur and MacArthur 1961, Holmes et al 1986, Mitra and Sheldon 1993, Hansen et al 1995). Insectivores in both seasons responded to high basal area which formed a structural gradient separating the three strata ($F_{(5.160)}$ $p<0.05$), that was greatest in natural forests. This resulted in a high density and diversity of this guild in these habitats. Phytophagous guild densities were primarily governed by epiphytic parasite abundance and all the other correlations, like the relationship with high tree density and low GBH and low canopy cover are an artefact of the same.

5.5.2 Seasonal Patterns

Winter

Contrary to Daniels et al (1992) who reported that bird species diversity increased with increased patchiness of canopy, the current study shows a strong correlation of overall winter bird diversity and canopy intactness and continuity. In fact canopy cover also explains the density of insectivorous guild in winter. Hence canopy cover and intactness are the most important governing factors of bird diversity in the winter.

Canopy cover has been recognized as an important factor for bird diversity in many studies (Mazerrole and Villard 1999, Rotenburg 2007, Raman 1998, Wilson 1974, Malcom et al 2006). Most of these studies also show that bird diversity of evergreen and semi-evergreen forests are most severely affected changes in canopy structure, a trend seen in the current study. Resident bird composition was also correlated to tree composition a plausible phenomenon as natural forests with high floristic diversity offers food resources during the winter 'resource-crunch' period.

In summer, canopy did not play a role in determining bird responses to habitat (as most tree species were leaf less or sprouting new leaves). Although the effect of floristics between habitats is known to be minimal, plant species diversity increases the strength of the correlation between bird diversity and vegetation structure. Tree composition was not correlated to bird composition in summer.

Teak plantations hence emerge as seasonally variable bird habitats. Natural forests being stable ecosystems change very little with seasons in terms of diversity. However teak plantations, although depauperate in terms of diversity and abundance in winters seem to offer subsistence to a large variety of birds with diverse life history traits in summer. Mature plantations are closer to natural forests in terms of structure and floristics and hence are more stable and change minimally across seasons. Young plantations are more dynamic. With their abundant parasites, they are home to an almost unnatural abundance of nectarivores. Insectivores also seem to seasonally exploit their resources to a greater degree than even mature plantations even though they are the most structurally and floristically homogenous of the three strata. This might have some explanation with shrub diversity which is highest in young plantations and almost negligible in mature plantations. Also, the presence of many insectivorous and phytophagous closed forest species within teak plantations during some seasons suggests that closed forest birds may use plantations more than previously believed.

5.6 Conclusion

Teak plantations do not harbour the same diversity and abundance of birds as natural forests especially that of closed forest frugivores and canopy specialist birds. A certain proportion of the landscape has to have native primary forest (possibly in a matrix) so as to function as a species pool. However, some pertinent points emerge as to what might be the characteristics of bird-friendly teak plantations. Distance to natural forests is an obvious and intuitive factor however that variable was controlled for in this study, so it cannot be discussed here. Teak plantations near natural forests may support many native bird species if certain habitat attributes are maintained. Canopy being an important determinant, some trees with large canopy spread like the locally occurring Dilenia spp. or Ficus spp. can be maintained in a mosaic to enhance the canopy structure of the forest. Also certain conventional practices like climber cutting and parasite removal can be less rigorous as these plants seem to enhance bird diversity especially that of phytophagous birds. Also, clear felling which is a common practice for extraction in teak plantations might be replaced by a system in which trees are felled selectively. This will increase the vertical heterogeneity and stratification of the habitat increasing the diversity of birds using the area. Teak plantations being actively guarded by authorities have very little anthropogenic disturbance. The natural forests of the area are heavily exploited for firewood and leaf litter collection in early summer, the breeding season for most bird species causing a great deal of disturbance. Hence the protected teak plantations might also be functioning as good and safe nesting habitats for birds. Also as they are protected from fire, they can grow a healthy shrub under storey which is an important structural component with regards to avifauna commercial gain derived from teak plantations.

Planted forests are neither inherently good nor bad; rather it is the choices we make about how to use them that determine whether they contribute to, or detract from, broader societal goals such as nature conservation. Whether we like it or not, plantations are here to stay and are capable of delivering ancillary social and environmental co-benefits. Dismissing plantations as just another agricultural crop is therefore counterproductive. Through intelligent research and management, we can work towards a system that facilitates the realization of many ancillary goals of plantations while maximizing output of the desired goods.

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APPENDIX A -Bird species used in the analysis

Common Name	Scientific Name	Habitat Guild	Feeding Guild	Seen in
Ashy Drongo	Dicrurus leucophaeus	G	I	W S
Ashy Prinia	Prinia socialis	G	I	S
Asian Brown Flycatcher	Muscicapa dauurica	G	I	S
Banded bay Cuckoo	Cacomantis sonneratii	G	O	S
Black crested Bulbul	Pycnonotus melanicterus	EvMD	O	S
Black headed Cuckooshrike	Coracina melanoptera	W	I	S
Black hooded Oriole	Oriolus xanthornus	G	O	W S
Black naped Monarch	Hypothymis azurea	G	I	W S
Black naped Oriole	Oriolus chinensis	Ev MD	O	S
Black rumped Flameback	Dinopium benghalense	G	I	W S
Blue capped Rock thrush	Monticola cinclorhynchus	Ev mD	O	S
Blue faced Malkoha	Phaenicophaeus viridirostris	Ev MD	O	S
Blue tailed Beeater	Merops philippinus	G	I	S
Blyth's Reed Wabler	Acrocephalus dumetorum	G	I	S
Booted Warbler	Hippolais caligata	G	I	W
Bronzed Dongo	Dicrurus aeneus	Ev MD	I	W S
Brown capped pygmy Woodpecker	Dendrocopos moluccensis	W	I	W S
Brown headed Barbet	Megalaima zeylanica	G	P	W S
Brown Shrike	Lanius cristatus	W	I	W
Chestnut shouldered Petronia	Petronia xanthocollis	G	P	S
Chestnut tailed Starling	Sturnia malabarica	W	O	S
Commmon Rosefinch	Carpodacus erythrinus	G	P	W S
Common Drongo	Dicrurus macrocercus	G	I	W S
Common Hawk Cuckoo	Cuculus varius	W	I	S
Common Myna	Acridotheres tristis	G	O	S
Common Woodshrike	Tephrodornis pondicerianus	G	I	S
Coppersmith Barbet	Megalaima haemacephala	G	P	W S
Coucal	Centropus sinensis	G	O	W S
Crimson backed Sunbird	Leptocoma minima	Ev MD	P	W S
Crimson Fronted Barbet	Megalaima rubricapillus	Ev MD	P	S
Crimson Sunbird	Aethopyga vigorsii	G	P	S
Dark fonted Babbler	Rhopocichla atriceps	Ev MD	I	W S
Emerald Dove	Chalcophaps indica	Ev MD	P	W S
Eurasian Blackbird	Turdus merula	Ev MD	O	W
Fairy Bluebird	Irena puella	Ev MD	O	S
Forest Wagtail	Dendronanthus indicus	G	I	W S
Gold fronted Chrolopsis	Chloropsis aurifrons	W	O	W S
Golden Oriole	Oriolus oriolus	G	O	W S
Great Tit	Parus major	G	O	W
Greater Flameback	Chrysocolaptes lucidus	Ev MD	I	W S
Greenish Warbler	Phylloscopus trochiloides	G	I	W S
Grey headed Flycatcher	Culicicapa ceylonensis	G	I	W

Hearspotted Woodpecker	Hemicircus canente	Ev MD	I	W S
Hume's Warbler	Phylloscopus humei	G	I	S
Indian Pitta	Pitta brachyura	G	O	S
Indian Scimitar Babbler	Pomatorhinus horsfieldii	G	I	W S
Iora	Aegithina tiphia	G	I	W S
Jungle Babbler	Turdoides striata	G	I	W S
Jungle Crow	Corvus macrorhynchos	G	O	W S
Jungle Myna	Acridotheres fuscus	W	O	S
Koel	Eudynamys scolopaceus	G	O	W S
Large Cuckooshrike	Coracina macei	G	O	W S
Large Woodhsrike	Tephrodornis gularis	Ev MD	I	W S
Lesser Yellownape	Picus chlorolophus	Ev MD	I	S
Loten's Sunbird	Cinnyris lotenius	G	P	S
Magpie Robin	Copsychus saularis	G	I	W S
Malabar Grey Hornbill	Ocyceros griseus	Ev MD	O	W S
Malabar Parakeet	Psittacula columboides	Ev MD	P	S
Malabar Pied Hornbill	Anthracoceros coronatus	Ev MD	P	S
Malabar Trogon	Harpactes fasciatus	Ev MD	O	W S
Malabar whistling thrush	Myophonus horsfieldii	EvMD	O	W
Nilgiri Flycatcher	Eumyias albicaudatus	Ev MD	I	S
Olive backed pipit	Anthus hodgsoni	G	I	S
Orange headed Thrush	Zoothera citrina	G	O	W S
Oriental Turtle Dove	Streptopelia orientalis	Ev MD	P	W S
Oriental White eye	Zosterops palpebrosus	G	O	W S
Pale billed Floerpecker	Dicaeum erythrorhynchos	G	P	W S
Paradise Flyatcher	Terpsiphone paradisi	G	I	W S
Pied Flycathershrike	Hemipus picatus	G	I	W S
Plain Flowepecker	Dicaeum concolor	Ev MD	P	W S
Plum headed Parakeet	Psittacula cyanocephala	G	P	W S
Pompadour Green Pigeon	Treron pompadora	EvMD	P	W S
Puff Throated Babbler	Pellorneum ruficeps	G	I	S
Purple rumped Sunbird	Leptocoma zeylonica	G	P	W S
Purple Sunbird	Cinnyris asiaticus	G	P	W S
Quaker Babbler	Alcippe poioicephala	Ev MD	I	W S
Red Turtle Dove	Streptopelia tranquebarica	G	P	W
Racket Tailed Drongo	Dicrurus paradiseus	G	I	W S
Red vented Bulbul	Pycnonotus cafer	G	O	W S
Red whiskered Bubul	Pycnonotus jocosus	G	O	W S
Red throated Flycatcher	Ficedula parva	G	I	W
Roseringed Parakeet	Psittacula krameri	G	P	W S
Rufous Treepie	Dendrocitta vagabunda	G	O	W S
Rufous Woodpecker	Celeus brachyurus	G	I	S
Scarlet Miivet	Pericrocotus flammeus	W	I	W S
Shama	Copsychus malabaricus	W	I	W S
Small Minivet	Pericrocotus cinnamomeus	W	I	W S
Speckled Piculet	Picumnus innominatus	G	I	S

Spotted Dove	Streptopelia chinensis	W	P	W S
Streak throated woodpecker	Picus xanthopygaeus	Ev MD	I	S
Sulphur bellied Warbler	Phylloscopus griseolus	G	I	S
Tailor bird	Orthotomus sutorius	G	I	S
Thick billed Flowepecker	Dicaeum agile	Ev MD	P	W S
Tickell's Flycatcher	Cyornis tickelliae	W	P	W S
Tree Pippit	Anthus trivialis	G	I	S
Velvet fronted Nuthatch	Sitta frontalis	G	I	W S
Verditer Flycatcher	Eumyias thalassinus	Ev MD	I	W S
Vernal Hanging Parot	Loriculus vernalis	Ev MD	P	W S
Western Crown leaf Warbler	Phylloscopus occipitalis	Ev MD	I	W S
White bellied blue Flycatcher	Cyornis pallipes	Ev S	I	W S
White bellied Drongo	Dicrurus caerulescens	G	I	W S
White bellied Woodpecker	Dryocopus javensis	Ev MD	I	W S
White browed Bulbul	Pycnonotus luteolus	W	O	W
White browed Fantail	Rhipidura aureola	G	I	W
White cheecked Barbet	Megalaima viridis	G	P	W S
White rumped Munia	Lonchura striata	Ev MD	P	S
White throated Kingfisher	Halcyon smyrnensis	G	O	S
Yelllow Browed Bulbul	Iole indica	Ev MD	O	W S
Yellow Footed Green Pigeon	Treron phoenicopterus	G	P	W S

Habitat Guild
EvMD- Evergreen and Moist Deciduous Forest, W- Woodland, G- Generalist

Feeding Guild
I- Insectivore, P- Phytophagous, O- Other

Season
W- Winter, S- Summer

APPENDIX B- Birds seen in Sagar Forest Division

Common name	**Scientific name**
PODICIPEDIFORMES: Podicipedidae	
Little Grebe	Tachybaptus ruficollis
PELECANIFORMES: Phalacrocoracidae	
Indian Cormorant	Phalacrocorax fuscicollis
Great Cormorant	Phalacrocorax carbo
Little Cormorant	Phalacrocorax niger
PELECANIFORMES: Anhingidae	
Darter	Anhinga melanogaster
CICONIIFORMES: Ardeidae	
Great Egret	Ardea alba
Intermediate Egret	Egretta intermedia
Cattle Egret	Bubulcus ibis
Black-crowned Night-Heron	Nycticorax nycticorax
Gray Heron	Ardea cinerea
Purple Heron	Ardea purpurea
Little Egret	Egretta garzetta
Malayan Night-Heron	Gorsachius melanolophus
CICONIIFORMES: Ciconiidae	
Painted Stork	Mycteria leucocephala
Asian Openbill	Anastomus oscitans
Woolly-necked Stork	Ciconia episcopus
CICONIIFORMES: Threskiornithidae	
Black-headed Ibis	Threskiornis melanocephalus
Glossy Ibis	Plegadis falcinellus
Eurasian Spoonbill	Platalea leucorodia
ANSERIFORMES: Anatidae	
Lesser Whistling-Duck	Dendrocygna javanica
Ruddy Shelduck	Tadorna ferruginea
Comb Duck	Sarkidiornis melanotos
Cotton Pygmy-goose	Nettapus coromandelianus
Spot-billed Duck	Anas poecilorhyncha
Northern Pintail	Anas acuta
Garganey	Anas querquedula
Northern Shoveler	Anas clypeata
FALCONIFORMES: Pandionidae	
Osprey	Pandion haliaetus
FALCONIFORMES: Accipitridae	
Oriental Honey-buzzard	Pernis ptilorhynchus
Black-shouldered Kite	Elanus caeruleus
Black Kite	Milvus migrans
Brahminy Kite	Haliastur indus

White-bellied Sea-Eagle	Haliaeetus leucogaster
Egyptian Vulture	Neophron percnopterus
White-rumped Vulture	Gyps bengalensis
Short-toed Eagle	Circaetus gallicus
Crested Serpent-Eagle	Spilornis cheela
Western Marsh-Harrier	Circus aeruginosus
Crested Goshawk	Accipiter trivirgatus
Shikra	Accipiter badius
Besra	Accipiter virgatus
White-eyed Buzzard	Butastur teesa
Tawny Eagle	Aquila rapax
Steppe Eagle	Aquila nipalensis
Bonelli's Eagle	Aquila fasciata
Booted Eagle	Aquila pennata
Changeable Hawk-Eagle	Spizaetus cirrhatus
FALCONIFORMES: Falconidae	
Eurasian Kestrel	Falco tinnunculus
Peregrine Falcon	Falco peregrinus
GALLIFORMES: Phasianidae	
Painted Francolin	Francolinus pictus
Gray Francolin	Francolinus pondicerianus
Red Spurfowl	Galloperdix spadicea
Gray Junglefowl	Gallus sonneratii
Indian Peafowl	Pavo cristatus
GRUIFORMES: Rallidae	
White-breasted Waterhen	Amaurornis phoenicurus
Ruddy-breasted Crake	Porzana fusca
Purple Swamphen	Porphyrio porphyrio
Common Moorhen	Gallinula chloropus
Eurasian Coot	Fulica atra
CHARADRIIFORMES: Jacanidae	
Pheasant-tailed Jacana	Hydrophasianus chirurgus
Bronze-winged Jacana	Metopidius indicus
CHARADRIIFORMES: Rostratulidae	
Greater Painted-snipe	Rostratula benghalensis
CHARADRIIFORMES: Recurvirostridae	
Black-winged Stilt	Himantopus himantopus
CHARADRIIFORMES: Glareolidae	
Small Pratincole	Glareola lactea
Red-wattled Lapwing	Vanellus indicus
Little Ringed Plover	Charadrius dubius
Lesser Sandplover	Charadrius mongolus
CHARADRIIFORMES: Scolopacidae	

Jack Snipe	Lymnocryptes minimus
Common Sandpiper	Actitis hypoleucos
Green Sandpiper	Tringa ochropus
Common Greenshank	Tringa nebularia
Marsh Sandpiper	Tringa stagnatilis
Wood Sandpiper	Tringa glareola
Common Redshank	Tringa totanus
Little Stint	Calidris minuta
CHARADRIIFORMES: Sternidae	
River Tern	Sterna aurantia
COLUMBIFORMES: Columbidae	
Rock Pigeon	Columba livia
Nilgiri Wood-Pigeon	Columba elphinstonii
Oriental Turtle-Dove	Streptopelia orientalis
Eurasian Collared-Dove	Streptopelia decaocto
Red Collared-Dove	Streptopelia tranquebarica
Spotted Dove	Streptopelia chinensis
Laughing Dove	Streptopelia senegalensis
Emerald Dove	Chalcophaps indica
Pompadour Green-Pigeon	Treron pompadora
Yellow-footed Pigeon	Treron phoenicopterus
Green Imperial-Pigeon	Ducula aenea
Mountain Imperial-Pigeon	Ducula badia
PSITTACIFORMES: Psittacidae	
Alexandrine Parakeet	Psittacula eupatria
Rose-ringed Parakeet	Psittacula krameri
Plum-headed Parakeet	Psittacula cyanocephala
Blossom-headed Parakeet	Psittacula roseata
Malabar Parakeet	Psittacula columboides
Vernal Hanging-Parrot	Loriculus vernalis
CUCULIFORMES: Cuculidae	
Common Hawk-Cuckoo	Cuculus varius
Indian Cuckoo	Cuculus micropterus
Banded Bay Cuckoo	Cacomantis sonneratii
Asian Koel	Eudynamys scolopaceus
Blue-faced Malkoha	Phaenicophaeus viridirostris
Sirkeer Malkoha	Phaenicophaeus leschenaultii
Greater Coucal	Centropus sinensis
STRIGIFORMES: Strigidae	
Collared Scops-Owl	Otus lettia
Rock Eagle-Owl	Bubo bengalensis
Spot-bellied Eagle-Owl	Bubo nipalensis
Brown Fish-Owl	Ketupa zeylonensis
Jungle Owlet	Glaucidium radiatum
Spotted Owlet	Athene brama
CAPRIMULGIFORMES: Podargidae	
Ceylon Frogmouth	Batrachostomus moniliger

CAPRIMULGIFORMES: Caprimulgidae	
Gray Nightjar	Caprimulgus indicus
Brown-backed Needletail	Hirundapus giganteus
Asian Palm-Swift	Cypsiurus balasiensis
Alpine Swift	Tachymarptis melba
House Swift	Apus nipalensis
APODIFORMES: Hemiprocnidae	
Crested Treeswift	Hemiprocne coronata
TROGONIFORMES: Trogonidae	
Malabar Trogon	Harpactes fasciatus
CORACIIFORMES: Alcedinidae	
Common Kingfisher	Alcedo atthis
Stork-billed Kingfisher	Pelargopsis capensis
White-throated Kingfisher	Halcyon smyrnensis
Black-capped Kingfisher	Halcyon pileata
Pied Kingfisher	Ceryle rudis
CORACIIFORMES: Meropidae	
Blue-bearded Bee-eater	Nyctyornis athertoni
Green Bee-eater	Merops orientalis
Blue-tailed Bee-eater	Merops philippinus
Chestnut-headed Bee-eater	Merops leschenaulti
CORACIIFORMES: Coraciidae	
Indian Roller	Coracias benghalensis
CORACIIFORMES: Upupidae	
Eurasian Hoopoe	Upupa epops
CORACIIFORMES: Bucerotidae	
Malabar Gray Hornbill	Ocyceros griseus
Indian Gray Hornbill	Ocyceros birostris
Malabar Pied-Hornbill	Anthracoceros coronatus
PICIFORMES: Capitonidae	
Brown-headed Barbet	Megalaima zeylanica
White-cheeked Barbet	Megalaima viridis
Crimson-fronted Barbet	Megalaima rubricapillus
Coppersmith Barbet	Megalaima haemacephala
PICIFORMES: Picidae	
Speckled Piculet	Picumnus innominatus
Brown-capped Woodpecker	Dendrocopos moluccensis
Yellow-crowned Woodpecker	Dendrocopos mahrattensis
Rufous Woodpecker	Celeus brachyurus
White-bellied Woodpecker	Dryocopus javensis
Lesser Yellownape	Picus chlorolophus
Streak-throated Woodpecker	Picus xanthopygaeus

Black-rumped Flameback	Dinopium benghalense
Greater Flameback	Chrysocolaptes lucidus
Heart-spotted Woodpecker	Hemicircus canente
PASSERIFORMES: Pittidae	
Indian Pitta	Pitta brachyura
PASSERIFORMES: Alaudidae	
Black-crowned Sparrow-Lark	Eremopterix nigriceps
Crested Lark	Galerida cristata
Malabar Lark	Galerida malabarica
Oriental Skylark	Alauda gulgula
PASSERIFORMES: Hirundinidae	
Dusky Crag-Martin	Ptyonoprogne concolor
PASSERIFORMES: Motacillidae	
Olive-backed Pipit	Anthus hodgsoni
Tree Pipit	Anthus trivialis
Forest Wagtail	Dendronanthus indicus
White-browed Wagtail	Motacilla madaraspatensis
Gray Wagtail	Motacilla cinerea
PASSERIFORMES: Campephagidae	
Large Cuckoo-shrike	Coracina macei
Black-headed Cuckoo-shrike	Coracina melanoptera
Small Minivet	Pericrocotus cinnamomeus
Scarlet Minivet	Pericrocotus flammeus
Bar-winged Flycatcher-shrike	Hemipus picatus
PASSERIFORMES: Pycnonotidae	
Black-crested Bulbul	Pycnonotus melanicterus
Red-whiskered Bulbul	Pycnonotus jocosus
Red-vented Bulbul	Pycnonotus cafer
White-browed Bulbul	Pycnonotus luteolus
Yellow-browed Bulbul	Iole indica
Black Bulbul	Hypsipetes leucocephalus
PASSERIFORMES: Chloropseidae	
Blue-winged Leafbird	Chloropsis cochinchinensis
Golden-fronted Leafbird	Chloropsis aurifrons
PASSERIFORMES: Aegithinidae	
Common Iora	Aegithina tiphia
PASSERIFORMES: Turdidae	
Blue-capped Rock-Thrush	Monticola cinclorhynchus
Blue Rock-Thrush	Monticola solitarius
Malabar Whistling-Thrush	Myophonus horsfieldii
Orange-headed Thrush	Zoothera citrina
Eurasian Blackbird	Turdus merula
White-bellied Shortwing	Brachypteryx major

PASSERIFORMES: Cisticolidae	
Zitting Cisticola	Cisticola juncidis
Jungle Prinia	Prinia sylvatica
Ashy Prinia	Prinia socialis
Plain Prinia	Prinia inornata
PASSERIFORMES: Sylviidae	
Blyth's Reed-Warbler	Acrocephalus dumetorum
Clamorous Reed-Warbler	Acrocephalus stentoreus
Booted Warbler	Hippolais caligata
Common Tailorbird	Orthotomus sutorius
Sulphur-bellied Warbler	Phylloscopus griseolus
Hume's Warbler	Phylloscopus humei
Greenish Warbler	Phylloscopus trochiloides
Western Crowned Leaf-Warbler	Phylloscopus occipitalis
PASSERIFORMES: Muscicapidae	
Asian Brown Flycatcher	Muscicapa dauurica
Red-breasted Flycatcher	Ficedula parva
Taiga Flycatcher	Ficedula albicilla
Verditer Flycatcher	Eumyias thalassinus
Nilgiri Flycatcher	Eumyias albicaudatus
White-bellied Blue-Flycatcher	Cyornis pallipes
Tickell's Blue-Flycatcher	Cyornis tickelliae
Gray-headed Canary-flycatcher	Culicicapa ceylonensis
Indian Blue Robin	Luscinia brunnea
Oriental Magpie-Robin	Copsychus saularis
White-rumped Shama	Copsychus malabaricus
PASSERIFORMES: Rhipiduridae	
White-browed Fantail	Rhipidura aureola
PASSERIFORMES: Monarchidae	
Black-naped Monarch	Hypothymis azurea
Asian Paradise-Flycatcher	Terpsiphone paradisi
PASSERIFORMES: Timaliidae	
Puff-throated Babbler	Pellorneum ruficeps
Indian Scimitar-Babbler	Pomatorhinus horsfieldii
Common Babbler	Turdoides caudata
Jungle Babbler	Turdoides striata
Yellow-billed Babbler	Turdoides affinis
Brown-cheeked Fulvetta	Alcippe poioicephala
Dark fronted Babbler	Rhopocicla altriceps
PASSERIFORMES: Paridae	
Great Tit	Parus major
Black-lored Tit	Parus xanthogenys
PASSERIFORMES: Sittidae	
Chestnut-bellied Nuthatch	Sitta castanea
Velvet-fronted Nuthatch	Sitta frontalis

PASSERIFORMES: Nectariniidae	
Purple-rumped Sunbird	Leptocoma zeylonica
Crimson-backed Sunbird	Leptocoma minima
Purple Sunbird	Cinnyris asiaticus
Western Crimson Sunbird	Aethopyga vigorsii
Little Spiderhunter	Arachnothera longirostra
Loten's Sunbird	Cinnyris lotenius
PASSERIFORMES: Dicaeidae	
Thick-billed Flowerpecker	Dicaeum agile
Pale-billed Flowerpecker	Dicaeum erythrorhynchos
Plain Flowerpecker	Dicaeum concolor
PASSERIFORMES: Zosteropidae	
Oriental White-eye	Zosterops palpebrosus
PASSERIFORMES: Oriolidae	
Eurasian Golden Oriole	Oriolus oriolus
Black-naped Oriole	Oriolus chinensis
Black-hooded Oriole	Oriolus xanthornus
PASSERIFORMES: Irenidae	
Asian Fairy-bluebird	Irena puella
PASSERIFORMES: Laniidae	
Brown Shrike	Lanius cristatus
Long-tailed Shrike	Lanius schach
PASSERIFORMES: Prionopidae	
Large Woodshrike	Tephrodornis gularis
Common Woodshrike	Tephrodornis pondicerianus
PASSERIFORMES: Dicruridae	
Black Drongo	Dicrurus macrocercus
Ashy Drongo	Dicrurus leucophaeus
White-bellied Drongo	Dicrurus caerulescens
Bronzed Drongo	Dicrurus aeneus
Hair-crested Drongo	Dicrurus hottentottus
Greater Racket-tailed Drongo	Dicrurus paradiseus
PASSERIFORMES: Artamidae	
Ashy Woodswallow	Artamus fuscus
PASSERIFORMES: Corvidae	
Rufous Treepie	Dendrocitta vagabunda
White-bellied Treepie	Dendrocitta leucogastra
House Crow	Corvus splendens
Large-billed Crow	Corvus macrorhynchos
PASSERIFORMES: Sturnidae	
Common Hill Myna	Gracula religiosa
Jungle Myna	Acridotheres fuscus

Common Myna	Acridotheres tristis
Asian Pied Starling	Gracupica contra
Chestnut tailed starling	Sturnia malabarica
PASSERIFORMES: Passeridae	
House Sparrow	Passer domesticus
Chestnut-shouldered Petronia	Petronia xanthocollis
PASSERIFORMES: Estrildidae	
White-rumped Munia	Lonchura striata
PASSERIFORMES: Fringillidae	
Common Rosefinch	Carpodacus erythrinus