HABITAT SELECTION OF BIRDS IN NEW FOREST, DEHRADUN, INDIA

THESIS

**SUBMITTED TO THE
FOREST RESEARCH INSTITUTE UNIVERSITY
DEHRADUN, UTTARAKHAND
For
THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY IN FORESTRY
(Wildlife Science)**

BY

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2007

DECLARATION

I hereby declare that the thesis entitled "**Habitat selection of Birds in New Forest, Dehradun, India**" submitted for the award of the degree of Doctor of Philosophy in Forestry, to Forest Research Institute University, Dehradun, is a record of original research work done by me under the supervision of Dr. A J T Johnsingh, Professor and Dean (Retd.), Faculty of Wildlife Sciences, Wildlife Institute of India, Dehradun, and it has not formed the basis for the award of any other degree or diploma. I also declare that the thesis embodies my own work, observation and analysis and in that respects the investigation appears to advance knowledge in the subject.

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Place: Dehra Dun

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CERTIFICATE

This is to certify that the thesis entitled "**Habitat selection of Birds in New Forest, Dehradun, India**" submitted for the award of the degree of Doctor of Philosophy in Forestry, to Forest Research Institute University, Dehradun, embodies original research work carried out by Mr. Dhananjai Mohan under my guidance and supervision. No part of this thesis has been submitted for any other degree and it fulfills all the requirements laid down in the ordinance of Forest Research Institute University, Dehradun for this purpose.

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Acknowledgements

A large number of people and organisations helped me in many ways in this work and I wish to thank them all from the deepest core of my heart. The list is long, but I would definitely like to name some important ones.

I would like to place on record my gratitude for Government of Uttar Pradesh, my employer, for not only permitting me to carry out this research work but also sanctioning study leave which enabled me to collect field data over the two year period. I would like to name certain senior officers of Govt. of Uttar Pradesh in particular viz. Ms. Surjit Kaur Sandhu and Sh. V K Sharma, Principal Secretaries, Sh. K Prasad and Sh. B K Patnaik, PCCFs and Sh. R K Garg, CF who were particularly helpful in this regard. I would also like to thank Sh. Atul Jindall, Sh. Aditya Kumar and Sh. Arvind Gupta, my colleagues from UP Forest department.

I do not have words to thank my supervisor Dr. A J T Johnsingh, Dean and Professor, WII (Retd.). It was an honour for me to work under his supervision and despite his shifting to Bangalore in the middle of the present work, I never felt that he was far away as I could frankly discuss and seek guidance from him at any time through phone or emails. He has also been instrumental in shaping up my interest in nature and its observation and I owe to him a lot of learning and appreciation for the beautiful natural world around us.

I would like to thank Director and Silviculturist, Forest Research Institute, Dehradun for according permission to work in the New Forest campus.

I am thankful to Sh. Vinod Rishi, Director, Indira Gandhi National Forest Academy (Retd.) for giving formal permission to me carry out the research work as I was serving in the academy at the time of registration for the same at Forest Research Institute, University. My colleagues at IGNFA were very helpful particularly Dr S P Kulshreshtha, Principal Systems Analyst, who helped me with GIS work.

The faculty members and researchers of Wildlife Institute of India, Dehradun helped me in countless ways. I cannot refrain from naming some of them.

Raman Kumar, helped me at all stages of the work from writing up the synopsis, to collection of field data, to analysis and finally to thesis writing and presentation. I could request him at any time for help and he never expressed the slightest hesitation even though it would mean many hours of time in the field or in front of the computer. Rajah Jayapal and Rashid Raza were very helpful in analysis and clearing many a doubts regarding it and their own doctoral works which concluded about a year ahead of this one were so helpful to me. They were also very kind to have looked at the draft thesis and given their valuable comments for its improvement. K Ramesh, Mousumi Ghosh and Abhishek Harihar also commented on my draft thesis and I am thankful to them.

Of the faculty members, Sh Qamar Qureshi, was particularly helpful in analysis of data giving me the much needed insights into Distance analysis and commenting on my draft thesis and giving extremely valuable comments despite his immense busyness. Dr Y V Jhala, commented on my synopsis and I thank him for the same. Dr Karthik Vasudevan not only commented on my thesis but was always available to clear my doubts on anything to everything on ecology. Sh. Pratap Singh, my friend, fellow birder and colleague, was always there with me to provide with the much needed confidence when it was waning. He was kind enough to comment on my thesis and also give me update on the birds when I was not watching them during the time of thesis writing. Thanks are also due to my other faculty colleagues for company and encouragement particularly Sh. A. Udhayan and Sh. N. K. Vasu.

I would also like to thank Director, Dean and Research Coordinator, WII for all the help. Thanks are also due to Dean and Registrar, FRI, University.

I would also like to thank Dr. Trevor D Price, Professor, University of Chicago, for painstakingly going through my draft thesis and giving very detailed comments although he was traveling from and to India between field, seminars and again field areas. His comments and the discussions during the fortnight I spent with him in the field helped in shaping up many aspects of the thesis.

My family was extremely helpful and cooperative during this entire exercise. My kids Kartikeya and Ishanvi are at an age when it is very difficult to refrain from seeking time and attention from a father but they managed to do so. My parents successfully tried to fill that gap and I thank them for the same and also for encouraging me and helping me forget about the day to day responsibilities of running a household. My father in addition was always there to discuss about the statistical analysis of the data and clear my doubts. My wife played a very special role in this endeavour by not only being a perfect partner but also by assisting me in the field in the measurement of the vegetation plots braving tick-bites and *Lantana* undergrowth despite her completely urban upbringing. She also helped in the long hours of computer data entry.

Thanks are also due to Sh Mahendra Singh Rawat for assisting in typing work and Sh. Virendra Sharma for formatting the thesis on the computer.

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Summary

1. Studies of bird communities have emerged as a major area of research in community ecology. A study on bird community broadly works at two levels: (a) patterns and, (b) processes. The recognition of a pattern involves studies that search for and describe the structure and organisation of communities. Community processes refer essentially to the functional component that includes interactions within communities. In brief, process stands for the cause while pattern is the effect. The focus of most of the bird community studies in the past has been on patterns as the study on process, on the one hand calls for a great deal of knowledge of pattern, and hypothesis about processes on the other hand, are considerably more difficult to frame and test. Because of the interest shown by people in birds, small forests, particularly the ones close to urban centers (often called urban forests) have assumed a special significance as repositories of local avian diversity that are easily accessible, thus serving as a vital interface between people and nature. Therefore these small forests need to be managed to maintain high wildlife diversity by meeting the habitat requirements of a variety of wildlife, including birds. In order to achieve this, it is important to understand the manner in which different bird species from the local species pool select different habitats in such forests in different seasons. The present study was initiated to investigate the habitat selection of birds in the forested part of New Forest campus.

2. The New Forest campus is primarily a man-made ecosystem created in the 1920s mainly to house the Forest Research Institute. Much of the area of what is New Forest today was under agricultural fields till they were acquired in 1920s by the British and there after considerably large areas of this sprawling campus were developed into demonstration forests, gardens, experimental plantations areas, and arboretum by planting them up. In addition, there is a block of natural forest on the northern part of the campus which belongs to 3C2b(i) type (Moist Bhabhar Sal forests). The present study was restricted to ca. 150 ha of wooded part of the 463 ha of the campus. Two hundred and seventy six birds have been reported from the campus till date. The campus is managed through management plans prepared at a ten year cycle.

3. Four distinct vegetation types were identified in the wooded parts of the New Forest campus based on the vegetation composition and structure. These, namely, Chir Pine plantations, Gardens, Mixed plantations and Natural forests were recognized as the four distinct habitats for the birds, the first three being man-made. The bird abundance was estimated by conducting point transects which were done over a two year period from October 2004 to June 2006. I collected habitat structure and composition data by laying out vegetation plots around the point locations for the bird transects (bird centered vegetation sampling). For each bird point-transect location, two such circular plots were laid with centre at a distance of 30 m on either side of the point, one to the north of the bird point and one to the south of it.

4. Bird densities were calculated for all the species in each season and each habitat. Oriental White-eye and Black Bulbul emerged as the commonest birds in summer and winter respectively. The abundance versus rank order curves for both the seasons followed log-normal distribution indicating undisturbed, fully developed communities. Densities pooled for all species indicated that the natural forest habitat supported the highest densities of birds and both natural forests and Chir Pine plantations exhibited significantly higher densities in summer as compared to winters. Both the insectivorous and phytophagous guilds also displayed similar results when analysed separately. Natural forest was the most bird-rich habitat in both the season but the diversity was much the same across habitats in the breeding season. The flock sizes were consistently higher in non-breeding (winter) season. Bird biomass also declined from summer to winter and it compared well with many other studies done in tropical areas in other parts of the world.

5. Floristics seemed to play a greater role in deciding the bird composition in New Forest in both the seasons. Habitat physiognomy also influenced the bird composition in summer season though it became almost insignificant in winters. While looking at the two basic guilds as expected floristics played a major role in deciding the bird composition for both the guilds but physiognomy influenced only the insectivorous guild as insect abundance is

known to respond positively to vegetation structure. The results were in conformity with studies done over small geographical scale elsewhere in the world.

6. To study the influence of structural parameters of vegetation they were ordinated using principal component analysis. Three components explained more than 77% of variation. First axis explained horizontal heterogeneity of the habitat; the second axis represented the vertical stand structure and canopy and the third represented the stand maturity. The Bird Species Diversity (BSD) and Bird Species Richness (BSR) were strongly correlated in both the seasons. In the summer season BSD was strongly correlated with Principal Component (PC) factor 1 indicating the positive influence of horizontal heterogeneity on the bird diversity. Being in the Himalayan foothills, there is a large species pool of timalids and other bird groups, which prefer dense habitats with profuse understorey vegetation, and these seem to have colonised the plantations of New Forest for breeding in summers. The BSR as well as bird density showed a highly significant and strong negative correlation with PC factor 2. This factor indicates that higher canopy cover and high top heights which lead to high Foliage Height Diversity (FHD) due to the additional layers present. A high canopy would indicate a poorer understorey vegetation and thus poorer richness of birds. The BSD in New Forest also shows a significant negative correlation with PC factor 3 which is indicative of stand maturity. Mature stands may have rarer specialist birds with higher conservation importance, but they often support fewer species and hence lead to a poorer BSD.

7. The classical enquiry into the relationship between BSD and FHD was explored for birds of New Forest. Various combinations of height bands were tried to classify the vertical foliage profile and different results were obtained for various combinations. Positive correlations were obtained only in the breeding season for certain height bands indicating that the birds were preferring these as layers of vegetation. The highest correlation was obtained for a six layered FHD with the highest layer comprising foliage above 12 m.

8. The guild structure of the birds of New Forest was investigated and factors determining it were identified. The seasonal change in guild structures both within and across various habitat types was also looked into. Birds were divided into fifteen fine feeding guilds. The change in composition of birds in different guilds across the two seasons was investigated using Morisita-Horn Index of Similarity (MHIS). It was seen that tree-bark feeder and nectarivore-insectivore guild experienced negligible change in bird composition across seasons. On the contrary the canopy insectivore, sallying insectivore and fruit-seed-nectarivore-insectivore guilds showed very low values of the MHIS indicating major change in the guild composition across seasons with the exception of natural habitat for insectivore-sallying guild. A careful look at the composition of these guilds indicated that the wintering species appear to 'fit into' niches vacated by similar summer visitors which were wintering elsewhere.

9. Majority of guilds show a decline in biomass from summer to winter as has been the general trend for the total biomass. The guilds which show a reverse trend were fruit-seed-nectar-insectivore guilds in Chir and mixed habitats owing to availability of winter fruits and presence of gregarious winter flowering trees respectively. Nectarivore-insectivore guild also shows an increase in biomass in winter season in the garden and mixed habitats owing to the presence of many exotics which flower in winter season. The Chir plantation provides the members of this guild with food and breeding resources primarily in summer. Hence there is a complementarity between these habitats in supporting the biomass of this guild in the two seasons.

10. A distinct habitat selection by birds was observed amongst the four identified habitats of New Forest as seen from multiple response permutation procedure (MRPP) and hierarchical clustering of sample points in different habitats on the basis of bird composition. While the natural habitat is the most species-rich habitat in New Forest in both the seasons, the other habitats also support reasonably high bird species richness. The Chir Pine habitat is the most similar in bird composition to the natural habitat in summer while in winter the garden habitat comes closest to the natural habitat. The two plantation habitats *viz.*

Chir Pine and Mixed plantations have a high bird compositional similarity in both the seasons. The bird species which show definite habitat preference amongst small and abutting habitats of New Forest were identified using indicator species analysis. The analysis provides a measure of importance of that habitat to the species called indicator values (IV) which range from 0 to 100 where perfect indication (100) means that the species indicates a particular habitat without error. Out of the 93 bird species recorded in the point transects up to a distance of 40m in summer season, 36 species exhibited statistically significant ($p<0.05$) indicator values, where as in winter season out of the 92 species recorded 28 showed significant indicator values.

11. Based on the above observations and relationships the importance of the different habitats for the birds was arrived at. The present study shows that despite some degree of biotic pressures, **natural forest habitat** still possesses the highest bird richness as compared to the well-preserved mature plantations even with mixed crop. It also supports the highest density of birds of all the habitats of New Forest. The highest number of indicator birds has also been reported from this habitat. A large number of biome restricted bird are reported from this habitat which has led to the declaration of New Forest as an Important Bird Area. This habitat which is typical of northern part of Dehradun valley is under great threat in most parts owing to a rapid spread of urbanization and the patch in New Forest may be the only one to provide long term preservation to its typical flora and birds. Of the three man-made wooded habitats of the campus the **Chir Pine plantations** harbour a number of indicator bird species which is only second to the natural forest habitat. This habitat supports the highest biomass of tree-bark-feeder and omnivorous guilds and in summers the nectarivores-insectivore guild too. These 'old growth plantations' with an average age of over 80 years have been proposed to be cleared in the management plan which needs to be amended looking at the good bird diversity that they harbour. The **garden habitat** comprising of the Botanical Garden and the Arboretum has the highest biomass for two guilds during the summer months viz. Fruit-seed-nectarivores (parakeets) and Fruit-seed-nectarivores-insectivores (bulbuls, mynas and orioles) owing to a wide variety of native and exotic plants which flower and fruit during this

period. The **mixed plantation habitat** though structurally similar to the Chir Pine plantations is floristically very different as it has a large diversity of mosaic of small plantation blocks (*ca.* 0.4 ha each) with different admixture of tree species. This habitat is an important one for the cavity nesting birds. This habitat supports the highest biomasses of two guilds viz. Fruit-seed-nectarivores (parakeets) and Fruit-seed-nectarivores-insectivores (bulbuls, mynas and orioles) in winter season thus complementing the Garden habitat which supports similar biomasses in summers. The primary reason behind this is presence of trees like *Acrocarpus fraxinifolius* which bears profuse inflorescence in February-March and Teak trees which bear seeds consumed by Parakeets.

12. All the habitats of New Forest have some unique values for birds and although the natural forests are the richest and irreplaceable in their bird-diversity values, there is no doubt that even the man-made habitats (the plantations), have their own importance in this regard. Thus the forests of New Forest give certain clues towards management of small urban forests often found in large campuses with the aim of maintaining high diversity. Forest managers can improve habitat for birds in such plantations by ensuring habitat heterogeneity through maintenance and encouragement of under-storey vegetation diversity, and vine thickets by creating gaps in the canopy if required, and encouraging native upper-storey trees. Such prescriptions can also be extended on an experimental basis to the larger existing plantations and those which need to be raised in India to achieve 33% forest cover as stipulated in the National Forest Policy, 1988 so that they can also harbour a fair share of our native biodiversity as in New Forest. The forests of the campus also need to be promoted as a birdwatching destination and as a training tool in plantation biodiversity management to harness their great potential in this regard.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Community ecology is concerned with identifying the patterns that characterize natural assemblages of species, understanding what has caused these patterns, and determining how general they are. Birds have been especially popular with ecologists investigating communities, perhaps because birds are largely diurnal and often conspicuous, their behaviour can be documented with relative ease, and their distribution, natural history, and systematics are generally well known (Wiens 1989). The extent of interest shown by people in this taxonomic group world over is exceptional and even for a layperson birds are one of the most visible and interesting components of the biodiversity of an area. There has been a marked increase in awareness towards birds among people in India in the last one decade or so, which is evident from the increasing number of clubs, associations and e-mail discussion groups on birds and bird-watching. Birds are proving to be an effective tool to introduce people to nature and conservation.

Studies on bird communities have emerged as a major area of research in community ecology. A study on bird community broadly works at two levels: (a) patterns and, (b) processes (Wiens, 1989). The recognition of a pattern involves studies that search for and describe the structure and organisation of communities, patterns in species diversity, distribution along environmental gradients, correlation to habitat (vegetation) structure and dynamics, and their adaptive disposition *vis-à-vis* the cycling and availability of food resources. Community processes refer essentially to the functional component that includes interactions within communities such as competition, resource division, or niche-shift and, factors operating in habitat selection by particular taxa. In brief, process stands for the cause while pattern is the effect (Jayapal, 1997). The focus of most of the bird community studies in the past has been on patterns, for a study on process, on the one hand calls for a great deal of knowledge of pattern, and hypothesis about processes on the other hand, are considerably more difficult to frame and test (Wiens, 1989).

1.1.1 Birds in urban forests

Because of the interest shown by people in birds, small forests, particularly the ones close to urban centers (often called urban forests) have assumed a special significance as repositories of local avian diversity that are easily accessible, thus serving as a vital interface between people and nature. The role that these small ecosystems play in providing the urban dweller with a "biological, psychological and romantic link with nature" is significant (Tregay, 1979). Several studies have shown that people who live in cities appreciate the chance to see wildlife, especially the opportunity to observe birds (Dagg, 1970; Brown and Dawson, 1978; Witter et al., 1981; Yeomans and Barclay, 1981). Birdwatching is enjoyed by a wide range of people and is considered a sport by some and a form of nature study by others (Tilghman, 1987). These small forests therefore need to be managed to maintain high wildlife diversity by meeting the habitat requirements of a variety of wildlife, including birds.

In order to achieve this it is important to understand the manner in which different bird species from the local species pool select different habitats in such forests in different seasons. In fact, the enquiry into the habitat selection of birds is one of the foremost steps to understand the complexity of their community. Perhaps no other taxonomic group has, and presumably exercises, the potential for habitats that birds do. Birds are extremely mobile and wide ranging, and of the range of habitats they pass through or over, only specific ones are used for breeding or foraging or wintering (Cody, 1985). Ecologists have been interested in the factors that affect habitat selection in birds for centuries, especially those that segregate taxonomically and ecologically related species (White, 1906; Hilden, 1965; Lack, 1971; Cody, 1974; Terborgh, 1985; Terborgh et al., 1990; Lee & Rotenberry, 2005). Cody (1981) identified three major factors influencing habitat selection – (i) vegetation structure, (ii) competitors, and (iii) productivity. However, his findings were mainly applicable to temperate avifauna and when extended to the tropical zone, another factor i.e., composition of vegetation became an important determinant of bird diversity (Terborgh, 1985). The distribution and abundance of many bird species are determined by the configuration and composition of the vegetation that comprises a major element of their habitat (e.g. Cody, 1985; Morrison et al., 1992; Block & Brennan, 1993).

1.1.2 New Forest: a managed urban forest

New Forest campus, nestled in the Dehradun (or Dehradoon) valley in north Indian state of Uttarakhand (formerly called Uttaranchal) in India, is a unique forested patch which has been under active management for more than 80 years. Housing the prestigious Forest Research Institute and now also the Indian Council for Forestry Research and Education, the apex national body to manage forestry research and education in India, the campus has a mosaic of man-made habitats created on erstwhile agricultural fields and a stretch of natural forest. Located only 5 kilometres away from the city centre of Dehradun, the capital of Uttarakhand, it is now surrounded by vast human inhabitation except for a weak linkage to degraded forests on the northern side at the base of the Mussoorie range of the outer Himalayas. Thus, the forests in the campus which extend to over 150 hectares are like forests in the middle of vast stretch of human habitation and can be viewed as an urban forest. The active management of New Forest over nearly a century has given rise to a very interesting matrix of natural forests and plantation habitats in the campus that is well protected.

New Forest was legally declared a Reserve Forest in 1942 although the active management of the estate was initiated in the early 1920s. Since its formation, the structure and composition of the major component habitats, together with the changes occurring in them, have been meticulously recorded in compartment-wise history registers.

Managed forests (forest areas other than Protected Areas) constitute nearly three fourth of the forest cover of India. These forests have a gradient from near pristine forests with a history of very few forestry operations to the mechanized monoculture plantations of exotics. They have been playing the role of multiple use forests for a long time by providing commercial wood and non-wood products, meeting the requirement of local people and soil, water, and biodiversity conservation. The last role being played by these forests is of immense importance considering the small size and coverage of our protected areas (PAs). The managed forests may not be as rich as the adjoining PAs in large mammalian fauna but often compare well with them in avifaunal diversity. Thus, birds can be the best *taxon* to monitor and assess biodiversity in the managed forest habitats. The forests in New Forest though small in extent for most mega-faunal species otherwise typical of the region viz. Asian Elephant, Tiger, Leopard and large ungulates, do harbour breeding and non-breeding population of a large number of bird species. The bird richness of this small expanse of land of area less than 5 km^2 is a phenomenal 276 species and it is interesting to note that many birds seem to be selective about the habitats within the campus despite their small extent and close proximity to one another. There is a distinct seasonality in avifauna of the campus leading to migration in and out of the campus in the two seasons which affects the bird community organisation in the campus in a substantial way. Hence, studying the utilization of the managed forest habitats of New Forest can provide insights about the significance of these for the purpose of bio-diversity conservation particularly in relation to birds. The learning from such studies can then be extended to other larger tracts of managed forests which cover extensive areas of our country as habitat management programme that proves beneficial in one part of the breeding range of a species has a high likelihood of success in an area hundreds of kilometers away (Noon et al. 1985).

The present study was initiated to investigate the habitat selection of birds within the forested habitats of New Forest campus. I have been watching birds continuously since 1983 in New Forest campus. Through my long period of bird watching in the campus spanning over two decades, I made many observations which led to certain questions in my mind such as why are certain bird species seen more frequently in certain parts of the campus. Is there a relation between the species of birds leaving the campus and those arriving at the change of seasons? Have all the birds native to natural forests of the region adapted to the man-made plantation habitats? Is the bird fauna of New Forest changing over time?

To address to some of these and many more similar questions, I undertook a detailed study on the habitat selection of birds in the forests of the New Forest.

1.1.3 Objectives of the study

The objectives set for the study were:

(i) to delineate the various vegetation types and quantify them in New Forest campus.

(ii) to study the spatial and temporal species composition and density of birds.

(iii) to examine the relationship between the habitat selection of birds and vegetation structure and composition.

(iv) to understand seasonal changes in guild structure both within and across various habitat types.

1.1.4 Expected outcome

Being the first systematic study on the birds of New Forest, it was expected to generate quantified information on birds and their habitats and explore their inter-relationships on the campus. Through a look at the way birds have adapted to the plantation habitats, important clues were likely to emerge for the management of such habitats. Besides, management recommendations for maintaining the bird diversity in the various habitats of the campus were expected to emerge out of the study. Considering the location of important forestry training institutions of national importance in the campus, all the learning from the study was likely to be extended to the trainees there, thereby benefiting them for their future management stints as forest managers. An improved understanding of avifauna of the campus was likely to enhance its value as a birdwatching destination.

1.2 ORGANISATION OF THE THESIS

This thesis is organized in seven chapters. The first chapter provides an introduction to the topic of habitat selection of birds and the significance of taking up such a study in New Forest campus in Dehradun, India. In addition, I discuss the importance of studying birds in small urban forests. The second chapter describes in detail the study area illustrating its basic floral and faunal characteristics with a special mention of the bird communities there, along with the history of birdwatching and other related studies done there. It also discusses the past and present management of the forests of the campus. The third chapter describes the methodology for the study and also attempts to classify the wooded areas into distinct habitats. Intensive data on birds and vegetation in the present study was collected over a two-year period based on the chosen methodology. The various bird and vegetation attributes of the study area as arrived at in the present study are given in the fourth chapter. Their inter-dependence is considered in the subsequent chapters. The fifth chapter explores the relationship between the birds and vegetation attributes. The relative influence of habitat physiognomy and composition on the bird composition has been discussed in this chapter. The sixth chapter provides an insight into the guild structure of birds in New Forest, seasonal changes in it and its relationship with vegetation attributes. The seventh and final chapter synthesizes the findings of the previous chapters and investigates the similarity of habitats on the basis of bird composition and identifies indicator species for different habitats. On the basis of these there is an attempt to highlight the values of different habitats in the campus for birds and identify the important results for the management of plantation forests towards more effective biodiversity conservation.

CHAPTER 2

STUDY AREA

2.1 INTRODUCTION

The New Forest campus is primarily a man made ecosystem created in the 1920s mainly to house the Forest Research Institute (then Imperial Forest Research Institute). Much of the area of what is New Forest today was under agricultural fields (with paddy as a major crop) till they were acquired in 1920s by the British. Commensurate with the objectives of the institute, considerably large areas of this sprawling campus were developed into demonstration forests, gardens, experimental plantations areas, and arboretum. While these areas were in active management till about 1970, they have been left largely untended since then, as is evident from the compartment history registers. This perhaps is a result of the shift of India's forest policy that was largely production-centric till the 1970s but afterwards became conservation-oriented. In addition, there is a block of near natural forest on the northern part of the campus. This patch of forest grows on the slopes leading to the valley of the Tons River, which makes the northern boundary of the campus. This natural forest forms a strip which continues for about a kilometer into the Indian Military Academy campus beyond the legal limits of the New Forest campus.

The entire New Forest campus is a compact block of reserved forest lying north of Dehradun – Chakrata road about 5 km from Dehradun city. The campus is spread over an area of 463 ha and is situated between 30° 19' 55" and 30° 21'16" North latitude and 77°59'12" and 78°01'01" East longitude. The average length of the New Forest block is about 3 km and the average width is about 1.5 km. The area lies in the catchment of River Yamuna, and is drained by eastern Tons which in turn drains into River Asan that subsequently joins the Yamuna near Rampur Mandi within Dehradun district.

In the south-west side of the campus, borders the premises of the Indian Military Academy and the cantonment areas of Prem Nagar. The Oil & Natural Gas Corporation (ONGC) complex is situated on the north-eastern side. Together, these three campuses make a large sprawling area with woodlands, gardens, and planned and spread out human inhabitations. A detailed map showing the major features of New Forest campus is given on figure 2.1. The location of the campus within the surrounding landscape in given on a Google image in appendix 1.

The general elevation is 640.06 m (2100') above the mean sea level. The land is more or less level with very gradual slope towards south-west with the exception of the slopes on the banks overlooking the Eastern Tons which are cut up by water channels and have a slope with a northern aspect (Bahuguna, 1989).

2.2 GEOLOGY, ROCK AND SOIL

The New Forest area consists of old village land, including actual village sites, cultivated field mainly terraced and irrigated for rice, wheat etc., and small orchards of litchi, guava and mango. The village sites have been leveled and the old hedges removed. Rock is chiefly exposed on the slopes and in the water channels. It consists mainly of conglomerates and the Middle Shiwalik Sand rock, quartzite, or a fine gravelly semi crystalline sand stones, in a highly calcareous matrix.

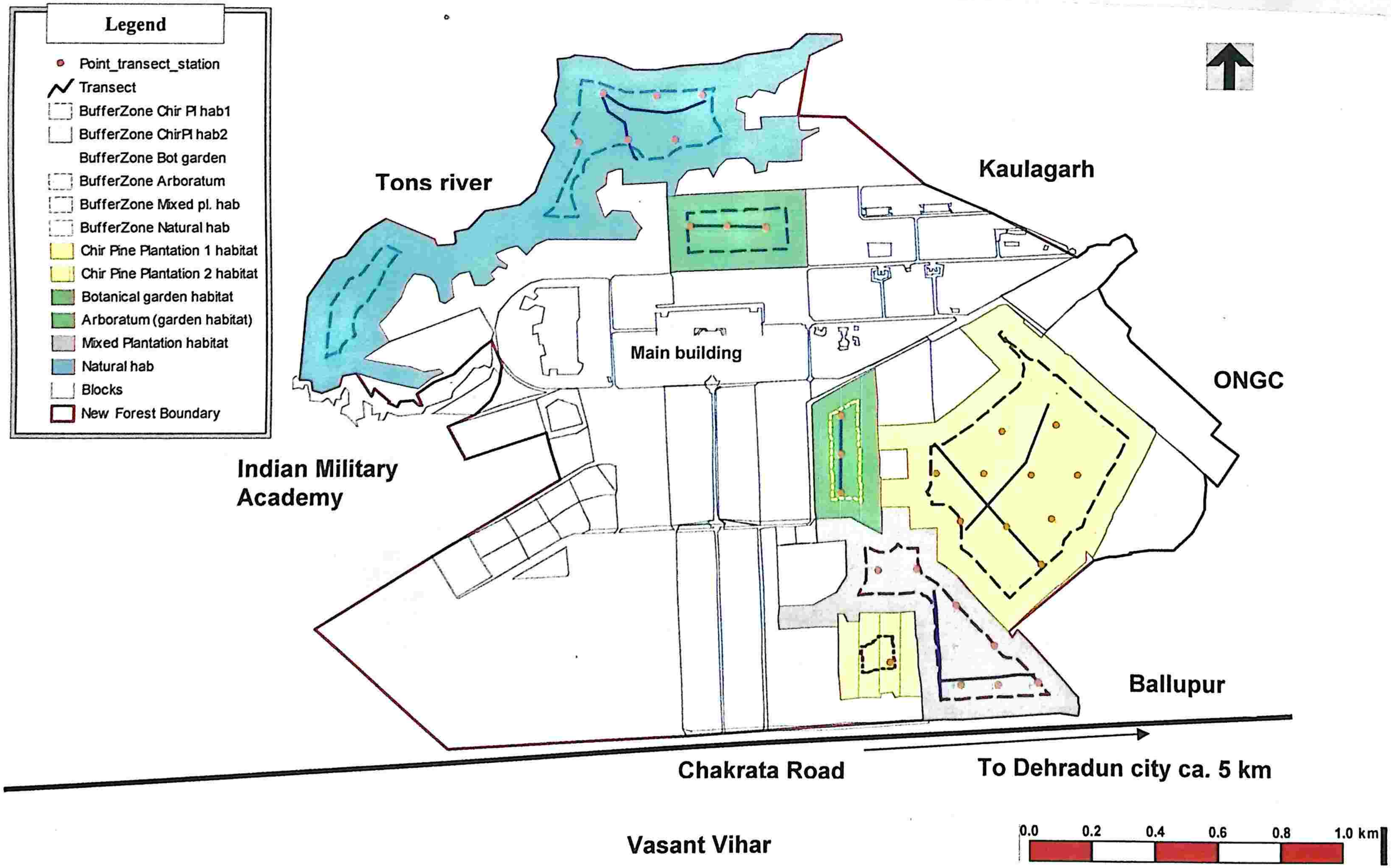


Figure 2.1 Map of New Forest, showing major wooded habitats.

The soil is generally a medium silt clay loam, overlying boulder deposits at great depth. It is often shallow and stony. The water table is very deep. The soils and sub-soils are porous and extremely well drained, as the ground slopes gently southwards with a sufficient fall to ensure good drainage.

The area was under cultivation until August 1920, when the land was taken over and constituted as the New Forest Estate. The soil is thus extensively an agricultural soil. Preview analysis showed that it mainly contained adequate minerals salt for plant growth but is generally rich in lime and deficient in nitrogen. Over the years the plantations raised on the campus have changed the soil characteristics in the forested areas (Singh, 2000).

2.3 CLIMATE

2.3.1 Rainfall

The area receives over 1600 mm of rainfall annually. The monsoon generally breaks at the end of June and the rains continue until about the middle of September, the heaviest falls normally occur in July and August. Occasional showers may continue till September and October after which, there are usually little rain, until about the end of December. Some rain usually falls in January and February due to westerly depressions, after which there is very little rain except for occasional thunder shower in the summer months until the break of monsoon. The average yearly rainfall for a ten year period from 1988 to 1997 was 1659.5 mm. August and July were the wettest months receiving 630.2 mm and 525.5 mm of rainfall respectively. November was the driest month with only 8 mm of rainfall (Singh, 2000). A detail of monthly rainfall for the same period is given in appendix 3.

For the ten-year period from 1988 to1997 the campus had an average of 81 rainy days in a year. The highest number of 20 rainy days was in the month of August, closely followed by July with 18 while October and November had only 1 rainy day each on an average (Singh, 2000).

2.3.2 Frost

Occurrence of frost is common feature during peak winter months in Dehradun Valley and New Forest Estate is no exception to this phenomenon. Severe frost occurs in the months of January and the beginning of February. Frost mainly occurs during night time, generally at an interval of four to five days. Due to frost the soil temperature falls and causes damage to young regenerating seedlings of Sal and other miscellaneous species planted in field. The impact of frost is more in the experimental research plots, nurseries and young plantations raised by different branches (Singh, 2000).

2.3.3 Temperature

From the weather records for the period 1988 to1997 the mean monthly temperature varied from a maximum of 26.9 °C in the month of June to 11.3 °C in January. Overall mean monthly temperature for a year was 20.1 °C (Singh, 2000). Monthly mean minimum temperature was the highest in July at 22.6 °C and the lowest in January at 3.9 °C. The mean maximum temperature was 35.6 °C in May while it was lowest in January at 19.7 °C. The details of monthly mean, monthly maximum and monthly minimum temperature for the ten year period from 1988 to 1997 are given in appendix 4, 5 and 6 respectively. There is no appreciable change in the pattern of temperature during this ten year period. The temperature inside the campus is appreciably less as compared to Dehradun City. It may be due to the woods covering large parts of the campus. The difference is greatest during the winters in the minimum temperature (Singh, 2000).

2.4 STATE OF BOUNDARIES

The boundary of the New Forest campus is marked by brick masonry pillars. Besides pillars a part of the north boundary has been defined by barbed wire fencing, although much of it is in poor condition and at many places non-existent. The eastern, southern and a portion of the western boundary have been defined by brick masonry wall. A portion of main block is occupied by the Indian Military Academy which has been defined by barbed wire fencing (Singh, 2000).

2.5 LEGAL POSITION

The entire New Forest Campus is a reserve forest under section 26 of the Indian Forest Act 1927 (IFA) and is under the administrative control of the Director, Forest Research Institute (FRI), Dehradun. The estate management is done by the Forest Range Officer, under the guidance of Assistant Silviculturist (Departmental), who works under Head, Division of Silviculture, FRI.

The land for the New Forest Campus was originally acquired vides notifications 1148/XIV/250 dated 4th November, 1919 and 787/XIV-144-1922 dated 15th August, 1924. Subsequently, there were transfers of land of the Indian Military

Academy. The main block was declared as reserved forest vide notification 767-AF/XIXV-111 AF 44 dated 2nd December, 1942. The revised boundary description was notified vide notification No. 767-AF/XIV-111 A.F. 41 dated 5th January, 1943 (Bahuguna, 1989).

2.6 VEGETATION

2.6.1 Semi-natural forests

According to the Champion and Seth (1968) classification, the natural forests of the campus fall in the forest type 3C2b Moist Bhabhar Sal forests (sub type Bhabhar –Dun Sal forest (i)). However, because of sloped terrain interspersed with deep ravines and northern aspect, Sal is not the dominant vegetation. These semi-natural forests are in the form of a long strip in the northern part of the campus, and the major tree species here besides *Shorea robusta* (Sal) are *Dalbergia sissoo* (Sissoo), *Heynea trijuga, Xylosma longifolium, Acacia catechu*, and naturalized exotics like *Melia azederach* and *Broussonetia papyrifera.* These forests have good undergrowth of shrubs and climbers which add to the structural diversity. These forests do experience low to moderate biotic pressures in the form of fodder and firewood collection by the villagers of nearby area (mainly Bajawala village) and a little grazing by their cattle. There is a large patch of planted bamboo (*Dendrocalamus strictus*) in the flatter part of this forest which flowered in 1988-89 but is now fully regenerated and established. These forests comprise the bungalows block of the New Forest reserved forest. The working plan map of the campus does not show this block divided into compartments. As a result the compartment histories of the block are not available, indicating that there was little or no management of this part of the campus.

2.6.2 Man-made forests

Plantations of different species have been raised in compact blocks and there are abrupt changes in the plantations species and distinct habitats can be delineated based on the major plantation species. The unit of area for forestry working in these blocks is compartment. The history of forestry works undertaken in each compartment is elaborately documented in the voluminous compartment history registers which are being maintained since the acquiring of land from villagers in the early1920s. These were studied in detail for knowing the history of management. Most of this area is near completely free from human disturbance. Based on the principal species or management treatment these man-made forests/woodlands can be classified into the following:

a) **Pine plantations:** The largest area amongst the man-made forests is covered by mature Chir pine (*Pinus roxburghii*) plantations occurring in two disjunct blocks: Champion and Riding School. In addition to this, the research block (adjoining Champion block) also hosts some plantations of exotic pines. The well-developed middle storey in these Chir plantations comprises mainly of *Cinnamomum camphora* (Camphor) and *Michelia champaca* (Champ) and the ground covered by natural and exotic shrubs and herbs. These Chir pine plantations were raised in the 1920s that have attained maturity in present times, and show regular natural mortality patterns typical of the species. The Pines have failed to regenerate naturally in these plantations while Camphor and Champ show a good regeneration. The Pine plantations cover an area of 53.67 ha.

b) **Mixed plantation:** The forest of Teak block and adjoining parts of Riding School and Research blocks have different species planted in each compartment, resulting in a block of plantation with species mix changing at approximately every 50 m. Major species in this compact block are *Tectona grandis* (Teak), *Acrocarpus fraxinifolius*, *Litsea monopetala*, *Dalbergia latifolia*, *Markhamia platycalyx*, *Hovenia dulcis*, *Pinus carribea*, *Chukrasia tabularis*, *Acacia catechu*, *Melia azederach* and many species of exotic bamboo. Some of the compartments here have a poor middle storey and ground flora while the leaf litter is high. This is particularly so in case of compartments with Teak and *A fraxinifolius*. The mixed plantations cover an area of 25 ha in one compact block.

c) **Gardens:** The Botanical Garden, spread over an area of 8.84 ha, contains a collection of large number of trees, flowering shrubs and climbers, a majority of which are exotics. The tree density is low and the ground is cleared of shrubs and maintained as lawn-like grassland. The grass here is periodically mowed. A similar area is the Arboretum, which is situated in the northern part of the campus and spreads over an area of 10.64 ha. Here too, a large number of species of trees are planted usually with a cluster of 5-7 trees for each species. The tree density here is considerably higher than in the Botanical Garden but the shrubs and grasses are cut periodically. However, the grass is not mowed and as a result it is not very even.

d) **Other plantations:** Certain other areas have also been planted up e.g. Canal Block with *Shorea robusta* (Sal). Similarly, there are some smaller patches of plantations like that of Chir pine near the Golf Course and *Eucalyptus* sp. near Takle Road, but these are too small or narrow to be sampled without getting influenced by the adjoining habitats.

2.7 FAUNA

2.7.1 Birds

New Forest has a long history of bird watching, with Osmaston (1935) and Wright (1949, 1955) publishing extensive notes on the avifauna of the campus. Important contributions were made by George (1957, 1962), who listed 220 birds in the campus, with details of their habitat use and migration, after studying them for over a decade. I have been studying the birds of New Forest since 1983. Two hundred and seventy six species of birds have been recorded from New forest campus till date. 261 of these were reported by me (Mohan, 1996) of which, 111 are migratory, 120 residents and 30 are considered vagrants. Thereafter, another 15 species were added to the list (unpublished pers. obs.). The campus, owing to its location in the foothills of the Himalayas, still springs up surprises in the form of new additions to its bird list despite more than seven decades of active birdwatching.

New Forest also has a unique distinction of being one of the first areas in the country (if not the first) where a systematic attempt to count birds was undertaken (Wright, 1949). The count was attempted by traversing a large area within the campus and some adjoining landscapes. In another study (Mohan and Singh, 2000) the changes in the avifauna of the campus over a period of three decades were evaluated. This was primarily based on a comparison of bird accounts in two studies spanning over a decade each by George (1957, 1962) and Mohan (1996). George recorded 220 species of birds in his observations from 1944 to 1962 while Mohan recorded 224 species in his study from 1983 to 1996. There after Mohan was able to add another 15 species by 2006 (unpublished pers. obs.). Of the birds sighted by George, 40 species were never sighted by Mohan, while 41 birds recorded by Mohan were never sighted by George. In addition a large number of birds showed changed abundance levels across the two periods.

Based on the classification of Birdlife International (undated), the New Forest Campus lies within Sino-Himalayan Subtropical Forest (Biome-8). Ninety –five bird species represent Biome-8 and 15 of them occur in New Forest Campus. As this site is in the foothills of the Himalayas, many migratory birds from other biomes are also seen. For instance, Tickell's Leaf Warbler (*Phylloscopus affinis*), Sulphur-bellied Warbler (*Phylloscopus griseolus*) and Wallcreeper (*Tichodroma muraria*), the birds listed in Biome-5 (Eurasian High Montane-Alpine and Tibetan) by Birdlife International (undated), occur here in winter only. Similarly, 14 species of Biome-7 (Sino-Himalayan Temperate Forest) have been identified from this area, most of them winter migrants. However, the greatest overlap is seen with Biome-11 (Indo-Malayan Tropical Dry Zone). BirdLife International (undated) has listed 59 species in this biome, of which 22 occur in New Forest Campus. This is to be expected, for though this site occurs in the Doon Valley and is surrounded by the Shiwalik Hills, it is close to the large Tropical Dry Zone of central and peninsular India. Therefore, many species of the latter biome move to the Doon Valley as summer or winter migrants. Some summer migrants breed as well. The list of all the biome restricted birds reported from the campus is given in appendix 7. Because of these reasons the area was declared an Important Bird Area (Islam and Rahmani, 2004).

2.7.2 Mammalian Fauna

The campus has a small area and hence there aren't many mammals in the campus. However Wild Pigs (*Sus scrofa*) and Jackals (*Canis aureus*) are abundant in the campus and breed regularly. One may come across Jungle cats (*Felis chaus*) if lucky, and rarely Leopards (*Panthera pardus*) have made visits to campus. Barking Deer (*Muntiacus muntjak*) have been sighted in the campus albeit very rarely and I was fortunate to see a Sambar (*Cervus unicolor*) doe with a fawn in May 2006 in the Chir plantations of Champion block, perhaps the first ever sighting of it from the campus. Two Sambars were again seen in the campus in October, 2006 (M. Ghosh pers. comm.). Common Palm Civets (*Paradoxurus hermaphroditus*) are regularly seen, often living in the bungalows and other old buildings with false ceiling. Five Striped Palm Squirrels (*Funambulus pennantii*), Indian Hare (*Lepus nigricollis*) and Grey Mongooses (*Herpestes edwardsii*) are common sight in the campus. Rhesus Macaques (*Macaca mulatta*) are common but the Hanuman Langurs (*Semnopithecus entellus*) are met with occasionally. Indian Flying Foxes (*Pteropus giganteus*) have a day time resting colony in the arboretum where hundreds of them could be seen.

2.8 MANAGEMENT

The management of the New Forest campus is carried out through working plans which are prepared at a cycle of 10 years. The Silviculturist FRI is responsible for implementing the prescriptions of the working plan.

2.8.1 Past management

The first management scheme for systematic management was sanctioned in 1921. An area of 232 acres was divided into six working sections with an aim to allow students to practice methods of planting and sowing; to illustrate methods of reproduction/working/coppicing clear felling/artificial regeneration of Bamboo, Chir Pine, Sal and some other species. The planting started in the year 1924. From 1930 to 1942, the area was worked on an annual programme with the object of getting it stocked and provide material for experimental work.

In 1942, the second plan was formulated with the following objectives of management-

1. Efficient utilization of the estate in the best interest of forest research.
2. Preservation and improvement of the aesthetic amenities of the estate.

Eighteen Working Circles were constituted. The period of the Plan was prescribed from 1943-44 to 1947-48. The whole estate was divided into fourteen permanent blocks and all the blocks were divided into compartments and sub-compartments. However, no records are available to show the extent to which this plan was implemented.

After this plan, the estate was managed on adhoc basis. Certain areas have been clear felled and planted. Areas were allotted to different departments/branches of the FRI for laying out their experiments. The same practice followed till 1997, after which, a working scheme for the forests was prepared and approved by the Government of India and the forests are being managed as per the prescriptions of this Working Scheme since then (Singh, 2000).

2.8.2 Present management

The objectives of management of the estate as per the on-going working plan (Singh, 2000) are:

1. to utilize the land resources available in the Forest Research Institute Estate for the maximum benefits of the research activities.
2. to create and maintain recreational and aesthetic spots in the estate for the benefits of the residents and the visitors.
3. to establish and maintain demonstration forest plantations, gardens, arboretums etc. for the benefit of the researchers and visitors.
4. to utilize the exploitable forest produces so as to obtain the benefits they provide.
5. to manage the forests and wildlife of the estate in a systematic manner.

2.8.2.1 Working Circles and Area Distribution

Based on the objects of management, eight working circles have been proposed in the latest working plan five of which are overlapping working circles (Table 2.1). The main overlap of the study area is with the experimental and protection-cum-improvement working circles and hence the prescriptions about these have a special relevance. Prescriptions of the protection-cum-improvement working circle do not affect the existing crop in a negative manner as operations are limited to harvesting of dead/diseased/uprooted trees and trees dangerous to human life and property, and of minor forest produce. However, for the experimental working circle which includes much of the old and mature plantations of Chir Pine (raised in the years 1925, 1926, 1929, 1938 and 1939) in Champion and Riding School blocks, the prescriptions do include removal of this old crop to make way for new forestry experiments.

Table 2.1 Area distribution in working circles in FRI Estate

	Working Circles	Area (in ha.)
1.	Experimental Working Circle	42.47
2.	Aesthetic and Avenue W.C	56.26
3.	Protection cum Improvement W.C	394.82
4.	Bamboo Overlapping W.C	394.82
5.	Non-wood Forest Produce Overlapping W.C	493.55
6.	Construction Overlapping W.C	493.55
7.	Fire Protection Overlapping W.C	493.55
8.	Wild Life Overlapping W.C	493.55

2.8.2.2 Period of the Plan

The period of the plan is fixed to 10 years effective from 2001 to 2010, after which, it will be revised. Mid-term review of the working plan prescriptions are proposed to be done after the passage of 5 years (Singh, 2000). However, no information is available about the mid-term evaluation.

2.9 AREA COVERED IN THE PRESENT STUDY

The present study was confined to a part of the New Forest estate. The area of the study was confined to the wooded part of the estate, excluding the smaller patches of forest. The areas included in the study were in the Bungalows, Champion, Research, Garden, Riding School blocks and Arboretum comprising compartments 2 and 3 of the main block. Further specific details of the study area are given in Chapter 3.

CHAPTER 3

METHODS

3.1 INTRODUCTION

In trying to answer questions on community ecology, the most fundamental issue that one has to bear in mind is that of choosing the right methodology for collecting field data (Daniels, 1989). The species in question, the nature of the habitat and its extent, availability of resources etc. play an important role in deciding the method to be adopted for the field data collection. As the present study focuses on habitat selection of birds within the forested habitats of New Forest, the data had to be collected for birds along with corresponding habitat variables. All the sampled habitats were in close proximity of one another and the maximum spread of the study area was less than 3 kilometers. Moreover, as the terrain was largely gentle the environmental variables were not expected to vary significantly across the various sample points in different habitats and did not warrant a measurement. The field data were therefore restricted mainly to birds and vegetation.

3.2 HABITAT CLASSIFICATION

Various vegetation types in the New Forest campus were delineated *a priori* owing to vast differences in composition and structure because of very different management histories. This was primarily done using the following tools:

1) The histories of the compartments were studied to get an idea about the trees planted in them and also their age and management treatments they were subjected to in the past. The working plan map (Bahuguna, 1990) was used for getting an idea about the geographical spread of the

compartments and identifying compartments of similar floristics and proximity with each other.

2) The entire area was also traversed for corroborating the compartment histories as they were not properly updated beyond 1970. There has neither been much forestry intervention nor biotic interference since then (Singh, 2000 and pers. obs.). This step helped in critically observing the vegetation structure of various compartments and also growth of vegetation other than the primary planted species.

3) Remote sensing data in the form of IRS IC LISS-PAN data and IKONOS imageries were used to further help in delineation of habitats based on observing their reflectance.

The information from the above three sources was brought together in a GIS platform using the software Geomedia Professional version 03.00.17.06 (1999). Thus, four distinct vegetation types were identified in the wooded parts of the New Forest campus based on the vegetation composition and structure. These, namely, Chir Pine plantations, Gardens, Mixed plantations and Natural forests were recognized as the four distinct habitats for the forest birds of New Forests following the definition of habitat 'as a spatially continuous vegetation type that appears more or less homogeneous throughout and is physiognomically distinctive from other such types' (Hutto, 1985). The basic features of these four habitats are given in Table 3.1. The location of these habitats is shown on a map in appendix 2. A photograph of a typical area of each habitat is included in appendix 18.

Table 3.1 Description of the habitats

Habitat name (code)	Major tree species	Management history	Area	General features
Chir plantation (C)	*Pinus roxburghii* (Chir or the Long-leaved Pine)	Raised as plantation in the 1920s. Untended but compartment lines maintained annually	53.67 ha in two blocks in the Champion (entire)+ Research (part) blocks (47.27 ha.) and Riding school (part) block (6.4 ha.)	Mature large trees of Chir Pine forming a close canopy of over 30 m height. Clear middle storey of *Michelia champaca* and *Cinnamomum camphora*. Shrub layer present but herbs low and leaf litter high.
Gardens (G)	Large number of exotics	Shrubs not allowed to grow by periodical mowing/ cutting.	19.48 ha in two disjunct units- Botanical garden (8.84 ha.)and Arboretum (10.64 ha)	Botanical gardens mainly open canopied with varying tree height while Arboretum closed canopy with considerable exotic bamboo. Ground largely grass covered with little or no leaf litter.
Mixed plantation (M)	Large number of exotics including *Tectona grandis* (Teak) and exotic bamboo	Compartments with average size 0.4 ha. planted with different species mix; 40 - 80 years old; compartment lines maintained annually	25ha in a compact block spreading over Teak (entire), Riding school (part) and research (part) blocks.	Largely closed canopy showing wide variation in structure and composition. Shrub layer dense but herbs low and leaf litter high.
Natural forests (N)	*Shorea robusta* (Sal), *Dalbergia sissoo* (Sissoo), *Syzigium cumini* (Jamun), *Heynea trijuga* and *Xylosma longifolia* and naturalized exotics *Melia azederach* (Bakain) and *Brossonetia papyrifera* (Paper Mulberry)	Forests on slopes leading to Tons river. The only patch of near natural vegetation. It has one small patch of planted bamboo	49.93ha in single block	Open to closed canopy forests with high diversity of vegetation structure and composition. Tree height medium and habitat little disturbed owing to pressures from nearby villages.

Besides these there were a few more wooded patches which were too small in extent to have a representative core free from edge effect to have adequate sample points. The natural forests had certain naturalized exotics and hence had to be treated as a habitat and not a control.

3.3 BIRDS

3.3.1 Point transects

Point transects (variable circular plot) were conducted to gather data on the bird abundance in different habitats (Reynolds et al., 1980). Point transects are more suitable than line transects where habitat is patchy (Sutherland, 1996; Buckland et al., 2001). They are more suited for dense woodlands where access is limited compared to line transects which are more suited for extensive open and uniform habitats. Most of the habitats in New Forest are dense woodlands with some having gently sloping topography cut by deep ravines and heavy undergrowth where line transects may be difficult to walk (Anon, 2001). They are also small in extent. The Variable Circular-Plot method is probably the most effective technique for estimating bird numbers in difficult terrain (Dawson, 1981). As studying the habitat selection of birds was the main objective of this study, it was important to relate the habitat variables with the bird attributes which made the point transects very suitable for the study. If the habitat is measured around the census point, inferences can also be drawn about habitat selection and preferences of individual bird species or communities (Bibby et. al, 2000; Das, 2000).

The number of sample points (replicates) for each habitat for each season were limited by the habitat area as only a limited number of points could be laid in each habitat owing to their small size. The number of surveys to each point in a season (pseudo-replicates) was decided upon by carrying out preliminary surveys and by plotting cumulative frequency curve of bird species richness against number of plots (Jayapal, 1997). However, these were extended to as much as the two year field data collection period could permit, so that the fewer number of points could be to some extent be compensated by higher number of pseudo-replicates. The summer season was the limiting season here, because of lesser number of effective mornings as nearly half of the season is unsuitable for such surveys owing to heavy monsoon rains. The duration of the point transects was decided as 10 minutes. It was observed that there were no substantial additional observations beyond the 10-minute period. Moreover, the chances of double counting get enhanced for longer periods. A 10-minutes count gave enough opportunity to the bird species that do not sing/call frequently or skulk in the dense undergrowth to get detected. New Forests has a good number of such bird species. To avoid double counting and to enable distance to be recorded accurately, the location of each bird-detection was graphically marked on the data sheet generated for each point separately on which five concentric rings indicating distances in the intervals of 10 m (up to 50 m) and sixth ring at a distance of 75 m were marked. Prominent 'landmark' features such as easily identifiable trees were also marked on the same point specific data sheet. The four cardinal directions were also marked on the data sheet with their origin at the common centre of the rings and before the start of the point counts the directions were ascertained using a digital compass using a Casio Triple Sensor wrist watch. The locations of the bird detections were transformed into radial distances later on after returning from the field.

Proper identification of bird species is a *sine qua non* for tropical forest bird communities (Shankar Raman, 1995). I have been watching birds in New Forest in particular and western Himalayas in general since 1983 and have developed high levels of familiarity with them (Mohan, 1996). During the period 2002-04 while I was doing preparatory work including pilot surveys for the present study, I could get even more familiar to the birds of the campus particularly their vocalizations as also the methodology of point transects. All the point transects were conducted by me alone to eliminate observer bias. Overall policy of 'no record at all is better than an erroneous one' was adhered to while making observation on transects. When there was a problem in correctly identifying a bird, it was recorded on the data sheet and identified after the count got over. In few cases identification was left at the generic level and not to the specific level particularly where often either only aural clues (e.g. drumming of woodpeckers and single call notes of flowerpeckers were obtained) or the identification was difficult (Leaf Warblers). In very rare cases when the bird could not be identified at all, the observation was discarded. Unidentified birds and calls comprised less than 1 % of the detections.

The points were located systematically (with a random start) within each habitat by ensuring that they are at least 75 m from the edge of the habitat (60 m for garden and mixed plantation habitats) and are at least 150 m (120 m for garden and mixed plantation habitats) apart (as in Hansen et al., 1995;, Tilghman, 1987). This was achieved using the GIS platform which was developed initially to delineate the different habitats in New Forest. The coordinates of the points so generated were noted from the GIS domain and marked in the field using a GPS (Garmin Etrex) taking help from the compartment lines as well. Details about the numbers of point transect stations in each habitat are given in Table 3.2. The coordinates of the points are given in Appendix 8. The location of the points is shown on a map in appendix 2.

Table 3.2 Details of point transects used in study

Habitat name	Area (ha)	No of points	Point codes	Minimum distance between points (m)	Minimum distance from the edge of the habitat (m)
Chir plantations	53.67	11	C2,C3,C5,C6, C7,C8,C9,C10, C11,C12,C13	150	75
Gardens	19.48	6	G1,G2,G3, G4,G5,G6	120	60
Mixed plantation	25.0	7	M1,M2,M3,M5, M6,M7,M8	120	60
Natural forests	49.93	6	N1,N2,N3, N4,N5,N6	150	75

Bird observations were made between 0.5 and 3 hrs after sunrise when visibility and bird activity is the highest (Shankar Raman et al., 1998). Suitable period was chosen within this time window in the two different seasons depending on the peak bird activity. In summer the counts ended well before 3 hours from sunrise while in winters they started a little late and continued till 3 hours from sunrise. The time of sunrise was noted from the weather observation published in daily newspaper. The data collected during the point transect were point code, climatic factors at the time of the count (temperature using the Casio triple sensor wrist watch, wind, sky condition, date and time), all the birds recorded during a 10 minutes duration including their sex (wherever possible), distance to the bird (by marking a point in the graphical representation of the area being searched) taking the help of trees and permanent features marked on the point specific data sheets and perch height in six height bands (0m, 0-2m, 2-5m, 5-10m, 10-20m and above 20m) based on ocular estimation. These height bands best reflected the average height of strata of foliage in the various habitats of New Forest as observed during the surveys and also from the pilot counts. On reaching a point the count was started only after 1-2 minutes had elapsed so that the birds got used to the observer i.e. me. While the counts were being done I slowly rotated at the point by 360° to cover birds in all directions. Most of the birds gave away their presence through their vocalizations. On hearing a bird I attempted to locate it visually so that it may be correctly identified and distance to it may be assessed. Sometimes the bird was not properly visible and I had to suffice from the approximate location for assessing the distance and strata used. Vocalizations came in handy for identifying such birds. Fly-overs were not recorded. The Large-billed Crow (*Corvus macrorhyncus*) was ignored during the data gathering because of its large unpredictable movements during the transects, high continuous vocalization and frequent 'swarming' behaviour where a large number of them would often fly around the observer and even follow him to point locations.

Distance to each observation in point transects should be recorded with a good accuracy to obtain reliable results. Bias in distance measurements generates greater bias in point transect estimates of density than in line transect (Buckland, 2006). Bird counts and distance estimates are facilitated in point transects because the observer is stationary (Dawson, 1981). As New Forest has a good bird density, there was high number of observations in each point transect (averaging to approximately 12 per count in the present study with a maximum of 24). As a result, it was difficult to accurately measure distance even by using a modern instrument such as laser rangefinder and hence point specific data sheets were developed with the major easily identifiable trees (or any other feature) marked on the data sheet (sample on appendix 9). Such trees (or features) could number from 10 to 25 around a point. The exact distance to such trees (or features) was measured by a laser rangefinder (Bushnell Yardage pro 500) and they were marked at the mapped location on the data sheet's concentric distance rings considering their bearing with respect to the magnetic North calculated using a digital compass on Casio triple sensor watch. With the help of trees marked on the data sheets it was possible to assess the exact distance to the bird observed when it perched on the marked tree or distance to it could be assessed reasonably accurately relative to these marked trees. The general rules of conducting the point transects were adapted from Ralph, 1995.

The period from Oct 2002 to June 2004 was spent in familiarization with the bird vocalizations and also the methodology, and developing the datasheets. The two-year period thereafter was utilized for collecting the data. The total number of point transects conducted during the two year period from Oct 2004 to June 2006 are given in Table 3.3.

Table3.3 Number of point transect surveys per season per habitat

Season	**Summer**			**Winter**		
Habitat	2005	2006	Total	2004-05	2005-06	Total
Chir	66	55	**121**	57	66	**123**
Garden	46	35	**81**	49	46	**95**
Mixed	54	49	**103**	48	49	**97**
Natural	52	48	**100**	54	55	**109**
Total	**218**	**187**	**405**	**208**	**216**	**424**

3.4 HABITAT VARIABLES

I collected habitat structure and composition data by laying out vegetation plots around the point locations for the bird transects (bird centered vegetation sampling) (Tilghman, 1987; Askins and Ewert, 1991; Bibby et al., 2000; Das, 2000). For each bird point-transect location, two circular plots were laid with centre at a distance of 30 m on either side of the point, one to the north of the bird point and one to the south of it. This was done to facilitate the efforts to elicit correspondence of structural variables of vegetation to bird communities at finer scale as the same points are used to lay vegetation plots.

Tree vegetation parameters were collected in circular plots of 10 m radius. All woody vegetation having a girth of 20 cm or more was considered as trees (Shahabuddin and Kumar, 2006). The parameters recorded included tree species, tree girth at breast height (GBH), height of canopy top of each tree and height of canopy bottom of each tree. Canopy density was calculated at each bird point by averaging the spherical densiometer readings in the four cardinal directions.

Shrub cover was measured in circular plots of 5 m radius nested in the tree plots mentioned above. All woody vegetation with girth at breast height (GBH) less than 20 cm was considered as shrubs. All the shrubs were identified to species level and their height was measured. To evaluate the canopy spread and shrub volume the crown of the shrubs were measured in two perpendicular directions. Ground cover was ocularly assessed in three categories, expressed as percentages: herb, litter, and bare earth. Most of the trees and shrubs in New Forest were nearly evergreen and the few which shed their leaves did so for a very short period spanning into a few weeks.

Hence the vegetation attributes were measured in March-April when the bird census was suspended owing to large efflux of passage migrants. This was the period between the two seasons and so had an averaging effect on the data collection making it relevant to both the seasons. Owing to difficult terrain and very thorny and impenetrable bushes three plots could not be measured and for these bird points only one vegetation plot was laid and measured. For these bird points the average of the two plots could not be taken and single plot was considered to be representative. Hence, a total of 57 vegetation plots were measured.

From the variables measured the following vegetation parameters were calculated at each bird point by adding the figures obtained from the two plots around it.

i) Tree numbers or tree density for each point

ii) Canopy cover in percentage

iii) Tree species diversity index (Shannon-Wiener index) as a measure of species compositional diversity

iv) Basal area of the trees in meter square/point
This was calculated from the girth at breast height (GBH)

v) Number of snags/point. Snags were defined as standing dead trees.

vi) Number of shrubs/point

vii) Total shrub cover which was calculated in three components viz. Shrub cover, Climber cover and regeneration (of tree species) cover all expressed in meter square/point

viii) Shrub species diversity index (Shannon-Wiener index)

ix) Shrub volume in m^3/point
This was calculated by averaging the two perpendicular diameters (spread) and thereafter calculating the volume using it and the height of the shrub presuming the shrub to be a cylinder

x) Tree height diversity (Shannon-Wiener index)

This was calculated by using the top height of all the trees in the vegetation plot(s) at each bird point as a measure of unevenness of the top canopy.

xi) Mean canopy top height mean

xii) Mean vertical canopy spread

This was calculated by subtracting the top height and the bottom height of the canopy of each tree and averaging it for a point. The stray branches from the lower part of the tree trunk were not considered to be the part of the canopy.

xiii) Foliage height diversity from both tree as well as shrub layers and their combination for each point.

This was calculated by assessing the contribution of tree and shrub canopy in the vertical profile of the vegetation. The vertical zone was divided into categories of 1 meter height. Each tree was then scored in these height bands using their lower and upper canopy heights. In this zone they were given a score of 1 (present) and in the rest 0 (absent) in each 1m height band. The shrubs were similarly scored with their lower canopy height taken as 0m. The shrub scores were however scaled down by a factor of their spread to average tree spread as their canopy spread was much lower than the trees. The shrub scores were also compensated for the size of the shrub plots (5m radius) as compared to the tree plot (10m radius), by multiplying by 4.

Once the total scores in each height class (of 1m height) were available for each bird point (combination of two or one vegetation plot), the foliage height diversity was calculated using the Shannon-Wiener index. As the information on presence or absence of canopy was available from all trees and shrubs in all 1m height bands, it was possible to club them in various height class bands and calculate corresponding foliage height diversities using the Shannon-Wiener diversity index.

3.5 HABITAT SEGREGATION

Based on the floristic (considering only the 13 commonest trees which had their presence in at least 5 of the 30 sample points) and 13 structural parameters a dendrogram was obtained (PC-ORD 4.20 software using Linkage method: flexible beta (beta = -0.25) and Distance measure: Sorensen). The Kulczynski, Sorensen (Bray-Curtis) and relativized Manhattan measures are found to have not only a robust monotonic relationship with ecological distance, but also a robust linear (proportional) relationship until ecological distances became large. Less robust measures included Chord distance, Kendall's coefficient, Chisquared distance, Manhattan distance, and Euclidean distance (Faith 1987). Flexible beta is a space-conserving linkage method which helps in avoiding distortions and has a less propensity to chain and Sorensen is a compatible distance measure (McCune and Grace, 2002).

This clustered the sample points near perfectly as per the *a priori* classification of habitats (Fig 3.1). Thus the *a priori* division of the study area was further corroborated.

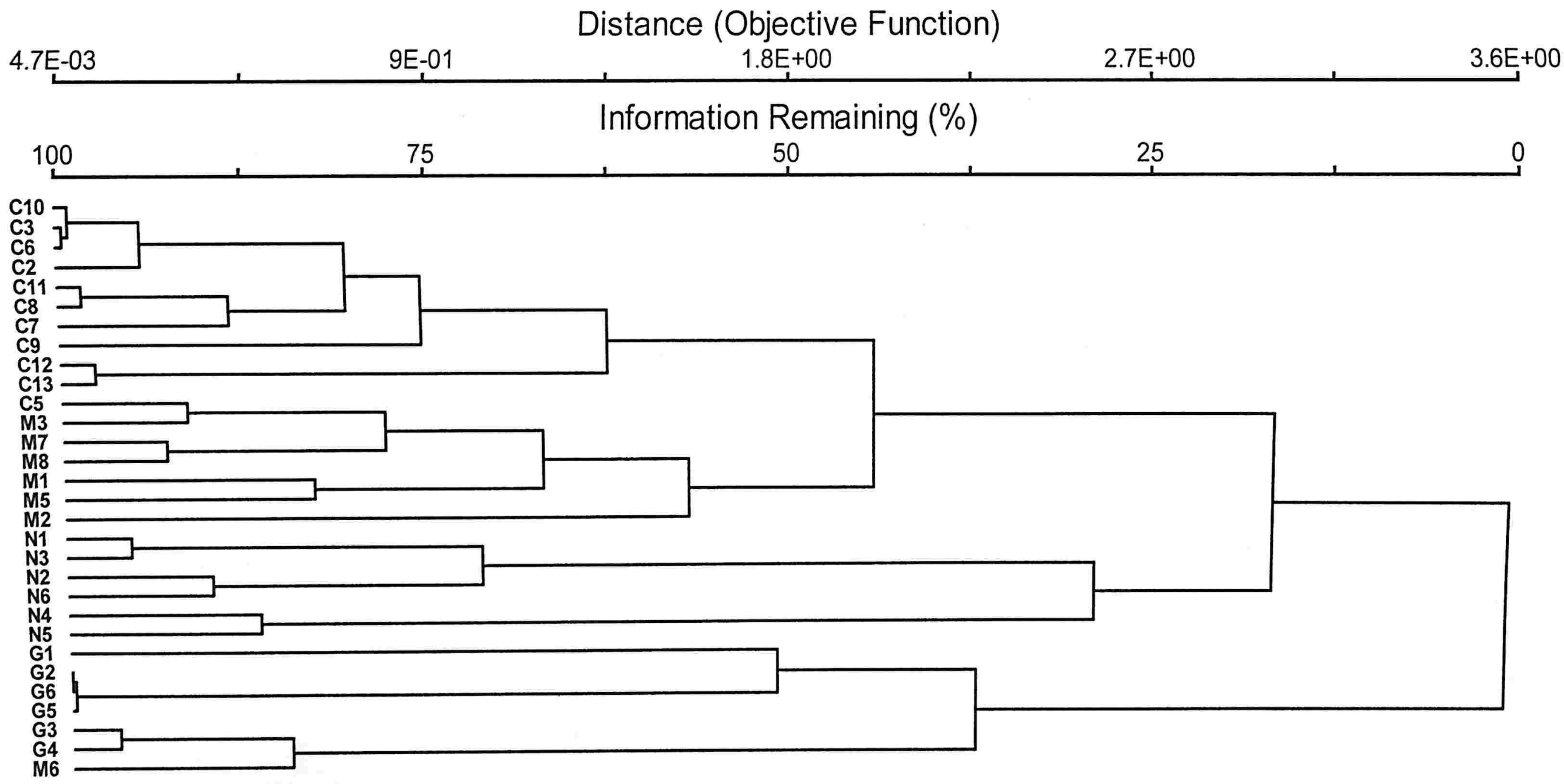


Figure 3.1 Cluster dendrogram of the sample points for bird point transects based on vegetation structure and composition

Distance measure: Sorensen (Bray-Curtis) and linkage method is flexible beta with beta = -0.25.

Codes for point habitats:- C: Chir Pine plantations, G: Garden, M: Mixed plantations, N: Natural forests

CHAPTER 4

ATTRIBUTES OF VEGETATION AND AVIFAUNA IN NEW FOREST

4.1 INTRODUCTION

I present the various attributes of vegetation and birds of the study area in this chapter. The inter-relationships between these parameters are explored in the subsequent chapters.

4.2 STUDY AREA AND METHODS

The birds were surveyed using point transects the details of which are given in the previous chapter.

Of the 276 birds reported from the New Forest campus a total of 128 species were recorded in the point transects during the present study. Of these a total of 100 species were recorded in the point transects during summer while 99 species were identified in winter season. Hence, only a little less than half of the total bird diversity was registered during the point transects which numbered 829 with 8290 minutes (nearly 138 hours) of effort in duration. This was primarily due to a near total absence of water birds as the transects were only located in the well wooded areas of the campus, absence of commensal species as the areas of human inhabitation were not covered in the study area and the omission of very rare or vagrant species.

The point transects were done with high pseudo-replication as the areas of the various habitat were small. As many points were located in the different habitats as the area of the habitats could allow. Because of high pseudo-replication, point-wise information could also be obtained for certain bird attributes, while for some only habitat level information could be arrived at with acceptable levels of confidence. Line transects were run as per the details given in section 3.3.2.

The habitats were quantified by laying bird point centred vegetation plots (details in section 3.4).

4.3 RESULTS AND DISCUSSION

4.3.1 Vegetation

4.3.1.1 Structural and compositional parameters

Major structural and compositional parameters calculated from the vegetation plots are given in table 4.1.

It can be seen that the two plantation habitats have distinctly higher canopy cover as compared to the natural and garden habitats. The garden habitat also had the maximum unevenness in canopy cover as is evident from the high standard deviation of the canopy cover. The two plantations had a higher tree and shrub density as compared to the natural habitat while the values for the garden habitat were much lower. However the Chir Pine habitat had a much lower basal area owing to the presence of very few mature Chir trees and high number of tall and thin trees of other species. The diversity also did not vary much across the natural and the two plantation habitats. Only the two plantation habitats had few snags in them indicating the maturity of these plantations. These also had the highest shrub cover as also the

Table 4.1 Attributes of vegetation of New Forest[1]

Variable	Habitat							
	Chir (n = 11)		Garden (n = 6)		Mixed (n = 7)		Natural (n = 6)	
	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev
Canopy %	94.99	2.39	73.97	23.27	94.68	1.38	73.71	10.33
No. trees*	34.82	4.85	6.33	4.76	39.57	9.11	30.17	7.76
Tree H'	0.67	0.17	0.48	0.32	0.74	0.2	0.66	0.31
Basal area*	2.91	0.54	2.84	3.6	5.72	4.71	5.13	4.63
No. Snag*	1.18	1.33	0	0	5	3.11	0.33	0.82
No. shrubs**	86.64	35.74	8.33	18.03	94.71	28.53	57.17	25.33
Sh. Cov.**	75.91	37.38	3.12	6.34	50.78	20.79	59.84	28.44
Reg. Cov.**	61.24	36.05	0.48	0.78	68.61	63.98	13.23	6.83
Cl. cov.**	7.73	7.07	0	0	19.71	37.12	3.02	4.29
Tot. Sh. Cov.**	144.88	39.68	3.6	7.08	113.84	57.84	76.08	32.14
Lantana Cov.**	32.40	34.9	0.24	0.58	8.20	11.3	40.43	29.66
Shrub H'	0.86	0.16	0.21	0.32	0.89	0.17	0.8	0.25
Tree ht. Div.	0.84	0.08	0.5	0.26	0.92	0.08	0.73	0.07
Can. top. ht .	19.72	2.86	14.52	2.65	14.25	1.54	8.73	1.05
Can. bot. ht.	14.01	2.36	5.75	2.11	9.66	1.76	3.7	1.29
Vert. Can Spr.	5.75	1.28	8.78	2.31	5.26	1.07	5.09	0.67
FHD_TRSH	3.28	0.15	2.8	0.31	3.11	0.19	2.74	0.13

* Based on measurements done in two 10 m radius circular plots (628 m^2 area)

** Based on measurements done in two 5 m radius circular plots (157 m^2 area)

Lantana cover. The plantations had the highest tree height diversity indicating a high variability in canopy height of trees.

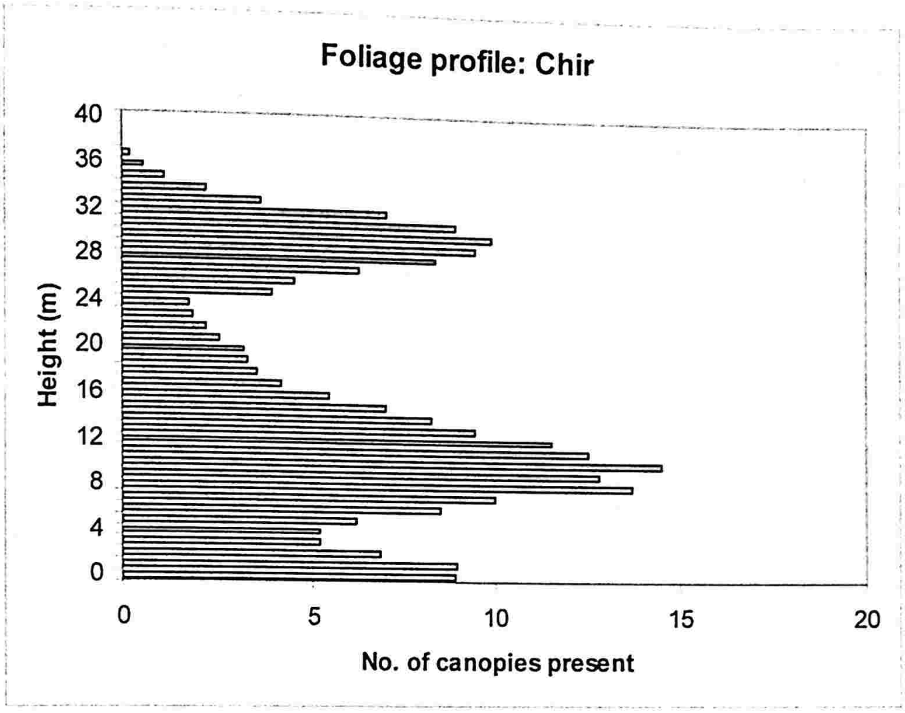
In all 59 species of trees were recorded in the vegetation plots laid in the study area. Of these five could be identified only up to the generic level. The average

[1] **Abbreviations** used in the table are **Canopy %**: Canopy percentage; **No. trees**: Number of trees; **Tree H'**: Tree species diversity as Shanon-Weiner index; **Basal area**: Basal area of trees in m sq per point; **No. snag**: Number of snags per point; **No. shrubs**: Number of shrubs per point; **Sh. Cov.**: Shrub cover in m sq per point; **Reg. Cov.**: Regeneration cover in m sq per point; **Cl. cov.**: Climber cover in m sq per point; **Tot. Sh. Cov.**: Total shrub cover in m sq per point; **Lantana Cov.**: Lantana cover in m sq per point; **Shrub H'**: Shrub species diversity as Shanon-Weiner index; **Tree ht. Div.**: Tree height diversity as Shanon-Weiner index; **Can. top. ht.**: Mean canopy top height in m; **Can. Bot. Ht.**: Mean canopy bottom height in m; **Vert. Can. Spr.**: Vertical canopy spread in m; **FHD_TRSH**: Foliage height diversity of trees and shrubs as Shanon-Weiner index.

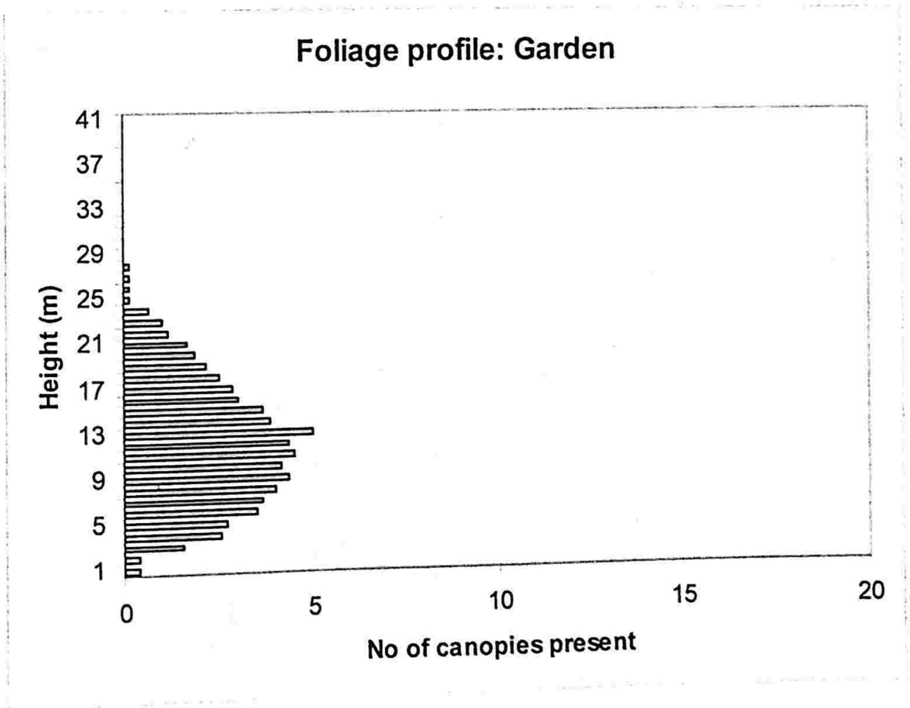
species composition of the habitats as obtained from the vegetation plots is given in appendix 10 indicating the densities of the trees found there. Only the tree species having a density more than 0.1 trees/ha in any of the habitats have been given in the table thus ignoring the very rare ones. *Pinus roxburghii, Alangium chinensis, Cinnamom camphora, Mallotus phillipensis* and *Michelia champaca* were found to be the commonest trees in Chir Pine plantation habitat. The garden habitat which had a much lower tree density compared to the other habitats, had exotics *Cupressus torulosa, Peltophorum pterocarpum* and *Callistemon viminalis* as the major species. The mixed plantation habitat had mix of exotics and native species like *Syzygium cumini, Alangium chinensis, Markhamia platycalyx, Acacia catechu* and *Mallotus phillipensis* as its major species. The natural habitat had native species dominating the tree vegetation namely *Pyrus pashia, Shorea robusta, Syzygium cumini, Xylosma longifolia* and *Dalbergia sissoo.*

4.3.1.2 Foliage profiles

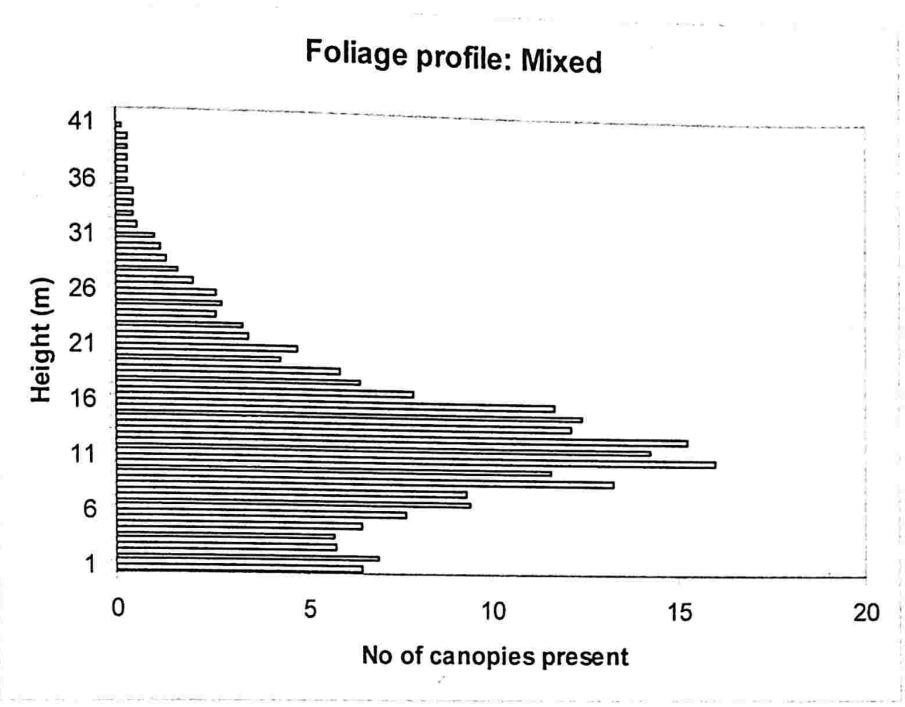
Foliage profiles for different habitats were obtained by plotting the number of canopies of trees and shrubs present in different 1 m height bands. These are shown in figure 4.1. Looking at these profile diagrams it is clear that the Chir Pine habitat is the only habitat having a distinct two layers of tree canopy with a shrub layer segregated from it. In all the other habitats the tree layer and the shrub layers merge with each other gradually. The Chir Pine plantation habitat has the maximum foliage height diversity (FHD_TRSH in table 4.1) owing to high top height and distinct vegetation layers. The lack of shrub layer in the garden habitat is also evident from the foliage profiles.



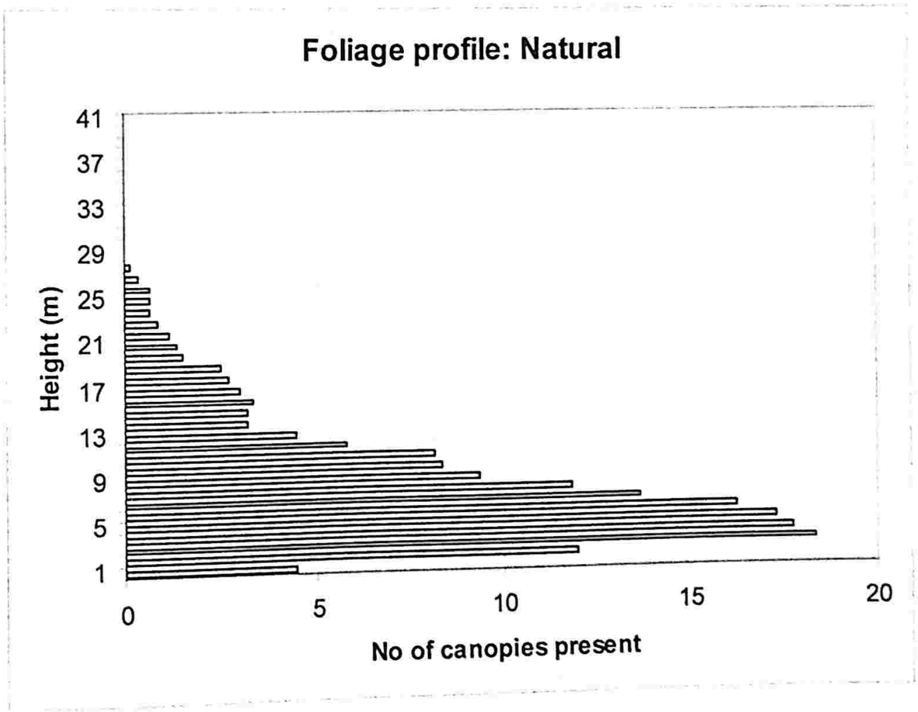
(a) Chir Pine plantations



(b) Garden habitat



(c) Mixed plantations



(d) Natural forests

Figure 4.1 Foliage profiles for (a) Chir Pine plantations (b) Garden (c) Mixed plantations (d) Natural forests.

4.3.2 Birds

A total of 8,939 individuals belonging to 105 species (100 correctly identified and 5 species identified up to genus level) were recorded during the summer season in 405 point transects done over the 30 fixed sample points. Similarly, in the winter season 9,338 individuals belonging to 104 species (99 correctly identified and 5 species identified up to genus level) were recorded in 424 point transects done over the same 30 sample points. Oriental White-eye (*Zosterops palpebrosus*) was the most observed species with 1,787 individuals recorded over both seasons (833 in summer and 954 in winters). 1180 Black Bulbuls (*Hypsipetes leucocephalus*) were observed in winter season only, thus making it the most numerous winter bird of the study area.

4.3.2.1 Bird species densities

To calculate the density of individual bird species in the two seasons in different habitats, their detection pattern was studied. Looking at the collective detection functions generated on the software Distance 5.0 (Thomas et al, 2006), it was observed that the sharp declines in detections occurred at around 40 m distance from the observer. The detection distances for individual bird species were then studied by plotting them on a graph. Based on it, the birds were classified in two groups:

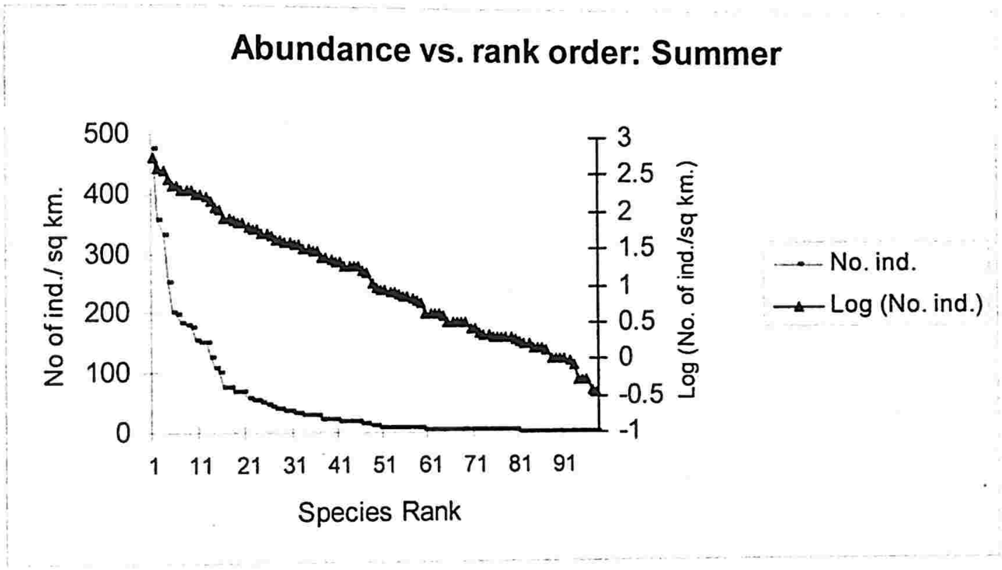
1) Species which were primarily detected within 40 m distance from the observer. These mainly included relatively small bodied birds e.g. Oriental White-eye, Black-chinned Babbler etc. which were observed ocularly often after giving out an aural clue. Certain large bodied birds such as Hair-crested Drongo and Rufous Treepie were also included in this category as they were also detected primarily within 40 m distance owing to their behaviour.

2) Species which were primarily detected beyond 40 m distance from the observer. These mainly included relatively large bodied forest birds which were heard more often than seen. Some of the birds included in this group are Red Junglefowl, cuckoos, Black-hooded Oriole, and large woodpeckers.

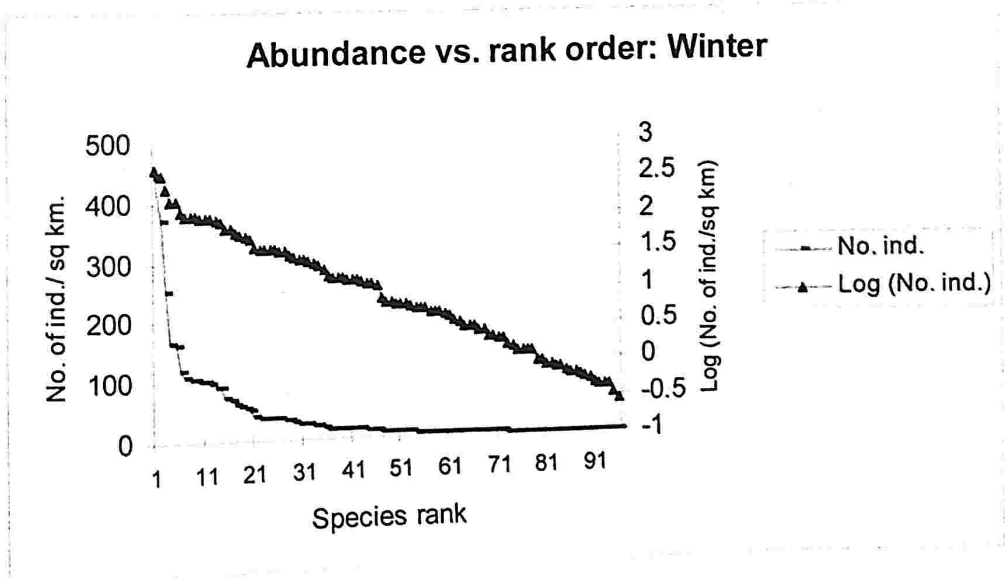
Separate detection functions were fitted for each of these groups in different habitats and seasons. Density for individual species was extracted by 'post-stratification' of density of each group (Raza, 2006, Alldredge et al, 2007).

Based on the above procedure Oriental White-eye (*Zosterops palpebrosus*) was found to be the commonest bird of the study area in the summer season with a density of 4.755 birds/ha. Its density varied from 2.584 birds/ha (CV = 28.42%) in the garden habitat to 8.291 birds/ha (CV = 15.19%) in the natural forests which was less than 14.3 birds/ha of density obtained in a survey in southern western ghats using the same methodology (Shankar Raman, 2003). Grey-breased Prinia (*Prinia hodgsonii*) was the second most abundant species with the density of 3.545 birds/ha followed by the Himalayan Bulbul (*Pycnonotus leucogenys*) with density of 3.318 birds/ha. The winter season saw Black Bulbul (*Hypsipetes leucocephalus*) emerging as the bird with the highest density in the study area. Its overall density of 4.428 birds/ha varied from 2.405 birds/ha (CV = 26.47%) in garden habitat to 8.921 birds/ha (CV = 33.05%) in mixed plantations. Oriental White-eye (*Zosterops palpebrosus*) was the second most abundant species with the density of 3.698 birds/ha followed by the Slaty-headed Parakeet (*Psittacula himalayana*) with density of 2.526 birds/ha. A list of 20 commonest birds separately for summer and winter seasons for New forest is given in appendix 15.

The abundance versus rank order curves for both the seasons are given in Figure 4.1. This distribution follows log-normal distribution which is an indication of undisturbed, fully developed communities (Patrick, 1973; Bazzaz, 1975; Gray, 1978; Gray & Mirza, 1979; Gray & Pearson, 1982; Ugland & Gray, 1982; Jeffrey & Hallegraeff, 1987). Majority of communities studied by ecologists display a log normal pattern of species abundance (Sugihara, 1980).



(a)



(b)

Figure 4.2 Abundance vs. rank order curves for birds of New Forest (a) for summer season and (b) for winter season

4.3.2.2 Habitat-wise bird densities

As the point transect data generated was substantial (5610 observations in summer and 4587 observation in winters) the habitat-wise densities could be calculated using the DISTANCE 5.0 software (Thomas et al., 2006). The densities were first separately calculated for both the years for each season and habitat. It was observed that in each habitat and season the densities in general did not differ significantly across the two years as is evident from the overlap of their confidence intervals (Fig 4.3). The data from the two years was pooled in each season and habitat and more robust estimates of densities were then calculated. In brief the densities observed are given in tables 4.2. Only in the Chir Pine plantations the summer densities in the two years seem to differ significantly perhaps due to extraction of dead trees (both standing and fallen from a large part of the habitat in early 2006). The pooled values here indicate the average values across the two summers.

Table 4.2 Bird densities as obtained from point transects in number of birds/ha. Coefficient of variation in parenthesis

Summer season

Habitat	**Density 2005**	**Density 2006**	**Density Pooled**
Chir	32.79 (6.74%)	61.75 (7.11%)	**41.89 (5.3%)**
Garden	39.60 (8.23%)	31.86 (13.28%)	**31.07 (7.18%)**
Mixed	29.28 (5.77%)	29.17 (6.36%)	**31.54 (5.4%)**
Natural	70.16 (6.8%)	94.62 (7.22%)	**79.09 (6.28%)**
All habitats (pooled)			**47.51 (3.8%)**

Winter season

Habitat	Density 2004-05	Density 2005-06	Density Pooled
Chir	22.85 (6.08%)	24.20 (6.71%)	**22.53 (4.9%)**
Garden	25.73 (8.15%)	30.48 (10.46%)	**26.85 (8.2%)**
Mixed	29.91 (7.15%)	31.62 (6.7%)	**32.52 (5.5%)**
Natural	33.60 (10.84%)	32.25 (7.7%)	**37.40 (7.75%)**
All habitats (pooled)			**27.90 (3.3%)**

Coefficients of variation (CV) well below 11% were obtained in the pooled density estimates across all habitats and both seasons.

As is evident from the results, the natural habitat supported highest densities of birds in both the seasons. The densities in summers usually exceeded the densities in winters in most of the habitats in New Forest. Breeding season densities in forests are generally above winter densities, although the magnitude of the difference varies with forest type (Karr, 1976). Seasonal changes in avifauna of temperate forests are more extreme than changes in avifauna of tropical forests. Seasonal changes in the avifauna of the tropical forest (except north temperate migrants) were relatively minor (maximum-minimum monthly ratio 1.0), while temperate forest ratios ranged from 1.5 to 4.0 (excluding migration seasons which make the figures much larger) (Karr, 1976). In New Forest the density pooled across all the habitats displayed a ratio of 1.7 between summers (breeding) and winter (non-breeding). The natural as well as the Chir habitat showed significant rise in densities in the summer season (Fig.4.3). These habitats have fewer exotic trees as compared to the other two habitats viz. gardens and mixed plantations. Higher number of exotics in the garden and mixed habitat perhaps

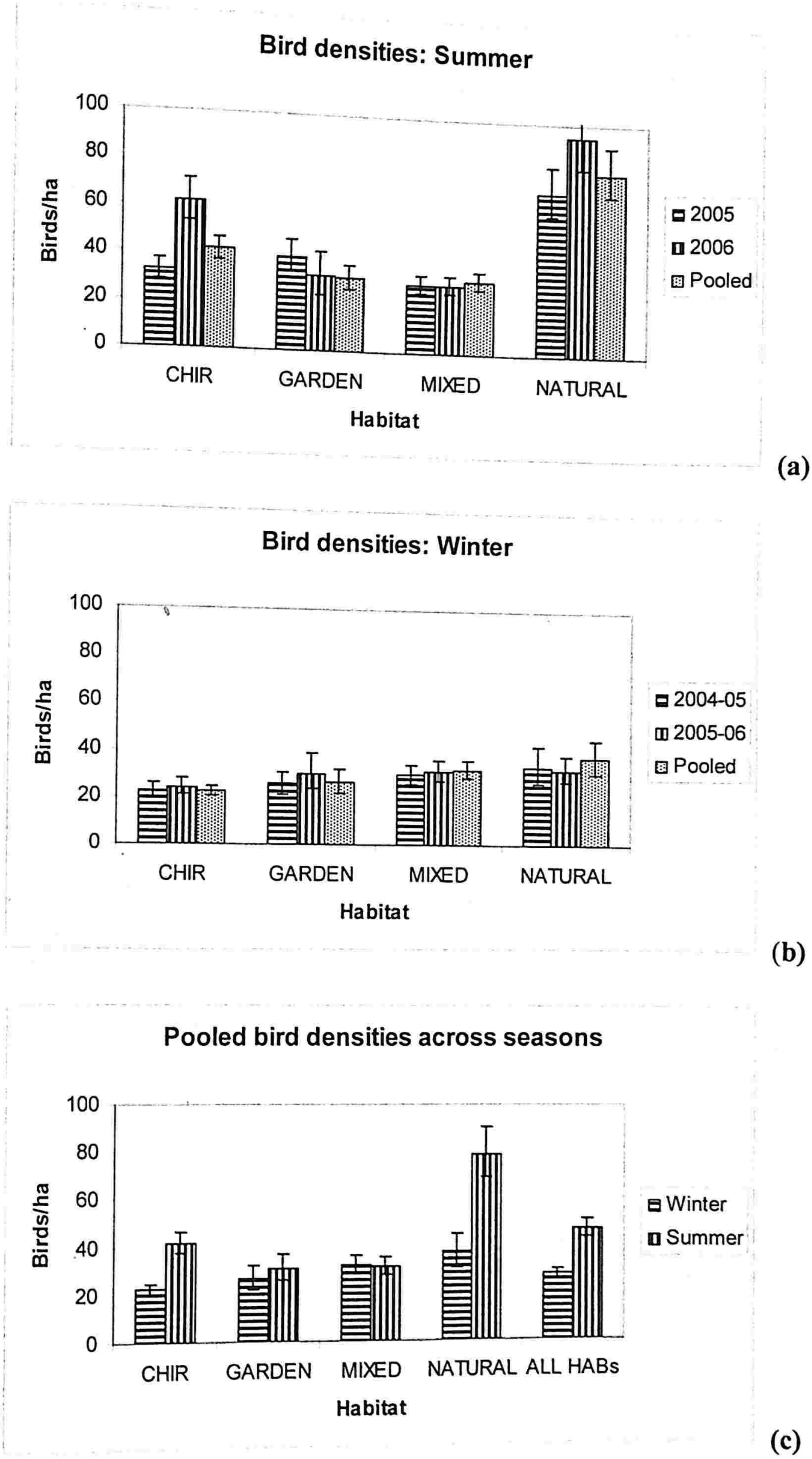


Figure 4.3 Bird densities in New Forest as obtained from point transects (a) summer (b) winter (c) pooled densities for both seasons. Error bars show the confidence intervals at 95% confidence limits.

result in a higher resource availability of certain phytophagous resources in the winter season resulting in higher use by the respective guilds, thus leading to maintenance of similar bird densities in winter season as in the breeding season.

Bird abundances in urban woodlands differ with the physical characteristics of the woodland (size, shape and isolation), the variety of microhabitats provided and the level of human activity in and around the woods (Tilghman, 1987). New Forest has the advantage on all these fronts as it is large sized woodland nearly 150 ha in extent, has connectivity with larger natural forest areas to its north and owing to the different management histories has a good mosaic of microhabitats.

4.3.2.3 Guild densities

Bird densities in basic guilds i.e. insectivorous and phytophagous were calculated using Distance version 5.0 software (Thomas et al., 2006) using the point transect data pooled for both the years. The birds were classified into basic and fine guilds based on their feeding behaviour as detailed in section 6.2.4. These densities are given in Table 4.3 and 4.4. However bird densities for fine guilds were not calculated as there wasn't sufficient data for certain fine guilds.

Table 4.3 Bird densities of Basic guilds of birds in New Forest in summer season in birds/ha.

	Basic guilds			
Habitat	**Insectivorous**	**Phytophagous**	**Others***	**Total density**
Chir	22.32(6.7%)	19.12(5.7%)	0.45	41.89(5.3%)
Garden	8.21(14%)	16.19(6.6%)	6.68	31.07(7.2%)
Mixed	10.21(6.5%)	16.01(5.2%)	5.33	31.54(5.4%)
Natural	37.85(3.1%)	36.81(9.2%)	4.44	79.09(6.3%)

Coefficient of variation in parenthesis.

* obtained by subtracting insectivorous and phytophagous guild densities from total densities

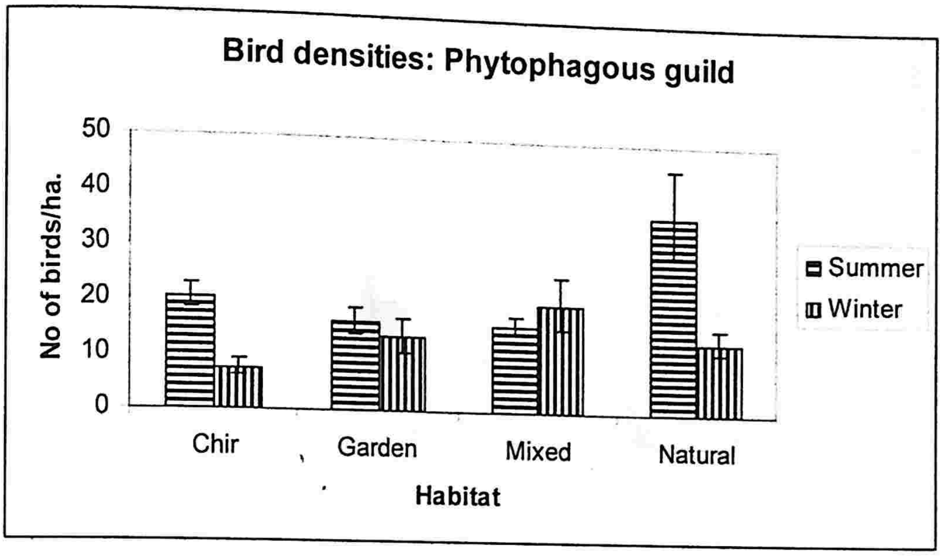


Figure 4.4 Bird densities of phytophagous guild across the two seasons. Error bars show the confidence intervals at 95% confidence limits.

Table 4.4 Bird densities of Basic guilds of birds in New Forest in winter season in birds/ha.

	Basic guilds			
Habitat	**Insectivorous**	**Phytophagous**	**Others***	**Total density**
Chir	13.09(7.8%)	7.52(10.1%)	1.92	22.53(4.9%)
Garden	10.80(9.3%)	13.56(10.5%)	2.49	26.85(8.2%)
Mixed	12.29(7.7%)	19.83(11.3%)	0.41	32.53(5.5%)
Natural	20.83(10.2%)	13.46(8.5%)	3.11	37.40(7.75%)

Coefficient of variation in parenthesis

* obtained by subtracting insectivorous and phytophagous guild densities from total densities

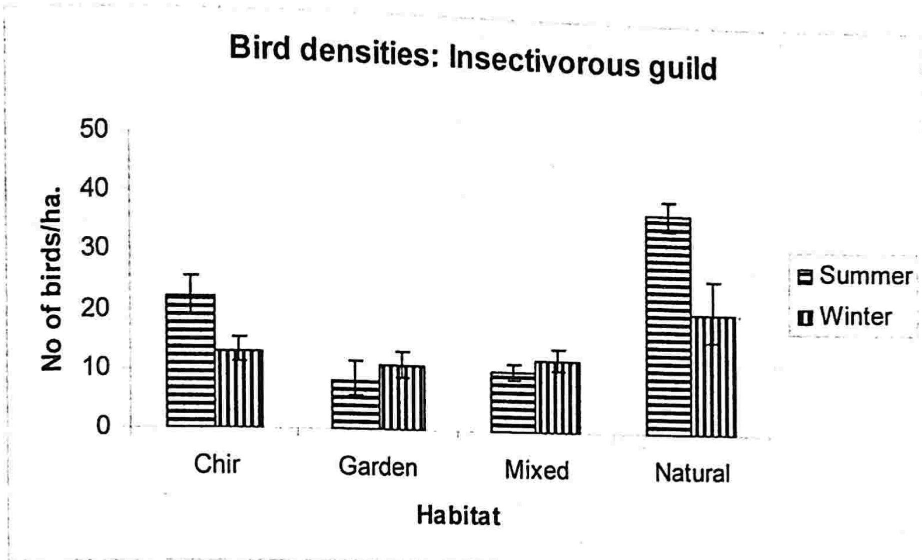


Figure 4.5 Bird densities of insectivorous guild across the two seasons. Error bars show the confidence intervals at 95% confidence limits.

The guild densities for the basic guilds indicated a general decline in bird densities in both the phytophagous as well as insectivorous guilds from summer to winter season. These declines were significant in Chir Pine plantations and the natural forests while they were insignificant in the other two habitats as is evident from the error bars in Fig. 4.4 and 4.5. This may again be because of a good admixture of native and exotic species of vegetation in the garden and mixed plantation habitat buffering the effect of seasonal changes.

4.3.2.4 Response of birds to habitats

In order to see if the birds were showing any preference among the four identified habitats, Multiple Response Permutation Procedure (MRPP) was applied (McCune and Grace, 2002). MRPP is one of the numerous independently developed nonparametric methods for testing for group differences. PC-ORD 4.20 software (McCune and Mefford, 1999) was used for this analysis. The following results were obtained.

Season	T statistic	*A*	p value
Summer	-14.102375	0.21584564	>0.001
Winter	-10.771640	0.15500092	>0.001

This clearly indicates that the birds definitely show an association with habitats, the associations being more explicit in the summer season as T values are more negative. The chance corrected within group agreement *A* is also high indicating reasonably high homogeneity within groups (habitats). It is higher in summers indicating a higher homogeneity within group as compared to winters. In community ecology, values for *A* are commonly below 0.1 even when the observed delta (weighted mean within group distance) differs significantly from the expected. An *A*> 0.3 is fairly high (McCune and Grace, 2002).

Many species of birds showed significant indicator values for various habitats when the data was subjected to Indicator value analysis (Dufrene and Legendre, 1997). This further substantiates a high level of habitat selection by the birds in New Forests. The indicator values and their interpretation are discussed later in this report in section 7.2.2.

The extent of habitat segregation of birds was also investigated by subjecting the bird composition to cluster analysis in both the seasons. These cluster dendrograms are shown in appendix 11. It is clear from the dendrograms that in summer season, the bird community segregated perfectly according to the habitats, except for those in the vicinity of sample point C5 where the community appeared to be closer to the mixed habitat and those at point M5 where it was similar to the Chir habitat. In addition, the two units of the garden habitat i.e. Botanical Garden and Arboretum also segregated separately. In winters however the bird community did not segregate as perfectly as it did in the summer season. Notably, in both the seasons the natural habitat stood out clearly, with all its sample points clustering together showing high levels of similarity. Thus the natural habitat maintained a significantly different bird community throughout the year from the man-made habitats.

4.3.2.5 Bird Species Richness (BSR)

Computation of bird richness was done using point transect data. To make comparisons unbiased, the data was truncated to 40m. The richness was calculated by simply calculating the number of bird species detected in different habitats in the two seasons and also by the Jackknife estimators as a sample will almost always underestimate the true species richness. The Jackknife estimators improve accuracy and reduce bias, at least when sub-sampling a restricted area. (McCune and Grace, 2002). The second order Jackknife was least biased estimator of species richness when the sample size was small (Hellman and Fowler, 1999).

Table 4.5 Bird species richness as obtained from point transects data

Summers

Habitat	**Species richness**	**Jackknife 1 estimate**	**Jackknife 2 estimate**
All	93	111.37	119.19
Chir	61	76.45	82.26
Garden	52	64.5	70.23
Mixed	55	65.29	70.29
Natural	72	85.33	89.6

Winters

Habitat	Species richness	Jackknife 1 estimate	Jackknife 2 estimate
All	92	108.43	115.29
Chir	58	68	73.32
Garden	61	74.33	79.13
Mixed	56	68	72.64
Natural	69	87.33	95.04

The natural habitat supported the maximum number of species in both the seasons. Even though the bird species pool in summer and winter differed considerably, the richness remained almost the same. Thus, the species immigration and emigration were largely similar.

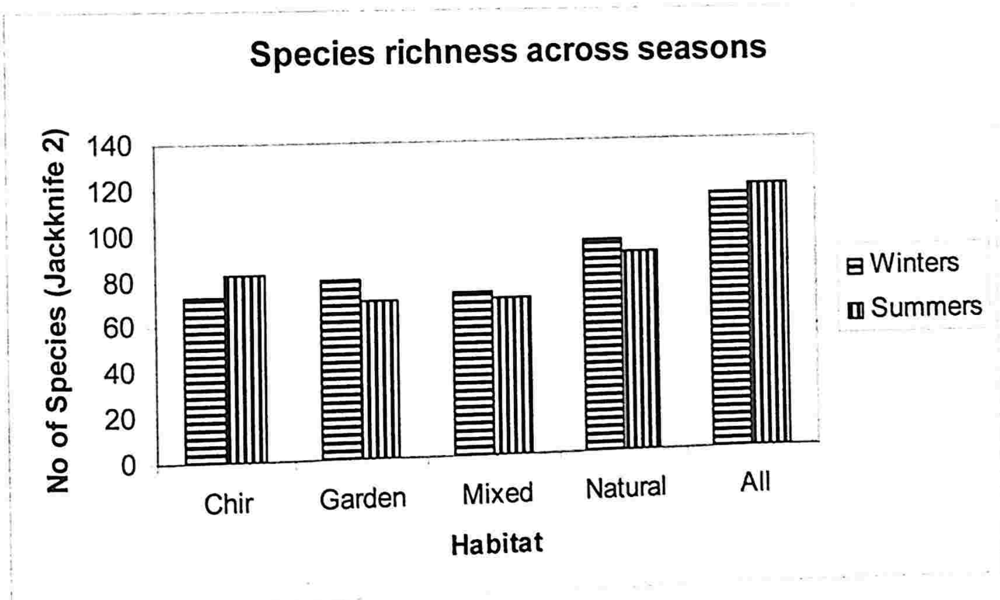


Figure 4.6 Bird species richness as estimated by Jackknife 2 estimator

4.3.2.6 Bird clusters

Flocking is an important attribute of many bird species. It varies across seasons and many birds show higher levels of flocking in the non-breeding season (winters) (Emlen, 1952). The cluster size as recorded during the point transects is a direct measure of flock size. It is estimated during the distance analysis of the data using Distance 5.0 software (Thomas et al., 2006). The average cluster sizes detected for individual bird species in different habitats in the two seasons in New Forest during the study period are given in table 4.6.

Table 4.6 Habitat-wise average cluster (flock) size seen in birds of New Forest across the two seasons.

Summer season			
Habitat	Cluster size 2005	Cluster size 2006	**Cluster size Pooled**
Chir	1.61 (1.84%)	1.65 (1.9%)	**1.63 (1.32%)**
Garden	1.75 (2.68%)	1.69 (2.42%)	**1.73 (1.89%)**
Mixed	1.55 (1.81%)	1.53 (1.75%)	**1.54 (1.27%)**
Natural	1.61 (1.73%)	1.48 (1.67%)	**1.55 (1.2%)**
Winter season			
Habitat	Cluster size 2004-05	Cluster size 2005-06	**Cluster size Pooled**
Chir	1.99 (4.31%)	2.31 (15.67%)	**2.14 (8.59%)**
Garden	1.92 (3.71%)	2.06 (4.41%)	**2.04 (3.36%)**
Mixed	2.36 (5.18%)	2.13 (4.5%)	**2.25 (3.47%)**
Natural	1.79 (3.35%)	1.74 (3.45%)	**1.75 (2.45%)**

(Coefficient of variation in parenthesis)

It can be seen that the cluster sizes are consistently higher in winters when the birds tend to be forming large flocks. The coefficient of variation was also higher in winter indicating varying degrees of flocking by different bird species. It may be mentioned here that the Chir habitat had the exceptionally high CV in the winter of 2005-06 owing to the detection of certain very large flocks of Slaty-headed Parakeets which often congregated to bask in the early morning sun on snags. Flocks of 200 and 70 birds were detected on 21st and 25th January 2006 respectively.

Average flock sizes were calculated for all the birds in winter season when birds are known to form large flocks. These are given for the most flocking species (which have been recorded with flocks of 5 or more at least once) in Figure 4.8. The birds which formed flocks of 4 or above on an average were Slaty-headed Parakeet which formed flocks of 12.80 birds, Black Bulbuls (5.31 birds), Jungle Babbler (5.16 birds), Small Minivet (4.56 birds) and Yellow-eyed Babbler (4.00 birds).

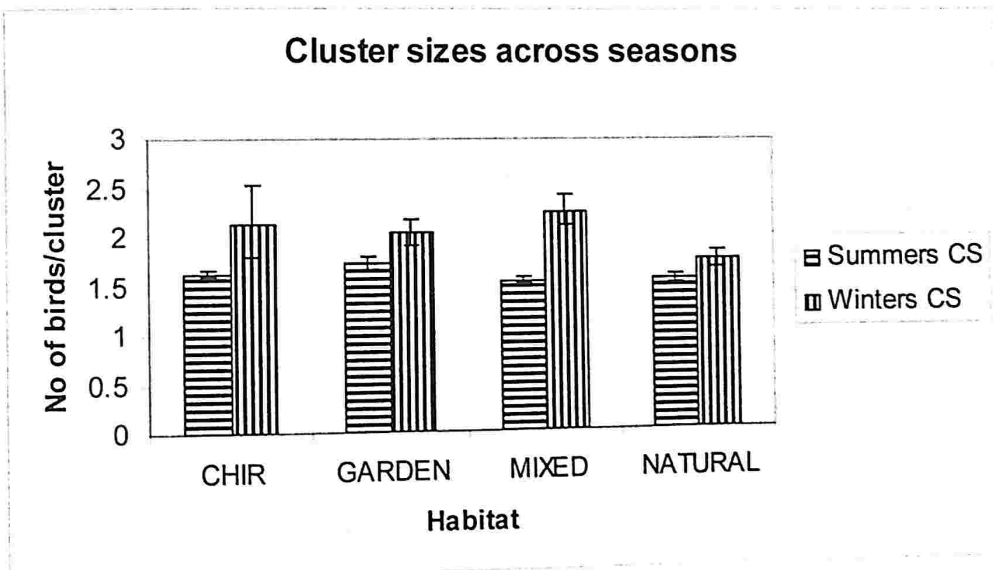


Figure 4.7 Cluster size of the birds in New Forest

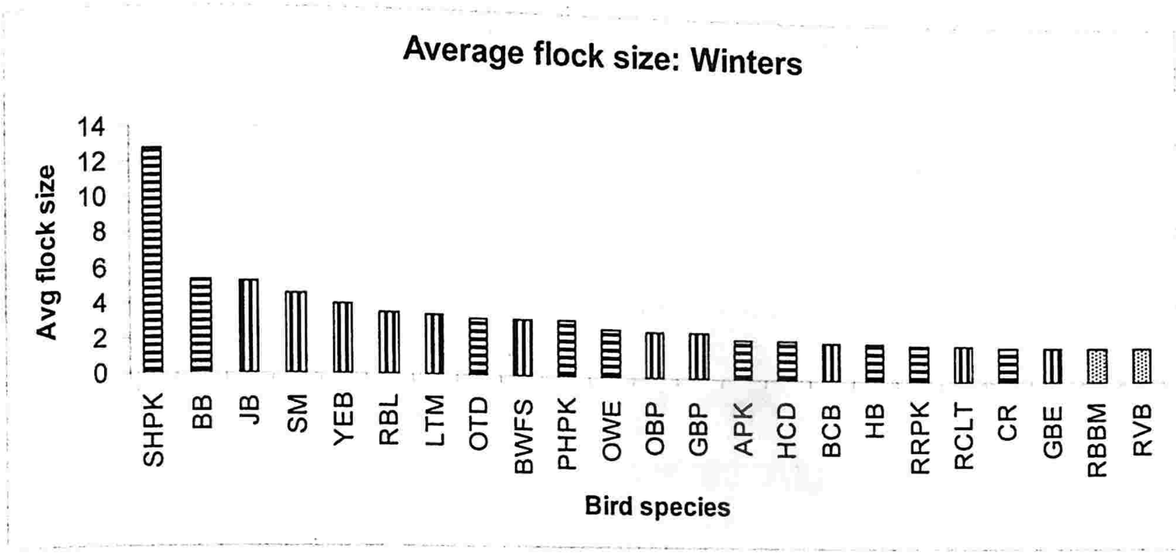


Figure 4.8 Average flock size of the most flocking species in the winter season as obtained from point transect data. (for species code see appendix 17)

Horizontal fill for bars: Primarily phytophagous birds

Vertical fill for bars: Primarily insectivorous birds

Dotted fill for bars: Omnivorous birds

4.3.2.7 Bird Species Diversity (BSD)

Bird species diversity was calculated using the Shannon-Wiener index.

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

where p_i is the proportion of ith species. This was calculated by pooling all the observations up to 40 m radius within a habitat. The diversity was also calculated for each point and expressed as an average in the Table 4.7 and depicted after normalization (dividing it by the row average to present in the same graph) in figure 4.9 and 4.10.

Table 4.7 Diversity, evenness and estimated richness of birds in New Forest across seasons

Summer season

Habitat	Chir	Garden	Mixed	Natural
Shannon Wiener Diversity	3.31	3.26	3.25	3.30
Shannon Evenness	0.81	0.83	0.81	0.77
Richness	61	52	55	72
Estimated Richness (Jackknife 2)	82.26	70.23	70.29	89.6
Mean Shannon Wiener Diversity (points)	2.95	2.84	2.99	3.08
Mean Shannon Wiener Evenness (points)	0.89	0.86	0.86	0.83

Winter season

Habitat	Chir	Garden	Mixed	Natural
Shannon Wiener Diversity	3.28	3.35	2.93	3.20
Shannon Evenness	0.81	0.82	0.73	0.76
Richness	58	61	56	69
Estimated Richness (Jackknife 2)	73.32	79.13	72.64	95.04
Mean Shannon Wiener Diversity (points)	2.82	2.83	2.56	2.91
Mean Shannon Wiener Evenness (points)	0.86	0.83	0.77	0.82

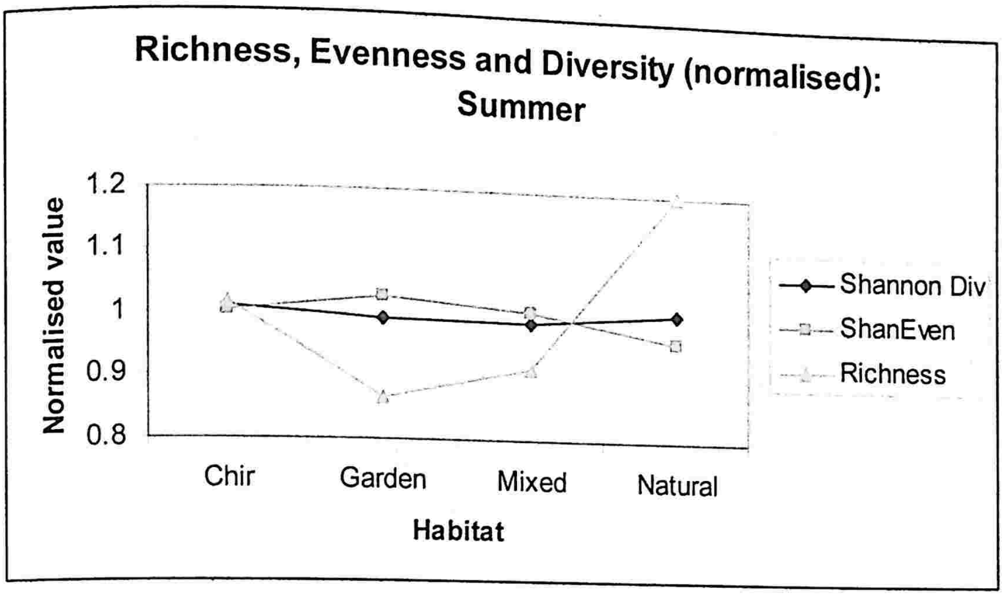


Figure 4.9 Bird Richness, Evenness and Diversity (normalised) for Summer Season

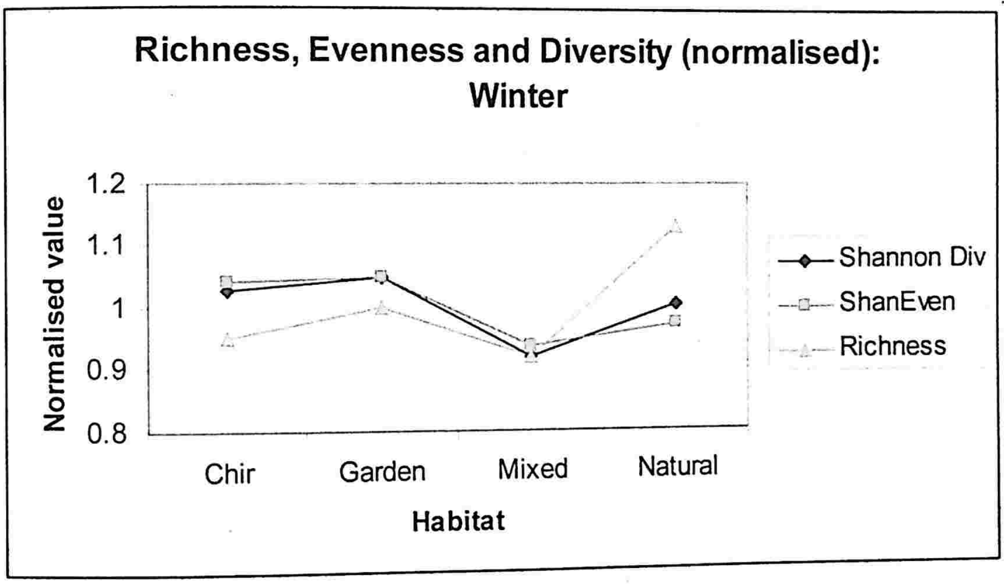


Figure 4.10 Bird Richness, Evenness and Diversity (normalised) for Winter Season

In summer season while the diversity did not show variation across habitats, it did show significant variations when values were averaged across different points within a habitat. The natural habitat which showed a high richness had the poorest evenness leading to substantial reduction in its diversity. In winter season a higher variation in the bird species diversity was registered and though the natural habitat had the maximum richness, it was much lower in evenness leading to a lower diversity than the Garden and Chir habitats.

Karr and Roth (1971) predicted low avian diversities in dense uniform stands of conifers. However in the present study the Chir Pine plantations which had dense and uniform top storey of mature Chir Pine trees, displayed high diversity in both the seasons comparing well with the natural habitats. This could primarily be a result of a dense middle and under-storey of various broad leaved species in these plantations which are usually absent in the natural Chir Pine forests in its natural zone (pers. obs.) and also in most of the coniferous forest in the different parts of the world.

4.3.2.8 Bird Biomass

Of the several levels at which bioenergetic approaches may be applied to community analysis, the expression of patterns in terms of biomass is the simplest (Wiens, 1989). Standing crop biomasses of species' populations and of entire communities have been calculated in a number of community studies (e.g. Raitt and Pimm, 1976; Wiens, 1973 and 1974; Vaisanen and Jarvinen, 1977; Glowacinski, 1979; Folse, 1982). The patterns that emerge when communities are considered in terms of biomass may differ from those determined by density calculations. Biomass measures may also produce patterns that are not at all apparent when density values are used. They may bear a closer relationship to the demands placed by bird populations on the energy resources of an environment than do densities (Wiens, 1989). Biomass is a much better reflection of energy use than number of species or number of individuals (Pearson, 1975).

The standing bird biomasses in different habitats of New Forest were calculated by utilizing the densities of different bird species in different habitats and different seasons as calculated earlier in section 4.3.2.1. The biomass of different bird species was taken from secondary literature (Ali and Ripley, 1983). The biomasses obtained are presented in Table 4.8 and Figure 4.11. Except for the mixed habitat, all other habitats displayed a significant reduction in biomass during the winter months. The mixed plantation habitat had two plots of huge *Acrocarpus fraxinifolius* plantations which bear gregarious flowers in February-March resulting in large congregations of nectar loving birds like Spangled Drongo, Black Bulbul and all the species of Parakeets. This resulted in enhanced bird densities in winters in this habitat.

Table 4.8 Bird biomass in grams/ha for the two seasons in New Forest

Habitat	Summer	Winter
Chir	2576.13	1848.49
Garden	2991.44	1838.52
Mixed	2195.93	2263.5
Natural	2658.72	1411.62
All habitats	2594.42	1769.94

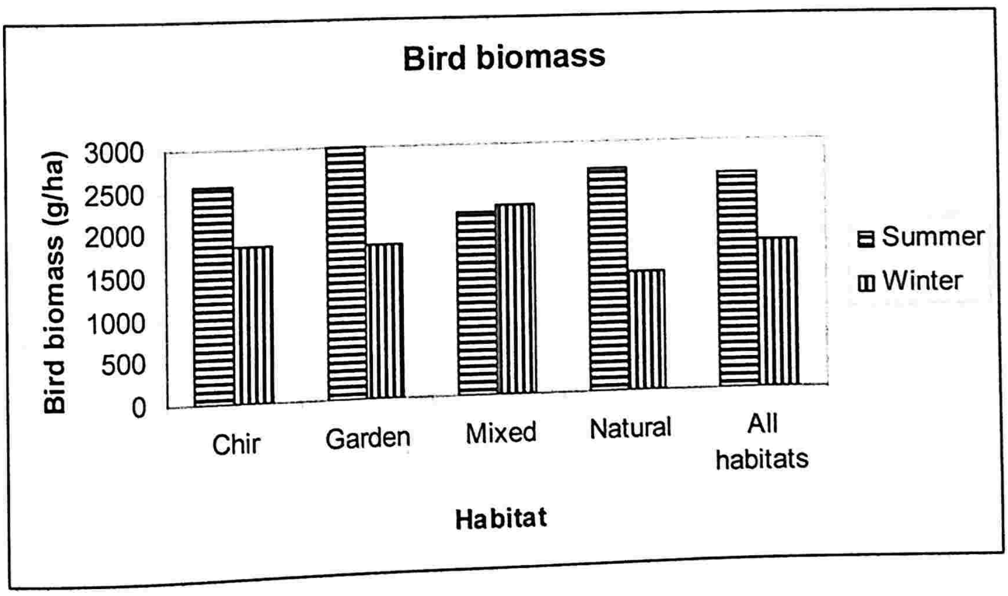


Figure 4.11 Bird biomass for different habitats across seasons

Thus the wooded parts of New Forest support 259.4 kg km^{-2} and 177 kg km^{-2} of bird biomass in summer and winter seasons respectively. This compares well with the biomass recorded in many other studies in the tropical countries. Terborgh et al. (1990) conservatively estimated the biomass at 190 kg km^{-2} for Amazonian bird community. Karr (1971) reported 131 kg km^{-2} of bird biomass on a 2 ha plot in Panama. Thiollay (1986) reported 148 kg km^{-2} in a study in French Guiana, Brosset and Erard (1986) estimated it to be 187 kg km^{-2} in Gabon, Africa. The only study with a much higher biomass was the one from New Guinea which reported a bird biomass of 496 kg km^{-2} (Bell 1982), which according to Terborgh et al. (1990) may partially be because of a general scarcity of competing arboreal mammals. The higher biomass densities in New Forest compared to most of the other studies in natural forests mentioned above is a result similar to one found in many other studies where urban forest bird densities have been found to be higher than other forests (e.g. in Woolfenden and Rohwer, 1969; Emlen, 1974; Guthrie, 1974; Walcott, 1974; DeGraaf, 1978).

CHAPTER 5

INFLUENCE OF VEGETATION COMPOSITION AND STRUCTURE ON BIRD SPECIES COMPOSITION

5.1 INTRODUCTION

Ever since the seminal work by MacArthur and MacArthur (1961), the subject of avian communities and its relation to habitat structure has been a very popular theme of research for community ecologists. The conclusion by MacArthur and MacArthur (1961) that the diversity in vertical stand structure, or foliage height, was strongly related to bird species diversity was re-examined by many bird community ecologists. These could be broadly divided into two categories: those investigating the relationship between habitat heterogeneity and bird species diversity (MacArthur et al, 1962, 1966, Recher 1969, Karr and Roth, 1971) and between habitat structure and bird species composition (Cody 1974, Anderson and Shugart 1974). Most of them established a strong correlation between habitat physiognomy and avian community composition.

When focus started shifting from temperate to tropical forests particularly in the 1970s and 1980s, habitat physiognomy alone was found to be insufficient to explain the extraordinary bird species diversity that existed there. The tropical vs. temperate contrast in bird diversity particularly intrigued Robert MacArthur, and in a 1966 paper with two associates the question was raised of whether the higher species number found in tropical bird communities were due to truly greater levels of alpha diversity or merely to higher beta diversity (finer sub-division of habitats) (MacArthur et al., 1966, Terborgh et al., 1990). In discussing their results of a study done in Panama, MacArthur et al. (1966) concluded that the additional species could be accounted for solely on the basis of the structurally more complex habitat if it was assumed that the Panamanian birds were recognizing five foliage layers versus the three that gave the best fit with the temperate birds. However when this logic was extended to Amazonia it failed to explain a much higher bird diversity in structurally similar forests as that of Panama (Terborgh, 1985). Thus it was realized that besides the habitat structure, other factors also play important role in determining the diversity of birds in habitats which get even more pronounced in tropics. The increased diversity of tropical bird communities is due to: (1) greater structural complexity of the habitat, (2) the presence of entire guilds that are not represented in temperate bird communities, (3) larger guild niches reflecting broader underlying resource spectra, and (4) tighter species packing (Terborgh, 1985).

Composition of vegetation thus became an important determinant of bird diversity. The distribution and abundance of many bird species are determined by the configuration and composition of the vegetation that comprises a major element of their habitat (e.g. Cody, 1985; Morrison et al., 1992; Block and Brennan, 1993). Documentation of the relationships between habitat and bird communities has been a major part of avian ecology for decades (Rotenberry, 1985; Wiens, 1989). It has even been suggested that the vegetation–habitat concept is one of the unifying theories in avian biology (Block & Brennan, 1993).

Two aspects of vegetation as habitat affect birds: the physical structure or configuration of the vegetation (physiognomy) and its plant species composition (floristics) (Rotenberry, 1985; Block & Brennan, 1993). Moreover, the relative influence of these two components varies as a function of the spatial scale over which bird–habitat relationships are examined. Based on an analysis of structurally simple grassland and shrubsteppe vegetation types, Rotenberry (1985) observed that physiognomic features appeared to be more important over relatively coarse biogeographical scales (or among-habitat comparisons), whereas floristic features seemed more important at finer scales within regions (or within-habitat comparisons). This was consistent with the view of a hierarchical decision-making process by birds in habitat selection (Johnson, 1980; Hutto, 1985), with an emphasis on coarse physiognomic features, followed by finer selection based on floristic details within a gross habitat type, presumably to find a suitable location to fit requirements for foraging, protection from predators and reproduction.

Numerous subsequent studies have explicitly examined the relative roles of physiognomy vs. floristics in association with variation in both individual bird distributions and bird communities from a variety of spatial scales and in many different biomes or general vegetation types, but especially in forested ecosystems (e.g. Arnold, 1988; Mac Nally, 1990; Virkkala, 1991; Bersier & Meyer, 1994, 1995; Neave et al., 1996; Estades, 1997; Cueto & de Casenave, 2000; Johnson & Freedman, 2002; Laiolo, 2002; Rodewald & Abrams, 2002; MacDonald & Kirkpatrick, 2003).

The question as to how much vegetation composition and structure independently contribute to bird species composition was first addressed by Rotenberry (1985), who demonstrated that 55% variation in species composition in grassland birds was due to floristics and 35% could be explained by vegetation structure. In a majority of subsequent studies most of which were on forest bird communities, vegetation composition emerged as the most significant factor (e.g., Lopez & Moro, 1997; Fleishman et al., 2003; Lee & Rotenberry, 2005). While others found both floristics and physiognomy as equally important (e.g., MacNally, 1990; Bersier & Meyer, 1994), a few studies could not find any evidence for either of the components (e.g., Koen & Crowe, 1987). Such variations in avian responses have been attributed to several factors, among which the scale of investigation and the food habits of birds have emperical support (Jayapal, 2006).

Consistent with a food resource-driven pattern, Cueto & Casenave (2000) detected foraging guild-specific variation in whether structure or floristics were more important; the insectivore guild responded primarily to structural differences, whereas the frugivore-insectivore responded more to differences in floristic composition. This study was somewhat limited, however, as it was based on a survey encompassing only two types of forest. In a more detailed analysis, Laiolo (2002) observed that understorey plant species richness influenced shrub feeders (as well as shrub nesters and edge species), whereas canopy species richness affected trunk feeders. Canopy species richness also correlated with overall bird diversity, richness, and biomass, abundance of hole-nesters and forest interior species.

In the present study I investigated the relative role of habitat floristics and physignomy in determining the bird species composition in New Forest in the breeding and the non-breeding seasons. The relative influence of these two habitat parameters on the two major feeding guilds (i.e. primarily insectivores and primarily phytophagous) has also been investigated.

In addition, I investigated the influence of various vegetation compositional and structural parameters of the habitat on the bird species diversity, richness and density. The relationship of these attributes of bird communities with the foliage height diversity has also been explored.

5.2 METHODS

5.2.1 Study area

The entire study area for the study i.e. the forested part of the New Forest campus was considered for this analysis.

5.2.2 Birds

The point transect data for the two years pooled across each season i.e. summer and winter was utilised for this investigation. The detection functions from the Distance analysis were studied and it was realised that there was a significant drop in detections only after a distance of 40 m across all the four habitats. Thus the entire data was truncated to 40 m so that comparisons amongst habitats would become meaningful with lower biases.

5.2.3 Vegetation

Vegetation data obtained from the vegetation plots was utilised for this part of the analysis. The species compositional information was utilised for building the vegetation composition matrix. Thirteen structural variables were utilised to draw upon the vegetation structural matrix a list of which is given in section 5.3.6.

5.2.4 Analysis

I derived dissimilarity matrices using Bray-Curtis distance for bird compostion, vegetation composition and vegetation structure. The bird composition was normalised based on the survey effort in each point. The vegetation structure matrix was relativised using general relativisation using PC-ORD 4.20 software (McCune and Mefford, 1999) before calculating the dissimilarity matrix as various variables had different scales of measurement. Dissimilarity matrices were obtained using the software Bio-diversity Professional version 2 (McAleece et al. 1997) using Bray-Curtis distance measure as recommended by Krebs (1999). The dissimilarity matrices were then analysed using simple Mantel's and partial Mantel's tests to detect any significant associations with 10,000 randomised runs (McCune & Grace 2002). To control for the influence of proximity partial Mantel's test were carried out keeping the matrix of physical distances between the points as covariate. The distances were obtained by measuring them between points on the GIS platform. The Mantel's and partial Mantel's test were carried out using the software **zt** version 1.0 (Bonnet and Van de Peer, 2002).

Mantel's test is a method that tests for associations among two or more variables using randomization procedures rather than parametric methods (Legendre & Fortin, 1989; McCune & Grace, 2002).Variables to be tested are first converted to similarity matrices that are based on the degree of likeness between sites, based on the attributes that are recorded. Mantel's test calculates the degree of association between the two distance matrices using a simple correlation test. However,the significance of the correlation coefficient is tested by comparing it with values generated by randomizing the matrix many times (10,000 times, in this case). The alternative hypothesis in a Mantel's test is that the observed value of the correlation between two distance matrices is greater than values that may be observed by chance. The advantage of using Mantel's tests is that inference is possible without assumptions of normality and much greater power than parametric tests (Manly, 1991). Additionally, Mantel's tests allow the incorporation of species composition into the analysis along with other variables through the use of similarity indices, which is not possible otherwise.

To investigate the influence of food resource on relative role of habitat physiognomy and floristics on bird composition, the birds were categorised into feeding guilds. This was done at two levels. At the coarser level they were divided into three categories (basic guilds): (1) primarily insectivores, (2) primarily phytophagus and (3) others i.e. those species which could not be classified under in either of two categories. At a finer level the birds of New Forests were classified into 15 feeding guilds which are described in Chapter 6. A detailed listing of the bird guilds is given in appendix 12. For the analysis in this chapter only basic guilds were used.

The relationship between different compositional and structural parameters of the habitat with the bird species diversity (BSD) (section 4.3.7) and richness (BSR) (section 4.3.5) was investigated by calculating the Pearson's product moment correlation coefficients using the software SPSS version 8.0 (1997). Simple species richness was used for this. These were calculated for different habitats separately to see if they behaved differently as far as these relationships were concerned. In addition, the habitat structural parameters were ordinated using Principal Component

Analysis to reduce them to fewer composite (synthetic) variables using their mutual association. These principal component factors were interpreted and related to the bird parameters BSD and BSR using the software SPSS version 8.0 (1997).

5.3 RESULTS

5.3.1 Birds

A total of 105 bird species were recorded during the summer months. This included 5 species which were not identified correctly up to the species level and were left at the genus level. On truncating the data to 40 m distance from the point station, the number of species decreased to 98 including 5 species not identified to species level.

In winters, the number of bird species detected in point counts was 104 including 5 which could not be identified to the species level. On truncating the data to a distance of 40 m from the point station, the number of species decreased to 97 including 5 which could not be identified to species level.

5.3.2 Vegetation

The data obtained from the 57 plots around the 30 bird points revealed that, the four habitats differed considerably from one another. This is also evident from the cluster analysis based on vegetation structure and composition as shown in section 3.5. A total of 59 tree species were recorded from the plots which included many species of exotic trees introduced in New Forests for trials in Indian conditions. The vegetation is described in section 4.3.1.1. A summary account of major the woody plant species recorded in four habitats along with their abundances is given in appendix 10.

5.3.3 Bird composition, floristics and vegetation structure

Table 5.1 displays the association between bird composition, floristics and vegetation structure as shown by Mantel's tests. The geographic distance between sites was found to have a significant influence over bird species composition in both the seasons ($r = 0.38$, $p<0.001$ in summer and $r = 0.37$, $p<0.001$ in winter). Interestingly floristics and vegetation structure were significantly associated after partialling out the effect of geographic distance, an attribute which is typical of moist habitats. Partial Mantel's tests, after controlling for geographic distance, showed that the bird species composition had significant association with floristics and physiognomy. However between the two, floristics seemed to play a greater role in deciding the bird composition as was evident from a high value 0.39 of Mantel's *r* in summer and moderate value 0.29 in winters after partialling out the effect of vegetation structure (physiognomy). Habitat physiognomy seemed to have much lower though significant influence on bird composition in summer season as the value of Mantel's r was 0.19. The association however became almost insignificant in winters. The associations showed similar trends across the two seasons although they were weaker in winter indicating a poorer habitat selection. This has also been corroborated by the Multiple Response Permutation Procedure earlier in this report (Section 4.3.2.4).

Table 5.1 : Association among birds species composition, floristics, vegetation structure and distance between points, as shown by Mantel's tests across wooded habitats in New Forests (Matrix size: 30)

Season	Contrasted matrices		Covariate	Mantel's *r*	*P*
Summers	Bird composition	Distance		0.377	**<0.001**
	Floristics	Veg. Struc.	Distance	0.559	**<0.001**
	Bird composition	Floristics	Veg. Structure	0.392	**<0.001**
		Veg. Struc.	Floristics	0.191	**0.011**
Winters	Bird composition	Distance		0.366	**<0.001**
	Floristics	Veg. Struc.	Distance	0.559	**<0.001**
	Bird composition	Floristics	Veg. Structure	0.294	**<0.001**
		Veg. Struc.	Floristics	0.097	0.082

5.3.4 Guild composition, floristics and vegetation structure

An analysis of results yielded 61 insectivorous species of birds and 25 species which were primarily phytophagous in summer season while 65 insectivorous bird species and 25 phytophagous birds were encountered in winter season. 12 species recorded in summers and 7 in winters could not be clearly attributed to either of the guilds and were kept out of this analysis. The insectivorous guild included woodpeckers, cuckoos, drongos, minivets, flycatchers, chats, thrushes, nuthatches, babblers and warblers. The phytophagous guild consisted of parakeets, barbets, hornbills, pigeons, doves, koel, sunbirds, bulbuls, white-eyes and flowerpeckers.

Table 5.2 displays the association between bird composition of feeding guilds, floristics and vegetation structure as shown by Mantel's tests.

Table 5.2 : Association among birds species composition of feeding guilds, floristics, vegetation structure and distance between points, as shown by Mantel's tests across wooded habitats in New Forests (Matrix size: 30)

Season/guild	Contrasted matrices		Covariate	Mantel's *r*	*p*
Summers/P*	Bird composition	Distance		0.317	**<0.001**
	Bird composition	Floristics	Veg. Structure	0.406	**<0.001**
		Veg. Structure	Floristics	0.034	0.310
Winters/P*	Bird composition	Distance		0.236	**<0.001**
	Bird composition	Floristics	Veg. Structure	0.226	**<0.001**
		Veg. Structure	Floristics	0.029	0.313
Summers/I**	Bird composition	Distance		0.349	**<0.001**
	Bird composition	Floristics	Veg. Structure	0.290	**<0.001**
		Veg. Structure	Floristics	0.187	**0.009**
Winters/I**	Bird composition	Distance		0.475	**<0.001**
	Bird composition	Floristics	Veg. Structure	0.256	**<0.001**
		Veg. Structure	Floristics	0.090	0.096

* P: Phytophagous guild;** I: Insectivorous guild

It is clear from the above results of the Mantel's test that the phytophagous guild displays a strong relationship with floristics and does not show any significant relationship with vegetation structure (physiognomy). The strong relationship with floristics however weakens out in winters though it maintains its statistical significance. The Insectivore guild also shows a significant relationship with floristics which weakens a little in winters although it is less than the one shown by the phytophagous guild in summers. The Insectivores however do show a significant association with vegetation structure in summer which becomes insignificant in winters.

5.3.5 Influence of habitat variables on Bird species diversity, richness and density

The relationship of the bird species diversity, richness and density with habitat parameters was investigated by computing linear correlation coefficients. Conventionally, the inter-relationships between synthetic measures like the bird species diversity and plant species diversity have been very popular in bird-habitat studies, but certain authors have opined that simple indices like species richness and direct vegetation measurements perform much better than derived indices like species diversity or structural diversity like FHD (Erdelen, 1984; Ganeshaiah et al., 1997). These three attributes of the birds were calculated for all the 30 sample points (point transect locations). The results of the correlations are presented in appendix 13a and appendix 13b for winter and summer seasons respectively. The interpretation is presented below discussing the relationships habitat wise, as bird attributes in different habitat often had a different response to a particular habitat variable.

5.3.5.1 Summer season

Canopy: No significant correlation was found between canopy and BSD and BSR. However when the natural habitat was considered alone (N = 6) strong correlation (r = 0.79) was detected with BSD which was significant (p = 0.062). Bird density showed a negative correlation with canopy when all the habitats were considered together (r = -0.36, p < 0.05, N = 30). This may be owing to a better shrub growth in open canopy areas leading to the habitats becoming suitable for under-storey birds which is a large group in New Forest.

Tree density: The only habitat which showed a positive significant correlation of BSD with tree density was the garden habitat (r = 0.871, p < 0.05, N = 6) in summer season. This was the most open habitat of all the habitats of New Forest and hence the higher tree density must be resulting in a better microclimate in the warm summer months, leading to better food resources.

Tree species diversity: Only the natural habitat had a BSD strongly and very significantly correlated with tree species diversity in summer season (r = 0.925, p < 0.01, N = 6). Being the natural habitat the trees here may be of greater value as a food resource for the birds and hence their higher diversity led to a higher BSD.

Shrub density: The BSR for natural habitat had a strong and very significant correlation in summer season (r = 0.945, p < 0.01, N = 6), as a higher shrub density may be providing a breeding space for large number of under-storey breeding birds.

Shrub cover: BSD, BSR and bird density were significantly strongly correlated with shrub cover in the Chir habitat ($r = 0.78$, $p < 0.01$; $r = 0.74$, $p < 0.01$ and $r = 0.7$, $p < 0.05$, $N = 11$ respectively). This was perhaps due to shrub layer being the most productive layer in the habitat where the tree layers were of exotics (Pine, *Michelia* and *Cinnamomum*) and not so suitable for breeding.

Tree height diversity: Although the four habitats did not show a significant correlation with tree height diversity, when pooled together they displayed a significant but moderate correlation with BSD. Higher tree height diversity may lead to more uneven canopy and hence more light penetrating to middle and under storey vegetation leading to a better development of the same resulting in better development of food resources for the birds.

Vertical canopy spread: BSD showed significant negative correlation with vertical canopy spread in summer season in Chir Pine habitat ($r = -0.77$, $p < 0.01$, $N = 11$). This may be because of the high canopy difference to the Chir pine canopies and other middle story trees which had elongated canopies but not utilized by an under-story rich avifauna.

Basal area, snag density, regeneration cover, climber cover and **shrub volume** did not show significant linear correlation with BSD, BSR and density in summer season.

5.3.5.2 Winter Season

Canopy: In winters none of the habitats displayed significant correlation between Canopy and BSD. With all the habitats put together there was a weak negative correlation ($r = 0.36$, $p = 0.054$, $N = 30$). This is perhaps due to much less light penetrating into the forest in dense canopy forests leading to low day temperature and therefore poorer insect activity leading to a poor bird assemblage particularly of insectivores resulting in poorer BSD.

Tree density: Only in natural habitat these was a significant but negative correlation of bird density with tree density ($r = 0.85$, $p < 0.05$, $N = 6$). In the winter season poorer tree density would indicate a higher insolation being received by all layers in the vegetation which may lead to more insect life in the foliage leading to better bird density.

Basal area and number of snags: Both these variable although failed to show a significant correlation with BSD in any habitat, they showed a significant negative correlation for all the habitats put together ($r = -0.39$, $p < 0.05$ and $r = -0.54$, $p < 0.01$, $N = 30$ respectively). Both these variables are indicative of old growth which would mean a denser closed canopy forest which may be suitable to a more specialist bird species which are fewer in numbers and not so for the generalist. However these had a positive correlation with density indicating a higher number of birds with increasing maturity of forests (climax vegetation).

Shrub density: Shrub density was positively correlated with BSR in Chir Pine habitat ($r = 0.62$, $p < 0.05$, $N = 11$). This was perhaps due to shrub layer being the most productive layer in the habitat where the tree layers were of exotics (Pine, *Michelia* and *Cinnamomum*) and not so suitable for breeding.

Shrub cover: BSD was strongly and significantly correlated with shrub cover ($r = 0.838$, $p < 0.05$, $N = 6$) for natural habitat. This may be because of open canopy of the habitat resulting in more light falling on the under-storey vegetation and consequently more insect life in it.

Tree height diversity: This was strongly and significantly correlated with BSD in Chir habitat in winters ($r = 0.71$, $p < 0.05$, $N = 11$). The Chir habitat had a very uniform canopy and wherever it showed unevenness, it led to more light penetrating and better shrub growth. This is also indicated by a high correlation between tree height diversity and shrub volume for the Chir habitat.

Canopy top height: The average top height of the trees was negatively correlated with BSR and bird density for all the habitats pooled ($r = -0.53$, $p < 0.01$, $N = 30$). This may be because greater top height may lead to low sunlight reaching the middle and under storey vegetation leading to a poor richness and density of birds.

All other variables failed to show any significant correlation with the BSD, BSR and density in winter season.

5.3.5.3 *Lantana camara* cover: *Lantana* an invasive exotic shrub from South America has invaded many large tracts of tropical India. It has invaded certain areas of the New Forest campus too. It is often considered to be a great threat for the native biodiversity and large amounts of money and effort are spent to control or eradicate it particularly from the protected areas (pers. obs.). However it is often said that certain elements of our biodiversity have 'well' adjusted to *Lantana*. In fact birds have been aiding the spread of *Lantana* often at the cost of native vegetation (Swarbrick et al., 1998; Loyn & French, 1991). Bird species feed on *Lantana* fruits and, in some locations, seed dispersal has been facilitated by the introduction of exotic bird species (Sharma et al., 2005).

To investigate the influence of *Lantana* on the avifauna of New Forest, the *Lantana* cover at different point locations was correlated with the bird attributes. *Lantana* is the most widespread shrub in the study area, and contributes nearly a fourth of the total shrub cover. As garden and mixed habitats had negligible *Lantana* they were kept out of this analysis and only Chir Pine plantation and Natural forests were considered. *Lantana* displayed a positive correlation with BSD in summer season ($r = 0.39$ $p = 0.088$, $N = 17$) while there was no relationship seen in winter season. The other two attributes namely BSR and bird density failed to show any significant correlation with *Lantana* cover. The BSD in the two habitats however had different response to the presence of *Lantana* as is evident from figure 5.1. While in summer season the natural habitat did not show any correlation with the extent of *Lantana*, the Chir plantation habitat was positively correlated. This may be because of a good microclimate in the dense canopied Chir plantations. In winter season however the open canopy of the natural forests helped in maintenance of warmer microclimate in the shrub zone of the habitat leading to a better correlation with *Lantana* cover.

5.3.5.4 Perch height and foliage height

As bird perch height was also recorded during the point transects, a correlation was computed between the bird observations in different perch height classes and foliage count (number of canopies) in the same height classes using Mantel's test.

This resulted in a significant correlation between the two (Mantel's r =0.32, p<0.001) indicating that the birds are using the full spectrum in the *a-priori* perch height categories.

5.3.5.5 Foliage height diversity

FHD was calculated with 1m foliage height bands considering tree and shrub vegetation and correlated with the bird attributes. Only Chir Pine habitat had a significant negative correlation between BSD and FHD owing to extra canopy layers which were poorly utilized by the birds. Bird density also behaved similarly indicating the 'extra' layers actually were leading to impoverishment of avifauna both in numbers and diversity. The correlation in other habitats was not significant (figure 5.2). Taking a cue from the work of McArthur, 1966 various combinations of height bands were used to classify the vertical foliage profile. These are given in Table 5.3.

Table 5.3 Height bands for calculation of foliage height diversity

Name of combination	Band 1	Band 2	Band 3	Band 4	Band 5	Band 6
FHD_TR	Height bands of 1m interval from 0m to 40m considering only tree foliage					
FHD_TRSH	Height bands of 1m interval from 0m to 40m considering tree and shrub foliage					
FHD5_20	0-2	2-5	5-10	10-20	20+	-
FHD5_10	0-2	2-5	5-10	10+	-	-
FHD6_15	0-1	1-2	2-4	4-8	8-15	15+
FHD4_10	0-2	2-4	4-10	10+		
FHD5_15	0-2	2-5	5-10	10-15	15+	-
FHD6_12	0-1	1-2	2-4	4-8	8-12	12+
FHD4_12	0-1	1-2	2-4	4-8	8-12	12+

Name of combination	Band 1	Band 2	Band 3	Band 4	Band 5	Band 6
FHD5_8	0-1	1-2	2-4	4-8	8+	
FHD4_8	0-1	1-2	2-4	4-8	8+	-
FHD4_4	0-1	1-2	2-4	4+	-	-

The BSD and BSR did show linear relationships with foliage height diversity (FHD) for certain combination of height bands of the foliage. While BSD correlated significantly with FHD only for a few combinations of height bands, BSR was significantly positively correlated with BSD for both the seasons for most of the height band combination of FHD. Interestingly the relationship of BSR and FHD was negative when the latter was calculated with 1 m interval height bands (the FHD calculation with finest classes); the relationship turned positive for FHD calculated with coarser height bands. FHD was calculated here by clubbing the foliage count from the FHD categories of 1 m interval. This suggests that the birds were responding to only certain foliage height categories.

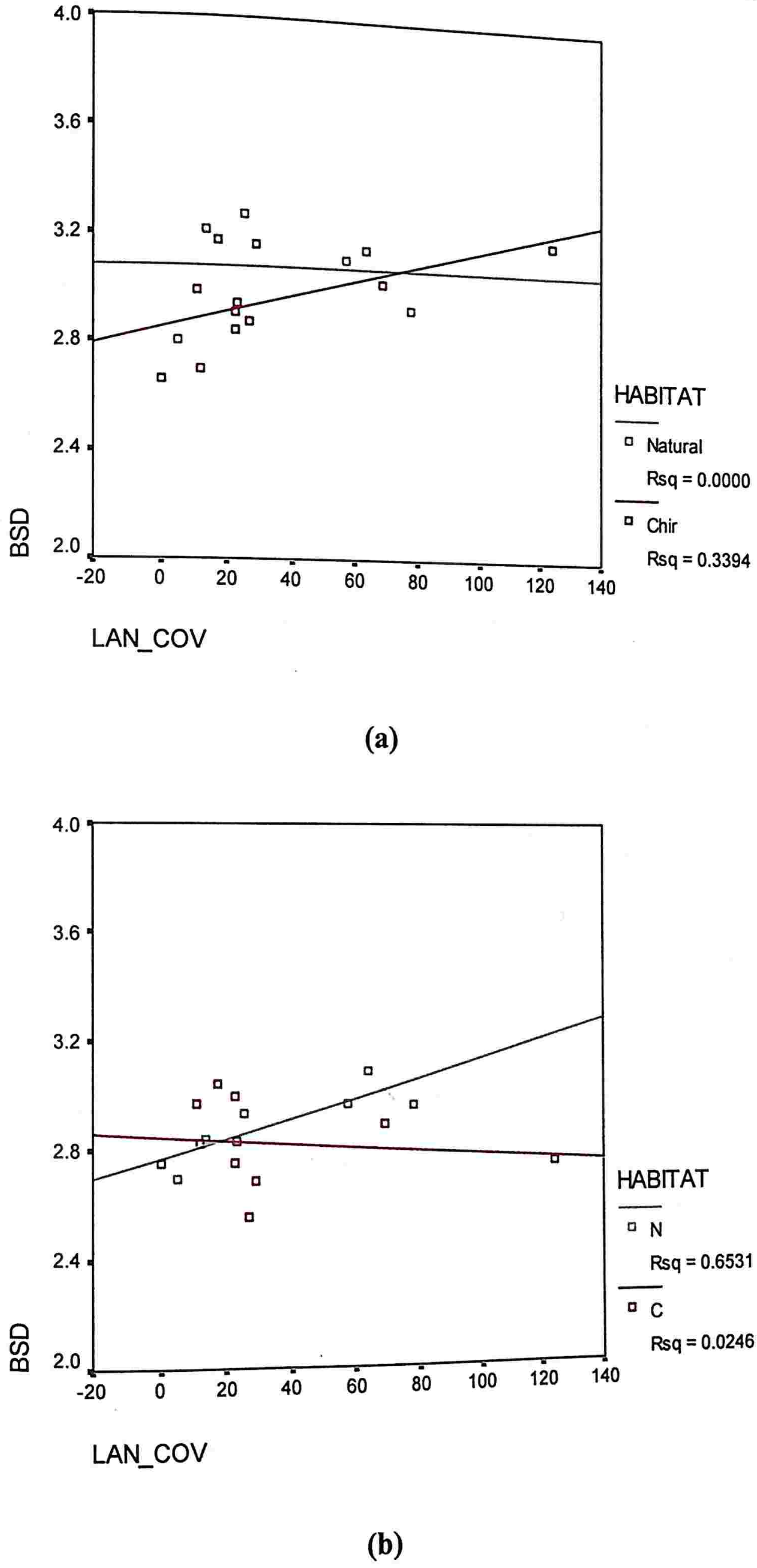


Figure 5.1 Relationship between BSD and *Lantana* cover (in sq m per plot) in natural and Chir pine habitats in (a) summer and (b) winter season.

Table 5.4 Pearson correlation between BSDand BSR with FHD from various combinations of foliage height bands (in bold for FHDs with significant correlations)

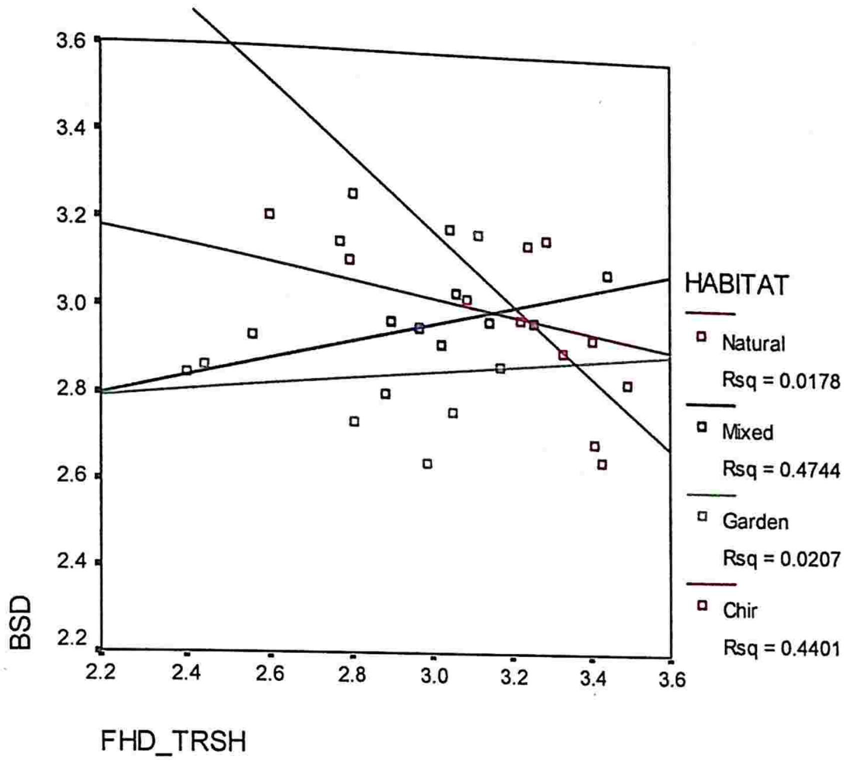
Summer		FHD_TR	FHD_TRSH	FHD4_10	FHD6_12	FHD5_8	FHD4_4	BSD
BSD	Pearson Correlation	-0.20	-0.1	**0.38***	**0.44***	0.35	**0.4***	1
	N	30	30	30	30	30	30	30
BSR	Pearson Correlation	**- 0.56****	**- 0.54****	**0.56****	**0.45***	**0.6****	**0.56****	**0.67****
	N	30	30	30	30	30	30	30
Winter								
BSD	Pearson Correlation	-0.34	-0.33	0.25	0.19	0.31	0.27	1
	N	30	30	30	30	30	30	30
BSR	Pearson Correlation	**- 0.4***	**- 0.42***	**0.5****	**0.41***	**0.56****	**0.46***	**0.5****
	N	30	30	30	30	30	30	30

* Correlation is significant at the 0.05 level

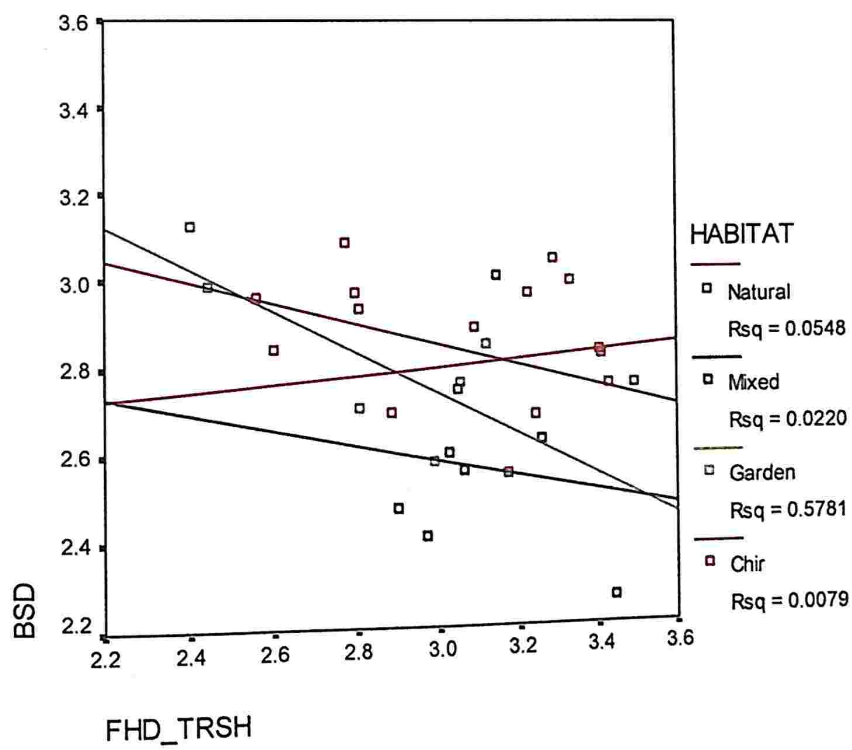
** Correlation is significant at the 0.01 level

The highest and most significant value for the correlation between BSD and FHD for summer season was obtained with the FHD 6_12 height bands combination. However when considered separately BSD of none of the habitats correlated significantly with FHD of any combinations. In winter season no significant correlation was obtained for any combination of FHD but the values from the Natural habitat did correlate significantly with FHD 6_12 ($r = 0.846$, $p < 0.05$, $N = 6$).

BSR correlated significantly with most combinations of FHD. In both the seasons the FHD 5_8 had the maximum and most significant correlation with BSR. Here the BSR correlated negatively with FHD_TR and FHD_TRSH.



(a)



(b)

Figure 5.2 Relationship between BSD and Foliage height diversity at 1 m height bands cover in natural and Chir pine habitats in (a) summer and (b) winter season.

5.3.6 Ordination of habitat variables

Principal component Analyses (PCA) method of ordination was applied to 13 habitat structural variables viz. Canopy cover, tree density (indicated by the number of trees in a sample plot), basal area of the trees, number of snags, shrub density (through the number of shrubs in a plot), shrub cover, regeneration cover, total shrub cover, shrub volume, tree height diversity, canopy top height, vertical canopy spread, and foliage height diversity at 1m interval height categories).

Sampling was found to be adequate (Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.614).

Table 5.5 Variance explained by the principal components (Only top three components displayed)

	Initial Eigenvalues			Rotation Sums of Squared Loadings		
Component	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	6.36	48.90	48.89	4.41	33.96	33.96
2	1.99	15.31	64.20	3.53	27.15	61.11
3	1.67	12.88	77.08	2.08	15.98	77.08

Extraction Method: Principal Component Analysis.

Table 5.6 Rotated Component Matrix indicating correlations of the structural variables with the principal components (only component scores above 0.4 displayed)

	Component		
	1	2	3
TOTAL SHRUB COVER	.870	.446	
VER. CANOPY SPREAD	-.808		
SHRUB COVER	.807		
TREE DENSITY	.787		.475
SHRUB VOLUME	.739	.525	
SHRUB DENSITY	.659	.440	
REGENERATION COVER	.596	.497	
FOLIAGE HT. DIVERSITY		.909	
CANOPY TOP HEIGHT		.877	
CANOPY COVER		.725	
BASAL AREA			.824
NUMBER OF SNAG			.803
TREE HEIGHT DIVERSITY	.480	.526	.534

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Rotation converged in 5 iterations.

As is evident from table 5.5, the rotated PC1 factor explained 33.96% of variation PC2 explained 27.15 % and PC3 explained 15.98 % of variance totaling to 77.8%. An interpretation of the component matrix in table 5.6 shows that the first axis is strongly correlated to shrub cover and volume, tree and shrub density and thus explained horizontal heterogeneity of the habitat. The second axis is strongly correlated with foliage height diversity, canopy top height and canopy cover and thus explained the vertical stand structure and canopy. The third axis is strongly correlated to basal area and number of snags (or snag density) and thus represents the stand maturity. The factors were then correlated to the BSD, BSR, Density and biomass for both the seasons the results of which are shown in table 5.7 and 5.8.

Table 5.7 Pearson Correlation of PC factors with BSD, BSR, Bird density and Bird biomass in Summer season

N=30	BSD	BSR	DENSITY	BIOMASS	FACT1	FACT2	FACT3
BSD	1	**0.67****	**0.47****	-0.07	**0.46****	-0.25	0.24
BSR	**0.67****	1	**0.72****	-0.04	0.17	**-0.66****	0.14
DENSITY	**0.47****	**0.72****	1	-0.01	0.34	**-0.57****	-0.1
BIOMASS	-0.07	-0.04	-0.01	1	**-0.38***	-0.32	-0.22

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 5.8 Pearson Correlation of PC factors with BSD, BSR, Bird density and Bird biomass in Winter season

N=30	BSD	BSR	DENSITY	BIOMASS	FAC1_1	FAC2_1	FAC3_1
BSD	1	**0.5****	-0.01	-0.34	-0.01	-0.23	**-0.52****
BSR	**0.5****	1	**0.7****	0.34	-0.04	**-0.43***	0.11
DENSITY	-0.01	**0.7****	1	**0.42***	0.09	**-0.54****	**0.44***
BIOMASS	-0.34	0.34	**0.42***	1	0.02	0.2	**0.36***

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

5.4 DISCUSSION

The breeding birds of New Forest did show a result in conformity with many similar studies across the globe. As the study has been done at a small geographical scale floristics did play an important role in influencing the bird community composition as expected. The influence was interestingly maintained in the non-breeding season as well though its strength was reduced. However, the role of habitat physiognomy was not completely ruled out, as a weak but significant association was found in the breeding season although it became insignificant in winter (non-breeding) season. This is in contrast with many other studies where the spread of the study area is very small. However in New Forest because of varied man-made forests in large parts of the study area, the changes in the habitat are large and abrupt despite short distances, something which is usually encountered only after traversing considerable distance in a large natural/semi-natural landscape. Thus, this man-made habitat structural heterogeneity of New Forest renders it somewhat similar to larger landscapes. This is also evident from the cluster dendrogram as shown in appendix 14a where in the clustering of sample points on the basis of structural attributes is not so strong yet it cannot be ruled out, as sample points belonging to a particular habitat do show some extent of clustering. The clustering on the basis of floristics is however much stronger indicating very distinct identity of the habitats based on the tree species present there (appendix 14b). However, the clustering is near perfect when the two attributes i.e. structural and compositional are combined (Figure 3.1). Thus distribution of birds seems to be actually dependent on the extent of dissimilarity amongst the habitat based on floristics and physiognomy. The cluster dendrogram based on bird composition (appendix 11a & b) also show clustering of sample points based on habitats indicating preference shown by the birds. This is stronger in summer as compared to winters.

The BSD and BSR were strongly correlated in both the seasons though a little less so in winters (Figure 5.7). In both the seasons the relationship was highly significant ($p<0.01$). The bird density too was strongly correlated with both BSD and BSR in summer season while in winters it was correlated with only BSR. In the summer season BSD was strongly correlated with PC factor 1 indicating the positive influence of horizontal heterogeneity on the bird diversity. Being in the Himalayan foothills, there is a large species pool of timalids and other bird groups available, which prefer dense habitats with profuse understorey vegetation, and these seem to have colonised the plantations of New Forest for breeding in summers. The BSR as well as bird density showed a highly significant and strong negative correlation with PC factor 2. This factor indicates that higher canopy cover and high top heights which lead to high FHD due to the additional layers present. A high canopy would indicate a poorer understorey vegetation and thus poorer richness of birds. In winter (non-breeding) season the BSR continues to be negatively correlated with PC factor 2 for similar reasons as in the breeding season. Chettri (2001) also found that the BSD and BSR were higher at the open canopy conditions compared to the closed canopy, but the differences were not significant in forest birds in temperate Sikkim, India. Sekercioglu (2002a) also found a negative correlation of canopy with BSR and bird abundance (density). The BSD in New Forest also shows a significant negative correlation with PC factor 3 which is indicative of stand maturity. Mature stands may have rarer specialist birds with higher conservation importance, but they often support fewer species and hence lead to a poorer BSD. Similar trends were noticed by Daniels et al. (1992) where-in in the Uttar Kannada district of Karnataka, India the more stratified and diverse evergreen forest vegetation harbours fewer bird species compared with less stratified and less diverse deciduous vegetation of drier tracts. Bird biomass shows a negative correlation with PC factor 1 in breeding season which may be because of poor productivity in habitats with high horizontal heterogenity. It however shows a positive correlation with PC factor 3 in winter season indicating a higher use by birds in mature stands with high basal area and snag density as they may be providing the much needed basking perches in the cold morning. This was observed in winter season where many birds were seen basking in early mornings on the leafless (often dead) branches emerging from the canopy. Biomass also showed a positive correlation with density in summer season.

The foliage height diversity (FHD) and its influence on bird species diversity has been a much researched aspect of bird-habitat relationship. While in the temperate forests a positive correlation was observed between the two (MacArthur and MacArthur, 1961; Recher 1969; Karr and Roth 1971; Willson, 1974; Terborgh, 1977; Erdelen, 1984; Verner and Larson, 1989), most of the Indian studies failed to find a correlation (Daniels, 1989; Rai, 1991; Johnsingh and Joshua, 1994; Javed, 1996; Jayapal, 1997).

In the present study the different habitats being so different in vegetation composition and structure were interpreted separately for relationships between BSD and FHD. When the FHD was calculated using one metre height bands (represented by code FHD_TRSH), natural forest habitat failed to show a relationship between BSD and FHD in conformity with other similar studies in India. A significant negative correlation was observed between BSD and FHD in Chir Pine habitat in summer season. This is perhaps due to a high FHD in this habitat owing to high tree height of the Chir Pine canopy (averaging at 32.2 metres for all the sample points) with a distinct middle tree canopy owing to not so dense canopy of Chir (see figure 4.10 showing the average vegetation profiles for different habitats). These additional 'layers' in the vegetation do not seem to be utilised by the birds in proportion to their contribution to FHD. Thus this leads to a negative correlation between the BSD and FHD in this habitat. On the contrary the mixed plantation habitat shows a positive relationship with the BSD ($r = 0.69$, $p = 0.087$, $N = 7$). The average canopy top height at 28.4 metres here is not much lower than the Chir Pine habitat, but the vegetation profile is much more even (figure 4.10) and the top canopy comprises of many species unlike the Chir Pine plantations where it is uniformly *Pinus roxburghii*. Many of the canopy tree species in the mixed plantation habitat provide direct food resource to the phytophagous birds (e.g. *Acrocarpus fraxinifolius, Litsea monopetala, Garuga pinnata, Tectona grandis, Gmelina arborea* etc). Thus the mixed plantation habitat supports a larger number of bird species and shows a good correltion between BSD and FHD.

When the height bands were clubbed to calculate a FHD, a positive correlation was observed for certain combinations of height bands of foliage in the summer season only. Perhaps the reason why most of the Indian studies have not found a relationship between the two is that they used *a priori* height classes for calculation of FHD. This they perhaps decided on the basis of general appearance of the vertical profile of the foliage. However the birds may not recognise the same layers as are evident to a human eye or interpretation. In fact, in the present study the relationship was found only when the higher canopy classes were clubbed. The Chir Pine habitat, though structurally much more complex owing to an extra top canopy layer of Chir Pine trees with top height more than 30 m actually did not have as much structural diversity in the layers which were more important to a large number of species particular understory insectivores which is a very diverse guild in New Forest. The best correlations between BSD and FHD were obtained when the foliage was divided into six categories of increasing height interval size with the highest category being 12 m and above indicating that the birds were responding more to the layers in the lower height classes (Table 5.4). The validity of *a priori* decision on foliage height bands was discussed by Jayapal (1997) at length. He stresses that '*a priori*' determination of foliage height bands is actually unwarranted as the hypothesis is to find out any correlation between FHD and BSD, rather than to elicit any structural patterns of vegetation in terms of FHD. Wiens (1989) says that 'as a way of detecting patterns, there is nothing wrong with using the sub-division that maximises the fit of data to the BSD-FHD regression'. In fact a division of the foliage profile into three layers in North America, two layers in Puerto Rico, and four layers in Panama gave the straight-line relationship between BSD and FHD (MacArthur, Recher, and Cody, 1966).

CHAPTER 6

BIRD GUILDS AND THEIR DYNAMICS

6.1 INTRODUCTION

A guild is defined as a group of species that exploit the same class of environmental resources in a similar way (Root, 1967). This term groups together species without regard to taxonomic positions that overlap significantly in their niche requirements (Simberloff et al., 1991). Guilds are groups of species in a community that exploit the same set of resources in a similar manner, but are not necessarily closely related taxonomically (Ehrlich et al., 1988).

Breaking down assemblages of species into feeding guilds (Root, 1967) or functional groups (Cummins, 1973) is one of the main techniques animal ecologists have developed to try to come to grips with community structure and dynamics. Determining guild structure has been beneficial for many reasons (Hawkins & MacMahon, 1989; Simberloff & Dayan, 1991), not the least of which are that: (i) guilds bring or impose order on systems that may appear to be difficult to interpret otherwise; and (ii) guilds have been viewed as 'natural ecological units' (Hawkins & MacMahon, 1989), which are recurrent in different communities and are, in a sense, the building blocks of ecological communities. When using guilds for management purposes, biologists assume that species in a guild respond similarly to environmental change (Verner, 1984), a fact which may be of use in managing and monitoring forest ecosystem. Guild studies are valuable to identify the resources that determine the structure of the animal communities (Terborgh & Robinson, 1986). Guilds have been used extensively in analyses of many taxonomic groups and in many types of biome, but ornithologists have been among the most active in interpreting assemblages of species in these terms (e.g. Salt, 1953 &1957; Emlen, 1977; Holmes et al., 1979; Wiens & Rotenberry, 1979; Landres & MacMahon, 1980; Sabo & Holmes, 1983; Recher et al.,1985).

Some advantages of using guilds to breakup animal community structure were touched upon briefly above. It is important to realize, however, that guilds are human constructs that may indeed impose structure that is not necessarily of ecological relevance (Landres & MacMahon, 1980). In particular, many, perhaps most, species of birds display some level of opportunism in feeding (Coward, 1985; Dial & Vaughan, 1987; Ford et al., 1990). Diets reflect the incidence of greater food generalization than is apparent in foraging activities (e.g. Lea & Gray, 1935a,b; Hawkins & MacMahon, 1989; French, 1990). Another problem is that some species show idiosyncratic combinations of foraging activities, which makes them difficult to place in a general guild structure. Thus, although powerful, the guild idea does have its limitations (Hawkins & MacMahon, 1989). Guilds are used here in the sense of the traditional manner and location in which individuals of a species gather food (see Holmes et al., 1979; Vale et al., 1982).

In the present study the guild structure of the birds of New Forest was investigated and factors determining it were identified. The seasonal change in guild structures both within and across various habitat types was also looked into.

6.2 METHODS

6.2.1 Study area

The entire study area for the study i.e. the wooded part of the new Forest campus was considered for this analysis.

6.2.2 Birds

The point transect data for the two years pooled across each season i.e. summer and winter was utilised for this investigation. The detection functions from the Distance analysis were studied and it was realised that there was a significant drop in detections only after a distance of 40 m across all the four habitats. Thus the entire data was truncated to 40 m so that comparisons amongst habitats would become meaningful with lower biases for studying the composition of guilds. Guild biomasses were however calculated by using true densities as calculated using Distance 5.0 software (Section 4.3.2.1).

6.2.3 Vegetation

Vegetation data obtained from the vegetation plots was utilised for this part of the analysis. The phenology of the woody trees and climbers was also recorded in New Forests. Based on the extent of flowering and fruiting relevant to birds and their duration in a season, each species was scaled in a scale from 0 to 5 (Appendix 16).

6.2.4 Analysis

To investigate the influence of food resource on relative role of habitat physiognomy and floristics on bird composition the birds were categorised into feeding guilds. This was done at two levels at two levels. At the coarser level they were divided into three categories: primarily insectivores, primarily phytophagus and those which could not be kept in either of these categories which also included the omnivores. This third category was termed 'others'. At a finer level the birds of New Forest were classified into 15 feeding guilds, five of which did not figure significantly in the point transect data. A standard approach to designating the guilds in a community is to define a small number of very general ecological categories more or less intuitively, and then to assign the species present in the community to these categories on the basis of one's own observations, published information, or previous guild classification of other authors (Eckhardt, 1979; Alatalo & Alatalo, 1979; Airola & Barrett, 1985; Wiens, 1989). In the present study too, the birds were kept in particular category of feeding guild based on their food habits as given in literature (Ali & Ripley 1983 and Grimmet et al. 1997) coupled with own personal observations while the guild categories were adapted primarily from Mehta (1998). The guilds with their characteristics and major bird groups of New Forest representing them are described in subsequent sub-sections.

6.2.4.1 Guilds with primarily insectivorous diets:

Birds in this large guild included birds with insects as their primary diet. This was further divided into categories depending primarily upon foraging height and foraging behaviour.

Canopy insectivores (IC): Birds included in this guild were the ones which gleaned/ hopped in the tree canopies for insects. The bird groups included in this guild were Cuckoo-shrikes, Cuckoos, Minivets and Ioras and most Leaf Warblers.

Sallying Insectivores (IS): Sallying insectivores preyed upon insects by making sallys at various heights from the trees. The birds included diverse groups like Flycatchers, Drongos, Bee-eaters and Flycatcher-shrikes.

Understory insectivores (IU): These are birds which fed on insects in the understory vegetation and also in leaf litter. This is the largest guild amongst all the guilds in New Forest. It includes Babblers, Warblers, Flycatchers, Chats, Thrushes and Jungle Fowls.

Ground Insectivores (IG): These are birds known to feed on insects in the soil surface. This is not a significant guild amongst the birds during this study as most of the birds in this guild are of open areas and not wooded areas.

Trunk/Bark feeder (TBF): This guild includes birds which are adapted to feed on insects on the tree trunk, branch and barks. The birds included here are Woodpeckers, Nuthatches, Tree-Creepers and Tits.

Water Insectivores (IW): Includes birds which feed on insects along water courses and include the water birds and the Redstarts.

6.2.4.2 Guilds with primarily phytophagous diets

Fruit-insectivore (IF): An essentially phytophagous guild with birds feeding primarily on fruits but may consume insects at times. Includes Barbets, Grey Hornbill and Asian Koel.

Granivore (G): An essentially phytophagous guild which includes birds which are adapted to a diet of grains and seeds. It includes the bird groups like Sparrows and Weavers, Buntings and Finches, Munias, Doves and Pigeons.

Nectarivore-Insectivores (NI): These are primarily nectar feeding birds which may also feed on insects occasionally. The birds included are sunbirds, flowerpeckers, white-eyes and Spangled Drongos.

Obliagate Frugivore (F): A truly phytophagous guild which has a very poor representation in New Forest. The birds are known to feed almost exclusively on fruits. The birds in this guild include only the Green Pigeons.

Fruit-Seed-Nectar (FSN): The birds in this guild include the Parakeets. These are known to feed on fruits, seeds and Nectar.

6.2.4.3 Guilds with insectivorous and phytophagous diets

Fruit-seed-nectar-insectivore (FSNI): A very generalist guild with birds feeding on fruits, seeds, nectar and insects. The birds included are most mynas and starlings, orioles and bulbuls. Depending on the share of food of plant origin or insects they are categorised individually into the two basic guilds i.e. Phytophagous, Insectivores and Omnivores.

Omnivores (O): The birds in this guild are known to feed on all types of food ranging from fruits and nectar to insects and carrion. The birds .include Crows, Treepies, Magpies and Coucal.

6.2.4.4 Other guilds

Raptors (R): All the birds of prey are included in this guild. Few of them are further categorised into Insectivorus guild while most fall into the category 'others'.

Piscivores (P): An insignificant guild in the present study and includes the Kingfishers except White-throated Kingfisher which is included in insectivore guild.

A detailed listing of all the bird of New Forest with their guilds is given in appendix 12.

Number of species in each guild was listed for both the seasons. To check if the composition of birds within a guild changes across the two seasons of summer and winter, Morisita-Horn index of similarity (MHIS) was used. The Morisita-Horn index of similarity (Wolda, 1981, Magurran, 1988, Krebs, 1989, Shankar Raman, 1998) was used to calculate similarity (or dissimilarity) between bird populations from two seasons within a guild in a particular habitat.

The Morisita-Horn, *M,* index was calculated using the formula

$$M = \frac{2\sum a_i b_i}{(d_a + d_b)T_a T_b}$$

which expresses the similarity between two sites, *a* and *b*, in which a_i and T_a are the number of individuals of the i^{th} species and total number of species at site *a* respectively and

$$d_a = \frac{\sum a_i^2}{T_a^2}$$

The index is independent of sample size and diversity (Wolda, 1981) and is an appropriate measure to compare community structure at two time periods (Green, 1999). It was calculated using the software Estimate S (Colwell, 2006). Pearson's correlation was used to check the relationship between guild composition and biomass and the habitat variables. Mantel's test were used to see the determinants of guild structure.

Pearson correlation was used to investigate the relationship between the bird abundances and their biomass in different guilds and habitat variables (through ordinated composite variables as arrived at in section 5.3.6 in the previous chapter).

6.3 RESULTS

Within the 40 m radius in the point transects 128 species were recorded across all the habitats. The normalised abundances were compiled after dividing the abundances with a factor proportional to the survey effort at each point. Rare species which had less than 5 observations were removed from the analysis bringing down the number of species to 87.

6.3.1 Species numbers

The number of species in different guilds is given in Table 6.1 for both the seasons. Three guilds namely obligate frugivores (F), Piscivores (P) and Water Insectivores (IW) did not figure in the birds detected.

Table 6.1 Number of species in different fine guilds in different habitats excluding the rare species.

Habitat	Chir		Garden		Mixed		Natural	
Guild	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
FI	3	1	3	1	3	2	3	2
FSN	4	4	3	4	3	4	3	4
FSNI	5	5	7	6	7	5	6	4
G	3	2	3	2	2	1	3	1
IC	6	5	5	4	5	5	6	5
IG	0	1	0	1	0	0	0	0
IS	4	5	3	6	3	4	4	6
IU	10	16	9	15	11	14	12	18
NI	5	3	5	7	5	6	6	6
O	3	3	4	2	4	3	4	3
R	1	0	1	0	0	0	1	0
TBF	8	10	6	9	8	9	8	8
Grand Total	52	55	49	57	51	53	56	57

6.3.2 Bird composition

It was important to see if the composition of birds changed in different guild across the two seasons. To check this, the bird composition in different guilds was compared across seasons using MHIS. Table 6.4 and Table 6.5 present the values of this index for different basic and fine guilds respectively when their bird composition was compared across the two seasons.

Table 6.2 Morisita-Horn index of similarity (MHIS) for bird composition in basic guilds in New Forests across seasons

Habitat	I*	O*	P*
Chir	0.616*	0.737	0.531*
Garden	0.548*	0.852	0.775
Mixed	0.61*	0.152**	0.478*
Natural	0.609*	0.241**	0.827

*I: Insectivorous; P: Phytophagous; O: Others

** Low values of MHIS indicating large changes in composition across seasons

* Mid values of MHIS indicating moderate changes in composition across seasons

The MHIS values for the major guilds i.e. insectivorous and phytophagous show moderate variation across the habitats with most of the values in the mid level. The only exception is the Natural and garden habitats for the phytophagous guild indicating very low variation of bird composition. It thus becomes important to look at the similarity index values for fine guilds. The guilds having very few species were not considered for this analysis.

Table 6.3 Morisita-horn index of similarity for bird composition in fine guilds in New Forests across seasons

	Fine guilds#									
Habitat	FSN	FSNI	G	IC	IF	IS	IU	NI	O	TBF
Chir	0.809	0.304*	0.111**	0.046**	0.519*	0.201**	0.802	0.982	0.925	0.99
Garden	0.946	0.368*	0.23**	0.344*	0.6*	0.052**	0.634*	0.971	0.746	0.937
Mixed	0.86	0.014**	0.282**	0.337*	0.683*	0.077**	0.562*	0.918	0.915	0.993
Natural	0.349*	0.508*	0.725	0.16**	0.829	0.711	0.748	0.978	0.824	0.839

#FSN: Fruit-seed-necatarivore; FSNI: Fruit-seed-nectarivore-insectivore; G: Granivore; IC: Insectivore-canopy; IF: Fruit-insectivore; IS: Insectivore-sallying; IU:Insectivore-understorey; NI: Nectarivore-insectivore; O: Omnivore; TBF: Tree-bark feeder

** Low values of MHIS indicating large changes in composition across seasons
* Mid values of MHIS indicating moderate changes in composition across seasons

It can be seen that tree-bark feeder and nectarivore-insectivore guild have a very high MHIS in all the habitats indicating negligible change in bird composition of these guilds. On the contrary the insectivore-canopy, insectivore-sallying and fruit-seed-nectarivore-insectivore guilds show very low values of the index indicating major change in the guild composition across seasons with the exception of natural habitat for insectivore-sallying guild.

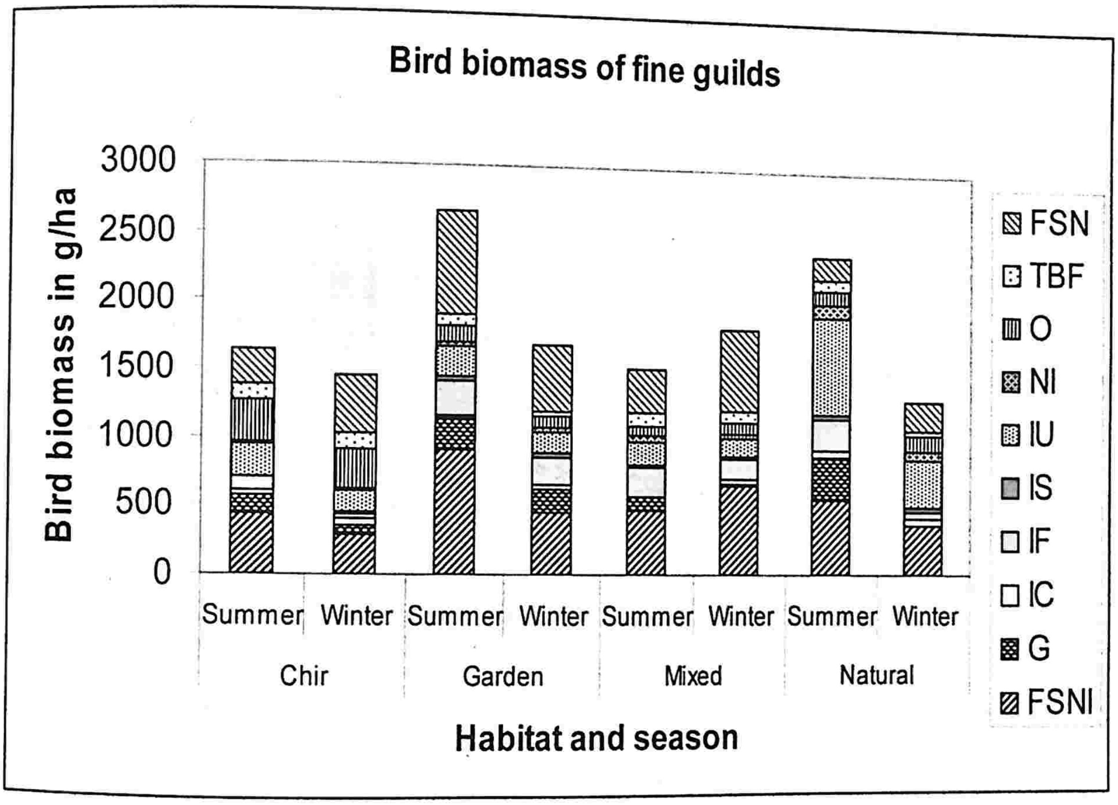


Figure 6.1 Bird biomass for different fine guilds across different habitats in the two seasons. (For fine guild codes see section 6.2.4)

6.3.3 Bird biomass in different guilds

It would be worthwhile to see how the bird biomass is distributed in these major guilds across seasons as the patterns that emerge when communities are considered in terms of biomass may differ from those determined by density calculations (Wiens, 1989). The bird biomass was calculated using the bird densities calculated earlier in each habitat and each season using the point transects data and excluding the only Galliform (Red Junglefowl) is depicted in figure 6.1. The bird species biomasses were obtained from literature (Ali and Ripley, 1983). The only Galliform recorded during the study Red Junglefowl was removed from this analysis as it is a heavy bird (one of the heaviest amongst birds of New Forest) whose density seems to have been altered in certain habitats of the campus because of human actions (like poaching) and its inclusion in biomass calculations was likely to bring large bias (Raza, 2006).

Table 6.4 Bird guild biomass in major fine guilds (g/ha) in different habitats across seasons

Guilds	FSN		FSNI		G		IC		IF	
Habitat	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win
Chir	250	420	146	202	135	70	33	38	100	35
Garden	762	488	751	267	236	166	17	32	263	197
Mixed	330	611	327	490	100	17	9	36	219	146
Natural	174	214	532	354	328	5	52	46	224	55
Grand Total	1516	1733	1757	1313	798	259	111	151	805	433

Guilds	IS		IU		NI		O		TBF	
Habitat	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win
Chir	9	15	223	154	320	103	298	287	114	118
Garden	33	29	219	155	185	230	120	92	85	35
Mixed	5	14	177	139	188	202	74	87	95	81
Natural	34	32	728	347	123	91	106	124	81	25
Grand Total	80	90	1347	795	817	626	599	590	375	259

6.3.4 Determinants of guild structure

In order to see whether the vegetation structure or composition plays an important role in determination of the guild structure of the birds in New Forest, Mantel's test was used. The results obtained when the guild abundance (pooling all species within a guild) matrix was correlated with the vegetation structure and compositional matrix are given in table 6.5. Verner (1984) advocated using the total number of individuals of all species (pooled abundance) in a guild as a measure of guild response.

It is clear from the result that while floristics plays major role in determining the guild composition of bird communities in New Forest, vegetation structure also influences it in summer season while it looses the influence in winter season. In their classic study of the Hubbard Brook bird community Holmes et al. (1979) stressed the role of floristics by observing that the bird community composition within and between forest habitats is largely dependent on physical structure of the vegetation, the kind of feeding substrates, and the availability and abundances of insect resources, all of which are influenced by the species composition of the plant community.

Table 6.5 Association of guild composition with floristics and vegetation structure between points, as shown by Mantel's tests across wooded habitats in New Forests (Matrix size: 30)

Season	Contrsted matrices		Mantel's *r*	*P*
Summer	Guild composition	Floristics	0.322	**<0.001**
		Veg. Struc.	0.285	**0.001**
Winter	Guild composition	Floristics	0.188	0.013
		Veg. Struc.	0.103	0.128

6.3.4 Relationship of guild attributes with habitat

Guild attributes for all the fine guilds such as abundance and biomass were correlated with the principal component factors of the habitat as obtained through the principal component analysis (section 5.3.6).

6.3.4.1 Guild abundances and habitat variables

The guild abundances were calculated for all the species pooled together at every sample point and correlated with the three principal component factors. The results for the two seasons are shown in table 6.10 and table 6.11. Sample points having more than 10 zero values of guild abundances were removed from the analysis.

Table 6.6 Pearson correlations between bird abundances of different fine guilds and the principal component factors in summer (only guilds with significant correlations shown)

N=30	FSN	FSNI	G	IC	IS	IU	NI	O	TBF
PC1	**-0.44***	-0.19	0.22	**0.38***	0.17	**0.38***	**0.37***	0.05	0.11
PC2	-0.08	**-0.6****	**-0.45***	0.23	**-0.41***	**-0.55****	-0.1	**0.53****	**0.54****
PC3	0.07	-0.12	-0.31	-0.26	-0.28	-0.03	0.06	-0.02	0.24

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Table 6.7 Pearson correlations between bird abundances of different fine guilds and the principal component factors in winter (only guilds with significant correlations shown)

N=30	FSN	FSNI	IS	NI	O	TBF
PC1	0.11	0.07	-0.08	-0.35	**0.42***	0.2
PC2	0.24	-0.04	**-0.41***	**-0.47****	0.35	**0.36***
PC3	**0.37***	**0.6****	0.01	0.07	-0.15	0.13

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Except for the sallying insectivorous (SI) and tree-bark feeders (TBF), all other guilds showed dependence on different principal component factors in different seasons. Thus there was a perceptible shift in the dependence of the guild abundances on the PC factors for most of the guilds.

6.3.7.2 Guild biomass and habitat variables

The guild biomass for different guilds was calculated for all the species pooled together at every sample point and correlated with the three principal component factors. The results for the two seasons are shown in table 6.8 and table 6.9. Sample points having more than 10 zero values were removed from the analysis.

Table 6.8 Pearson correlations between bird biomass of different guilds and the principal component factors in summer season (only guilds with significant correlations shown)

N=30	FSN	FSNI	G	IS	IU	NI	O	TBF
PC1	**-0.53****	**-0.48****	0.19	0.02	0.24	-0.02	0.02	0.05
PC2	-0.15	**-0.47****	**-0.46***	**-0.5****	**-0.57****	**0.62****	**0.48****	**0.36***
PC3	-0.03	-0.1	-0.3	-0.27	-0.16	-0.04	0	0.24

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Table 6.9 Pearson correlations between bird biomass of different guilds and the principal component factors in winter season (only guilds with significant correlations shown)

N=30	FSN	FSNI	NI	O	TBF
PC1	-0.02	0.03	**-0.37***	**0.45***	0.26
PC2	0.22	0	0.15	0.35	**0.5****
PC3	**0.44***	**0.6****	-0.06	-0.17	0.24

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

Except for the tree-bark feeders (TBF), all other guilds showed dependence on different principal component factors in different seasons. Thus there was a perceptible shift in the dependence of the guild abundances on the PC factors for most of the guilds across seasons.

6.4 DISCUSSION

6.4.1 Seasonal changes in the bird composition

While the number of species in most guilds (except insectivore-understorey guild) remained nearly the same across the two seasons (Table 6.1), many guilds showed moderate to high changes in the composition across the two seasons in different habitats (Table 6.3). This indicates change in the species as well as their abundances in these guilds. A further investigation results in an interesting observation that the species migrating south from New Forests in winters get replaced by species belonging to the same guilds from higher altitudes/latitudes. Looking at the main guilds where this occurs substantially i.e. the insectivores-canopy and insectivores-sallying it can be seen that ecologically similar species replace each other across the two seasons. For the guilds showing large changes in bird composition the species have been identified and shown in Table 6.10. Cody (1985) observed that in some habitats wintering species appear to 'fit into' niches vacated by similar species of summer visitors which are wintering elsewhere and even year-round residents may shift their habitat occupancy during the non-breeding season.

Table 6.10 Complementary bird species in the same guilds across the two seasons in different habitats

Habitat	Guild	Species in summer	Species in winter
Chir	IC	Greenish Leaf Warbler, Western crowned Warbler	Grey-hooded warbler, Lemon-rumped warbler
		Small Minivet	Long-tailed Minivet
	IS	Drongo Cuckoo	Ashy Drongo
Garden	IS	Black Drongo	Ashy Drongo
Mixed	FSNI	Chestnut-tailed Starling, Jungle Myna, Red-vented Bulbul	Black Bulbul

	IS	Bar-winged Flycatcher Shrike	Grey-headed Canary Flycatcher, White-throated Fantail
Natural	IC	Greenish Leaf Warbler, Western crowned Warbler, Blue throated Flycatcher	Grey-hooded warbler, Lemon-rumped warbler, Hume's Warbler
		Small Minivet	Long-tailed Minivet
		Drongo Cuckoo	Ashy Drongo

6.4.2 Seasonal changes in guild bird biomass

Majority of guilds show a decline in biomass from summer to winter (Table 6.4) as has been the general trend for the total biomass (Table 4.9) except the mixed plantations habitat where it increases marginally. It would be important to discuss the guilds where the biomasses show a reverse trend of increase from summer to winter.

The fruit-seed-insectivore guild (which includes the Parakeets) shows a substantial biomass increase in winter in mixed as well as Chir Pine plantation habitats and a marginal increase in natural habitat. This is explained by the arrival of Slaty-headed Parakeet (*Psittacula himalayana*) in large numbers in winter. It is the third most abundant bird of this season (appendix 15). While it prefers the Mixed and Natural habitats owing to the presence of large nectar/fruit/seed yielding trees such as *Acrocarpus fraxinifolius* in mixed habitat which bears gregarious flowering in February and March, it likes to bask on the tall standing dead trees (snags) of Chir Pine in huge flocks (section 4.3.2.6).

The fruit-seed-nectar-insectivore guild also shows an increase of biomass in Chir and mixed habitats in winters. This is primarily explained by the presence of

Black Bulbul, the most common winter bird of New Forest in these habitats in large numbers. While in Chir Pine plantations it gets attracted towards the fruits of *Michelia champaca* which is ready in early winters, *Acrocarpus fraxinifolius* nectar attracts it to the mixed plantation habitat in late winters.

Another guild which shows an increase in biomass in winter season is the nectarivore-insectivore guild and this is seen in the garden and mixed habitats. This guild also shows a general composition similarity across seasons in all the habitats indicating that the birds are occurring in similar proportion in both the seasons in each habitat but getting redistributed from one habitat to another. There are distinct complementarities between the Chir Pine plantations on hand and the Garden and mixed plantation habitats on the other for this guild. The biomass from Chir habitat seems to be shifting to the Garden habitat in winter. The vegetation composition of Chir habitat is composed of a few species of trees which are either native such as *Alangium chinensis* or are exotics for New Forest but are native Indian trees from not so far off areas for example *Michelia champaca* which flower during summer and thus provide the nectarivores with food. In fact the Crimson Sunbird is very partial to the *A. chinensis* flowers in the month of April when the species flowers profusely but inconspicuously. The Spangled Drongo prefers the Chir habitat for nesting as the *A. chinensis* near horizontal branch forks are ideal for making nests. Four nests of the Spangled Drongo were observed in summer season on this tree species. Oriental White-eye, the most common bird of New Forest also reduces in numbers in the Chir Pine habitat in winters and increases in the adjoining garden habitat. In winters the birds move to abutting Garden and mixed plantation habitat which is dominated by exotics many of which are from the southern hemisphere and flower in winters e.g.

many species of Eucalypts and Bottle brush (*Callistemon viminalis*). Thus the nectarivores are able to get their food requirements from these two habitats round the year. The natural forests habitat does not show significant shifts in NI guild biomass owing perhaps to high plant species richness here which can provide food resources to nectarivores round the year. An elementary classification of flowering and fruiting resources of the woody vegetation of the campus has been attempted in appendix 16 which indicates that there is a considerable decline in flowering in each habitat in the winter season. The garden habitat has much lower flowering in summer compared to Chir Pine plantation habitat but in winters it is marginally higher extent of flowering. However despite the decline in flowering in woody species of trees and climbers across the habitats in winter season, the bird biomass remains much the same for NI guild indicating that the birds are meeting their requirements from some other source. This source is likely to be the plant partial parasites namely *Scurrula pulverulenta, Dendrophthoe falcata* and *S. cordifolia* which are common plant in New Forest. Although quantification of the extent of these plant parasites was not done in the present study, it was seen to be much more prevalent in garden, natural and mixed plantations than the Chir Pine plantations where it was almost completely absent. This perhaps explains the highly reduced biomass of the birds of NI guild in Chir Pine plantations in winters when the trees there do not flower. Thus these hemi-parasites seem to be playing a crucial role for the food requirement of the nectarivores in New Forests even though they been traditionally considered to be a pest for plantation forestry in India particularly for plantations of high economic value like Teak (Kallarackal et al., 2003) and systematic removals of these plants is recommended from them. However in urban and recreational forests they may be crucial for retaining the nectarivores in the winter season.

The tree-bark feeders (TBF) guild has the highest biomass in the Chir Pine plantation habitat. The large mature Chir Pine trees with its thick fissured bark perhaps provide a good substrate for the birds of this guild to look for insects. The bird biomass here remains nearly constant across the season. Similar constancy in densities have been observed in both temperate and new world tropics in tree bark insectivores as the birds which forage on bark exploit resources from a substrate of constant size throughout the year (Karr 1976).

6.4.3 Relationship of guild attributes with habitat

These were investigated both for the abundances as well as biomass of birds. Instead of finding the relationships with each habitat variable, the principal component factors representing composite habitat variables were checked.

Guild abundances were correlated to the PC factors 1 or 2 but none of the guilds had a significant correlation with PC 3 in summer season while in winter the generalist guilds (FSN and FSNI) displayed a significant correlation with PC factor 3. The TBF guild showed a significant positive correlation with the PC2 in both the seasons indicating a dependence on vertical stand structure. The FSN guild (comprising of Parakeets) had a negative correlation with PC1 (horizontal heterogeneity) in summer and positive correlation with PC3 (stand maturity) in winters. Another omnivorous guild, the FSNI also showed a positive correlation with PC 3 in winters. Mature stand perhaps would help these omnivores in finding a variety of foods in the resource scarce winters which explains the shift of correlation to PC 3 in winters. The granivores were correlated negatively with PC 2 in summer as they do not prefer close canopied habitats. The canopy insectivores (IC) preferred dense and heterogeneous habitats as they were significantly correlated with PC 1. The under-storey insectivores (IU) positively correlated with PC 1 indicating preference to dense habitats with good shrub cover and diversity while it correlated negatively with PC 2 as a poorer canopy would mean better shrub growth. Beedy (1981) also observed that in closed canopy forests, reductions in under-storey vegetation caused pronounced decreases in the under-storey bird guilds as well as flycatchers (sallying insectivores). In the present study too, the IS guild showed a significant negative correlation with PC 2 (which is strongly correlated to canopy cover) indicating that canopy with larger openings (less closed) suited the sallying insectivores in both the seasons. The omnivores displayed a positive correlation with PC 2. The nectarivores (NI) preferred denser habitats in summer while they correlated negatively with PC 2 in winters indicating their preference for open habitats.

As bird biomass may provide a different picture being more closely correlated to energetics and productivity, it was also correlated with the PC factors of habitat variables. However, for most of the guilds the relationships obtained were similar to those obtained from bird abundances.

CHAPTER 7

HABITAT SELECTION AND CONSERVATION IMPLICATIONS FOR BIRDS OF NEW FOREST

7.1 INTRODUCTION

Habitat selection, an almost universal activity among animals, affects nearly all of an individual's subsequent choices. As a result, considerable attention has been paid to both the theory of habitat selection and the ways in which organisms in different taxa actually evaluate and select from the different options available (Cody, 1985). A general guiding theoretical principle is that preferences among environments should co-evolve with the qualities of those environments. That is, organisms should respond positively to (prefer) environments in which their survival and reproductive success is good (Levins, 1968; Orians, 1980) Habitat selection can be viewed as a hierarchical decision making process (Hutto, 1985) in which an organism first chooses a general place in which to live (a habitat) and then makes subsequent decisions about the use of different patches, the search modes it employs, and its responses to specific objects that it encounters (Charnov & Orians, 1982). Because the available patches and the objects likely to be encountered strongly depend on the general habitat in which an organism has settled, selection of a micro-habitat is extremely important. The initial decision of whether to explore a habitat or to continue searching is often made quickly, usually on the basis of rather general features of the environment (Lack, 1940; Hilden, 1965; MacArthur et al., 1966; Cody, 1981 & 1985). Depending on the species and the environment, subsequent exploration of the environment and gathering of information used to make a definitive settling decision may be brief or protracted. Many habitats that are good enough to trigger initial exploration may not be good enough for settling (Orians & Wittenberger 1991). Food often emerges as the most important limiting factor for populations of passerines in non-breeding season (Hutto 1985, Schluter & Repasky 1991, Katti & Price 1996). In New Forest the geographic scale is much restricted and hence it can be viewed as a finer level of decision making in selection of a habitat within the campus.

This decision making has an annual cycle in New Forest owing to a high seasonality that the area goes through. Birds that face seasonal irregularity in the availability of food resources have two alternatives wherever they occur. A bird may shift to feeding on other resources, or it may move to another area where the original food is available. Where there is no seasonal irregularity in food availability and other factors are held constant, a species can maintain itself throughout the year (Karr 1976). Like New Forest the areas in the immediate north of it which constitute the Himalayas, the highest mountain chain of the world, also go through high seasonality of resources. This forces many species to visit the campus seasonally. While substantial number of species visit the campus to breed in summers from central and peninsular India, an even larger number visit the campus to winter from the high Himalayas and beyond.

7.2 HABITAT SELECTION OF BIRDS IN NEW FOREST

Preliminary explorations in this regard were conducted and dealt with in Chapter 4 in section 4.3.3 and further corroborated by the cluster analysis of bird community in both the seasons. Through MRPP test, it was confirmed that there definitely is a habitat selection of birds amongst the four identified habitats in the wooded parts of the campus. The cluster dendrograms also confirmed that the sample points in one habitat clustered together on the basis of bird community composition although this clustering was stronger in the resource rich summer season when most birds can afford to be more rigid in their home ranges and territories as compared to winter where they may be required to wander much more to meet their food requirements. The habitat selection was further explored using the similarity of bird composition across the habitats and identification of indicator bird species.

7.2.1 Bird composition similarity amongst the different habitats

Bird observations were pooled habitat wise in the four habitats of New Forest and then Morisita-Horn Index of Similarity (MHIS) was calculated using the software Estimate S (Colwell, 2006). The same software was also used to calculate the shared and exclusive birds amongst different habitats. The results are shown in table 7.1.

Table 7.1 Number of species (total and shared) amongst the habitats and MHIS between the pairs of habitats based on bird composition in summer and winter seasons in New Forest

Summer	Chir	Garden	Mixed	Natural
Chir	**61**	0.637	0.728	0.744
Garden	43	**52**	0.679	0.554
Mixed	47	41	**55**	0.678
Natural	47	45	48	**72**
Winter	Chir	Garden	Mixed	Natural
Chir	**58**	0.629	0.719	0.538
Garden	46	**61**	0.65	0.776
Mixed	48	43	**56**	0.531
Natural	47	47	44	**69**

The values along the diagonal indicate the number of species found in the respective habitats; the one on the lower triangle indicate the species shared between pairs of habitat and those in the upper triangle are the MHIS values based on the bird compositional similarity between pairs of habitats.

While the natural habitat is the most species-rich habitat in New Forest in both the seasons, the other habitats also support reasonably high bird species richness. The Chir Pine habitat is the most similar in bird composition to the natural habitat in summer while in winter the garden habitat comes closest to the natural habitat. The two plantation habitats *viz.* Chir Pine and Mixed plantations have a high bird compositional similarity in both the seasons.

7.2.2 Indicator species analysis

As is evident from table 7.1, a good number of bird species found in different habitats are shared between them but a substantial number shows definite preferences to certain habitats. In this section I have identified the bird species which show definite habitat preference amongst small and abutting habitats of New Forest.

I used method of indicator species analysis (Dufrene & Legendre, 1997) which is a non-parametric, intuitive technique to examine the specificity of use of the habitats by individual species (Jayapal, 2006). This method combines the faithfulness of occurrence of the species in a habitat with the abundance in that habitat and the occurrence and abundance of the species in other habitats. As such, it provides a measure of importance of that habitat to the species. Indicator values (IV) range from 0 to 100 where perfect indication (100) means that the species indicates a particular habitat without error. Randomization tests were used to evaluate the statistical significance of the indicator value, using 10,000 randomizations. The probability of Type I error is the proportion of times that the indicator value calculated from the randomized data set is equal to or greater than the indicator value from the observed data set. Indicator values of all the bird species were computed using indicator species analysis using PC-ORD 4.20 software (McCune & Mefford, 1999).

Out of the 93 bird species recorded in the point transects in summer season, 36 species exhibited statistically significant ($p<0.05$) indicator value (IV), where as in winter season out of the 92 species recorded 28 showed significant indicator values. These are listed in table 7.2.

Table 7.2 Indicator values of birds of New Forest (only the birds with statistically significant IV shown) arranged in decreasing order of IV within a habitat.

Season	Habitat		Indicator Species	Scientific Name	Indicator value	p
Summer	Chir Pine plantations	1	SLATY-HEADED PARAKEET*	*Psittacula himalayana*	90.9	0.0001
		2	**CHESTNUT-BELLIED NUTHATCH**	*Sitta castanea*	75.9	0.0001
		3	GREENISH WARBLER*	*Phylloscopus trochiloides*	54.4	0.0001
		4	**GREY TREEPIE**	*Dendrocitta formosae*	53.2	0.0042
		5	BLACK-HOODED ORIOLE	*Oriolus xanthornus.*	51.3	0.014
		6	RED JUNGLEFOWL	*Gallus gallus*	46	0.0434
		7	SPANGLED DRONGO	*Dicrurus hottentottus*	44.6	0.0061
		8	*HUME'S WARBLER**	*Phylloscopus humei*	39.4	0.0225
		9	**GREAT TIT**	*Parus major*	37.9	0.0119
	Gardens	1	**COMMON MYNA**	*Acridotheres tristis*	97.1	0.0001
		2	BLACK-RUMPED FLAMEBACK	*Dinopium benghalense*	70.9	0.0007
		3	**ROSE-RINGED PARAKEET**	*Psittacula krameri*	65	0.0018
	Mixed plantations	1	JUNGLE MYNA	*Acridotheres fuscus*	61.3	0.0083
		2	**PLUM-HEADED PARAKEET**	*Psittacula cyanocephala*	48.5	0.0479
		3	GREY-HEADED WOODPECKER	*Picus canus*	47.1	0.0173
		4	*CRIMSON SUNBIRD*	*Aethopyga siparaja*	44.1	0.0012
		5	GOLDEN-SPECTACLED WARBLER*	*Seicercus burkii.*	38.3	0.05

	Natural forests	1	BLUE-THROATED FLYCATCHER	*Cyornis rubeculoides*	96.9	0.0001
		2	BLYTH'S REED WARBLER*	*Acrocephalus dumetorum*	94.7	0.0001
		3	**RUFOUS-CHINNED LAUGHINGTHRUSH**	*Garrulax rufogularis*	88.5	0.0001
		4	**COMMON TAILORBIRD**	*Orthotomus sutorius*	67.4	0.001
		5	**RUSTY-CHEEKED SCIMITAR BABBLER**	*Pomatorhinus erythrogenys*	66.7	0.0015
		6	PURPLE SUNBIRD	*Nectarinia asiatica*	55.5	0.0043
		7	ASHY DRONGO	*Dicrurus leucophaeus*	55.4	0.0046
		8	**GREY-BREASTED PRINIA**	*Prinia hodgsonii*	53.5	0.0011
		9	RED-VENTED BULBUL	*Pycnonotus cafer*	53.1	0.0037
		10	COMMON IORA	*Aegithina tiphia*	50	0.0104
		11	WHITE-BROWED SCIMITAR BABBLER	*Pomatorhinus schisticeps*	50	0.0104
		12	PALE-BILLED FLOWERPECKER	*Dicaeum erythrorynchos*	50	0.0106
		13	FULVOUS-BREASTED WOODPECKER	*Dendrocopos macei*	50	0.011
		14	COMMON ROSEFINCH*	*Carpodacus erythrinus*	50	0.0119
		15	**BLACK-CHINNED BABBLER**	*Stachyris pyrrhops*	46.5	0.001
		16	**HIMALAYAN BULBUL**	*Pycnonotus leucogenys*	46.5	0.0019
		17	WHITE-THROATED FANTAIL	*Rhipidura albicollis*	44.6	0.0186
		18	PUFF-THROATED BABBLER	*Pellorneum ruficeps.*	43.1	0.0268
		19	**ORIENTAL WHITE-EYE**	*Zosterops palpebrosus*	35.3	0.0296
Winter	Chir Pine plantations	1	**GREY TREEPIE**	*Dendrocitta formosae*	64.5	0.0005
		2	**CHESTNUT-BELLIED NUTHATCH**	*Sitta castanea*	60.1	0.0011
		3	LONG-TAILED MINIVET	*Pericrocotus ethologus*	45.3	0.031
		4	TICKELL'S THRUSH	*Turdus unicolor*	38.1	0.0405
		5	**GREAT TIT**	*Parus major*	35.6	0.0306
	Gardens	1	OLIVE-BACKED PIPIT	*Anthus hodgsoni*	64.1	0.0019
		2	INDIAN GREY HORNBILL	*Ocyceros birostris*	60.6	0.002
		3	RED-THROATED FLYCATCHER	*Ficedula parva*	50	0.011
		4	**COMMON MYNA**	*Acridotheres tristis*	47.3	0.0125
		5	**ROSE-RINGED PARAKEET**	*Psittacula krameri*	45.8	0.0286
		6	FIRE-BREASTED FLOWERPECKER	*Dicaeum ignipectus*	37.5	0.032
	Mixed plantations	1	**PLUM-HEADED PARAKEET**	*Psittacula cyanocephala*	70.3	0.0002
		2	BLACK BULBUL	*Hypsipetes leucocephalus*	61.3	0.0144
		3	BROWN-HEADED BARBET	*Megalaima zeylanica*	51.9	0.0058
		4	SNOWY-BROWED FLYCATCHER	*Ficedula hyperythra*	45.8	0.0241
		5	MAROON ORIOLE	*Oriolus traillii*	37.7	0.0468
	Natural forests	1	**COMMON TAILORBIRD**	*Orthotomus sutorius*	84.8	0.0002
		2	**RUFOUS-CHINNED LAUGHINGTHRUSH**	*Garrulax rufogularis*	83.3	0.0001
		3	ORIENTAL MAGPIE ROBIN	*Copsychus saularis*	66.7	0.0008
		4	**RUSTY-CHEEKED SCIMITAR**	*Pomatorhinus erythrogenys*	66.7	0.0008

			BABBLER			
		5	*CRIMSON SUNBIRD*	*Aethopyga siparaja*	64.9	(
		6	SLATY-BLUE FLYCATCHER	*Ficedula tricolor*	62.5	(
		7	**BLACK-CHINNED BABBLER**	*Stachyris pyrrhops*	55.7	(
		8	**HIMALAYAN BULBUL**	*Pycnonotus leucogenys*	49.9	(
		9	**GREY-BREASTED PRINIA**	*Prinia hodgsonii*	49.1	(
		10	RUFOUS BELLIED NILTAVA	*Niltava sundara*	44.8	(
		11	**ORIENTAL WHITE-EYE**	*Zosterops palpebrosus*	40.2	C
		12	*HUME'S WARBLER*	*Phylloscopus humei*	37.6	C

* Passage migrant

Birds shown in **bold** remain indicator species in their respective habitats in both the seasons.

Birds in ***italics*** are species which are indicators for different habitats in different seasons.

7.3 SIGNIFICANCE OF HABITATS FOR BIRDS IN NEW FOREST

It is evident from the discussion so far that different habitats of New Forest have significance for birds in different ways. New Forest provides an unusual opportunity of assessing the man-made habitats (plantations) of the campus vis-à-vis the natural forest areas. The unusual feature is that while the natural forests do face moderate levels of biotic pressure from the surrounding rural populace, the plantations have been kept free from such pressure over very long periods of time. The plantations have had minimal management interventions except for the early period of their life. They have largely been kept untouched for at least last three decades and have multi-tier vegetation today. Except for the dominant species which often formed the top canopy, the remaining vegetation has largely come up on its own as is evident from no mention of any under-planting in the plantations in the compartment histories. Perhaps birds and other agents have played a crucial role in its development.

7.3.1 Natural forest

The natural forests of the campus support a vegetation community which is typical of the northern part of Dehradun valley. This part of the valley on the base of the Mussoorie range has a ravine-rich topography (making the catchment of Eastern Tons River) and supports luxuriant vegetation with an admixture of tropical and sub-tropical vegetation elements particularly in the *nullahs* and slopes. The flatter parts here have been under agriculture or inhabitation for a long time.

The present study shows that despite some degree of biotic pressures, natural forest habitat still possesses the highest bird richness as compared to the well-preserved mature plantations even with mixed crop. It also supports the highest density of birds of all the habitats of New Forest. The highest number of indicator birds has also been reported from this habitat (19 out of 36 in summers and 12 out of 28 in winters). Thus, these birds are largely confined to this habitat. Seven of these viz. Rufous-chinned Laughing Thrush, Common Tailorbird, Rusty-cheeked Scimitar Babbler, Grey-breasted Prinia, Oriental White-eye, Himalayan Bulbul and Black-chinned Babbler are significantly associated with this habitat in both seasons. The Blue-throated Flycatcher a breeding visitor to the campus with an IV of 96.9%, is almost totally exclusive to this habitat. Needless to say that this habitat has an immense value for birds. A look at the appendix 7 shows that many of the biome-restricted birds from the Eurasian High Montane (Alpine and Tibetan), Himalayan Temperate Forest, Sino-Himalayan Subtropical Forest and Indo-Malayan Dry Zone biomes reported from New-Forest are concentrated in this habitat (Mohan, 1996) because of which the campus is identified as an Important Bird Area (Islam and Rahmani, 2004).

However, all is not well with this habitat. Thanks to a series of Government-owned campuses situated here e.g. Indian Military Academy, New Forest (Forest Research Institute) and a large army cantonment, some portions of this vegetation community is well preserved, but in the remaining areas natural forest has come under heavy pressure from the land-hungry developers, particularly after the creation of the state of Uttarakhand in 2000, with Dehradun as its temporary capital. Owing to its interesting undulating topography and location between Dehradun and Mussoorie, these areas have been preferred by wealthy people from Delhi and other cities to build farm houses, often constructing grotesque concrete structures surrounded by huge masonry walls after clearing up the local vegetation (pers. obs.). Very few of these have tried to build smaller structure which merge well with the surroundings and have taken pains to retain the native flora. If urban development continues this way which seems to be likely, New Forest along with the adjoining campuses may be the only last hope for this unique forests of Dehradun valley and its birds.

7.3.2 The man-made habitats

The three major man-made wooded habitats of New Forest which were part of the study area for the present study, occupy nearly an area of 100 ha. Along with them there are a few more planted patches of forests taking this area to about 150 ha. These plantations were raised on lands which were under agriculture till about 1920. Hence, all these man-made habitats have a fairly long history nearing a century. the birds of the region have well adapted to these plantations which is evident from high species richness and moderate to high compositional similarity with the natural habitat (table 7.1) from where the birds must have colonized these habitats. Bird fauna in plantations is largely derived from natural forest sources in the vicinity (Daniels 1989, Estades & Temple 1999). Interestingly, all these man-made habitats support a higher bird biomass than the natural habitat despite a lower bird density and richness. Even the frugivores, nectarivores and hole-nesters which elsewhere are known to suffer most in exotic plantations (Clout and Gaze 1984) seem to be doing well in the plantations of New Forests as is evident from tables 6.1 and 6.4.

7.3.2.1 Chir Pine plantations

These plantations which have a mature over-wood of large Chir Pine trees (average height 32 m, SD = 2.38, and average diameter 49.1 cm, SD = 9.67, N = 119) with age exceeding 80 years, have the highest vegetation structural diversity. Chir here has been planted on flat terrain with deep soil because of which it has shown a growth rate faster than most of its natural zone where it grows on shallow mountainous very well drained soils. Perhaps because of this Chir Pine has started showing a high mortality in recent years. The dead and fallen Chir Pine trees from a substantial part of the Champion Block were removed by the FRI administration in 2005-06. These tree fall gaps are helping the other vegetation to come up. Hence the habitat is still very dynamic and it would be worthwhile to monitor changes here as in other parts of the campus.

The number of indicator bird species found in this habitat is only second to the natural habitat. Nine bird species in summer season and five species in winter show significant IV for this habitat. Three species of birds namely Chestnut-Bellied Nuthatch, Grey Treepie, and Great Tit are indicator species for this habitat for both the seasons. Two of these belong to the tree-bark feeder (TBF) guild. Owing to large number of mature Chir Pine trees having large diameters and thick furrowed and cracked barks, this habitat appears to be the most favoured one for the TBF guild which is evident from the high biomass of this guild which is supported by this habitat round the year (Table 6.4). The dying Chir Pine trees also are likely to be a big attraction for the woodpeckers from this guild for feeding as well as nesting. The very rare Greater Flameback (*Chrysocolaptes lucidus*) of which there are a handful of sightings from the campus over the last five decades was observed making an unsuccessful attempt to nest on a top broken dead Chir Pine tree in May-June 2005 in the Champion block about 15 m above ground. Hence, the Chir Pine plantations are extremely important for the tree-bark feeder guild of birds of New Forest.

Chir Pine habitat also supports the highest bird biomass for the Nectarivore-Insectivore (NI) guild in summer months. While the Crimson Sunbird is very partial to the very common *Alangium chinensis* flowers (density 114.46 plants/ha, SD = 7.08, N = 11) in the month of April, the Spangled Drongo finds this tree very suitable for nesting because of its near horizontal forking of branches. None of the *Alangium chinensis* trees in the habitat are large indicating that they have colonized this area in recent years, perhaps as a result of tree-fall gaps. At 1070.3 g/ha, the Chir Pine habitat supports the highest biomass of the under-storey insectivore (IU) guild too, of which 847.3 g/ha is contributed by the Red Junglefowl alone. The habitat supports a Red Junglefowl density of 0.97 birds/ha in summer season which is comparable to the best areas in its natural distribution viz. Rajaji and Corbett National Park (Collias & Collias, 1967). The habitat also supports the largest biomass of the omnivores, which is a small guild of relatively large birds, in both the seasons. The Grey Treepies which withdraw from most parts of the campus in peak summers to occupy areas higher up in the nearby hills, maintain a low breeding population in the Chir Pine habitat. The Red-billed Blue Magpie is regularly breeding in this habitat now, a bird which was a rare straggler to the campus a few decades back (George 1957).

With this I feel that the prescription of clear felling this habitat to make way for new plantations (Singh, 2000), needs a reconsideration. Fortunately this prescription has still not been implemented although more than half of the plan period has already elapsed.

7.3.2.2 The Garden habitat

The garden habitat comprising the Botanical Garden and the Arboretum is different from the other habitats in having negligible shrub cover owing to constant removal of any such growth by the FRI authorities commensurate with the objectives of the area. It has therefore the lowest bird biomass of under-storey insectivores (471g/ha) of which more than half is contributed by the Red Junglefowl which wander into the area from adjoining habitats. It has however the highest biomass for two guilds during the summer months viz. Fruit-seed-nectarivores (Parakeets) and Fruit-seed-nectarivores-insectivores (Bulbuls, Mynas and Orioles) owing to a wide variety of native and exotic plants which flower and fruit during this period. Common Myna and Rose-ringed Parakeet are two indicator species for both the seasons for this habitat. Common Myna has the highest indicator value (97.1) for this habitat of all the birds in the campus. Although common elsewhere in the campus, it breeds only in the garden habitat amongst the wooded parts of the campus.

The Garden habitat plays an important role for the maintenance of the population of nectarivores in the winter seasons when they are unable to get much food resources in the much larger Chir Pine plantations (Table 6.4). Thus the flowering plants as well as the flowering hemi-parasites provide the nectarivores with the much needed food resources in the pinch period and the habitat supports the highest biomass for this guild (NI) in winter season (section 6.4.2).

7.3.2.2 The Mixed habitat

Although structurally this habitat is similar to the Chir Pine plantations, floristically it has a large diversity as it is a mosaic of small plantation blocks (*ca.* 0.4 ha. each) with different admixture of tree species. It has five indicator bird species each in summer and winter of which Plum-headed Parakeet is common to both seasons. This Parakeet breeds in good numbers in this habitat particularly in the Teak and *Acrocarpus fraxinifolius* patches as these trees have a large number of natural tree cavities. Two other indicator species (Jungle Myna & Grey-headed Woodpecker) are also cavity nesters as is the Chestnut-tailed Starling which has an IV of 44% (p=0.059) for this habitat. Thus this habitat is an important one for the cavity nesting birds. This habitat supports the highest biomasses of two guilds viz. Fruit-seed-nectarivores (Parakeets) and Fruit-seed-nectarivores-insectivores (Bulbuls, Mynas and Orioles) in winter season thus complementing the Garden habitat which supports similar biomasses in summers. The primary reason behind this is presence of trees like *Acrocarpus fraxinifolius* which bears profuse inflorescence in February-March and Teak trees which bear seeds consumed by Parakeets. The habitat also supports a good biomass of the NI guild.

7.4 CONCLUSIONS AND MANAGEMENT IMPLICATIONS

All the habitats of New Forest have some unique values for birds and there is no doubt that even the man-made habitats (the plantations), have their own importance in this regard. Plantations, particularly monocultures have been under a lot of criticism in the last few decades owing to their general negative influence on the biodiversity. This happened at a time when the monoculture plantations started maturing and becoming more and more visible. In the Indian context, the exotic forestry really picked up in the 1950s and 1960s when in many regions of the country miscellaneous forests were cleared, or wastelands identified, to plant exotic species such as Eucalypts, Poplars, Teak (in northern India), tropical Pines, *Acacia* sp. etc. although such plantations were initiated as early as late nineteenth century. However, the late 1970s and 1980s saw an enormous criticism not only to this style of forestry but also attacked other prevailing systems of forestry where silvicultural systems were applied for a sustained harvest of forest produce (mainly timber) from the natural (managed) forest. This criticism culminated in the revision of National Forest Policy in 1988 which was a major paradigm shift from the prevailing production forestry. Forests in India were thus viewed as a resource for long term conservation of biodiversity, ecological values and also meeting the legitimate demands of the local population dependent on the forests (Anon., 1988).

Many sprawling campuses in the country, which mostly belong to government owned institutions, have sizeable areas under natural forests and/or plantations. These areas often serve as a refuge for a large number of bird species (and other animal species as well) and can serve as important recreational as well as monitoring sites in the middle of urban landscapes. Such areas need to be managed to maintain high diversity and here the learnings from the present study can be of use. We have seen in the preceding chapters that the plantation habitats of New Forest, despite having an over-wood of exotic tree species, have over a long period of time acquired much of the native bird fauna of the nearby natural forests. While there are a few 'exclusive' birds in the natural forests, the plantations too have some definite unique values for the birds in the form of special resources leading to exclusiveness of certain birds to these habitats. Considering birds as a representative *taxon* of the overall biodiversity, many plantations, particularly in large protected campuses if kept undisturbed over long periods of time are likely to acquire much of the native biodiversity. Thus wherever natural vegetation doesn't occur, well protected mature plantations can be an alternative (though not a replacement) to natural vegetation to support bird species which because of their vagility can occupy such suitable new habitats. These plantations can be called 'old growth plantations' and as in New Forest their vegetation structural and compositional diversity can be comparable to natural forests. In New Forest the Chir Pine and the Mixed plantation habitats having an age of 60-80 years can be regarded as 'old growth plantations' and not surprisingly a bird of old growth forests, the largest Forest Owl of the campus: the rare Brown Wood Owl (*Strix leptogrammica*), has been regularly seen only in the mixed and Chir Pine plantation habitat (pers. obs.).

India today stands at a daunting task of bringing 33% of its land area under forest or tree cover from the present figure of *ca*. 23% and a national strategy to achieve this is already on the anvil with a possibility of involving many land owning agencies through multi-stakeholder partnership framework (Ghosh, 2007). With this are coupled the challenges of protecting the biodiversity. However owing to enormous pressures on the land, many of these plantations are likely to be small in extent often in the midst of man-modified landscapes. The plantation blocks which would be raised to meet this requirement should not just be considered vegetative cover. If judiciously managed, they can harbour a fair share of our native biodiversity (particularly birds and lower *taxa*). They can thus receive and maintain a potentially increasing fauna of the natural forests and thus contribute in conserving biodiversity in a substantial way. Wildlife conservation efforts in tropical areas should include approaches that promote practices that mitigate detrimental effects of intensively managed monocultures and enhance wildlife habitat value (Petit et al., 1999). As has been seen in the 'old growth plantations' of New Forests where canopy openings through tree-fall gaps have led to a growth of thick native under-storey, forest managers can improve habitat for birds in plantations by ensuring habitat heterogeneity through maintenance and encouragement of under-storey vegetation diversity, and vine thickets by creating gaps in the canopy if required, and encouraging native upper-storey trees (Cruz, 1988; Christian et al., 1997; Estades, 1999). This is all the more important in Pine plantations as Pines are wind pollinated and lack nectar producing flowers and fruits, the absence of these resources would lead to a decreased use of such stands by frugivores and nectarivores which are important tropical avifaunal guilds. Thus the presence of under-storey plant species can be important in determining the occurrence, and probably the abundance of such bird species (Cruz, 1988; Gepp, 1976; Suckling et al., 1976). Plantations managed with high tree densities with no pruning have poorly developed under-storey that supports a very impoverished avifauna (Estades, 1994). Shrub species diversity should be maintained at high levels to provide habitat and resources for frugivores, nectarivores and the large guild of under-storey insectivores (Cruz 1988).

Although the learnings from the present study could be extended to similar protected urban forests of small extent, extending them to plantations in larger landscapes can at best be tried on an experimental basis with a lot of caution. Monitoring should go hand in hand with any such initiative.

The present study in New Forest provides some interesting insights into the management of urban forests. Very often the urban forests have an admixture of natural and man-made forest patches as is the case of New Forest. The habitat diversity in such patches can lead to enhanced biomass and diversity of birds as compared to nearby natural forests (e.g. in Woolfenden and Rohwer, 1969; Emlen, 1974; Guthrie, 1974; Walcott, 1974; DeGraaf, 1978). The urban forests need to be managed in a way so as to maintain a high habitat diversity to support a high diversity and biomass of birds as these are often important recreational centres for the surrounding urban populace, and birdwatching is particularly popular as a hobby for nature lovers. The high habitat diversity can be addressed through both the structure and the composition of the vegetation. Special efforts may be required to ensure the year round supply of food resources of resident phytophagous birds by studying the phenology of the local and available exotic species of trees (e.g. *Alangium chinensis*, *Acrocarpus fraxinifolius* and *Callistemon viminalis* which provide the phytophagous birds of New Forest with food at critical times and also provide nesting resources).

As already mentioned in section 2.8.2 creation and maintenance of recreational and aesthetic spots in the estate for the benefit of the residents and the visitors is the second most important objective of the working plan of the New Forest campus (Singh, 2000). The campus does receive a very large number of visitors mainly to visit its large and informative museums housed in its main building which is an architectural marvel from the Greco-Roman and Colonial styles of architecture. The wooded parts of the campus are actually out of bounds for the visitors. However, the campus is already on the bird map of the country. It has had a long history of documented birdwatching (Osmaston, 1935; Wright, 1949 & 1955; George, 1957 & 1962; Mohan, 1996). It has been referred to as a birding destination in the first and the only bird-watchers' guide to India (Kazmierczak and Singh, 1998) and is also now recognized as an Important Bird Area (Islam and Rahmani, 2004). It gets a low but a steady number of birdwatchers who visit mainly the northern part of the campus having the strip of natural forests as the path through it is a thoroughfare owing to access to the villages to the north of the campus. Thus, the potential of the campus as an important birding destination can be utilized to meet the objective of its management. Development of an appreciation of nature in early childhood can lead to years of enjoyment of the outdoors and a more environmentally concerned citizenry (Tilghman, 1987). Birdwatchers form the largest group of ecotourists, and are, on average, well-educated, wealthy and committed which makes them ideal ecotourists for community-based conservation (Sekercioglu, 2002b). The campus houses very important forestry training institution of national importance with a mandate to train the top echelons of forest and wildlife managers of India. The trainees here need to be trained in appreciating the biodiversity values of the plantations also, and in the plantations of the campus there lies a training resource of high quality for this purpose right in the backyards of these training schools. Thus the woods of the campus which long time back were training ground for traditional forestry can well be used for the biodiversity focused contemporary forestry as well. Therefore, these forests have a tremendous potential as an education and training tool. It is however important that these plantations may be maintained with least disturbance and management interventions to fulfill these potential functions.

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Appendix 1

New Forest campus in the Dehradun valley landscape

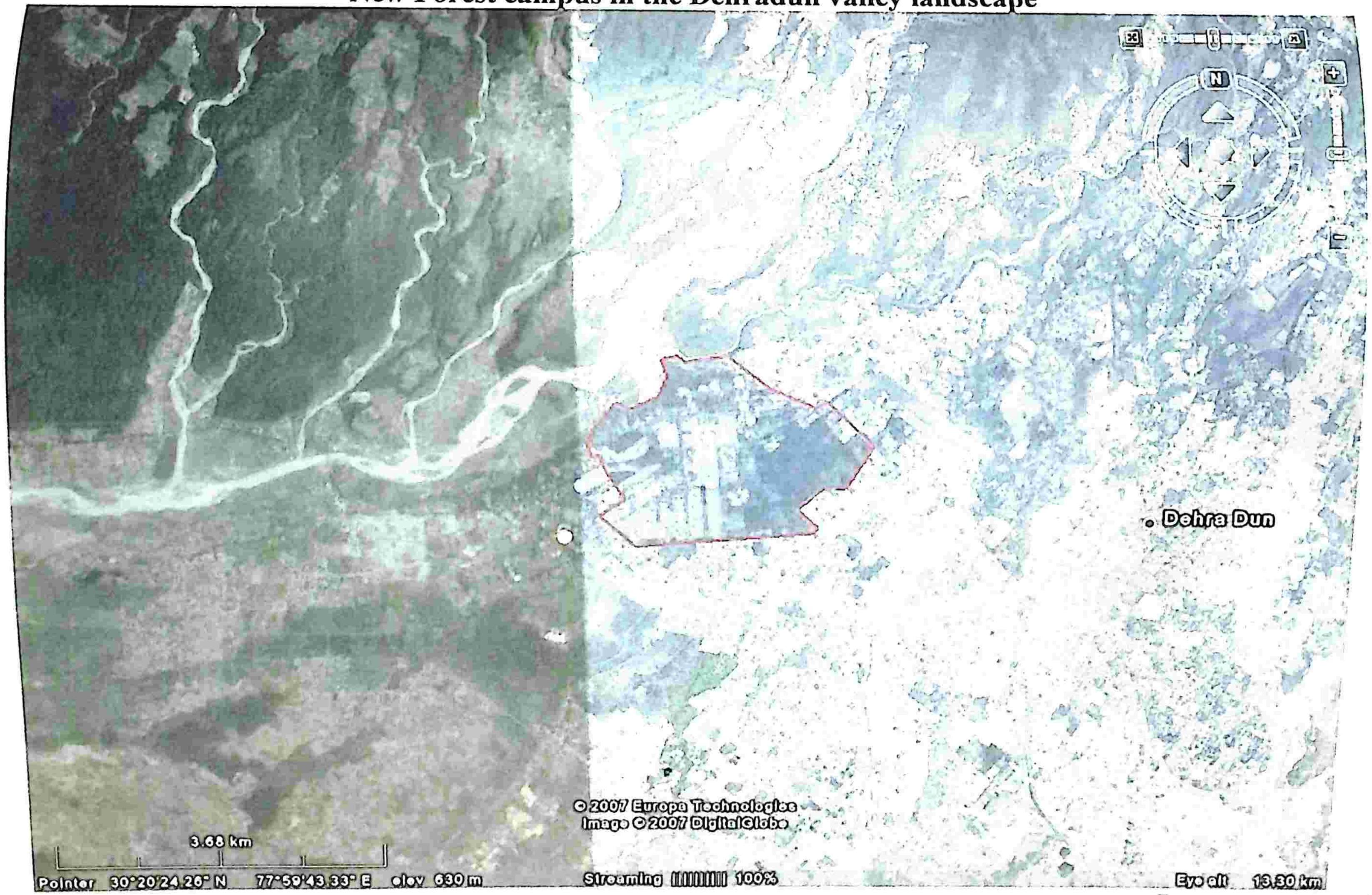
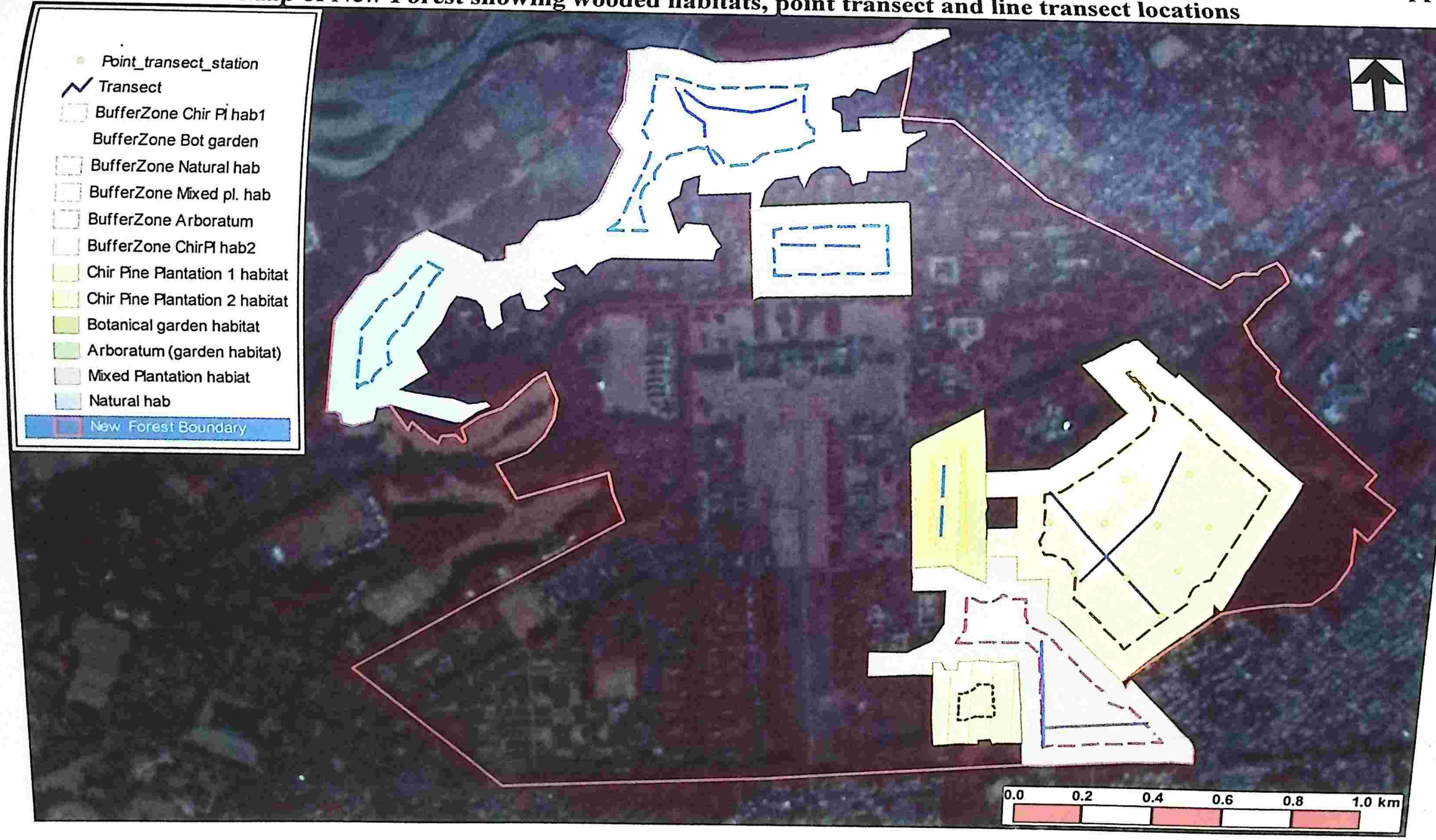


Image courtesy: *Google Earth*

Appendix 2

Map of New Forest showing wooded habitats, point transect and line transect locations



Appendix 3

Monthly Rainfall (mm.) in New Forest from 1988 to 1997*

Month Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1988	8.8	45	84.9	22.5	42.4	215.1	359.2	501.8	240.9	0	0	51.7	1572.3
1989	108.1	16.1	10.4	4.2	10.2	218.1	630	781.6	323.6	1.2	33.6	62.1	2199.2
1990	0.6	133.8	72.3	25.3	76.7	268.4	897.4	658	301.3	47.9	4.2	113.4	2599.3
1991	7.2	48.6	43	32.6	16.3	175.1	368.5	318.9	239.6	0	7	31.6	1288.4
1992	84.1	37.8	17.4	1	17	138.9	364.4	784.8	77.7	0	1.5	0	1524.6
1993	57.5	85.7	125.4	3.4	84.5	159.1	476.8	567.1	362	0	0.4	0	1921.9
1994	43.6	55.5	0.5	70.8	10.2	199	798.7	635.2	28.7	0	0	2.4	1844.6
1995	49	65.5	20.1	15.8	3	63.4	474.4	620.9	213.5	4.4	0.4	4	1534.4
1996	31.8	92.5	89	3.9	7	183	287.2	862.5	256.2	50.9	0	0	1864
1997	45	32.1	58.3	117.7	113.6	441.9	597.9	571.2	338.9	28.5	32.9	85.4	246.4
Total	435.7	612.6	521.3	297.2	380.9	2062	5254.9	6302	2382.4	132.9	80	350.6	16595.1
Mean	43.6	61.3	52.1	29.7	38.1	206.2	525.5	630.2	238.2	13.3	8	35.1	1659.51

* Source: Singh, R.K. (2000)

Appendix 4

Monthly Mean Temperature (°C) in New Forest from 1988 TO 1997*

Month / Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1988	12.3	14.7	17.5	24.1	26.7	26.7	25.8	25.3	24.8	20.7	16.2	13
1989	10.5	12.8	17.6	21.3	26.2	26	26.2	24.6	24.2	20.3	15.1	12.1
1990	13.2	13.6	16.1	21.6	25.5	27.5	25.6	26	25	20.6	16.8	12.4
1991	10.6	13.9	18.2	21.9	26.2	26.6	27.1	25.6	24.5	20.8	15.5	12.6
1992	12.1	12.8	17.7	22.9	24.1	26.9	25.7	25.4	24.4	20	16	12.1
1993	10.5	14.4	15.3	21.6	26.3	27.1	26.3	26	24	20.4	16.2	12.8
1994	12.4	13	19.6	21.2	26.1	28	26.6	25.9	24.7	20.4	16.1	12.8
1995	10.4	13.1	17.1	22	26.9	28.4	25.6	24.3	24.7	21.3	16.1	12.5
1996	10.8	13.6	18.7	22.8	25.8	26.6	25.7	24.8	24.2	20.8	16.2	12.3
1997	10.6	12.5	17.8	20.5	23.5	25.5	26	24.8	23.7	18.4	14.9	10.7
Total	113.4	134.4	175.6	219.9	257.3	269.3	260.6	252.7	244.2	203.7	159.1	123.3
Mean	11.3	13.4	17.6	22	25.7	26.9	26.1	25.3	24.4	20.4	15.9	12.3

* Source: Singh, R.K. (2000)

Appendix 5

Monthly Maximum Temperature (°C) in New Forest from 1988 to 1997*

Month / Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1988	21.4	23.8	26.1	34.1	37.6	34.4	29.8	29.4	30.5	30.1	26.2	21.6
1989	18.5	21.5	27	32	36.5	32.9	31.6	29.7	30.3	30	25.1	20.1
1990	22	20.5	23.4	31.5	33.2	35.2	29.8	30.5	29.8	28.6	26.3	21.7
1991	19.3	22.1	26	30.7	36.7	33.6	32.2	29.9	30.1	29.6	24.3	20.7
1992	19.5	20.4	26.1	32.3	34.7	35.7	31	29.7	30.3	28.9	25.3	21.9
1993	18.3	23.1	23.8	31.4	35.9	35.5	31.1	31.3	28.8	29.4	25.9	22.8
1994	20.9	21.3	28.7	30.3	35.5	35.7	31	30.4	30.6	29	25.3	21.4
1995	18	20.4	25.5	31.3	36.9	37.1	30.5	29	30.4	29.7	25.9	21.6
1996	19.5	21.6	26.6	31.9	36	33.3	30.2	29.1	29.4	28.2	25.5	22
1997	19.2	20.7	25.9	28.4	33.3	33.3	30.6	29.6	29.4	26	23.1	18.2
Total	196.6	215.4	259.1	313.9	356.3	345.7	307.8	298.6	299.6	289.5	252.9	212
Mean	19.7	21.5	25.9	31.4	35.6	34.6	30.8	29.9	30	29	21.2	21.2

* Source: Singh, R.K. (2000)

Appendix 6

Monthly Minimum Temperature (°C) in New Forest from 1988 TO 1997*

Month Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1988	4.1	6.2	9.1	14	17.2	20.8	23.1	22.3	20.3	12	7.2	5.4
1989	3.5	4.4	8.3	10.7	17.4	20.4	22	20.8	19.2	11.5	6.1	5.3
1990	5.1	7.6	8.8	11.7	19.1	21.5	22.6	22.8	21.4	13.6	8.1	4.6
1991	2.5	6	10.4	13	17.1	21.4	23.4	22.8	20.1	12.8	7.5	5.6
1992	5.5	5.5	9.8	13.9	14.8	20.3	21.8	22.4	19.7	12	7.7	3.5
1993	3.4	6.4	7.2	11.8	18.2	21.2	22.7	22.4	20.1	12.3	7.4	3.8
1994	5	5.3	10.5	12.2	17.8	22.1	23.2	22.8	20	12.7	7.8	5.3
1995	3.7	6.2	8.9	12.5	18.3	21.6	22	21.2	20.1	13.8	7.2	4.5
1996	3.2	5.8	11.3	13.5	17	21.7	22.4	21.8	20.2	14.2	7.8	3.6
1997	3.1	4.6	10.3	12.8	15.3	19.3	22.6	21.5	19.4	11.5	7.7	4.2
Total	39.1	58	94.6	126.1	172.2	210.3	225.8	220.8	200.5	128.4	74.5	45.8
Mean	3.9	5.8	9.5	12.6	17.2	21	22.6	22.1	20.1	12.8	7.5	4.6

* Source: Singh, R.K. (2000)

Appendix 7

Biome restricted species reported from New Forest*

Biome-5 : Eurasian High Montane (Alpine and Tibelan)	
Tickell's Warbler	*Phylloscopus affinis*
Olivaceous Leaf warbler	*Phylloscopus griseolus*
Wallcreeper	*Tichodroma muraria*
Biome-7: Himalayan Temperate Forest	
Himalayan Rubythroat	*Luscinia pectoralis*
Indian Blue Robin	*Luscinia brunnea*
Blue-capped Redstart	*Phoenicurus caeruleocephalus*
Striated Laughingthrush	*Garrulax striatus*
Scaly- breasted Wren-Babbler	*Pnoepyga albiventer*
Chestnut-headed Tesia	*Tesia castaneocoronata*
Western Crowned Warbler	*Phylloscopus occipitalis*
Orange-gorgeted Flycatcher	*Ficedula strophiata*
Ultramarine Flycatcher	*Ficedula superiliaris*
Slaty- blue Flycatcher	*Ficedula tricolor*
Rufous-bellied Niltava	*Niltava sundara*
Spot-winged crested Tit	*Parus melanolophus*
Green-backed Tit	*Parus moniticolus*
Yellow-breasted Greenfinch	*Carduelis spinoides*
Boime-8: Sino-Himalayan Subtropical Forest	
Blue-throated Barbet	*Megalaima asiatica*
Black-winged Cuckoo-Shrike	*Coracina melaschistos*
Rosy Minivet	*Pericrocotus roseus*
Himalayan Bulbul	*Pycnonotus leucogenys*
Black Bulbul	*Hypsipetes leucocephalus*
Blue-headed Rock-Thrush	*Monticola cinclorhynchus*
Tickell's Thrush	*Turdus unicolor*
Grey-winged Blackbird	*Turdus boulboul*
Rufous-chinned Laughingthrush	*Garrulax rufogularis*
Rusty-cheeked Scimitar-Babbler	*Pomatorhinus erythrogenys*
Black-chinnted Babbler	*Stachyris pyrrhops*
Grey-headed Flycatcher-Warbler	*Seicercus xanthoschistos*
Small Niltava	*Niltava macgrigoriae*
Maroon Oriole	*Oriolus traillii*
Grey Treepie	*Dendrocitta formosae*
Biome-11: Indo-Malayan Dry Zone	
Red-headed Vulture	*Sarcogyps calvus*
White-eyed Buzzard	*Butastur teesa*
Yellow-wattled Lapwing	*Vanellus malabaricus*
Yellow-legged Green-Pigeon	*Treron phoenicoptera*
Plum-headed Parakeet	*Psittaculd cyanocephala*
Indian Grey Hornbill	*Ocyceros birostris*
Brown-headed Barbet	*Megalaima zeylanica*
Lineated Barbet	*Megalaima lineata*

Lesser Golden-backed Woodpecker	*Dinopium benghalense*
Ashy-crowned Sparrow-Lark	*Eremopterix grisea*
Black-headed Cuckoo-Shrike	*Coracina melanoptera*
Common Woodshrike	*Tephrodornis pondiceranus*
Small Minivet	*Pericrocotus cinnamomeus*
Indian Robin	*Saxicoloides fulicata*
Jungle Babbler	*Turdoides striatus*
Ashy Prinia	*Prinia socialis*
White-browed Fantail-Flycatcher	*Rhipidura aureola*
Brahminy Starling	*Sturnus pagodarum*
Bank Myna	*Acridotheres ginginianus*
White-bellid Drongo	*Dicrurus caerulescens*

* Source: Islam and Rahmani, 2004

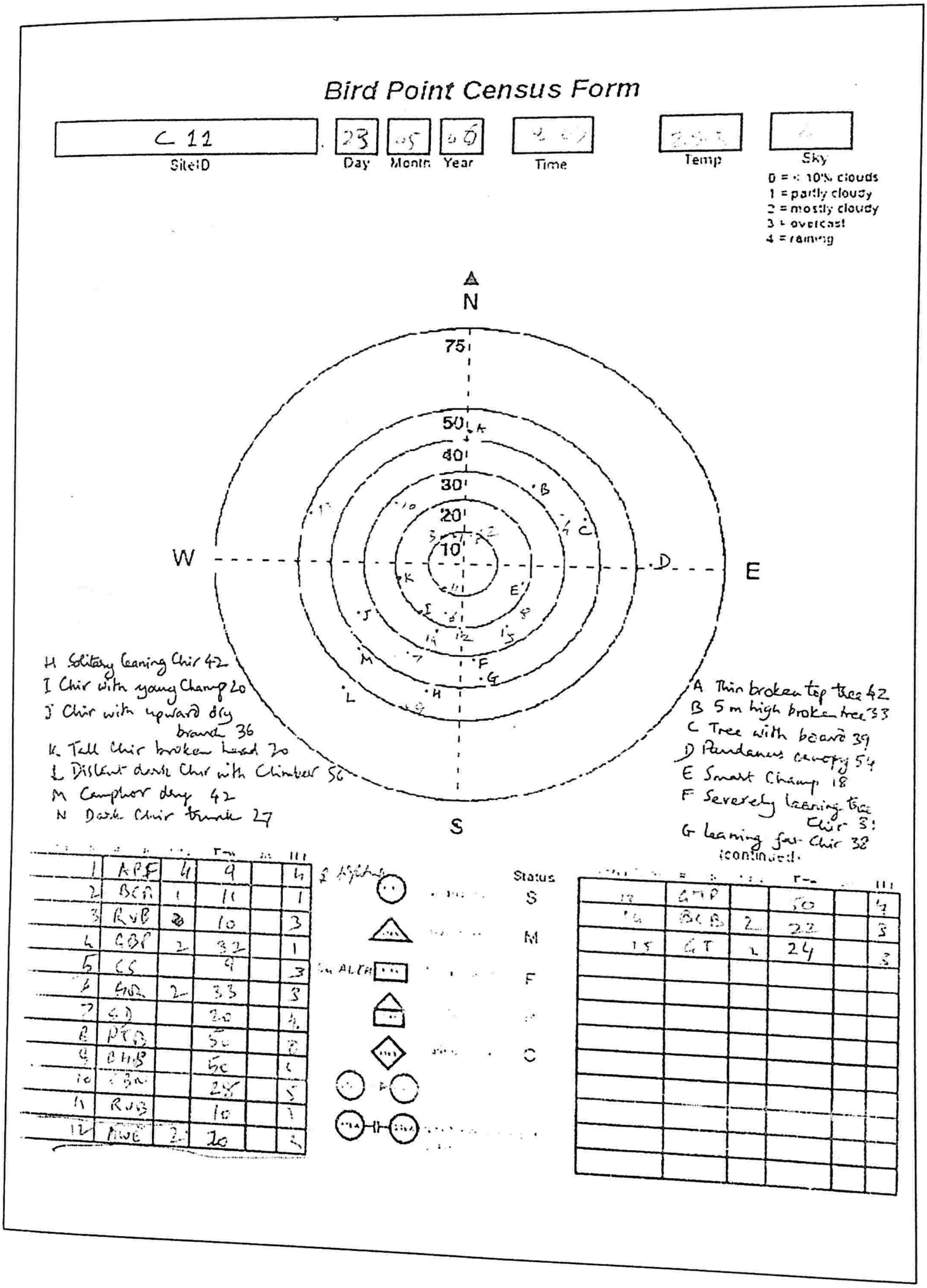
Appendix 8

Coordinates of points, used for carrying out bird point transects in New Forests

	Longitude			Latitude		
Point	**Deg.**	**Min.**	**Sec.**	**Deg.**	**Min.**	**Sec.**
Chir						
C2	78	0	33.16	30	20	28.56
C3	78	0	39.63	30	20	29.14
C5	78	0	25.47	30	20	24.22
C6	78	0	31.21	30	20	24.21
C7	78	0	36.73	30	20	24.11
C8	78	0	42.13	30	20	24.02
C9	78	0	28.37	30	20	19.29
C10	78	0	33.88	30	20	18.80
C11	78	0	39.18	30	20	19.62
C12	78	0	37.95	30	20	15.03
C13	78	0	20.23	30	20	4.98
Garden						
G1	77	59	56.44	30	20	49.55
G2	78	0	0.85	30	20	49.50
G3	78	0	5.36	30	20	49.50
G4	78	0	14.33	30	20	30.04
G5	78	0	14.30	30	20	26.17
G6	78	0	14.30	30	20	22.28
Mixed						
M1	78	0	18.67	30	20	14.26
M2	78	0	23.24	30	20	14.40
M3	78	0	27.92	30	20	10.73
M5	78	0	32.49	30	20	6.76
M6	78	0	28.47	30	20	2.75
M7	78	0	32.99	30	20	2.75
M8	78	0	37.61	30	20	2.99
Natural						
N1	77	59	46.30	30	21	3.18
N2	77	59	52.43	30	21	2.92
N3	77	59	57.78	30	21	3.03
N4	77	59	43.43	30	20	58.18
N5	77	59	49.09	30	20	58.42
N6	77	59	54.66	30	20	58.35

Appendix 9

Sample data sheet used for point transects



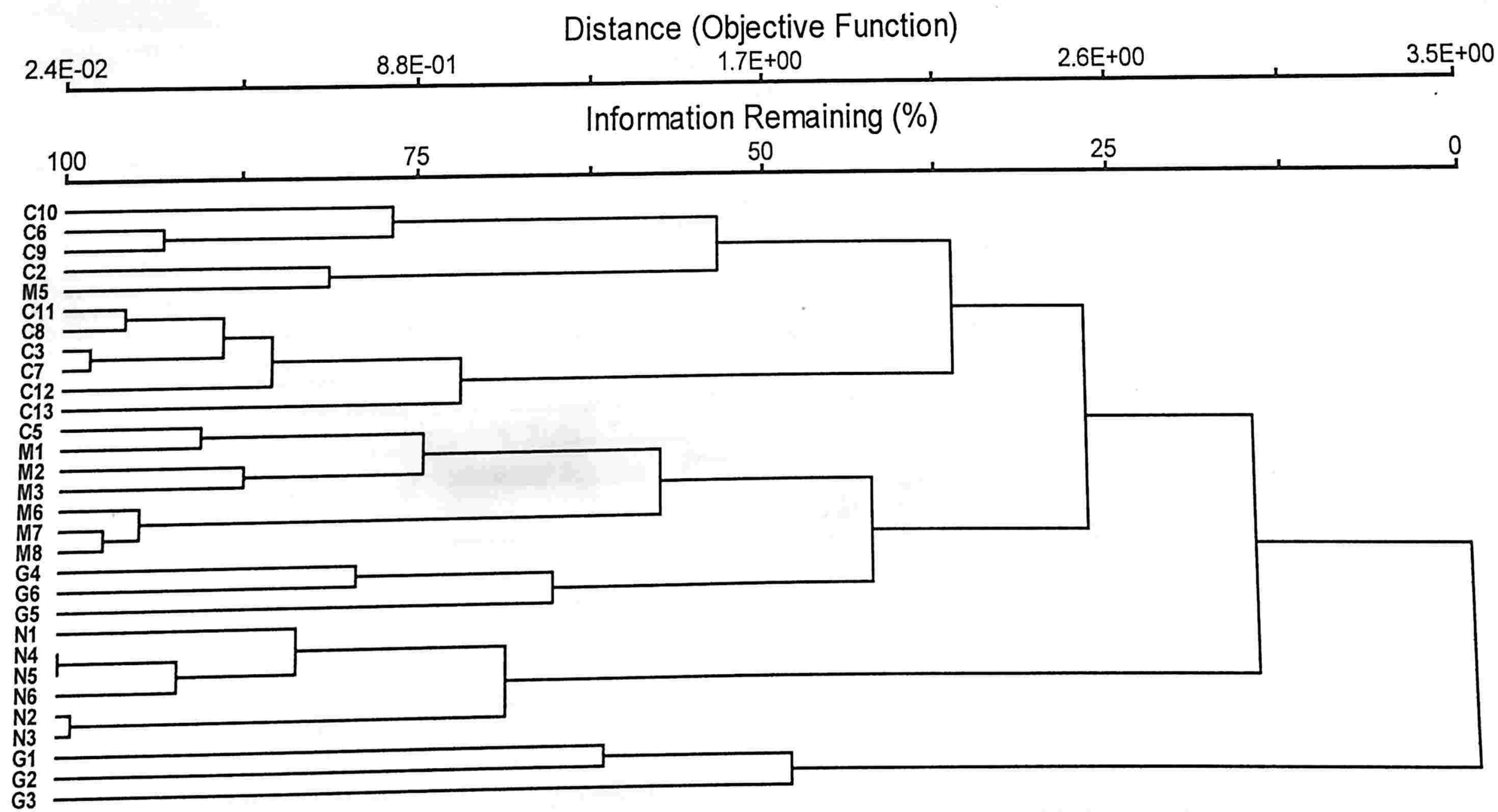
Appendix 10

Densities of major tree species in different habitats of New Forests

Name	Density in Number of trees/ha.			
	Chir	Garden	Mixed	Natural
Acacia catechu	0	0	61.42	0
Acacia conccina	0	0	0	15.92
Acrocarpus fraxinifolius	0	0	29.57	0
Alangium chinensis	114.36	0	79.62	0
Albizzia sp.	1.45	0	0	7.96
Bamboo sp.	1.45	7.96	4.55	217.62
Bombax cieba	0	0	0	2.65
Brossonetia papyrifera	0	0	4.55	5.31
Callistemon viminalis	0	7.96	0	0
Caryota urens	0	5.31	0	0
Cassia nodosa	0	5.31	0	0
Cinnamom camphora	79.62	0	4.55	0
Citrus sp.	0	0	6.82	0
Cudrenia javanica	0	0	0	7.96
Cupressus torulosa	0	10.62	0	0
Dalbergia sissoo	4.34	0	2.27	15.92
Ficus sp.	2.9	0	0	0
Flocortia indica	8.69	2.65	27.3	13.27
Garuga pinnata	2.9	0	9.1	0
Gmelina arborea	0	0	6.82	0
Heynea trijuga	4.34	5.31	0	10.62
Hovenia dulcis	0	0	6.82	0
Lannea coromendalica	0	0	0	5.31
Litsea monopetala	0	0	36.4	0
Litsea unbullata	0	5.31	0	0
Macaranga tomentosa	0	5.31	0	0
Mallotus phillipensis	70.93	0	40.95	15.92
Markhamia platycalyx	7.24	0	77.34	0
Melia azaderach	2.9	2.65	6.82	15.92
Michelia champaca	36.19	0	11.37	0
Miliusa velutina	0	5.31	6.82	0
Peltophorum pterocarpum	0	10.62	0	0
Pinus carribea	7.24	0	0	0
Pinus roxburghii	183.84	0	18.2	0
Prunus sp.	0	0	0	7.96
Pyrus pashia	1.45	0	2.27	34.5
Sapium insigne	1.45	0	0	10.62
Shorea robusta	0	0	0	31.85
Sygigium cumini	11.58	0	95.54	26.54
Tectona grandis	1.45	0	34.12	0
Xylosma longifolia	0	0	9.1	23.89

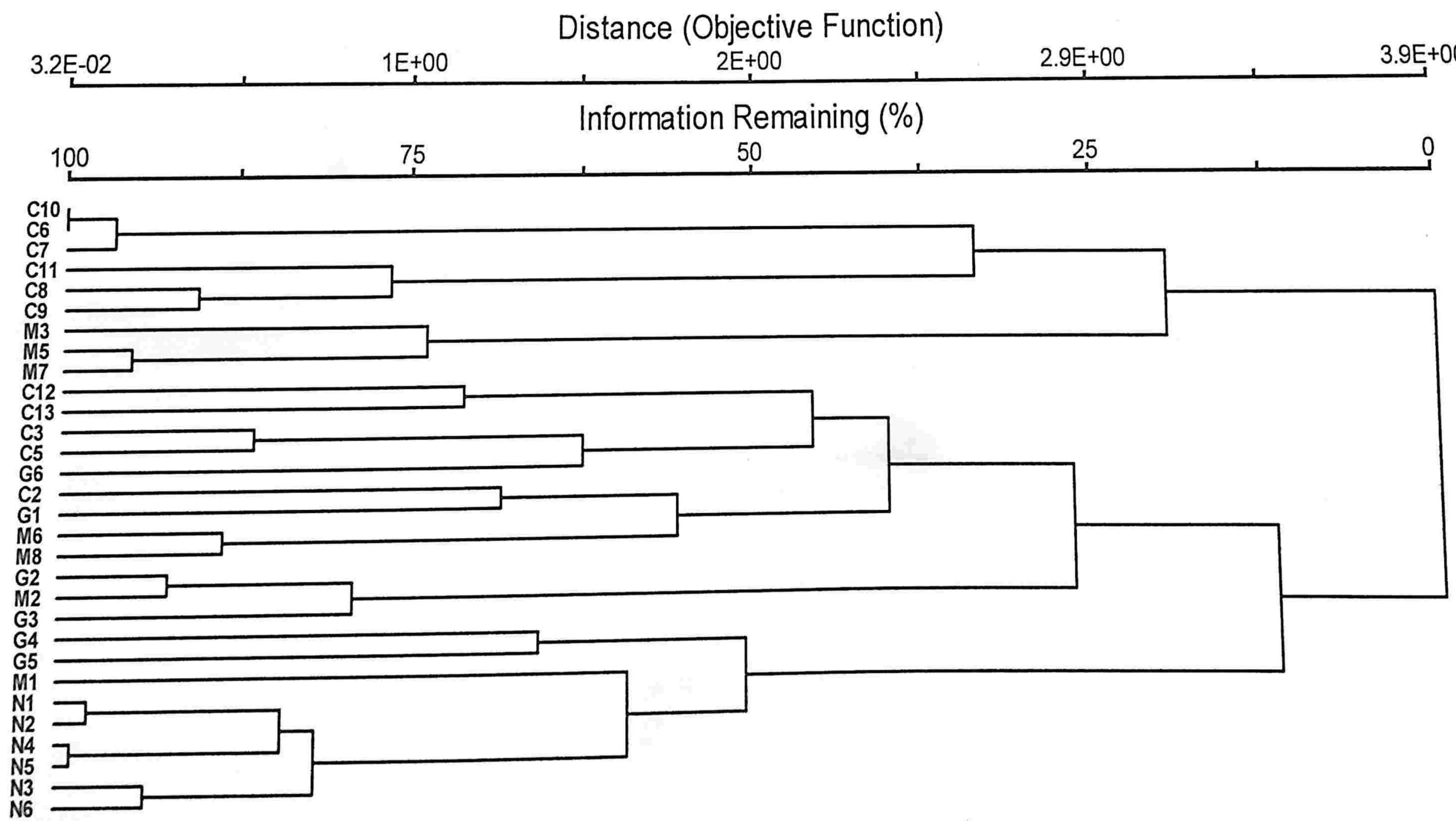
Appendix 11

Cluster dendrogram of the sample points for bird point transects based on bird composition for SUMMER season



Distance measure: Sorensen (Bray-Curtis) and linkage method is flexible beta with beta = -0.25.

Cluster dendrogram of the sample points for bird point transects based on bird composition for WINTER season



Distance measure: Sorensen (Bray-Curtis) and linkage method is flexible beta with beta = -0.25.

Appendix 12

List of birds reported from New Forest with feeding guilds
(Birds observed in the point transects in the present study indicated in bold)

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
1	**ABBERANT BUSH WARBLER**	*Cettia flavolivacea*	Understorey-insectivore	IU	I
2	**ALEXANDRINE PARAKEET**	*Psittacula eupatria*	Fruit-seed-nectar	FSN	P
3	ALPINE SWIFT	*Tachymarptis melba*	Sallying-insectivore	IS	I
4	**ASHY DRONGO**	*Dicrurus leucophaeus*	Sallying-insectivore	IS	I
5	ASHY PRINIA	*Prinia socialis*	Understorey-insectivore	IU	I
6	**ASHY THROATED WARBLER**	*Phylloscopus maculipennis*	Canopy-insectivore	IC	I
7	ASIAN BARRED OWLET	*Glaucidium cuculoides*	Raptor	R	O
8	ASIAN BROWN FLYCATCHER	*Muscicapa dauurica*	Sallying-insectivore	IS	I
9	**ASIAN KOEL**	*Eudynamys scolopacea*	Fruit-insectivore	FI	P
10	**ASIAN PARADISE-FLYCATCHER**	*Terpsiphone paradisi*	Sallying-insectivore	IS	I
11	ASIAN PIED STARLING	*Sturnus contra*	Fruit-seed-nectar-insectivore	FSNI	O
12	BANDED BAY CUCKOO	*Cacomantis sonneratii*	Canopy-insectivore	IC	I
13	BANK MYNA	*Acridotheres ginginianus*	Fruit-seed-nectar-insectivore	FSNI	O
14	BARN OWL	*Tyto alba*	Raptor	R	I
15	BARN SWALLOW	*Hirundo rustica*	Sallying-insectivore	IS	I
16	**BAR-TAILED TREECREEPER**	*Certhia himalayana*	Trunk/bark feeder	TBF	I
17	**BAR-WINGED FLYCATCHER-SHRIKE**	*Hemipus picatus*	Sallying-insectivore	IS	I
18	BAYA WEAVER	*Ploceus philippinus*	Granivore	G	P
19	BAY-BACKED SHRIKE	*Lanius vittatus*	Understorey-insectivore	IU	I
20	**BESRA**	*Accipiter virgatus*	Raptor	R	I
21	**BLACK BULBUL**	*Hypsipetes leucocephalus*	Fruit-seed-nectar-insectivore	FSNI	P
22	**BLACK DRONGO**	*Dicrurus macrocercus*	Sallying-insectivore	IS	I
23	BLACK EAGLE	*Ictinaetus malayensis*	Raptor	R	O

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
24	BLACK FRANCOLIN	*Francolinus francolinus*	Understorey-insectivore	IU	I
25	**BLACK KITE**	*Milvus migrans*	Raptor	R	O
26	BLACK LORED TIT	*Parus xanthogenys*	Trunk/bark feeder	TBF	I
27	BLACK REDSTART	*Phoenicurus ochrurus*	Understorey-insectivore	IU	I
28	**BLACK-CHINNED BABBLER**	*Stachyris pyrrhops*	Understorey-insectivore	IU	I
29	BLACK-CRESTED BULBUL	*Pycnonotus melanicterus*	Fruit-insectivore	FI	P
30	BLACK-CROWNED NIGHT HERON	*Nycticorax nycticorax*	Water-insectivore	IW	I
31	BLACK-HEADED BUNTING	*Emberiza melanocephala*	Granivore	G	P
32	**BLACK-HEADED CUCKOOSHRIKE**	*Caracina melanoptera*	Canopy-insectivore	IC	I
33	**BLACK-HOODED ORIOLE**	*Oriolus xanthornus.*	Fruit-seed-nectar-insectivore	FSNI	P
34	BLACK-NAPED MONARCH	*Hypothymis azurea*	Sallying-insectivore	IS	I
35	**BLACK-RUMPED FLAMEBACK**	*Dinopium benghalense*	Trunk/bark feeder	TBF	I
36	BLACK-SHOULDERED KITE	*Elanus caeruleus*	Raptor	R	I
37	BLACK-WINGED CUCKOOSHRIKE	*Coracina melaschistos*	Canopy-insectivore	IC	I
38	BLUE ROCK THRUSH	*Monticola solitarius*	Understorey-insectivore	IU	I
39	**BLUE WHISTLING THRUSH**	*Myophonus caeruleus*	Understorey-insectivore	IU	I
40	**BLUE-BEARDED BEE-EATER**	*Nyctyornis athertoni*	Sallying-insectivore	IS	I
41	BLUE-CAPPED REDSTART	*Phoenicurus coeruleocephalus*	Understorey-insectivore	IU	I
42	**BLUE-CAPPED ROCK THRUSH**	*Monticola cinclorhynchus*	Understorey-insectivore	IU	I
43	BLUE-TAILED BEE-EATER	*Merops philippinus*	Sallying-insectivore	IS	I
44	BLUETHROAT	*Luscinia svecica*	Understorey-insectivore	IU	I
45	BLUE-THROATED BARBET	*Megalaima asiatica*	Fruit-insectivore	FI	P
46	**BLUE-THROATED FLYCATCHER**	*Cyornis rubeculoides*	Canopy-insectivore	IC	I
47	**BLYTH'S REED WARBLER**	*Acrocephalus dumetorum*	Understorey-insectivore	IU	I
48	BRAHMINY KITE	*Haliastur indus*	Raptor	R	O
49	BRAHMINY STARLING	*Sturnus pagodarum*	Fruit-seed-nectar-insectivore	FSNI	O
50	**BRONZED DRONGO**	*Dicrurus aeneus*	Sallying-insectivore	IS	I
51	BROWN DIPPER	*Cinclus pallasi*	Water-insectivore	IW	I
52	BROWN HAWK OWL	*Ninox scutulata*	Raptor	R	O

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
53	BROWN ROCK-CHAT	*Cercomela fusca*	Understorey-insectivore	IU	I
54	BROWN SHRIKE	*Lanius cristatus*	Understorey-insectivore	IU	I
55	BROWN-FRONTED WOODPECKER	*Dendrocops auriceps*	Trunk/bark feeder	TBF	I
56	**BROWN-HEADED BARBET**	*Megalaima zeylanica*	Fruit-insectivore	FI	P
57	**BROWNISH FLANKED BUSH WARBLER**	*Cettia fortipes*	Understorey-insectivore	IU	I
58	CATTLE EGRET	*Bubulcus ibis*	Ground-insectivore	IG	I
59	**CHANGEABLE HAWK EAGLE**	*spizaetus eirrhatus*	Raptor	R	O
60	**CHESTNUT-BELLIED NUTHATCH**	*Sitta castanea*	Trunk/bark feeder	TBF	I
61	CHESTNUT-BELLIED ROCK THRUSH	*Monticola rufiventris*	Canopy-insectivore	IC	I
62	CHESTNUT-EARED BUNTING	*Emberiza fucata*	Granivore	G	P
63	**CHESTNUT-HEADED BEE-EATER**	*Merops leschenaulti*	Sallying-insectivore	IS	I
64	CHESTNUT-HEADED TESIA	*Tesia castaneocoronata*	Understorey-insectivore	IU	I
65	**CHESTNUT-SHOULDERED PETRONIA**	*Petronia xanthocollis*	Granivore	G	P
66	**CHESTNUT-TAILED STARLING**	*Sturnus malabaricus*	Fruit-seed-nectar-insectivore	FSNI	P
67	COLLARED OWLET	*Glaucidium brodiet*	Raptor	R	I
68	COLLARED SCOPS OWL	*Otus ḫakkamoena*	Raptor	R	I
69	COMMON BABBLER	*Turdoides caudatus*	Understorey-insectivore	IU	I
70	COMMON CHIFFCHAF	*Phylloscopus collybyta*	Understorey-insectivore	IU	I
71	**COMMON HAWK CUCKOO**	*Hierococcyx varius*	Canopy-insectivore	IC	I
72	COMMON HOOPOE	*Upupa epops*	Ground-insectivore	IG	I
73	**COMMON IORA**	*Aegithina tiphia*	Canopy-insectivore	IC	I
74	COMMON KESTREL	*Falco tinnunculus*	Raptor	R	I
75	COMMON KINGFISHER	*Alcedo atthis*	Piscivore	P	I
76	**COMMON MYNA**	*Acridotheres tristis*	Fruit-seed-nectar-insectivore	FSNI	O
77	**COMMON ROSEFINCH**	*Carpodacus erythrinus*	Granivore	G	P
78	COMMON SANDPIPER	*Actitis hypoleucus*	Water-insectivore	IW	I
79	COMMON STARLING	*Sturnus vulgaris*	Fruit-seed-nectar-insectivore	FSNI	O
80	COMMON STONECHAT	*Saxicola torquata*	Understorey-insectivore	IU	I
81	**COMMON TAILORBIRD**	*Orthotomus sutorius*	Understorey-insectivore	IU	I

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
82	COMMON TEAL	*Anas crecca*	Piscivore	P	O
83	COMMON WOOD PIGEON	*Columba palumbus*	Granivore	G	P
84	**COMMON WOODSHRIKE**	*Tephrodornis pondicerianus*	Canopy-insectivore	IC	I
85	**COPPERSMITH BARBET**	*Megalaima haemacephala*	Fruit-seed-nectar-insectivore	FSNI	P
86	CRESTED BUNTING	*Melophus lathami*	Granivore	G	P
87	CRESTED KINGFISHER	*Megaceryle lugubris*	Piscivore	P	I
88	CRESTED LARK	*Galerida cristata*	Granivore	G	P
89	**CRESTED SERPENT EAGLE**	*Spilornis cheela*	Raptor	R	O
90	CRESTED TREESWIFT	*Hemiprocne coronata*	Sallying-insectivore	IS	I
91	**CRIMSON SUNBIRD**	*Aethopyga siparaja*	Nectar-insectivore	NI	P
92	**DARK-SIDED FLYCATCHER**	*Muscicapa sibirica*	Sallying-insectivore	IS	I
93	DARK-THROATED THRUSH	*Turdus ruficillis*	Fruit-seed-nectar-insectivore	FSNI	I
94	DESERT WHEATEAR	*Oenanthe deserti*	Understorey-insectivore	IU	I
95	DOLLARBIRD	*Eurystomus orientalis*	Sallying-insectivore	IS	I
96	**DRONGO CUCKOO**	*Surniculus lugubris*	Sallying-insectivore	IS	I
97	DUSKY CRAG MARTIN	*Hirundo concolor*	Sallying-insectivore	IS	I
98	EGYPTIAN VULTURE	*Neophron percnopterus*	Raptor	R	O
99	**EMERALD DOVE**	*Chalcophaps indica*	Granivore	G	P
100	EURASIAN COLLARED DOVE	*Streptopelia decaocto*	Granivore	G	P
101	EURASIAN CRAG MARTIN	*Hirundo rupestris*	Sallying-insectivore	IS	I
102	**EURASIAN CUCKOO**	*Cuculus canorus*	Canopy-insectivore	IC	I
103	EURASIAN EAGLE OWL	*Bubo buba*	Raptor	R	I
104	**EURASIAN GOLDEN ORIOLE**	*Oriolus oriolus*	Fruit-seed-nectar-insectivore	FSNI	P
105	EURASIAN GRIFFON	*Gyps fulvus*	Raptor	R	O
106	EURASIAN HOBBY	*Falco subbuteo*	Raptor	R	I
107	EURASIAN THICK-KNEE	*Burhinus oedicnemus*	Ground-insectivore	IG	I
108	EURASIAN WRYNECK	*Jynx torquilla*	Understorey-insectivore	IU	I
109	EUROPEAN GOLDFINCH	*Carduelis carduelis*	Granivore	G	P
110	**FIRE-BREASTED FLOWERPECKER**	*Dicaeum ignipectus*	Nectar-insectivore	NI	P

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
111	**FULVOUS-BREASTED WOODPECKER**	*Dendrocopos macei*	Trunk/bark feeder	TBF	I
112	GOLDEN-FRONTED LEAFBIRD	*Chloropsis ourifrons*	Canopy-insectivore	IC	I
113	GREAT BARBET	*Megalaima virens*	Fruit-insectivore	FI	P
114	**GREAT TIT**	*Parus major*	Trunk/bark feeder	TBF	I
115	**GREATER COUCAL**	*Centropus sinensis*	Omnivore	O	O
116	**GREATER FLAMEBACK**	*Chrysocolaptes lucidus*	Trunk/bark feeder	TBF	I
117	**GREEN BEE-EATER**	*Merops orientalis*	Sallying-insectivore	IS	I
118	GREEN SANDPIPER	*Tringa ochropus*	Water-insectivore	IW	I
119	GREEN-BACKED TIT	*Parus monticolus*	Trunk/bark feeder	TBF	I
120	**GREENISH WARBLER**	*Phylloscopus trochiloides*	Canopy-insectivore	IC	I
121	**GREY BUSHCHAT**	*Saxicola ferrea*	Understorey-insectivore	IU	I
122	GREY FRANCOLIN	*Francolinus pondicerianus*	Understorey-insectivore	IU	I
123	**GREY TREEPIE**	*Dendrocitta formosae*	Omnivore	O	O
124	GREY WAGTAIL	*Motacilla cinerea*	Ground-insectivore	IG	I
125	GREY-BELLIED CUCKOO	*Cacomantis passerinus*	Canopy-insectivore	IC	I
126	**GREY-BREASTED PRINIA**	*Prinia hodgsonii*	Understorey-insectivore	IU	I
127	**GREY-CAPPED PYGMY WOODPECKER**	*Dendrocopos canicapillus*	Trunk/bark feeder	TBF	I
128	**GREY-HEADED CANARY FLYCATCHER**	*Culicicapaceylonensis*	Sallying-insectivore	IS	I
129	**GREY-HEADED WOODPECKER**	*Picus canus*	Trunk/bark feeder	TBF	I
130	**GREY-HOODED WARBLER**	*Seicercus xanthoschistos*	Canopy-insectivore	IC	I
131	**GREY-SIDED BUSH WARBLER**	*Cettia brunnifrons*	Understorey-insectivore	IU	I
132	GREY-WINGED BLACKBIRD	*Turdus boulboul*	Understorey-insectivore	IU	I
133	**HIMALAYAN BULBUL**	*Pycnonotus leucogenys*	Fruit-seed-nectar-insectivore	FSNI	P
134	HIMALAYAN SWIFTLET	*Collocalia brevirostris*	Sallying-insectivore	IS	I
135	HOODED PITTA	*Pitta sordida*	Understorey-insectivore	IU	I
136	HOUSE CROW	*Corvus splendens.*	Omnivore	O	O
137	HOUSE SPARROW	*Passer domesticus*	Granivore	G	P
138	HOUSE SWIFT	*Apus affinis*	Sallying-insectivore	IS	I
139	**HUME'S WARBLER**	*Phylloscopus humei*	Canopy-insectivore	IC	I

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
140	**INDIAN BLUE ROBIN**	*Luscinia Brunnea*	Understorey-insectivore	IU	I
141	**INDIAN CUCKOO**	*cuculus micropterus*	Canopy-insectivore	IC	I
142	**INDIAN GREY HORNBILL**	*Ocyceros birostris*	Fruit-insectivore	FI	P
143	**INDIAN PITTA**	*Pitta brachyura*	Understorey-insectivore	IU	I
144	INDIAN POND HERON	*Ardeola grayii*	Water-insectivore	IW	I
145	INDIAN ROBIN	*Saxicoloides fulicata*	Understorey-insectivore	IU	I
146	INDIAN ROLLER	*Coracias benghalensis*	Omnivore	O	O
147	INDIAN SILVERBILL	*Lonchura malabarica*	Granivore	G	P
148	ISABELLINE WHEATHER	*Oenanthe isabellina*	Understorey-insectivore	IU	I
149	**JUNGLE BABBLER**	*Turdoides striatus*	Understorey-insectivore	IU	I
150	**JUNGLE MYNA**	*Acridotheres fuscus*	Fruit-seed-nectar-insectivore	FSNI	O
151	**JUNGLE OWLET**	*Glaucidium radiatum*	Raptor	R	I
152	JUNGLE PRINIA	*Prinia sylvatica*	Understorey-insectivore	IU	I
153	KALIJ PHEASANT	*Lophura leucomelanos*	Understorey-insectivore	IU	I
154	LAGGAR FALCON	*Falco jugger*	Raptor	R	O
155	LAMMERGEIER	*Gypaetus barbatus*	Raptor	R	O
156	**LARGE CUCKOOSHRIKE**	*Caracina macei*	Canopy-insectivore	IC	I
157	LARGE-BILLED CROW	*Corvus macrorhynchos*	Omnivore	O	O
158	**LARGE-BILLED LEAF WARBLER**	*Phylloscopus magnirostris*	Canopy-insectivore	IC	I
159	LARGE-TAILED NIGHTJAR	*Caprimulgus macrurus*	Sallying-insectivore	IS	I
160	LAUGHING DOVE	*Streptopelia orientalis*	Granivore	G	P
161	**LEMON-RUMPED WARBLER**	*Phylloscopus chloronotus*	Canopy-insectivore	IC	I
162	**LESSER YELLOWNAPE**	*picus chlorolophus*	Trunk/bark feeder	TBF	I
163	LINEATED BARBET	*Megalaima lineata*	Fruit-insectivore	FI	P
164	LITTLE EGRET	*Egretta garzetta*	Water-insectivore	IW	I
165	LITTLE RINGED PLOVER	*Charadrus dubius*	Water-insectivore	IW	I
166	LONG- LEGGED BUZZARD	*Buteo rufinus*	Raptor	R	O
167	LONG-BILLED VULTURE	*Gyps indicus*	Raptor	R	O
168	**LONG-TAILED MINIVET**	*Pericrocotus ethologus*	Canopy-insectivore	IC	I

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
169	LONG-TAILED SHRIKE	*Lanius schach.*	Understorey-insectivore	IU	I
170	**MAROON ORIOLE**	*Oriolus traillii*	Fruit-seed-nectar-insectivore	FSNI	P
171	MISTLE THRUSH	*Turdus viscivorus*	Understorey-insectivore	IU	I
172	MRS GOULD'S SUNBIRD	*Aethopyga gouldiae*	Nectar-insectivore	NI	P
173	**NEPAL WREN BABBLER**	*Pnoepyga immaculata*	Understorey-insectivore	IU	I
174	NORTHERN LAPWING	*Vanellus vanellus*	Ground-insectivore	IG	I
175	**OLIVE-BACKED PIPIT**	*Anthus hodgsoni*	Ground-insectivore	IG	I
176	ORANGE-FLANKED BUSH ROBIN	*Tarsiger cyanurus*	Understorey-insectivore	IU	I
177	**ORANGE-HEADED THRUSH**	*Zoothera citrina*	Understorey-insectivore	IU	I
178	**ORIENTAL HONEY-BUZZARD**	*Pernis prilorhyncus*	Raptor	R	I
179	**ORIENTAL MAGPIE ROBIN**	*Copsychus saularis*	Understorey-insectivore	IU	I
180	ORIENTAL SCOPS OWL	*Otus sunia*	Raptor	R	I
181	ORIENTAL SKYLARK	*Alauda gulgula*	Ground-insectivore	IG	I
182	**ORIENTAL TURTLE DOVE**	*Streptopelia oricntalis*	Granivore	G	P
183	**ORIENTAL WHITE-EYE**	*Zosterops palpebrosus*	Nectar-insectivore	NI	P
184	PADDYFIELD PIPIT	*Anthus rufulus*	Understorey-insectivore	IU	I
185	PALE FOOTED BUSH WARBLER	*Cettia pallideps*	Understorey-insectivore	IU	I
186	**PALE-BILLED FLOWERPECKER**	*Dicaeum erythrorynchos*	Nectar-insectivore	NI	P
187	**PEREGRINE FALCON**	*Falco peregrinus*	Raptor	R	O
188	PIED BUSHCHAT	*Saxicola caprata*	Understorey-insectivore	IU	I
189	PIED CUCKOO	*Clamator jacobinus*	Canopy-insectivore	IC	I
190	PIED KINGFISHER	*Ceryle rudis*	Piscivore	P	O
191	PLAIN MARTIN	*Riparia paludicola*	Sallying-insectivore	IS	I
192	PLUMBEOUS WATER REDSTART	*Rhyacornis fuliginosus*	Water-insectivore	IW	I
193	**PLUM-HEADED PARAKEET**	*Psittacula cyanocephala*	Fruit-seed-nectar	FSN	P
194	**PUFF-THROATED BABBLER**	*Pellorneum ruficeps.*	Understorey-insectivore	IU	I
195	**PURPLE SUNBIRD**	*Nectarinia asiatica*	Nectar-insectivore	NI	P
196	RED AVADAVAT	*Amandava amandava*	Granivore	G	P
197	**RED JUNGLEFOWL**	*Gallus gallus*	Understorey-insectivore	IU	I

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
198	**RED-BILLED BLUE MAGPIE**	*Urocissa erythrorhyncha*	Omnivore	O	O
199	**RED-BILLED LEIOTHRIX**	*Leiothrix lutea*	Understorey-insectivore	IU	I
200	RED-BREASTED PARAKEET	*Psittacula alexandri*	Fruit-seed-nectar	FSN	P
201	RED-HEADED VULTURE	*Sarcogyps calvus*	Raptor	R	O
202	RED-RUMPED SWALLOW	*Hirundo daurica*	Sallying-insectivore	IS	I
203	**RED-THROATED FLYCATCHER**	*Ficedula parva*	Understorey-insectivore	IU	I
204	**RED-VENTED BULBUL**	*Pycnonotus cafer*	Fruit-seed-nectar-insectivore	FSNI	O
205	**RED-WATTLED LAPWING**	*Vanellus indicus*	Ground-insectivore	IG	I
206	RIVER LAPWING	*Vanellus duvaucelii*	Water-insectivore	IW	I
207	ROCK BUNTING	*Emberiza cia*	Understorey-insectivore	IU	I
208	ROCK PIGEON	*Columba livia*	Granivore	G	P
209	**ROSE-RINGED PARAKEET**	*Psittacula krameri*	Fruit-seed-nectar	FSN	P
210	**ROSY MINIVET**	*Pericrocotus roseus*	Canopy-insectivore	IC	I
211	**RUFOUS BELLIED NILTAVA**	*Niltava sundara*	Understorey-insectivore	IU	I
212	RUFOUS SIBIA	*Heterophasia capistrata*	Canopy-insectivore	IC	I
213	**RUFOUS TREEPIE**	*Dendrocitta vagabunda*	Omnivore	O	O
214	**RUFOUS-CHINNED LAUGHINGTHRUSH**	*Garrulax rufogularis*	Understorey-insectivore	IU	I
215	**RUFOUS-GORGETED FLYCATCHER**	*ficedula strophiata*	Understorey-insectivore	IU	I
216	RUSSET SPARROW	*Passer rutilans*	Granivore	G	P
217	**RUSTY-CHEEKED SCIMITAR BABBLER**	*Pomatorhinus erythrogenys*	Understorey-insectivore	IU	I
218	SAVANNA NIGHTJAR	*Caprimulgus affinis*	Sallying-insectivore	IS	I
219	**SCALY THRUSH**	*Zoothera dauma*	Understorey-insectivore	IU	I
220	**SCALY-BREASTED MUNIA**	*Lonchura punctulata*	Granivore	G	P
221	**SCALY-BREASTED WREN BABBLER**	*Pnoepyga albiventer*	Understorey-insectivore	IU	I
222	SCARLET MINIVET	*Pericrocotus flammeus*	Canopy-insectivore	IC	I
223	**SHIKRA**	*Accipiter badius*	Raptor	R	I
224	SHORT-TOED SNAKE EAGLE	*Circaetus gallicus*	Raptor	R	O
225	**SLATY-BLUE FLYCATCHER**	*Ficedula tricolor*	Understorey-insectivore	IU	I
226	**SLATY-HEADED PARAKEET**	*Psittacula himalayana*	Fruit-seed-nectar	FSN	P

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
227	SMALL BUTTONQUAIL	*Turnix sylvatica*	Understorey-insectivore	IU	I
228	**SMALL MINIVET**	*Pericrocotus cinnamomeus*	Canopy-insectivore	IC	I
229	SMALL NILTAVA	*Niltava macgrigoriae*	Understorey-insectivore	IU	I
230	**SNOWY-BROWED FLYCATCHER**	*Ficedula hyperythra*	Understorey-insectivore	IU	I
231	**SPANGLED DRONGO**	*Dicrurus hottentottus*	Nectar-insectivore	NI	P
232	**SPECKLED PICULET**	*Picumnus innominatus*	Trunk/bark feeder	TBF	I
233	**SPOTTED DOVE**	*Streptopclia senegalensis*	Granivore	G	P
234	SPOTTED OWLET	*Athene brama*	Raptor	R	I
235	SPOT-WINGED STARLING	*Saroglossa spiloptera*	Fruit-seed-nectar-insectivore	FSNI	P
236	SPOT-WINGED TIT	*Parus melanolophus*	Trunk/bark feeder	TBF	I
237	STREAK-THROATED SWALLOW	*Hirundo fluvicola*	Sallying-insectivore	IS	I
238	STREAK-THROATED WOODPECKER	*Picus xanthopygaeus*	Trunk/bark feeder	TBF	I
239	STRIATED LAUGHINGTHRUSH	*Garrulax striatus*	Understorey-insectivore	IU	I
240	**SULPHUR-BELLIED WARBLER**	*Phylloscopus griseolus*	Understorey-insectivore	IU	I
241	**THICK-BILLED FLOWERPECKER**	*Dicaeum agile*	Nectar-insectivore	NI	P
242	TICKELL'S BLUE FLYCATCHER	*Cyornis tickelliae*	Sallying-insectivore	IS	I
243	TICKELL'S LEAF WARBLER	*Phylloscopus affinis*	Canopy-insectivore	IC	I
244	**TICKELL'S THRUSH**	*Turdus unicolor*	Understorey-insectivore	IU	I
245	TREE PIPIT	*Anthus trivialis*	Ground-insectivore	IG	I
246	ULTRAMARINE FLYCATCHER	*Ficedula superciliaris*	Sallying-insectivore	IS	I
247	**VELVET-FRONTED NUTHATCH**	*Sitta frontalis*	Trunk/bark feeder	TBF	I
248	**VERDITER FLYCATCHER**	*Eumyias thalassina*	Sallying-insectivore	IS	I
249	WALLCREEPER	*Tichodroma muraria*	Trunk/bark feeder	TBF	I
250	WEDGE-TAILED GREEN PIGEON	*Treron sphenura*	Obligate-frugivore	F	P
251	**WESTERN CROWNED WARBLER**	*Phylloscopus occipitalis*	Canopy-insectivore	IC	I
252	WHISKERED YUHINA	*Yuhina flavicollis*	Canopy-insectivore	IC	I
253	**WHISTLER'S WARBLER**	*Seicercus whistleri.*	Understorey-insectivore	IU	I
254	**WHITE RUMPED SHAMA**	*Copsychus malabaricus*	Understorey-insectivore	IU	I
255	WHITE WAGTAIL	*Motacilla alba*	Ground-insectivore	IG	I

S No	NAME	Scientific Name	Fine Guilds	Fine Guilds codes	Basic guilds codes *
256	WHITE-BELLIED DRONGO	*Dicrurus caerulescens*	Sallying-insectivore	IS	I
257	WHITE-BREASTED WATERHEN	*Amaurornis phoenicurus*	Water-insectivore	IW	I
258	WHITE-BROWED FANTAIL	*Rhipidura aureola*	Sallying-insectivore	IS	I
259	**WHITE-BROWED SCIMITAR BABBLER**	*Pomatorhinus schisticeps*	Understorey-insectivore	IU	I
260	WHITE-BROWED WAGTAIL	*Motacilla maderaspatensis*	Ground-insectivore	IG	I
261	**WHITE-CAPPED BUNTING**	*Emberiza stewarti*	Granivore	G	P
262	WHITE-CAPPED WATER REDSTART	*Chaimarrornis leucocephalus*	Water-insectivore	IW	I
263	**WHITE-CRESTED LAUGHINGTHRUSH**	*Garrulax leucolophus*	Understorey-insectivore	IU	I
264	WHITE-EYED BUZZARD	*Butastur teesa*	Raptor	R	I
265	WHITE-RUMPED VULTURE	*Gyps bengalensis*	Raptor	R	O
266	WHITE-TAILED RUBYTHROAT	*Luscinia pectoralis*	Understorey-insectivore	IU	I
267	**WHITE-THROATED FANTAIL**	*Rhipidura albicollis*	Sallying-insectivore	IS	I
268	**WHITE-THROATED KINGFISHER**	*Halcyon smyrnensis*	Sallying-insectivore	IS	I
269	WIRE-TAILED SWALLOW	*Hirundo smithii*	Sallying-insectivore	IS	I
270	YELLOW WAGTAIL	*Motacilla flava*	Ground-insectivore	IG	I
271	**YELLOW-BELLIED FANTAIL**	*Rhipidura hypoxantha*	Sallying-insectivore	IS	I
272	YELLOW-BREASTED GREENFINCH	*Carduelis spinoides*	Granivore	G	P
273	**YELLOW-EYED BABBLER**	*Chrysomma sinense*	Understorey-insectivore	IU	I
274	**YELLOW-FOOTED GREEN PIGEON**	*Treron phoenicoptera*	Obligate-frugivore	F	P
275	YELLOW-WATTLED LAPWING	*Vanellus malarbaricus*	Ground-insectivore	IG	I
276	ZITTING CISTICOLA	*Cisticola juncidis*	Understorey-insectivore	IU	I

*** Basic guild codes: I:Insectivorous; P:Phytohagous; O:Omnivorous**

Appendix 13

Pearson's *Correlation* between BSD, BSR and Bird density and habitat parameters (only variables showing significant correlations in at least one habitat included)

WINTER SEASON

Winters		CANOPY	NOTREE	BASALAR	NOSNAG	NOSHRUB	SHCOV	SHDIV	TRHTDIV	CANTOP	FHDTRSH
All	BSD	**-0.36**	-0.33	**-0.39***	**-0.54****	-0.2	0.05	-0.24	-0.24	-0.17	-0.33
N=30	BSR	-0.44	-0.19	0.23	0	-0.1	0.01	-0.05	-0.11	**-0.53****	**-0.42***
	DENS_WIN	-0.33	0.06	**0.36***	**0.37***	0	0.03	0.11	0.06	**-0.7****	**-0.38***
Chir	BSD	-0.35	-0.5	-0.5	0.19	0.03	-0.3	-0.25	**0.71***	-0.39	0.09
N=11	BSR	0.02	-0.29	-0.15	0.58	**0.62***	0.22	0.31	**0.68***	-0.31	0.2
	DENS_WIN	-0.02	-0.26	-0.35	0.53	0.52	0.37	0.09	0.53	-0.44	-0.14
Garden	BSD	-0.47	-0.04	-0.06		-0.17	-0.17	-0.12	-0.41	-0.74	-0.76
N=6	BSR	-0.37	0.19	0.24		0.02	0.03	0.18	-0.12	-0.57	-0.53
	DENS_WIN	-0.56	-0.09	-0.1		-0.19	-0.19	-0.15	-0.3	**-0.88***	-0.61
Mixed	BSD	-0.12	-0.02	-0.65	-0.44	0.34	0.36	-0.16	0.28	0.33	-0.15
N=7	BSR	0.19	0.45	0.67	0.5	0.05	0.18	**0.9****	0.68	0.1	0.6
	DENS_WIN	0.43	0.46	0.78	0.63	0.1	-0.01	0.74	0.38	-0.3	0.48
Natural	BSD	0.42	-0.7	-0.34	0.2	-0.21	**0.84***	-0.31	0.31	-0.02	-0.23
N=6	BSR	-0.08	-0.63	-0.08	-0.21	-0.57	0.48	-0.75	-0.13	-0.44	-0.33
	DENS_WIN	0.02	**-0.85***	-0.65	0.33	-0.59	0.57	-0.42	0.46	0.14	0.24

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

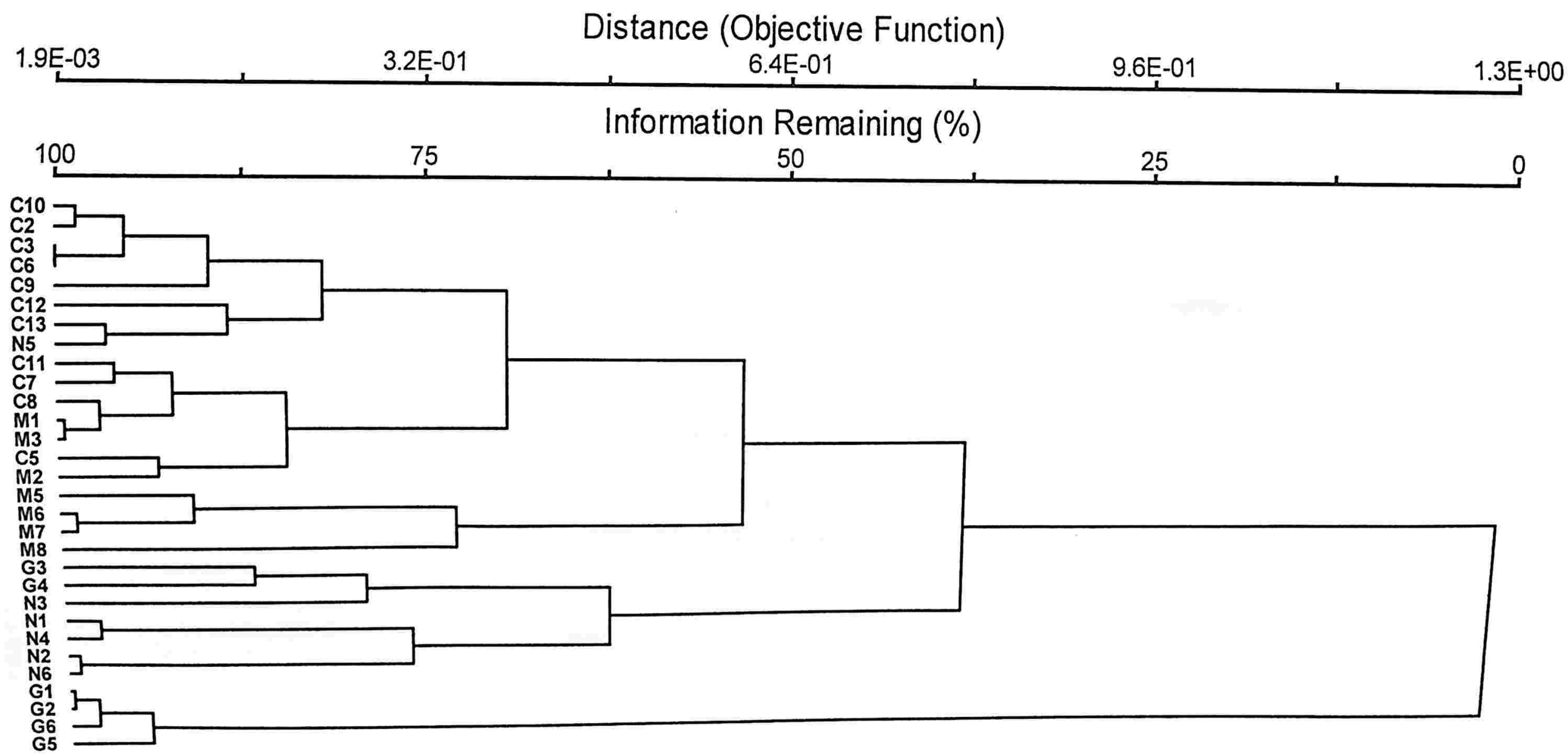
SUMMER SEASON

Summers		CANOPY	NOTREE	TREEDIV	NOSHRUB	SHCOV	TRHTDIV	CANTOP	VERCSP	FHDTRSH
All	BSD	0.08	0.35	0.31	0.19	**0.57****	**0.38***	-0.28	**-0.43***	-0.11
N=30	BSR	-0.34	0.06	-0.04	-0.15	0.14	-0.06	**-0.67****	-0.35	**-0.54****
	DENS_SUM	**-0.36***	0.1	0.02	-0.06	0.33	-0.02	**-0.53****	**-0.42***	**-0.41***
Chir	BSD	-0.46	0.18	-0.35	-0.25	**0.78****	0.05	-0.36	**-0.77****	**-0.66***
N=11	BSR	-0.22	-0.12	-0.56	-0.23	**0.74****	-0.09	-0.17	**-0.63***	-0.58
	DENS_SUM	0.05	-0.11	-0.59	-0.1	**0.7***	-0.17	-0.13	**-0.59***	**-0.62***
Garden	BSD	-0.02	**0.87***	0.32	-0.12	-0.04	0.54	-0.01	0.23	0.14
N=6	BSR	0	0.61	-0.08	-0.57	-0.52	0.09	-0.14	-0.29	-0.19
	DENS_SUM	-0.74	0.2	-0.29	-0.62	-0.6	-0.32	-0.76	-0.54	-0.63
Mixed	BSD	0.63	0.45	0.04	0.54	0.53	0.49	-0.03	0.21	0.69
N=7	BSR	0.01	0.35	-0.42	0.19	0.67	0.43	0.52	-0.03	0.78
	DENS_SUM	-0.43	-0.77	-0.35	-0.61	-0.55	-0.72	0.01	-0.26	-0.61
Natural	BSD	0.79	-0.32	**0.92****	0.59	0.51	0.46	0.33	-0.22	-0.13
N=6	BSR	0.61	0.4	0.61	**0.94****	-0.06	0.11	0.31	-0.54	-0.15
	DENS_SUM	0.01	-0.55	0.4	-0.37	0.29	0.47	0.06	0.11	0.28

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

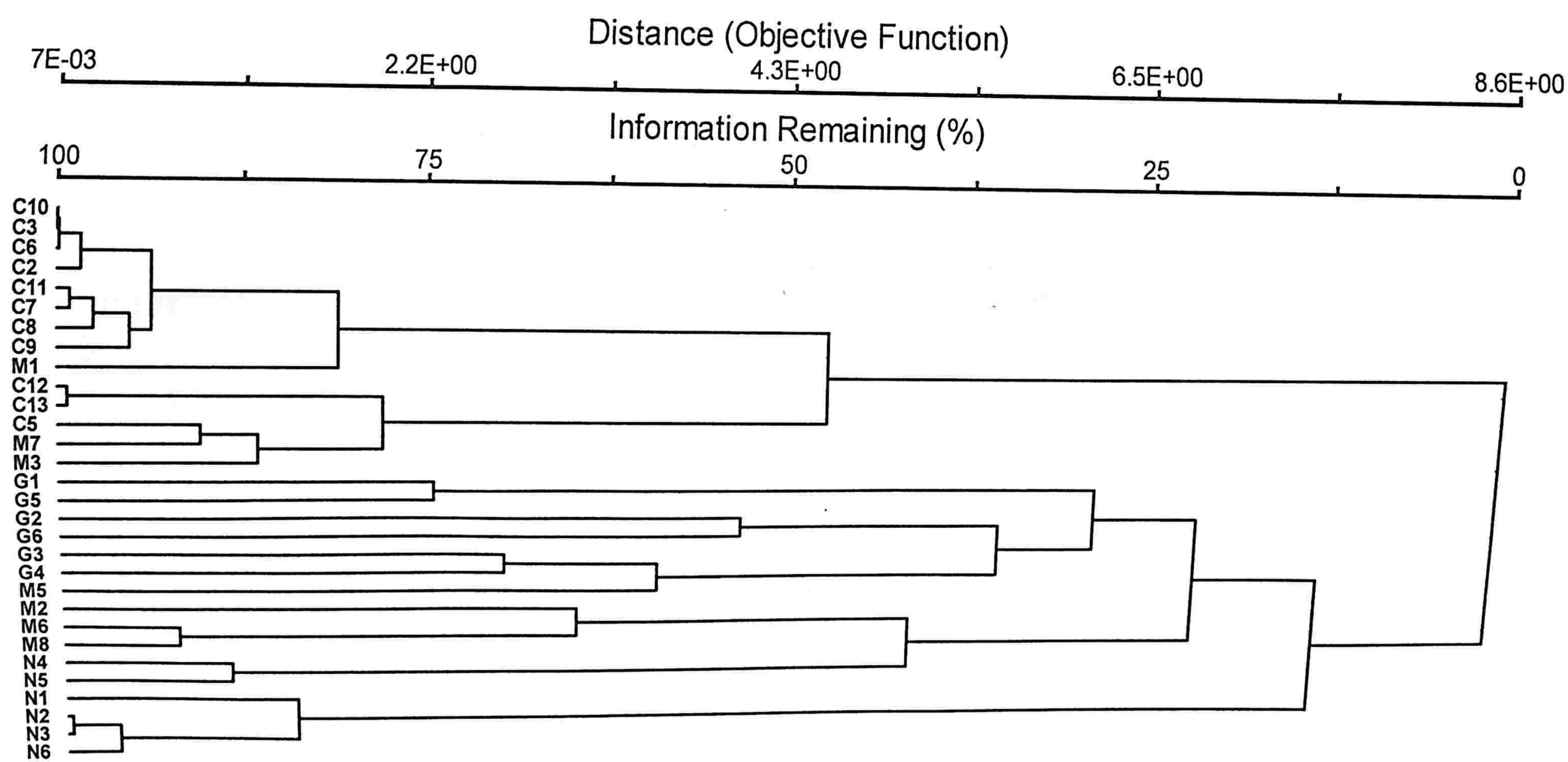
Appendix 14a

Cluster dendrogram of sample plots based on vegetation structure



Appendix 14b

Cluster dendrogram of sample plots based on tree composition



Densities of 20 commonest bird species in New Forest **Appendix 15**

SUMMER SEASON

Name	Summer density birds/ha.	Sum Rank	Win Rank
ORIENTAL WHITE-EYE	4.755	1	2
GREY-BREASTED PRINIA	3.545	2	13
HIMALAYAN BULBUL	3.318	3	4
JUNGLE BABBLER	2.521	4	12
PUFF-THROATED BABBLER	1.999	5	16
RED-VENTED BULBUL	1.992	6	36
BLACK-CHINNED BABBLER	1.823	7	14
ORIENTAL MAGPIE ROBIN	1.803	8	67
SPANGLED DRONGO	1.773	9	8
GREENISH WARBLER	1.546	10	0*
GREAT TIT	1.523	11	5
PLUM-HEADED PARAKEET	1.493	12	11
SPOTTED DOVE	1.256	13	73
JUNGLE MYNA	1.066	14	0*
CRIMSON SUNBIRD	1.015	15	22
CHESTNUT-TAILED STARLING	0.755	16	0*
COMMON MYNA	0.75	17	44
COMMON TAILORBIRD	0.685	18	23
BLYTH'S REED WARBLER	0.683	19	82
PURPLE SUNBIRD	0.68	20	78
TOTAL DENSITY SUMMER (all obs. sp.)	**45.193**		

WINTER SEASON

Name	Winter density birds/ha.	Win Rank	Sum Rank
BLACK BULBUL	4.428	1	0*
ORIENTAL WHITE-EYE	3.698	2	1
SLATY-HEADED PARAKEET	2.526	3	22
HIMALAYAN BULBUL	1.665	4	3
GREAT TIT	1.636	5	11
GREY-HOODED WARBLER	1.17	6	0*
GREY TREEPIE	1.078	7	23
SPANGLED DRONGO	1.039	8	9
HUME'S WARBLER	1.03	9	25
LONG-TAILED MINIVET	0.998	10	0*
PLUM-HEADED PARAKEET	0.995	11	12
JUNGLE BABBLER	0.979	12	4
GREY-BREASTED PRINIA	0.916	13	2
BLACK-CHINNED BABBLER	0.884	14	7
ROSE-RINGED PARAKEET	0.709	15	26
PUFF-THROATED BABBLER	0.689	16	5
FLOWERPECKER	0.611	17	41
GOLDEN-SPECTACLED WARBLER	0.576	18	51
GREY-HEADED CANARY FLYCATCHER	0.541	19	0*
LEMON-RUMPED WARBLER	0.499	20	0*
TOTAL DENSITY WINTER (all obs. sp.)	**33.962**		

* Rank indicates that the species was not recorded in that season

Appendix 16

Flowering and fruiting in the woody vegetation in New Forest

Num code	Code	Species	Habit	Flowering		Useful fruiting	
				Win	Sum	Win	Sum
1	ACCA	*Acacia catechu*	T	0	1	0	0
2	ACCO CL	*Acacia pennata*	C	0	2	0	0
3	ACFR	*Acrocarpus fraxinifolius*	T	3	0	0	0
4	AEMA	*Aegle marmelos*	T	0	1	0	0
5	ALBZ	*Albizzia sp.*	T	0	3	0	0
6	ALCH	*Alangium chinensis*	T	0	3	0	0
7	ALPR	*Albizzia procera*	T	0	0	0	0
8	ALSC	*Alstonia scholaris*	T	3	0	0	0
9	ANCA	*Anthocephalus cadamba*	T	0	3	3	1
10	BAMB	*Bamboo sp.*	B	0	0	0	0
11	BAVA	*Bauhinia varigeta*	T	1	2	0	0
12	BOCI	*Bombax cieba*	T	3	0	0	0
13	BRPA	*Brossonetia papyrifera*	T	3	0	0	5
14	CANO	*Cassia nodosa*	T	0	2	0	0
15	CAUR	*Caryota urens*	T	0	0	0	0
16	CAVI	*Callistemon viminalis*	T	2	3	0	0
17	CEAS	*Ceasalpenia sp.*	C	2	0	0	0
18	CHSW	*Chloroxylon swetenia*	T	0	2	0	0
19	CICA	*Cinnamom camphora*	T	0	0	3	0
20	CITRSP	*Citrus sp.*	T	0	1	0	0
21	CL	*Climber unidentified*	C	0	0	0	0
22	CUJA	*Cudrenia javanica*	C	0	2	3	0
23	CUTO	*Cupressus torulosa*	T	0	0	0	0
24	DALA	*Dalbergia latifolia*	T	0	2	2	0
25	DASI	*Dalbergia sissoo*	T	0	3	3	0
26	DERE	*Delonix regia*	T	0	3	0	0
27	DIBU	*Diplocnema butyrassea*	T	3	0	0	1
28	DYEM	*Dyospyros embryopteris*	T	0	1	0	1
29	EUTO	*Eucalyptus toreleana*	T	2	0	0	0
30	FICUS	*Ficus sp.*	T	0	2	0	2
31	FLIN	*Flacourtia indica*	T	1	0	2	2
32	GAPI	*Garuga pinnata*	T	1	0	0	2
33	GMAR	*Gmelina arborea*	T	1	2	0	3
34	HETR	*Heynea trijuga*	T	1	2	0	3
35	HOAN	*Holarrhena antidysentrica*	T	0	2	0	0
36	HODU	*Hovenia dulcis*	T	0	2	0	0
37	LACO	*Lannea coromendalica*	T	0	1	0	2
38	LAFL	*Lagerstroemia flosreginae*	T	0	3	0	0
39	LIMO	*Litsea monopetala*	T	1	3	0	0
40	LITSP	*Litsea sp.*	T	0	0	0	0
41	LITUN	*Litsea unbullata*	T	0	2	0	0
42	MAHE	*Manilkara hexandara*	T	0	2	0	0
43	MAIN	*Mangifera indica*	T	1	0	0	2
44	MAPH	*Mallotus phillipensis*	T	0	0	0	0
45	MAPL	*Markhamia platycalyx*	T	0	3	0	0
46	MATO	*Macaranga tomentosa*	T	0	0	0	0

Num code	Code	Species	Habit	Flowering		Useful fruiting	
				Win	Sum	Win	Sum
47	MEAZ	*Melia azaderach*	T	0	2	4	0
48	MICH	*Michelia champaca*	T	0	3	3	0
49	MIVE	*Miliusa velutina*	T	0	2	0	2
50	MOAL	*Morus alba*	T	0	2	0	2
51	ORIN	*Oroxylum indicum*	T	2	0	0	0
52	PEPT	*Peltophorum pterocarpum*	T	0	0	0	1
53	PICA	*Pinus carribea*	T	0	0	0	0
54	PIRO	*Pinus roxburghii*	T	0	0	2	0
55	PISP	*Pinus sp.*	T	0	0	1	0
56	PRSP	*Prunus sp.*	T	3	3	0	0
57	PYPA	*Pyrus pashia*	T	0	2	4	0
58	SAAL	*Santalum album*	T	1	3	3	1
59	SAIN	*Sapium insigne*	T	2	0	0	1
60	SHRO	*Shorea robusta*	T	0	1	0	2
61	SYCU	*Sygigium cumini*	T	0	2	0	3
62	TEGR	*Tectona grandis*	T	0	0	2	0
63	XYLO	*Xylosma longifolia*	T	3	0	0	2

Scale of 0 to 5 based on amount and period of flowering or fruiting within a season

Habit code

T *Tree*
C *Climber*
B *Bamboo*

Season	Period
Winter	mid Oct to mid March
Summer	April to June

Appendix V

Codes of certain bird species used in Figure 4.2

Abbreviations	NAME	Scientific Name
SHPK	SLATY-HEADED PARAKEET	*Psittacula himalayana*
BB	BLACK BULBUL	*Hypsipetes leucocephalus*
JB	JUNGLE BABBLER	*Turdoides striatus*
SM	SMALL MINIVET	*Pericrocotus cinnamomeus*
YEB	YELLOW-EYED BABBLER	*Chrysomma sinense*
RBL	RED-BILLED LEIOTHRIX	*Leiothrix lutea*
LTM	LONG-TAILED MINIVET	*Pericrocotus ethologus*
OTD	ORIENTAL TURTLE DOVE	*Streptopelia orientalis*
BWFS	BAR-WINGED FLYCATCHER-SHRIKE	*Hemipus picatus*
PHPK	PLUM-HEADED PARAKEET	*Psittacula cyanocephala*
OWE	ORIENTAL WHITE-EYE	*Zosterops palpebrosus*
OBP	OLIVE-BACKED PIPIT	*Anthus hodgsoni*
GBP	GREY-BREASTED PRINIA	*Prinia hodgsonii*
APK	ALEXANDRINE PARAKEET	*Psittacula eupatria*
HCD	SPANGLED DRONGO	*Dicrurus hottentottus*
BCB	BLACK-CHINNED BABBLER	*Stachyris pyrrhops*
HB	HIMALAYAN BULBUL	*Pycnonotus leucogenys*
RRPK	ROSE-RINGED PARAKEET	*Psittacula krameri*
RCLT	RUFOUS-CHINNED LAUGHINGTHRUSH	*Garrulax rufogularis*
CR	COMMON ROSEFINCH	*Carpodacus erythrinus*
GBE	GREEN BEE-EATER	*Merops orientalis*
RBBM	RED-BILLED BLUE MAGPIE	*Urocissa erythrorhyncha*
RVB	RED-VENTED BULBUL	*Pycnonotus cafer*

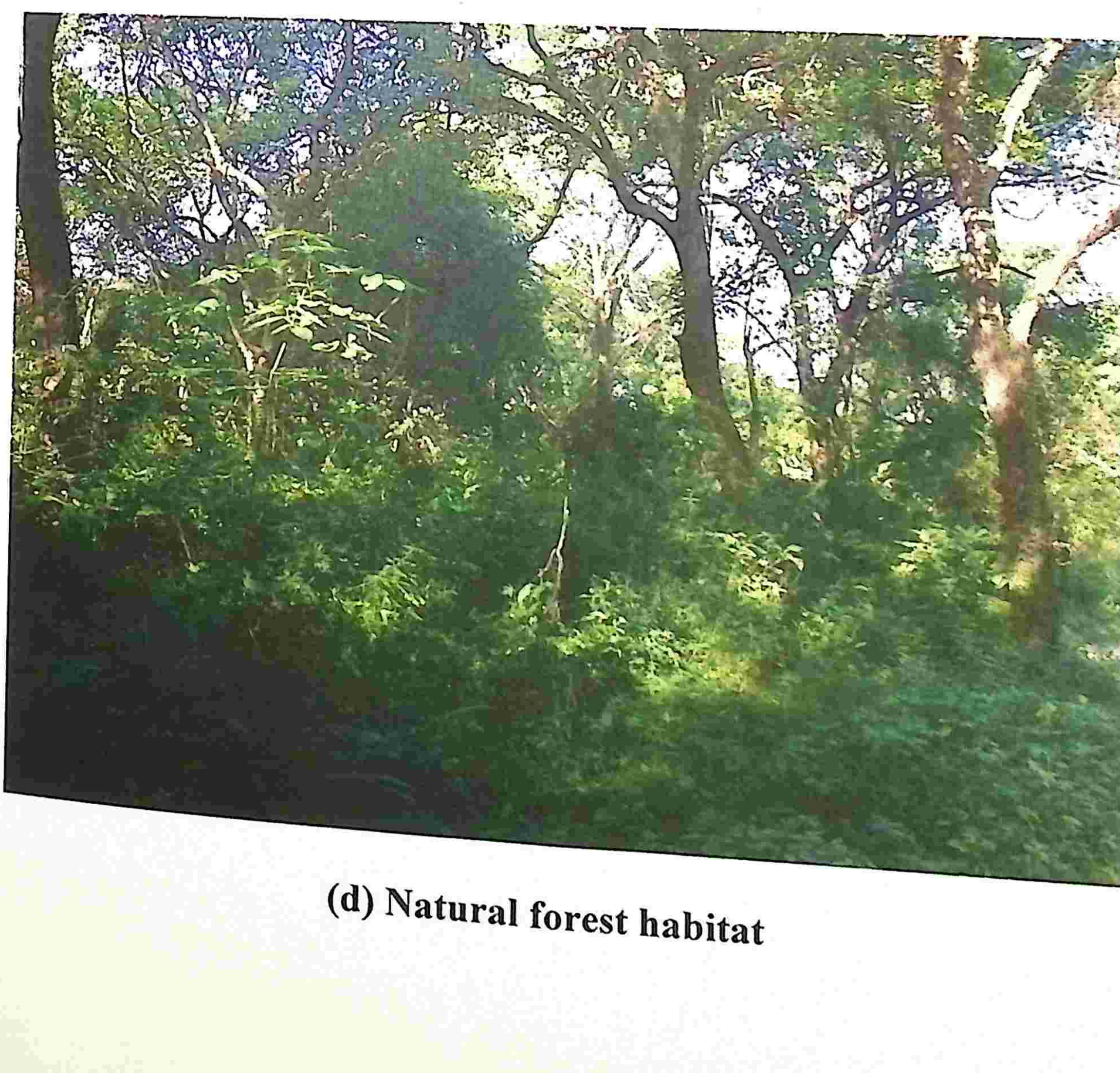
Appendi

Photographs of the habitats of New Forest

(a) Chir Pine plantation habitat

(b) Garden habitat

(c) Mixed plantation habitat



(d) Natural forest habitat