FACTORS ASSOCIATED WITH DIVERSITY OF BIRDS IN CHANDRAGIRI AND NAGARGUN FORESTS OF KATHMANDU

SAMIKSHA SAPKOTA 2020/02/12

T.U. Registration No.: 5-2-33-195-2011

T.U Examination Roll No.: 446/2073

Batch: 2073/2074

A thesis submitted in partial fulfillment of the requirements for the award of degree of the Master of Science in Zoology with special paper Ecology and Environment

Submitted to

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu

Nepal

August 2020

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the authors.

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RECOMMENDATIONS

This is to recommend that the thesis entitled "**FACTORS ASSOCIATED WITH DIVERSITY OF BIRDS IN CHANDRAGIRI AND NAGARJUN FORESTS OF KATHMANDU, NEPAL**" has been carried out by Ms. Samiksha Sapkota for partial fulfillment of the requirement for master's degree in Zoology with the special paper of Ecology. This is her original work and has been carried out under my supervision. To the best of my knowledge, this work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor Asst. Prof. Dr. Bishnu Prasad Bhattarai, Central Department of Zoology, Tribhuvan University, the thesis submitted by Ms. Samiksha Sapkota entitled "**Factors associated with diversity of birds in Chandragiri and Nagarjun forests of Kathmandu**" is approved for the examination in partial fulfillment of the requirement for the Master's Degree of Science in Zoology with special paper Ecology and Environment.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Ms. Samiksha Sapkota entitled "**FACTORS ASSOCIATED WITH DIVERSITY OF BIRDS IN CHANDRAGIRI AND NAGARJUN FOREST OF KATHMANDU, NEPAL** " has been accepted as a partial fulfillment for the requirement of master's degree of Science in Zoology with special paper Ecology.

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ACKNOWLEDGEMENTS

Foremost, I would like to express my heartfelt gratitude and indebtedness to my honorable supervisor Asst. Prof. Dr. Bishnu Prasad Bhattarai, Central Department of Zoology (Ecology) for his guidance, immense help, valuable suggestions, information and knowledge regarding the subject matters. This thesis would not have taken its present shape and quality without his untiring efforts.

My sincere thanks and gratitude are due to Prof. Tej Bahadur Thapa, PhD, Head of the Central Department of Zoology for providing administrative support and facilities. I am highly obliged and extend my thanks to all of my respect teachers and staffs of the Central Department of Zoology, TU, Kirtipur.

I am thankful to Department of National parks and Wildlife Conservation (DPNWC) and Ministry of Forest and Soil Conservation for research permission.

I am thankful to my friends Juna Neupane, Basanta Gyawali, Shruti Shakya and Nabina Kunwar for their immense help and assistance during field data collection.

I too extend my heartfelt gratitude to my guardians who supported economically, encouraged me throughout the time and during field work. I am very much grateful to all people who encouraged for my study and all my friends for their direct and indirect help in completing this work.

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ABSTRACT

Comparative study of the avian diversity is important to understand the variation in species richness and associated factors in two forest sites (Protected and Unprotected area) of Kathmandu valley. This study aimed to explore the bird diversity, variation in two different sites and associated factors in Chandragiri and Nagarjun Forests of Kathmandu. Bird survey was carried out from April 2 to June 2, 2019, in both sites. Point count method was used with a total of six birding routes were, three in each site, observed in eight circular plots at an interval of 100 m elevation, each with a 50 m radius from the fixed point in a center, for 15 minutes. A total of 24-point count locations were set up in both study area. Data on environmental variables like elevation and habitat types were collected as well as distance to road and distance to human settlement were also estimated in the field. All the collected data were analyzed by using Microsoft excel 2016, PAST software and CANOCO 4.56. Species richness was higher in Nagarjun forest, a protected forest patch of Shivapuri-Nagarjun National Park as compared to Chandragiri forests. Shannon Wiener diversity index (Nagarjun forest, H'=3.841 and Chandragiri forest, H'=3.851 indicated slightly diverse bird assemblage in Chandragiri forest in comparison to Nagarjun forest. Analysis of variation T-test showed statistically insignificant variation (T stat= 0.366) in species richness in two sites during the study period. Decline in species richness along elevation was illustrated as a pattern of diversity (Chandragiri forest, $P < 0.001$ and Nagarjun forest, $P < 0.001$). GLMs illustrated that the species richness was negatively associated with distance to road and distance to human settlement, indicating reverse pattern with more species near roadsides and settlement area. Likewise, Canonical Correspondence analysis (Monte Carlo significance test with 499 permutations) showed that among different habitat types the species distribution and richness was strongly associated with forest habitat, highly in more open forest stands, followed by agricultural land and human settlement area. Study on avian fauna with their association with additional factors is needed in coming future. Comparison between two sites requires detailed and extensive survey to figure out the variation and to implement necessary measures in conservation of species both inside and outside the protected area.

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LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
asl	Above sea level
BCN	Bird Conservation Nepal
GLM	Generalized Linear Model
IUCN	International Union for Conservation of Nature
m	Meter
SNNP	Shivapuri Nagarjun National Park
SSI	Sorenson's Similarity Index
DNPWC	Department of National Parks and Wildlife Conservation
CITES	Convention on International Trade in Endangered Species
ICIMOD	International Centre for Integrated Mountain Development
CCA	Canonical Correspondence Analysis

1. INTRODUCTION

1.1 Background

Birds are important part of ecosystem and plays key role in food chain. For example: they eat insects, pollinate plants and disperse seed (Paulsch & Muller-Hohenstein 2008). Birds are some of the most prominent species of the Earth's biodiversity and acts as key indicators for assessing the status of ecosystem health as they are sensitive to environmental changes (Taper et al. 1995). Nepal, the Himalayan country is rich in landscape heterogeneity that supports diverse flora and fauna, including 8.87% of the global bird species and total of 887 species has been recorded from Nepal (DNPWC 2018). Diverse avian fauna of Nepal is attributed to complex physiographic and bioclimatic zonation; and also because of its location at the convergence of the Palaerctic and the Oriental zoogeography realms (Inskipp 1991). Nepal is of great value for birds, particularly, a total of 35 globally threatened species, 19 near threatened species and 15 restricted range species are recorded in Nepal (Bird Conservation Nepal 2018). Nine species; Himalayan monal, Cheer pheasant, Satyr tragopan, Bengal florican, Lesser florican, Great hornbill, Sarus crane, Black stork and White stork are protected birds of Nepal by National Park and Wildlife Conservation Act (NPWC) 1973. Spiny babbler (*Turdoides nipalensis)* is only one endemic bird in Nepal (Inskipp et al. 2016). The order Passeriformes has the highest representation among the bird species (465 spp.), followed by Chradriiformes (68 spp.), Falconiformes (59 spp.), Piciformes (33 spp.), Anseriformes (33 spp.), Ciconiformes (27 spp.), Galliformes (21 spp.), Columbiformes (33 spp.) etc (Shrestha 2016, Inskipp et al. 2008).

Birds are the good indicator of the quality of forest habitat as they respond to habitat structure (MacArthur & MacArthur 1961) and thus can guide management at regional and landscape levels (Canterbury et al. 2000). Birds occupy almost all habitat types and major habitat for Nepal's bird consists of forest, wetland and grassland. Forest is the most significant habitat for birds for supporting around 77% of all bird species (Bird Life international 2016). Over half (53%) of Nepal's nationally threatened birds inhabits in forests, 27% in wetlands, 15% in grasslands, eight percent in cultivated land, five percent in shrub, nine percent in open canopy, three percent near human habitation and one percent in semi-desert areas (Inskipp et al. 2013). Distribution and species richness of birds are highly affected by temperature and precipitation and hence birds are also the indicator of climate change (Bibby 1999). Therefore, studying and understanding the diversity and

structure of bird communities is essential to delineate the importance of regional or local landscape for avian conservation (Kattan & Franco 2004).

The study of avifaunal diversity is an essential ecological tool, which acts as an important indicator to evaluate different habitats both qualitatively and quantitatively (James et al. 2017). Diversity as a whole includes species richness, abundance, and evenness of a particular area. Understanding patterns of diversity is important in conservation of species (Spackman & Hughs 1995). Bird communities separated by 1000 m elevation are different from one another mainly due to change in precipitation (Prince et al. 2003). Analysis of altitudinal changes in diversity, abundance and species composition of biota can provide important information on such phenomena as aspects of environmental limiting the distribution of organisms, factor influencing the structure of communities and aspects of biogeography (Adolfo 1992).

Grasslands, wetlands, and forests not only provide feeding and breeding sites for a large number of threatened birds, mammals, reptiles, amphibians, fish, and invertebrates but also play a vital role in their conservation and in meeting the needs of the local people residing near those areas (Adhikari et al. 2018). The distribution of birds in the Himalayan region is associated with climatic factors (temperature, precipitation, seasons, area of landmasses etc.) and various kinds of anthropogenic activities, such as forest encroachment, livestock grazing, over extraction of forest products, forest fires etc (Basnet et al. 2016). Thus, several anthropogenic impacts such as destruction and fragmentation of habitat areas, illegal hunting, trapping, chemical poisoning, use of pesticides, agricultural run-off, pollution from the households, industrial pollution, and overgrazing of domestic cattle have created a serious threat to the several birds and their habitat leading towards their extinction (Inskipp et al. 2016). Thus, due to the lack of knowledge of birds conservation, importance of birds in ecological functioning among the people the several of the birds including the threatened species are pushing more towards their extinction.

Studying diversity and distribution of along the elevation gradient can be very helpful in understanding biodiversity and also aids in conservation of that species (Hunter & Yonzon 1993). A general pattern of decline in species richness with an increase in elevation is widely accepted but the evidences show that there is a humped shaped dominant in such cases with maximum richness at a mid- elevation point (Herzog et al. 2005). The relationship between habitat heterogeneity and richness and relationship between local

species richness and that of regional pool has provided information about the maintenance of diversity at large spatial scale (White et al. 2010). Although Nepal has greatest variation in elevation anywhere in the world (i.e. 60 m – 8848.86 m), there are very few studies have been done in biodiversity and distribution of bird while it is well studied in Europe and America as compared with Asia (Hunter 1993).

1.2. Objectives of the study

General objective

The main objective of this research was to explore factors associated with diversity of birds in Chandragiri and Nagarjun forests of Kathmandu, Nepal.

Specific objectives

1. To investigate diversity of birds in Chandragiri and Nagarjun forests of Kathmandu valley.
2. To explore environmental and anthropogenic factors affecting bird diversity within the study area.

1.3 Rationale of the study

The aim of this study was to explore the factors affecting diversity of bird species in Chandragiri and Nagarjun forest of the Kathmandu valley. These areas are known for wide varieties of bird species. Information on comparative study on avian fauna of Chandragiri and Nagarjun forest are lacking even the study sites are very close to Kathmandu valley. Only little information from records of bird watchers, nature guide and some researchers are available. This study is essential to provide a checklist of bird species as well as investigate the variation in diversity between two study areas. Since avifauna plays an important role of food chain in ecological unit of nature, it is very important to know the diversity, migratory status and conservation status of avian fauna (Jeevan et al. 2013). Hence this study is essential to provide baseline data on bird diversity and factors that affects the bird diversity. Baseline survey and data are necessary for the conservation and management initiatives.

2. LITERATURE REVIEW

2.1 Bird Richness and Diversity

Bird species diversity and distributions along the landscape is not uniform (Bibby et al. 1992). Their patterns are strongly related to environmental factors (climatic condition, topography and habitats) and human interventions which determine bird species diversity and abundance (Rodríguez-Estrella 2007, Jankowiski et al. 2009).

Species richness of any area is related to its habitat, elevation, topography, latitude and climate (Lopez- Gonzalez et al. 2014). Hawkins et al. (2007) studied that climate was responsible for species richness pattern. Likewise, Mittelbach et al. (2001) suggested other factors like productivity, species area effect (Rahbek 1997), vegetation types (MacArthur et al. 1962) and temperatures (McCain 2007) as responsible for the patterns of diversity and richness. The pattern of bird distribution and abundance within a landscape are influenced by multiple factors that interact in space and time (Orians & Wittenberger 1991).

Adhikari et al. (2018) recorded 304 bird species belonging to 18 orders and 69 families including 59% residential, 8% summer visitors, 32% winter visitors and 1% vagrants in the Barandabhar corridor forest. Chaudhari et al. (2009) studied the avifaunal diversity of Khata corridor forest and found 141 bird species belonging to 12 orders and 43 families. Harisha and Hosetti (2009) studied the diversity of birds in Lakkavali range forest, Bhadra wildlife sanctuary, Western Ghat, India and found a total of 132 species of birds belonging to 34 families under 11 orders. Adolfo et al. (1998), were studied altitudinal distribution of birds in the Sierra Madre and concluded that species richness is highest at low elevation while declines with increasing elevation. In the Western Himalayan region of Himachal Pradesh, total of 332 species recorded in which maximum avifauna was observed in pond wetland (73.60%), followed by Balh valley (59.32%) and Nalagarh areas (51.86%) of the Shiwalik zone whereas minimum diversity was seen in Kaza area (19.25%) of Trans-Himalayan region (Thakur 2013). According to Chetri et al. (2001), birds are habitat specific and there is trend of decrease in species richness of birds with the increasing elevation. Herzog et al. (2005) and Williams et al. (2009) concluded the hump shaped relationship between elevation and species richness in Neotropical birds and Australian wet tropical birds respectively.

Ruggiero and Hawkins (2008) showed that bird diversity gradient in mountains primarily reflect the local climatic gradient. Lowland has broad scale climatic patterns whereas mountain environment has mesoscale climatic variation which accounts for low species diversity comparing to lower elevations. The species richness is supposed to continuously decline with increase in elevation because of decreasing productivity due to decreasing in temperature (Rahbek 1995). As elevation increases, the availability of resources for birds diminishes reflecting differences in forest stand structure, site productivity, vegetation species composition, and disturbance patterns, secondary biotic interactions and available land area (Able & Noon 1976). Murgi (2007) studied the effects of seasonality on bird species in urban parks of Valencia (Spain) and found that bird richness became higher during breeding period i.e. in spring and summer than in the winter season due to the unfavorable climatic conditions, shortage of food and predation in winter season. Poudel (2005) observed higher number and diversity of birds in Kirtipur during winter season due to the suitable climatic condition in winter. Research done in Godavari forest concluded that species richness was the highest in winter and lowest in autumn due to the easy availability of food material and favorable climatic condition (Basnet 2010).

Rimal (2006) carried out a study in Shivapuri National Park on community structure and habitat association of birds and recorded 113 bird species from 25 families of 6 different orders, out of them 42 bird species were habitat specific, 23 species were restricted only in the undisturbed habitats. Katuwal et al. (2015) studied on Biodiversity of Chandragiri hill and recorded 137 species of bird. Basnet (2010) concluded that more species richness was found in moderately disturbed forest area than in highly disturbed one after analyzing the species richness and composition of breeding bird species along elevation gradients in central Nepal. Aryal (2013) studied on avian diversity along elevation and land use gradient in Ghunsa Valley of Kanchenjunga Conservation Area and concluded that the species richness was higher in natural forest followed by exploited forest, cultivated land and meadows. Malla (2006) studied the seasonal diversity, abundance and status of avifauna in Nagarjun Forest and found a total of 117 birds' species belonging to 12 orders and 37 families. Among them 76 were resident, 18 were winter visitors, 19 summer visitors and 4 of unknown status. Diversity index of birds resulted highest value during summer followed by winter, autumn and rainy season. Basnet (2006) studied species diversity, species richness and status of birds with seasonal variation and habitat types in six different habitat types in, out and around Godawari, south east of Kathmandu, altogether 161 species were

observed, belonging to 11 orders and 36 families. Shah (2000) studied seasonal variation of Taudaha lake and found highest numbers of birds in winter than in summer season.

Avian richness peaked at moderately disturbed sites (Robert 1996, Chettri et al. 2005). In contrast, species richness was relatively higher for natural forest than for other land use types (Palomino & Carrascal 2006, Waltert et al. 2004).

2.2 Factors affecting bird diversity

Goncalves and Sousa (2014) studied in Neo-tropical region and showed the climatic characteristics and complexity of the vegetation is strong determining factors for bird species distribution patterns in ecotone. Sousa et al. (2012) recorded 179 bird species in the Catimbau National park of Brazil and reported phyto-geographic heterogeneity and presence of aquatic habitats appear the main ecological factors determining the species richness. Habitat structure, floristic composition such as canopy cover, tree species diversity and distribution of specific plant taxa have significant role in defining the occurrence of species (Joshi et al. 2012). Ghimire (2009) reported the highest bird richness in Sal forest and lowest in mix forest in a study on seasonal diversity and habitat utilization of birds in BCF of Chitwan. Khanal (2008) concluded that species richness of birds was higher in agricultural farmland with wetland and lower in forest habitat while studying on seasonal diversity, status and habitat utilization of birds in a Nawalparasi forest in Nepal. Imai et al. (2017) studied on a traditional agricultural landscape in northern Japan and suggested that evenness of avian community increased in developed bush communities whereas some raptor species preferred an open forest understory.

Birds can be adversely impacted due to direct and indirect causes of habitat loss and degradation. Most of the causes are anthropogenic activities. Several of the direct causes includes timber and fuel wood extraction, infrastructure development, agricultural expansion or encroachment, livestock grazing, hunting and trade of wild birds and introduction of invasive species (BCN 2010). Human influence, through farming, cutting of forests, and urbanization, fragments the natural plant communities into smaller and smaller units. These activities affect not only the plant communities, but the animal communities as well (Adams 1994). Intensification of farming practices, over and excessive use of chemical compounds like pesticides and fertilizers, loss of crop diversity, destruction of grassland has degraded agricultural and semi-natural habitats leading to the

huge declines in biodiversity including the avian fauna (Birdlife International 2008). Roads contribute to biodiversity loss, both directly via animal mortality related to traffic (Bernard et al. 1987), and indirectly through the destruction and fragmentation of habitats (Meunier et al. 1999). Acharya et al. (2011) studied factors underlying in bird diversity in the Eastern Himalaya and found no evidence that geometric constraints influenced the bird species richness pattern, however actual evapotranspiration, plant species richness pattern, shrub density, basal area of trees, primary productivity and factors associated with habitat accounted for most of the variation in avian species richness. Basnet et al. (2016) identified main determinants of bird diversity and species composition of the bird communities in a Hilly region of Nepal in the central Himalayas and found that slope and habitat characteristics such as presence of forest edges and shrubs as important factors in driving species composition. Adhikari et al. (2019) studied on Chitwan National Park and found that the lower diversity of threatened bird was reported nearer to human settlements that experienced higher disturbance. They also reported that presence of livestock, people and distance from road and settlement negatively affects the species richness and abundance of birds. In contrast to this, Moller and Diaz (2017) studied on three small inlands in European cities and concluded that proximity to human habitation was a main driver of the distribution of birds, with most individuals and species tightly linked to inhabited houses.

By understanding the factors that influence the distribution of organisms, it becomes possible to use conservation tools necessary for the survival of endangered species of the geographical areas (Guisan & Zimmermann 2000). Availability of food, detectability and capture, location of nesting sites, availability of nesting materials, presence of predators and competitors are the major factors known to influence the population of birds (Wiens 1989).

3. MATERIALS AND METHODS

3.1 Study area

Chandragiri

Chandragiri lies in Mahabharat range forming a portion of southern western border between Kathmandu- Makawanpur and Kathmandu – Dhading districts. Chandragiri is located within 27°42’14.40" N latitude and 85°18'32.40" E longitude ranging from 1400 m to 2563 m in elevation. It lies in southwest corner of Kathmandu city and covers 65 km^2. It has temperate type of climate in high elevation with lower elevation of warm temperate semi-tropical climate. The hill contains both natural and reforested forest. Forest in Chandragiri can be categorized into four types: Pine forest, mixed broadleaved forest, evergreen oak forest and *Quercus semecarpifolio* forest (Kanai & Shakya 1970).

Nagarjun Forest

Nagarjun forest lies inside the Shivapuri Nagarjun National Park. The area covers 16 km^2 in the western part of National park and lies in northwest corner of Kathmandu. This forest is located within 27°43' to 27°46' N latitude and 85°13' to 85°18' E longitude. It lies at the boarder of Kathmandu, Dhading and Nuwakot Districts. It extends from base of Nagarjun forest (around 1350 m asl) to top of Nagarjun hill (2100 m asl). Nagarjun forest area is typical Mahabharat hill and bears mostly sub-tropical type of climate and partly temperate climate (Chaudhary 1998). Forests in Nagarjun can be categorized into four types: *Schima wallichii* forest, pine forest, mixed broadleaved forest (*Phoebe lanceolata, Machilus duthiei, Michelia kisopa* as major species) and dry oak forest (Kanai & Shakya 1970).

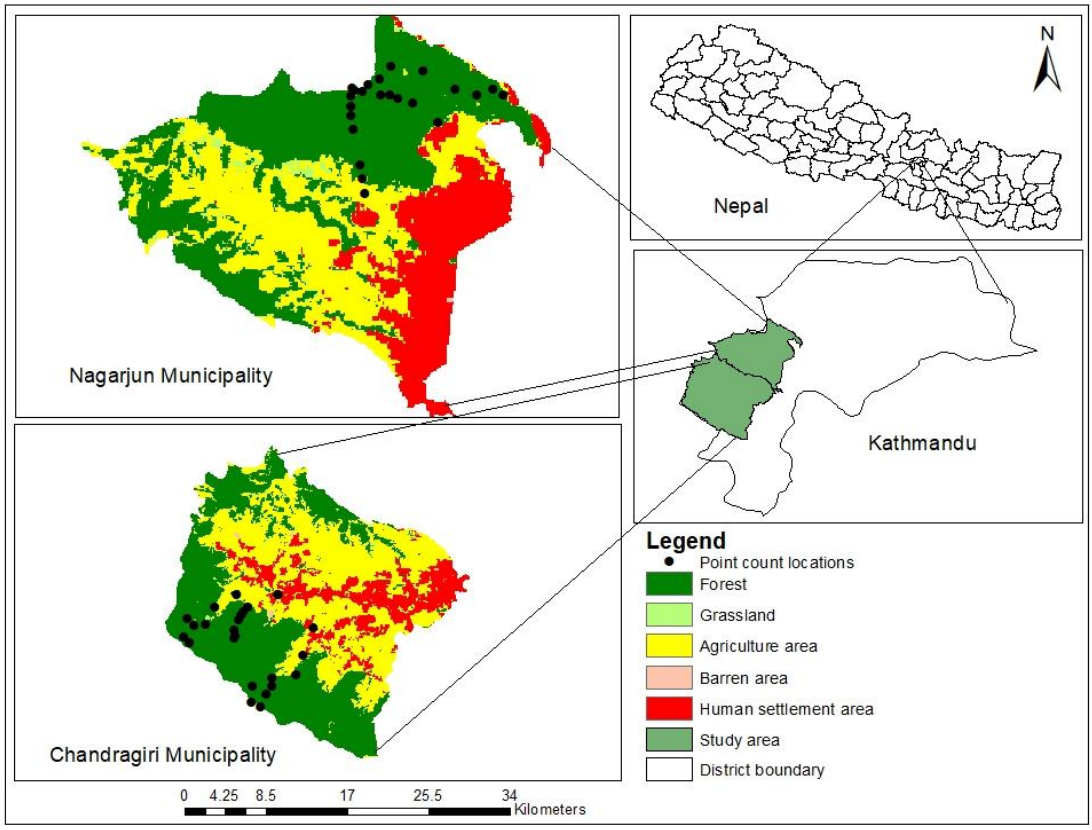


Figure 1: Map Showing Study Area

3.2 Materials

- GPS (Garmin eTrex® 10)
- Camera (Nikon 5300D)
- Binocular (12×42 Kylietech)
- Measuring tape
- Field stationary
- Field guidebook, Birds of Nepal (Grimett et al. 2016)

3.3 Data collection

3.3.1 Birds survey

3.3.1.2 Point count method

Point count method was used to count the number of birds in the study area. This method is used to estimate population densities, defining population trends, assessing habitat preferences, mostly in avian fauna. This method is undertaken from a fixed location for a fixed time and can be conducted at any time of the year (Sutherland 2006). Point count occurs at intervals along the route and for a given duration at each point.

The plots were set up with every 100 meters rise in elevation, which was recorded using GPS. A total of six birding routes were established, three in each site. In Chandragiri, Matatirtha, Chundevi and Ganeshdevi were birding routes whereas in Nagarjun, Fulbari gate, Raniban and Ichangu. In each birding route, birds were observed in eight circular plots, each with a 50 m radius from the fixed point in a center, for 15 minutes. In this way, 24-point count locations were set up in each site. The birds were observed directly using binoculars and photographs were taken whenever possible. For the identification of birds, field book, Birds of Nepal was used. The survey was started from 6:30 am to 11:00 am and conducted from elevation ranging from 1350 m to 2150 m in Nagarjun and 1450 m to 2250 m in Chandragiri. Bird survey in both sites was carried out from April 2 to June 2, 2019.

3.3.1.3 Call count method

This approach is used for recording birds, which are difficult to see or capture in their preferred habitat. Those species which are shy and cryptic can be rarely observed even in the open habitat. Similarly, in the dense habitat it is impossible to observe the birds in distance. Thus call count method is the approach of listening the sound and noise produced by the birds and recording them. Thus in the present study call count method was also employed for the identification of some birds that clearly produced sound and were familiar.

3.3.2 Environmental variables

Environmental variables like habitat types were classified as forest, grassland, agricultural area, human settlement area and barren area using ICIMOD Land cover map 2010.

3.3.3 Disturbance variables

Distance to road and nearest settlement as disturbance variables was estimated in the field and confirmed by aerial distance using Google Earth.

3.3.4 Feeding guild classification

Feeding guild were assessed by reviewing field guide book 'Birds of Nepal' (Grimmett et al. 2016) and categorized into five types on the basis of food as insectivores (feeding predominantly on insects, larva, worms, spiders, crustaceans, mollusks etc), omnivores (feeding on both plants and animals), frugivores (feeding on fruits, berries, figs and drupes and nectars), carnivore (feeding on fishes, amphibians, reptiles, birds and mammals), granivores (feeding on seeds, grains, acorns).

3.4 Data analysis

All the collected data from the survey of field were first entered in excel data sheet and then analyzed by using different statistical tools.

3.4.1 Shannon-Wiener Diversity Index

Biodiversity index (H') was calculated by using Shannon and Wiener Function. Shannon-Wiener Index assumes that individuals are randomly sampled from an independent large population and all the species are represented in the sample. It is very usually used for comparing diversity between various habitats and between different time periods. Shannon-Wiener diversity index was used to find the alpha (α) diversity of bird species of the study area across seasons and across point stations. It is calculated as,

$$H' = -\Sigma\, Pi\, (\ln Pi)$$

Where, Σ represents sum of Pi(lnPi)

H'= Index of species diversity

Pi = the proportion of individuals in the i^{th} species, $Pi = n_i/N$

ni = Importance value for each species (number of individuals)

N= Total importance value (total number of individuals)

3.4.2 Species richness and evenness index

When the complexity of the habitat increases, species diversity also increases. This species diversity considers both the species richness and species evenness.

Species Richness simply gives the presence of total number of species at a particular area. And it is simply calculated as,

S= total number of species recorded. Where, S= Species Richness

Evenness is a measure of the relative abundance of different species making up the richness of an area. This evenness is an important component of diversity indices and expresses evenly distribution of the individuals among different species. Thus, to calculate whether the species are evenly distributed among the different point count stations and among the different seasons, Evenness index was used. It is calculated as,

$E = H' / H'_{max}$

Where,

H' = Shannon-Wiener diversity index.

H'_{max} = maximum possible value of H', if every species is equally likely and equal to ln(S).

S= Species richness is the total number of species.

3.4.3 Abundance

Abundance was calculated by using following formula,

Abundance= Frequency of occurrence of species in each plot.

3.4.4 Sorenson similarity index

Sorenson's similarity index was used to find the beta diversity of birds which represents the unshared species, by finding the similarity between bird species composition across seasons. As Sorenson similarity index can be used for both qualitative and quantitative data,

here this index was used for the qualitative data (presence/absence). Sorenson's Index of similarity was calculated as;

SSI= 2C/ (A+B) *100 %

Where,

SSI is the similarity index and the value ranges from 0 to 100 in percent. Value of '0 %' refers for the no similarity between the communities/seasons whereas value of '100 %' refers for the complete similarity between communities/seasons. Value near to 100 percent represents more similarity whereas value near to zero percent represents less similarity between the communities/seasons.

C= Common number of species shared by two community (two seasons)

A= Number of species found in one community (one season)

B= Number of species found in another community (another season)

3.4.5 T-statistics

T- statistics was used to find out whether there is significant variation in species richness of birds in two forests. The following null hypothesis was assumed.

H_0 = There is no significant variation in species richness of birds between different forests.

3.4.6 Generalized Linear Model

The three different variables (Elevation, Distance to road and Distance to settlement) were used to perform Generalized Linear Model (GLM) using Past software.

3.4.7 Canonical Correspondence Analysis

Canonical Correspondence Analysis (CCA) was used to illustrate the species response to different environment variables (habitat types) in study areas. The significance of the predictors was tested by using a Monte Carlo permutation test in CANOCO 4.56 with 499 permutations.

4. RESULTS

4.1 Species richness and diversity

Chandragiri

A total of 442 individuals of 73 bird species from 29 families of nine orders were recorded by point count method during the study period. Out of nine orders, order Passeriformes had the highest species richness (53 species), followed by the order Piciformes (Five species), Cuculiformes (Four species), Galliformes and Columbiformes (Three species), Accipitriformes (Two species), psittaciformes, strigiformes and Pelecaniformes has single species in each family. Among 29 families recorded, family Muscicapidae has the highest number of bird species (Eight species), followed by Corvidae (Six species), Pycnonotidae and Cuculidae (Four species), Sturnidae, Turdidae, Dicruridae, Sittidae, Nectariniidae, Phasianidae, Columbidae and Megalaimidae were represented by equal numbers of species (Three species). Similarly, two species were observed each from 10 families (Passeridae, Paridae, Campephagidae, Cisticolidae, Accipitridae, Picidae, Sylviidae, Timaliidae, Zosteropidae and Motaciliidae), whereas single number of species was recorded each from seven families (Laniidae, Ardeidae, Aegithalidae, Hirundinidae, Psittacidae, Chloropseidae and Strigidae).

Nagarjun

A total of 460 individuals of 79 bird species from 29 families of 10 orders were recorded by point count method during the study period in Nagarjun Forest. Out of 10 orders, order Passeriformes had the highest species richness (59 species), followed by the order Piciformes (Seven species), Columbiformes (Three species), Cuculiformes, Pelecaniformes and Accipitriformes (Two species), Galliformes, Psittaciformes, Strigiformes, Bucerotiformes has single species in each family. Among 29 families recorded, family Muscicapidae has the highest number of bird species (11 species), followed by Turdidae (Eight species), Corvidae (Six species), Pycnonotidae (Five species), Piciidae and Sylviidae (Four species), Megalaimidae, Paridae, Columbidae and Zosteropidae (Three species). Similarly, two species were observed each from 10 families (Cuculidae, Accipitridae, Sittidae, Passeridae, Sturnidae, Campephagidae, Cisticolidae, Ardeidae, Laniidae and Dicruridae), whereas single number of species was recorded each

from nine families (Aegithalidae, Psittacidae, Strigidae, Phasianidae, Chloropseidae, Upupidae, Timallidae, Rhipiduridae and Nectariniidae).

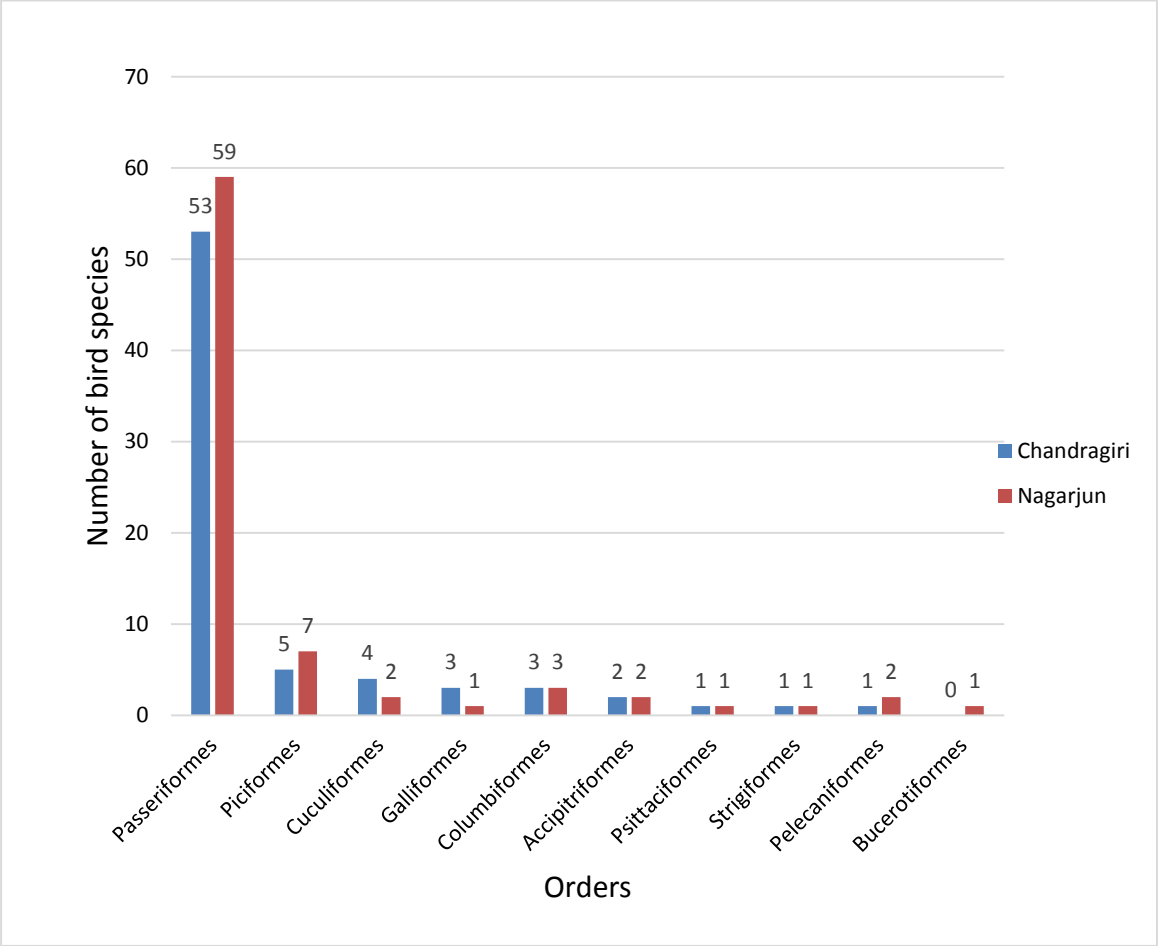


Figure 2: Number of bird species of different orders in Chandragiri and Nagarjun Forest

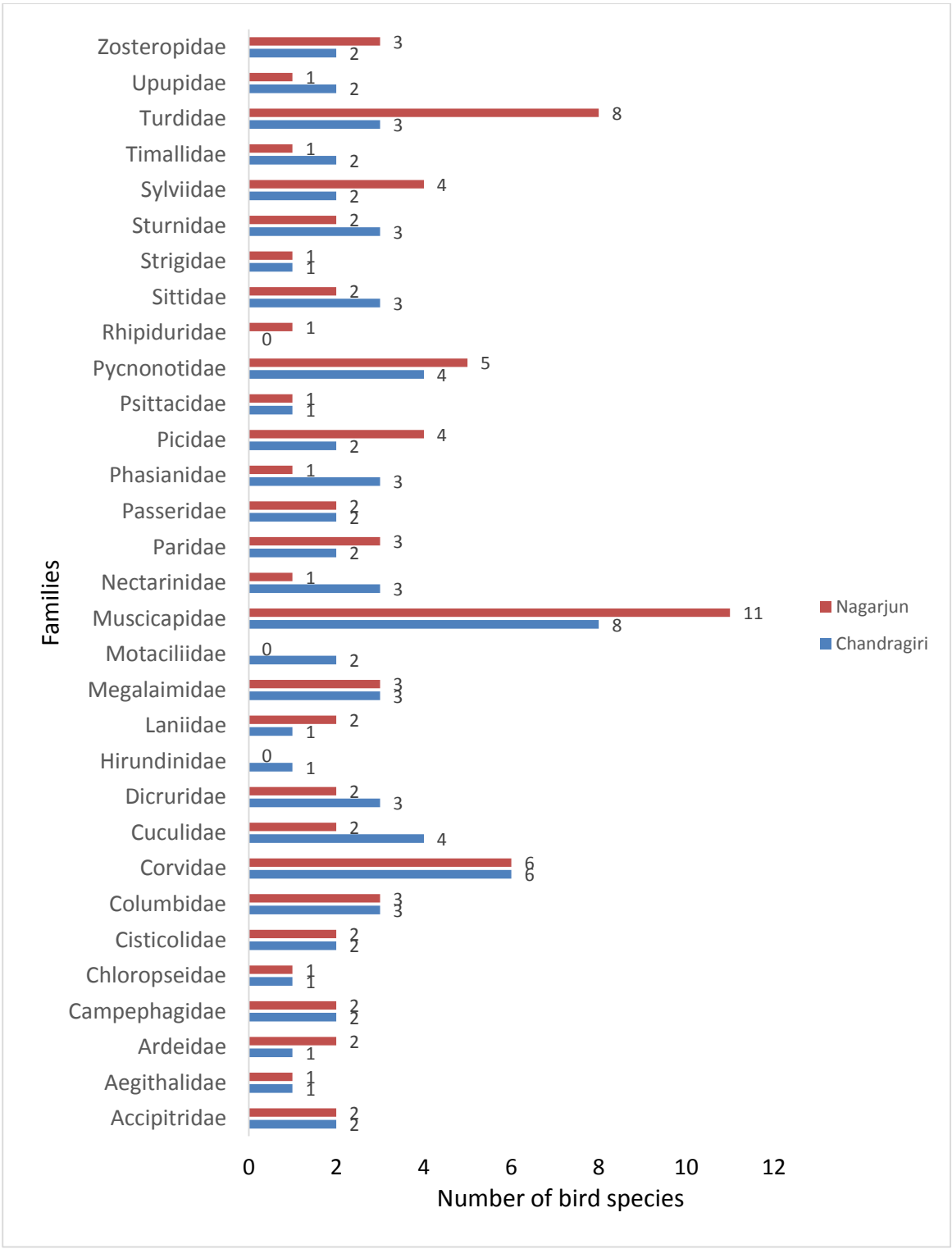


Figure 3: Number of bird species of different families in Chandragiri and Nagarjun Forest.

Analysis of bird data on residential status revealed that out of 73 species recorded from Chandragiri, 63 species (86%) were resident, seven species (10%) were summer visitors, two species (3%) were winter visitors and one species (1%) was passage migrants (Figure 4).

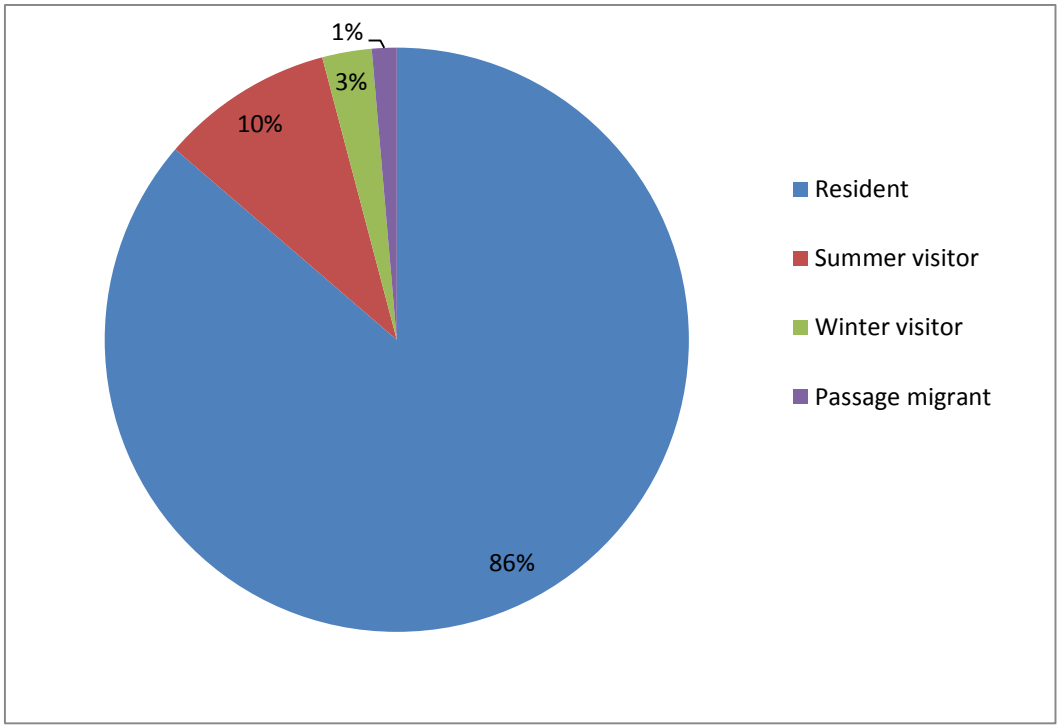


Figure 4: Residential status of birds in Chandragiri Forest.

Analysis of bird data on residential status revealed that out of 79 species recorded from Nagarjun, 67 species (86%) were resident, eight species (10%) were summer visitors, two species (3%) were winter visitors and one species (1%) was passage migrants (Figure 5).

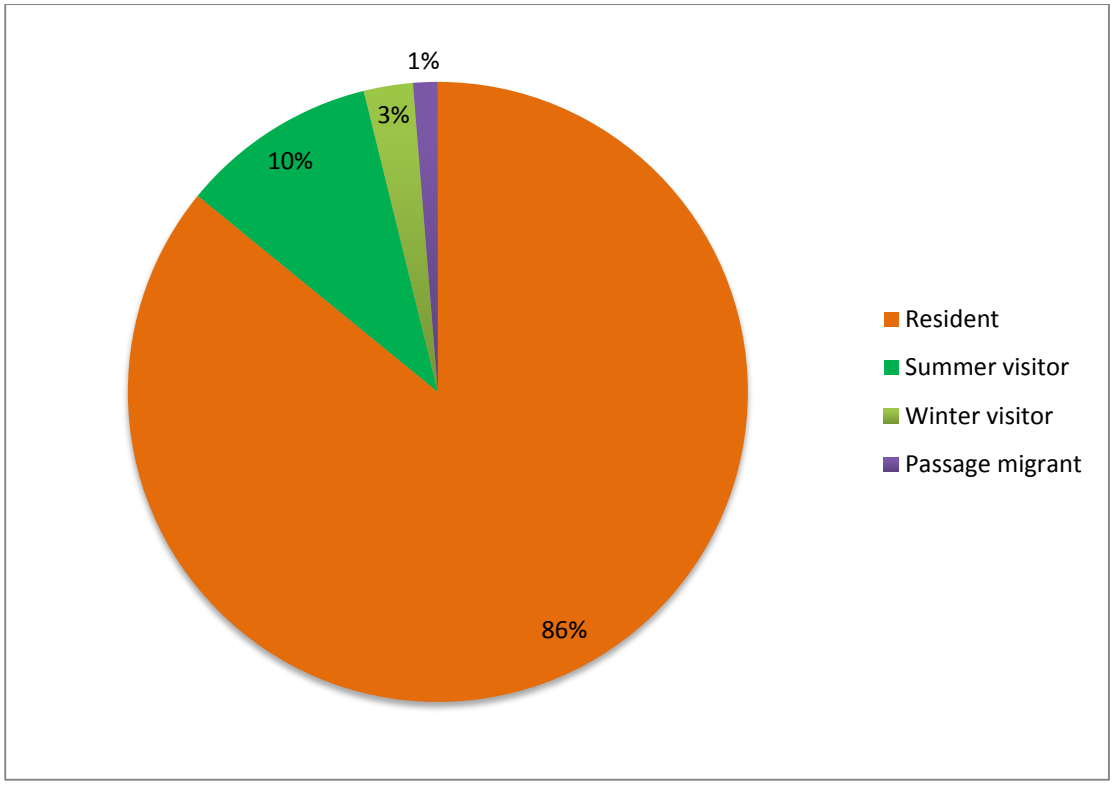


Figure 5: Residential status of birds in Nagarjun Forest.

Analysis of data on food guild structure of birds of Chandragiri forest and Nagarjun forest revealed that higher number of birds are found in insectivore feeding guild (Chandragiri: 31 species, Nagarjun: 39 species) followed by omnivores (Chandragiri: 21 species, Nagarjun: 20 species), frugivores (Chandragiri: 11 species, Nagarjun: eight species) and Carnivore(Chandragiri: five species, Nagarjun: seven species). Granivores were recorded to have the least species richness of five species in Chandragiri and four species in Nagarjun forest (Figure 6).

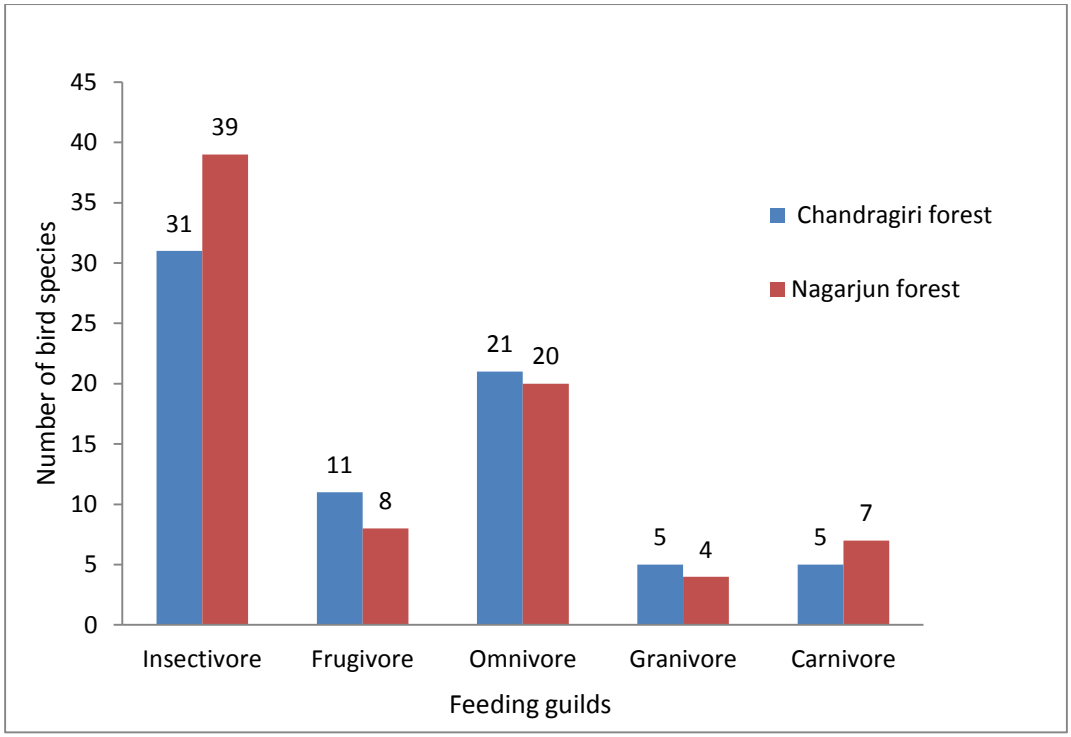


Figure 6: Species richness in different feeding guilds in Chandragiri and Nagarjun Forest.

Shannon Wiener diversity index (H') for Nagarjun forest was H'=3.841 whereas Chandragiri forest had the diversity index of H'=3.851 indicating slightly diverse bird assemblage in Chandragiri forest in comparison to Nagarjun forest. The evenness index was also found to be higher in Chandragiri forest (e=0.6446) than in Nagarjun forest (e=0.5894). Thus evenness index revealed that birds were slightly more evenly distributed in Chandragiri forest than in Nagarjun forest (Table 1).

Sorenson's similarity index (SSI) of species composition was observed to be 64% between Chandragiri and Nagarjun Forest which showed that bird communities were more similar in these two different forests.

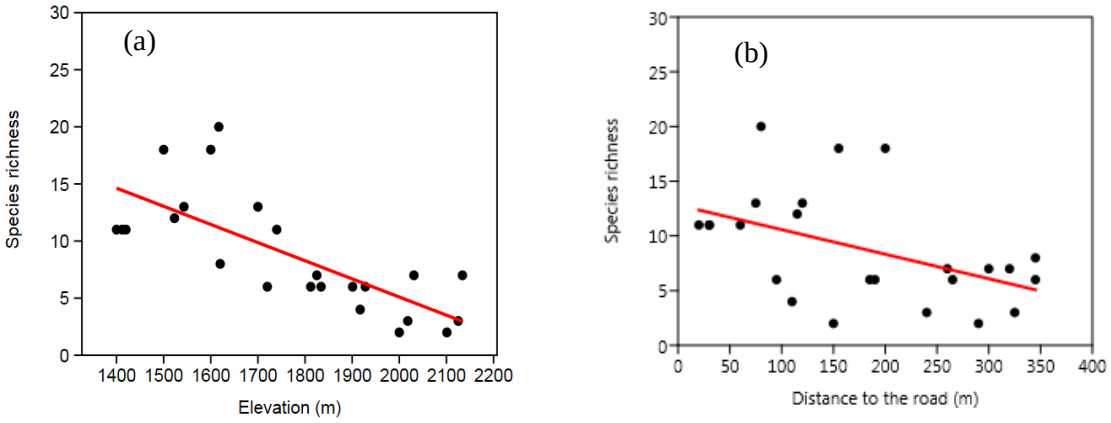
Table 1: Status of birds in Chandragiri and Nagarjun forests.

Forest	Orders	Families	Species richness	Common species	Number of individuals	Shannon's Index(H')	Evenness Index(E)	SSI
Chandragiri	9	29	73	49	442	3.851	0.644	64%
Nagarjun	10	29	79		460	3.841	0.589	

It was found that for species richness in two different forests, the critical (tabulated) value (t-statistics) with degree of freedom 23, at 5% level of significance is 2.06. Since the calculated value of the test statistics, T= 0.36 is less than the tabulated value, null hypothesis is accepted i.e., there is not any significant variation in species richness of birds between two forests in different point count locations.

4.2 Factors affecting bird diversity in Chandragiri and Nagarjun forests.

Among the three variables (elevation, distance to road and distance to the nearest settlement), GLMs illustrated that the major factors causing significant impact on species richness was elevation ($P < 0.001$) (Table 2). It showed that species richness decreases with increasing elevation. Similarly, variables like distance to road ($P = 0.011$) and distance to human settlement ($P = 0.004$) also showed significant negative association with species richness. Species richness decreased significantly with increase in distance to road and distance to human settlement in Chandragiri Forest (Figure 7).



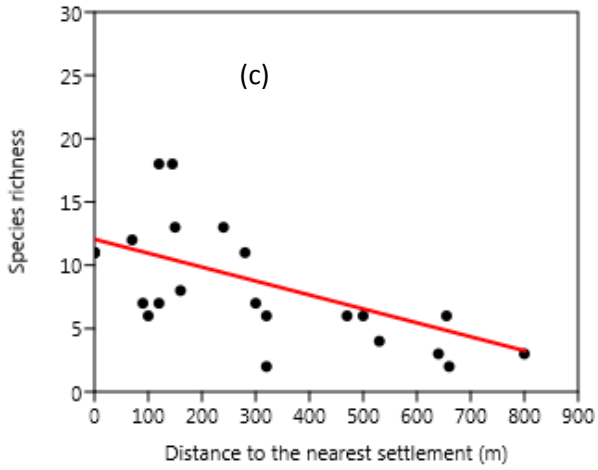
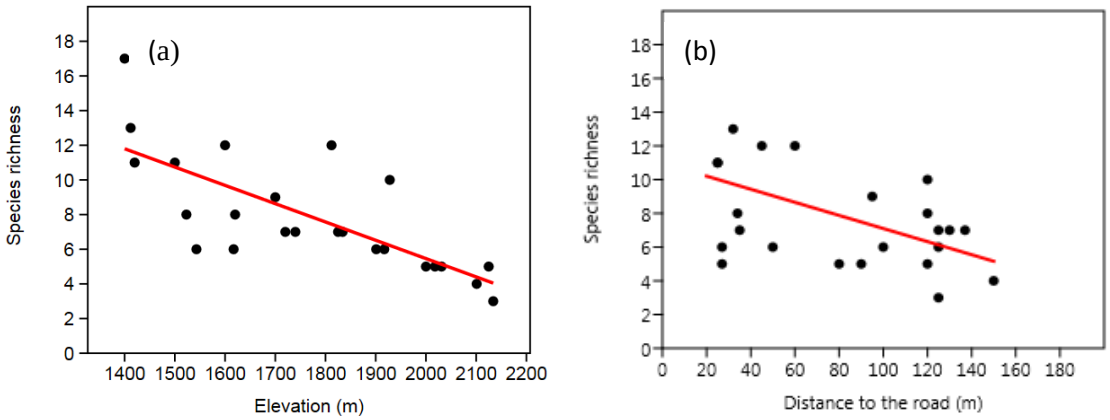


Figure 7: GLM results showing the relationship between species richness and (a) elevation, (b) distance to the road and (c) distance to the nearest settlement in Chandragiri Forest.

In Nagarjun forest, among the three variables (elevation, distance to the road and distance to the nearest settlement), GLMs illustrated that the major factors causing significant impact on species richness was elevation ($P < 0.001$) (Table 3). Species richness decreased significantly with increasing elevation. Likewise, variables like distance to the road ($P = 0.004$) and distance to the nearest settlement ($P = 0.019$) also showed significant negative association with species richness. Species richness decreased significantly with increase in distance to road and distance to human settlement (Figure 8).



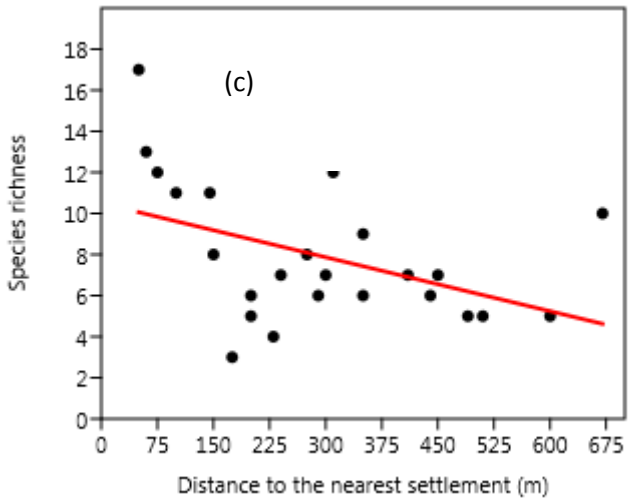


Figure 8: GLM results showing the relationship between species richness and (a) elevation, (b) distance to the road and (c) distance to the nearest settlement in Nagarjun Forest.

Table 2: Univariate GLM results showing the most significant factors that influence the species richness within the study area.

CHANDRAGIRI				
Environmental variables	Slope (a)	Intercept (b)	Estimated value	P value
Elevation	-0.015	36.778	12.26	< 0.001*
Distance to the road	-0.022	12.817	20.799	0.011*
Distance to the nearest settlement	-0.011	12.053	19.72	0.004*
NAGARJUN				
Environmental variables	Slope (a)	Intercept (b)	Estimated value	P value
Elevation	-0.010	26.488	5.232	< 0.001*
Distance to the road	-0.038	10.985	8.536	0.004*
Distance to the nearest settlement	-0.008	10.498	9.389	0.019*
Signif. codes: 0.05 '*'				

The habitat variables that were selected to find the relationship between habitat types and species richness were Forest habitat, Agricultural area, and Human settlement and Grassland habitat. The upright triangles in graph represent the species while the arrows represent selected habitat variables. The habitat variables with long arrowhead had more impact on species distribution. The angle between an arrow and each axis represents the degree of correlation with that axis. The species that were closest or nearer to the arrow were strongly affected by the factor and the species that were far away were less influenced. The distance between the points reflects the degree of association between different species within same quadrate. If in a quadrate, at the same point, multiple species were present than it means that they had same abundance value and influenced by particular factor in same way.

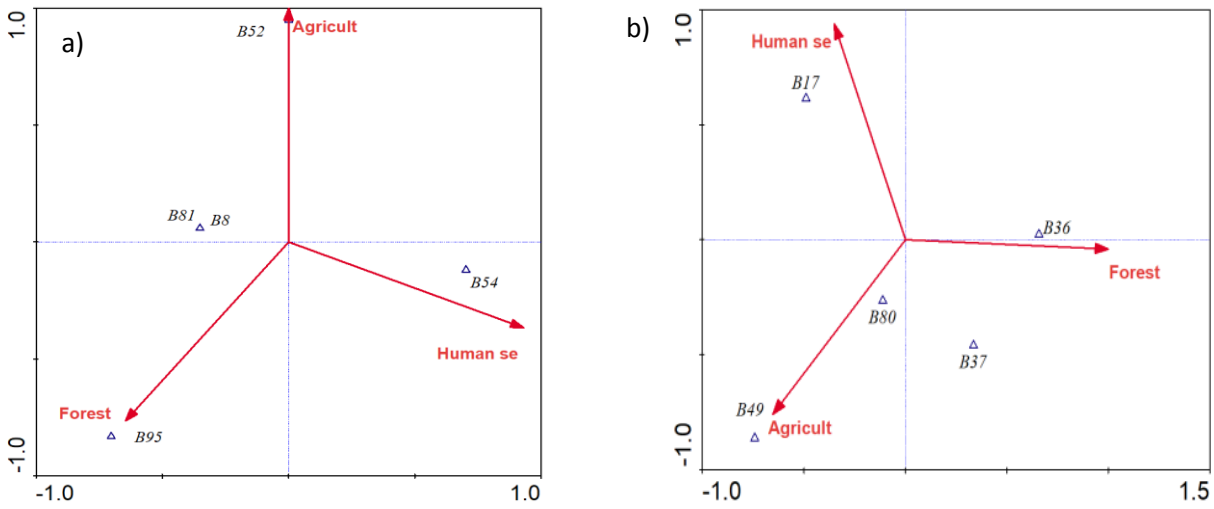
For carnivores, the Monte-Carlo permutation test of significance of all canonical axes showed a significant relationship between the species and habitat variables (Trace = 0.476 F-ratio = 0.408 P- value = 0.772). Species like Black kite (*Milvus migrans*), Shikra (*Accipiter badius*), and Cattle egret (*Bubulcus ibis*) were found to be associated with agriculture area. Similarly, Asian barred owl (*Glaucidium cuculoides*) showed significant association with forest habitat. The Long-tailed shrike (*Lanius schach*) was found to be associated with human settlement area (Figure 9 a).

Species of granivore feeding guild showed strong association with forest and agriculture habitat with two species in each habitat (Trace = 0.527 F-ratio = 2.174 P- value = 0.050). Species like Spotted dove (*Streptopelia chinensis*) and Oriental turtle dove (*Streptopelia orientalis*) were associated with forest habitat. House sparrow (*Passer domesticus*) was found to be associated with human settlement area (Figure 9 b).

For frugivore species, most of the species were associated with forest habitat (Trace = 0.796 F-ratio = 0.886 P-value = 0.606) like Black francolin (*Francolinus francolinus*), Great barbet (*Megalaima virens*), Green-tailed sunbird (*Aethopyga nipalensis*), Green-shrike babbler (*Pteruthius xanthochlorus*), Black-throated sunbird (*Aethopyga saturate*) etc. Similarly, Golden-throated barbet (*Psilopogon franklinii*) was associated with grassland habitat. Red-billed blue magpie (*Urocissa erythrorhyncha*) was in association with agriculture area. Similarly, in human settlement area, Rufous treepie (*Dendrocitta vagabunda*) and Blue-throated barbet (*Psilopogon asiaticus*) were associated (Figure 9 c).

For omnivores, forest habitat was most significantly associated with species richness and distribution (Trace = 0.561 F-ratio = 0.773 P-value = 0.688) with species like Grey bushchat (*Saxicola ferreus*), Chestnut-bellied nuthatch (*Sitta cinnamoventris*), Black bulbul (*Hypsipetes leucocephalus*), Blue whistling thrush (*Myophonus caeruleu*), Rufous sibia (*Heterophasia capistrata*) and Oriental white eye (*Zosterops palpebrosus*). Similarly, Himalayan bulbul (*Pycnonotus leuogenys*) was associated with human settlement. Large-billed crow (*Corvus macrorhynchos*) was in strong association with agriculture area (Figure 9 d).

Species of insectivore feeding guild showed strong association with forest habitat like Yellow-billed blue magpie (*Urocissa flavirostris*), Grey-hooded warbler (*Phylloscopus xanthoschistos*), Grey-headed canary flycatcher (*Culicicapa ceylonensis*), Bronzed drongo (*Dicrurus aeneus*), Scarlet minivet (*Pericrocotus flammeus*) etc. Similarly, species like Black-lored tit (*Parus xanthogenys*), Verditer flycatcher (*Eumyias thalassina*) and Grey wagtail (*Motacilla cinerea*) were associated with grassland habitat. Likewise, habitat types like human settlement and agriculture had least impact on species richness. Black drongo (*Dicrurus macrocercus*) and Oriental magpie robin (*Copsychus saularis*) were associated with human settlement. Ashy drongo (*Dicrurus leucophaeus*), Velvet-fronted nuthatch (*Sitta frontalis*), Barn swallow (*Hirundo rustica*), Long-tailed minivet (*Pericrocotus ethologus*), Fulvous breasted woodpecker (*Dendrocopos macei*) were found mostly associated with agricultural area (Figure 9 e).



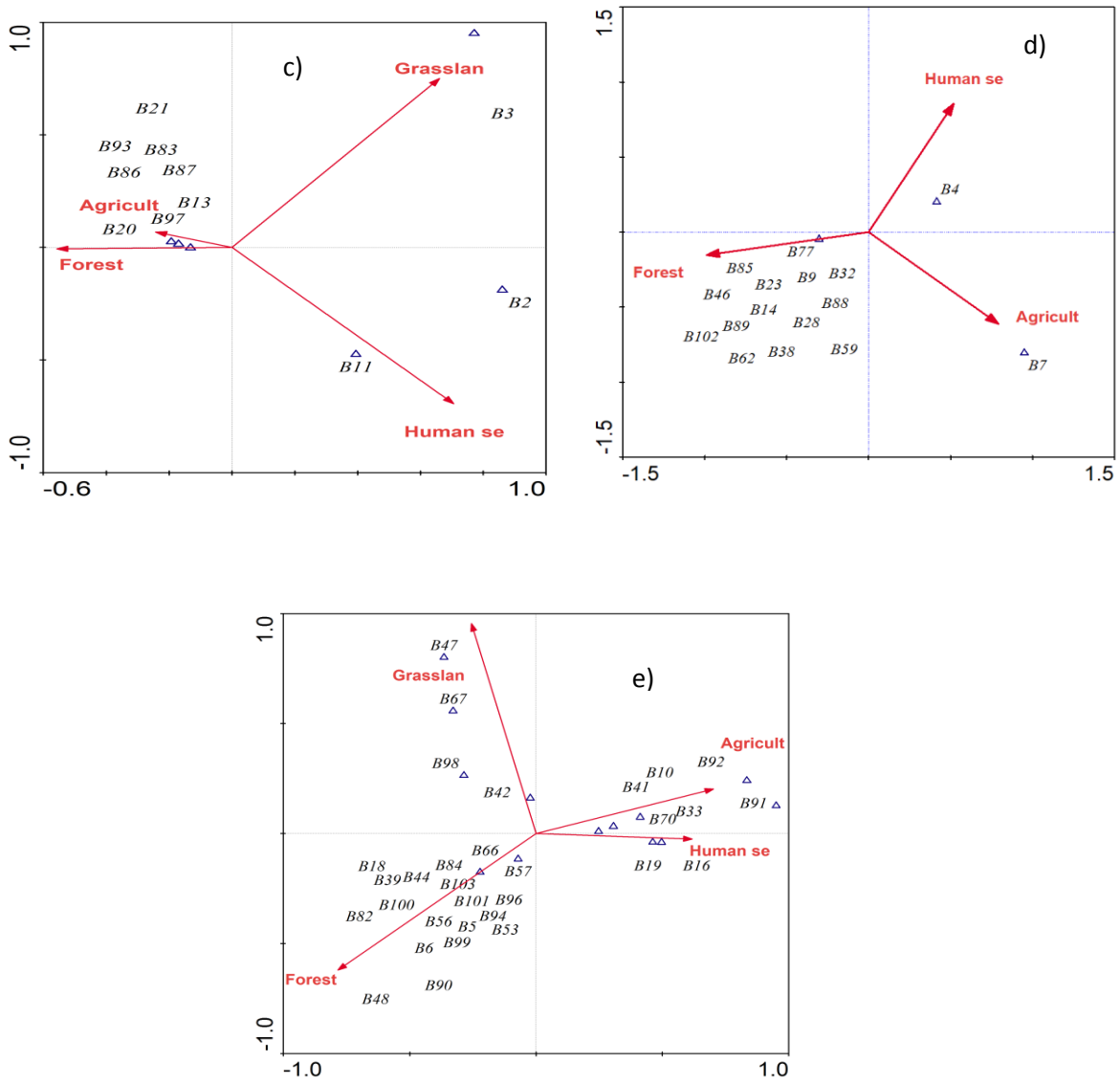


Figure 9: CCA ordination diagram showing species response to different habitat types in Chandragiri Forest (Monte Carlo permutation test of significance of all canonical with 499 permutations). (Forest= Forest habitat, Grasslan= Grassland, Agricult= Agricultural area and Human se = Human settlement area).

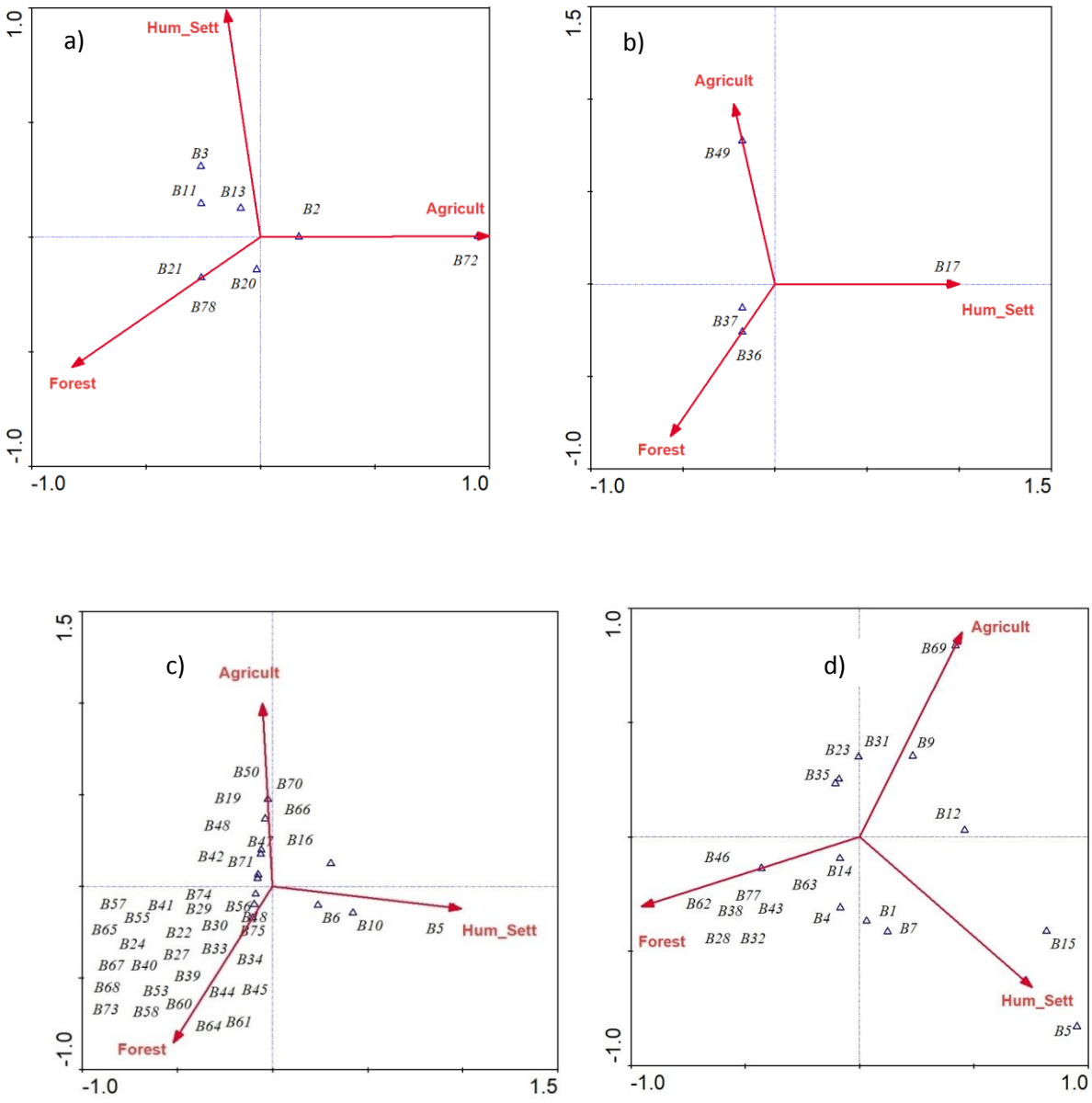


Figure 10: CCA ordination diagram showing species response to different habitat types in Nagarjun Forest (Monte Carlo permutation test of significance of all canonical with 499 permutations). (Forest= Forest habitat, Grasslan= Grassland, Agricult= Agricultural area and Hum_Sett= Human settlement area).

Species of frugivore guild were highly affected by forest habitat like Rose ringed Parakeet (*Psittacula krameri*), Red-billed blue magpie (*Urocissa erythrorhyncha*) and Crimson sunbird (*Aethopyga siparaja*). Three species were associated with human settlement area like Great barbet (*Megalaima virens*), Golden-throated barbet (*Psilopogon franklinii*) and Rufous treepie (*Dendrocitta vagabunda*). Ashy wood pigeon (*Columba pulchricollis*) and Blue throated barbet (*Psilopogon asiaticus*) were associated with agricultural area. (Trace = 0.495 F-ratio = 1.100 P- value = 0.328) (Figure 10 a).

For granivore species, Oriental turtle dove (*Streptopelia orientalis*) and Spotted dove (*Streptopelia chinensis*) were strongly associated with forest habitat. Similarly, House sparrow (*Passer domesticus*) and Eurasian tree sparrow (*Passer montanus*) were strongly associated with human settlement and agricultural area respectively (Trace = 1.708 F-ratio = 3.973 P- value = 0.024) (Figure 10 b).

Similarly, insectivore species were highly associated with forest habitat followed agricultural area (Trace = 3.000 P-value = 0.002). Species like Scarlet minivet (*Pericrocotus flammeus*), Orange-headed thrush (*Geokichla citrine*), Grey-hooded warbler (*Phylloscopus xanthoschistos*), Rufous woodpecker (*Micropternus brachyurus*), Striated prinia (*Prinia crinigera*), White capped redstart (*Chaimarrornis leucocephalus*), Black-throated thrush (*Turdus atrogularis*). Similarly, species like White-throated fantail (*Rhipidura albicollis*), Green-backed tit (*Parus monticolus*), Black drongo (*Dicrurus macrocercus*), Grey-headed canary flycatcher (*Culicicapa ceylonensis*) and Ashy drongo (*Dicrurus leucophaeus*) were associated with agricultural area. Few species like Black-throated tit (*Aegithalos concinnus*), Common tailor bird (*Orthotomus sutorius*) and Hume's warbler (*Phylloscopus humei*) were associated with human settlement area (Figure 10 c).

In Nagarjun, most of the omnivore bird species were associated with forest habitat (Trace = 0.674 F-ratio = 1.323 P- value = 0.172) like Blue whistling thrush (*Myophonus caeruleu*), Himalayan bulbul (*Pycnonotus leuogenys*), Grey bushchat (*Saxicola ferreus*), Orange-bellied leafbird (*Chloropsis hardwickii*), Striated bulbul (*Pycnonotus striatus*), Mountain bulbul (*Hypsipetes incclellandi*), Black bulbul (*Hypsipetes leucocephalus*) and Stripe-throated yuhina (*Yuhina gularis*). For agricultural area, the bird species associated were Common myna (*Acridotheres tristis*), Grey-headed woodpecker (*Picus canus*), Red-vented bulbul (*Pycnonotus cafer*) and Chestnut bellied nuthatch (*Sitta cinnamoventris*). Similarly, House crow (*Corvus splendens*), Asian koel (*Eudynamys scolopacea*) and Large-billed crow (*Corvus macrorhynchos*) showed strong association with human settlement area (Figure 10 d).

5. DISCUSSION

5.1 Species richness and diversity

Higher species richness was revealed from both study sites, Chandragiri and Nagarjun forests of Kathmandu which are true representation of mid-hills in Nepal, enclosing pristine forests and are rich in biodiversity. Species richness was found to be higher in Nagarjun forest than in Chandragiri forest which may be due to less disturbed habitat and conservation planning in SNNP as compared to Chandragiri forest which is highly exploited with human presence and construction activities as well as frequently used as trekking routes. Diversity index showed a slightly diverse avian community in Chandragiri forest as compared to Nagarjun forest which may be attributed to more open habitat in Chandragiri forest as compared to much dense forest in Nagarjun area.

T-test showing variation between species explored that there was no statistically significant variation in species richness between two study sites and most of the species are similar between Chandragiri and Nagarjun forest as calculated by Sorenson's Similarity Index, which may be due the overlapping of resident birds in both forests.

5.2 Factor affecting bird species richness and diversity

In both study sites, elevation was the most significant factor determining species richness which decreased significantly with increasing elevation. In most studies avian fauna shows a pattern revealing monotonic decline along elevation gradients (Rahbek 1995, 2005, Katuwal 2013). A few studies were contrast that revealed high species richness at middle elevation than higher and lower elevations (Acharya et al. 2011, Joshi et al. 2012, Joshi & Rautela 2014, Joshi & Bhat 2015). The most prominent reason for declining species richness as moving up along elevation could be habitat preference of birds in more open habitats, near settlement areas and agricultural areas in lower region rather than increasing forest stands and dense habitat with high canopy cover. This is supported by the study where higher bird species richness was observed under open canopy conditions in the lower forest (Chhetri et al. 2009). Birds which are familiar with human activities tend to stay nearer for food and nesting sites within settlement area (Joshi & Bhatnagar 2018).

Species richness decreased significantly with increase in distance to human settlement and distance to road in both study sites. Human proximity has positive impact on birds in terms

of availability of resources and protection against predators and parasites (Moller & Diaz 2017). For example, birds that breed inside buildings have significantly higher reproductive success than nearby conspecifics breeding outdoors (Yeh et al. 2007, Moller 2010). However, diversity of birds was lower near human settlements due to high disturbance (Adhikari et al. 2019). Generalist or common species were more abundant at the open canopy condition near human settlements (Restrepo & Gomez 1998) providing a more open understorey for generalist species, open canopy forest exhibited more species of bird that are perturbated by human settlements (Chettri et al. 2001). Moller et al. 2012 also reported that urban areas constitute refuges for prey against predators. In general, human disturbance such as vehicle, construction etc. cause the negative impact on avian species richness (Reijnen et al. 1995, Halfwerk 2011), mostly in heavy traffic area but in this study moderate disturbance was preferred by bird species as they were recorded higher near settlement area and nearby roads. This could be accredited to less traffic and comparatively thin human settlement within the study area which imposed only moderate disturbing effect to them.

The impacts of roads on wildlife populations are extensive and well documented around the world (Fahrig & Rytwinski 2009). In the case of birds, many studies have shown negative association i.e. abundance, occurrence and species richness of birds is mostly declined near roads, with heavier reductions near high-traffic roads than near lower traffic roads (Reijnen et al. 1995, Brotons & Herrando 2001, Fuller et al. 2001, Burton et al. 2002, Rheindt 2003, Peris & Pescador 2004, Pocock & Lawrence 2005, Palomino & Carrascal 2007, Griffith et al. 2010). Similar findings with road distance and species richness was discussed in threatened birds of Chitwan National Park that showed a negative impact of roads and settlements (Adhikari et al. 2019).

In accordance to the result of present study, it can be assumed that the main cause of the responses of birds near roads may due to open habitats near roads with less dense forest area as preferred by birds. Species richness generally decreases near roads due to direct and indirect effect of roads such as vehicle caused mortality, habitat loss and fragmentation, barrier to movement, artificial light (Koclolek et al. 2011) which is opposite to the result with this study. There are some evidences to suggest that some birds may benefit from roads as power lines, sign boards and roadside vegetation may serve as useful ecological corridors through the provision of suitable nesting, refuge and perching habitats (Morelli

et al. 2014). Road surfaces and verges may also act as potential foraging and scavenging sites.

Canonical correspondence analysis showed that feeding guilds of birds including insectivores, omnivores and frugivores were associated with forest, agricultural area and human settlements areas. The observed bird species preferred open forest habitat nearby human settlement area and roads. Main reason for such preference could be available resources supplement by forest area in comparison other land use types like agricultural area and shrub land and bushes. Forests provide the crucial resources required for the completion of life cycles of birds, including foods, nesting sites, perching sites and foraging sites. In forest as compared to other habitats, birds get different forms of nutrients like nectar, fruits, seeds and vegetative tissues including roots, shoots and leaves. Insectivores birds can supplement their diet with invertebrates found in different strata of forest along with plants parts (MacArthur & MacArthur 1961, MacArthur et al. 1962, Orians & Wittenberger 1991, MacArthur et al. 1966). Increasing foliage height diversity is associated with increasing avian diversity, particularly insectivores (MacArthur & MacArthur 1961, MacArthur et al. 1962) with increasing foraging sites and increased niches available to exploit (MacArthur et al. 1966). Similar findings were discussed by Pan et al. 2016 showing that the species richness of overall birds was positively correlated with forest habitat, productivity and habitat heterogeneity, indicating that the existing primary forest in the valley is important for avian conservation.

Similarly, agricultural areas comprise of few species of insectivorous birds mainly due to higher seed predation with low tree covers and insect outbreaks as use of pesticides which offered a prey base for insectivorous bird (Sekercioglu 2012). However, most of insectivore birds dwelling in forest area were not observed in agricultural area because of their dependency on forest insects and invertebrates. Low richness and abundance of insectivorous forest birds in agricultural areas may be also due to their poor dispersal abilities (Sekercioglu et al. 2002). Most of the granivore species in this study are associated with human settlement areas that may be due to availability of grains used mostly by humans which stored nearby houses or during sun-drying. This is in line with the study of Samia et al. 2015 which suggested that granivore and omnivore species have more tolerance to human and are more familiar tending to remain nearby people.

6. CONCLUSION AND RECOMMENDATIONS

Shannon Wiener diversity index was found slightly higher in Chandragiri forest with slightly higher evenness index in comparison Nagarjun forest. Analysis of the influence of elevation and human disturbance on species diversity and richness showed that elevation, distance to settlements and distance to road as a proxy of human disturbance consistently had negative influence on species richness and diversity. Most of the birds were associated with open forest habitats followed by agricultural area and human settlement area. Bird species richness was found more in Nagarjun forest, one of the protected areas as compared to Chandragiri forest, outside protected area.

Following recommendations can be generated from this study for upcoming researches:

- To explore further information on birds, seasonal variation can be carried out.
- More environmental variables can be used and analyzed in further researches for better findings on associated factors.

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APPENDICES

Appendix 1 Bird list with scientific name, orders, family, migratory status and feeding guilds in Chandragiri forest

Common name	**Scientific name**	**Migratory status**	**Feeding guilds**
GALLIFORMES			
Phasianidae			
Kalij pheasant	*Lophura leucomelanos*	Resident	Omnivore
Black francolin	*Francolinus francolinus*	Resident	Frugivore
Hill patriadge	*Arborophila torqueola*	Resident	Omnivore
PASSERIFORMES			
Pycnonotidae			
Red vented bulbul	*Pycnonotus cafer*	Resident	Omnivore
Black bulbul	*Hypsipetes leucocephalus*	Resident	Omnivore
Mountain bulbul	*Hypsipetes incclellandi*	Resident	Omnivore
Himalayan bulbul	*Pycnonotus leuogenys*	Resident	Omnivore
Hirundinidae			
Barn swallow	*Hirundo rustica*	Resident	Insectivore
Corvidae			
Rufous treepie	*Dendrocitta vagabunda*	Resident	Frugivore
Yellow billed blue magpie	*Urocissa flavirostris*	Resident	Insectivore
House crow	*Corvus splendens*	Resident	Omnivore
Grey treepie	*Dendrocitta formosae*	Resident	Omnivore
Large billed crow	*Corvus macrorhynchos*	Resident	Omnivore
Red billed blue magpie	*Urocissa erythrorhyncha*	Resident	Frugivore
Cisticolidae			
Striated prinia	*Prinia crinigera*	Resident	Insectivore
Sittidae			
Common tailor bird	*Orthotomus sutorius*	Resident	Insectivore
Velvet fronted nuthatch	*Sitta frontalis*	Resident	Insectivore
White tailed nuthatch	*Sitta himalayensis*	Resident	Insectivore
Chestnut bellied nuthatch	*Sitta cinnamoventris*	Resident	Omnivore
Aegithalidae			

Black throated tit	*Aegithalos concinnus*	Resident	Insectivore
Sylviidae			
Grey hooded warbler	*Phylloscopus xanthoschistos*	Resident	Insectivore
Hume,s warbler	*Phylloscopus humei*	Resident	Insectivore
Zosteropidae			
Whiskered yuhina	*Yuhina flavicollis*	Resident	Insectivore
Oriental white eye	*Zosterops palpebrosus*	Resident	Omnivore
Muscicapidae			
Chestnut bellied rockthrush	*Monticola rufiventris*	Resident	Insectivore
Little pied flycatcher	*Ficedula westermanni*	Summer visitor	Insectivore
Verditer flycatcher	*Eumyias thalassina*	Summer visitor	Insectivore
Grey headed canary flycatcher	*Culicicapa ceylonensis*	Winter visitor	Insectivore
Blue capped rockthrush	*Monticola cinclorhynchus*	Summer visitor	Insectivore
Blue rock thrush	*Monticola solitaries*	Resident	Omnivore
Oriental magpie robin	*Copsychus saularis*	Resident	Insectivore
Grey bushchat	*Saxicola ferreus*	Resident	Omnivore
Campephagidae			
Long tailed minivet	*Pericrocotus ethologus*	Resident	Insectivore
Scarlet minivet	*Pericrocotus flammeus*	Resident	Insectivore
Paridae			
Green backed tit	*Parus monticolus*	Resident	Insectivore
Black lored tit	*Parus xanthogenys*	Resident	Insectivore
Turdidae			
Rufous sibia	*Heterophasia capistrata*	Resident	Omnivore
Blue whistling thrush	*Myophonus caeruleu*	Resident	Omnivore
Streaked laughingthrush	*Trochalopteron lineatum*	Resident	Insectivore
Motaciliidae			
Grey wagtail	*Motacilla cinerea*	Resident	Insectivore
Timallidae			
Green shrike babbler	*Pteruthius xanthochlorus*	Resident	Frugivore

Rusty cheeked scimitar babbler	*Pomatorhinus erythrogenys*	Resident	Omnivore
Chloropseidae			
Orange bellied leafbird	*Chloropsis hardwickii*	Resident	Omnivore
Passeridae			
Eurasean tree sparrow	*Passer montanus*	Resident	Granivore
House sparrow	*Passer domesticus*	Resident	Granivore
Laniidae			
Long tailed shrike	*Lanius schach*	Resident	Carnivore
Sturnidae			
Brahminy starling	*Sturnia pagodarum*	Resident	Omnivore
Common myna	*Acridotheres tristis*	Resident	Omnivore
Jungle myna	*Acridotheres fuscus*	Resident	Omnivore
Dicruridae			
Ashy drongo	*Dicrurus leucophaeus*	Resident	Insectivore
Bronzed drongo	*Dicrurus aeneus*	Resident	Insectivore
Black drongo	*Dicrurus macrocercus*	Resident	Insectivore
Nectariniidae			
Fire tailed sunbird	*Aethopyga ignicauda*	Resident	Necterivore
Green tailed sunbird	*Aethopyga nipalensis*	Resident	Necterivore
Black throated sunbird	*Aethopyga saturate*	Resident	Necterivore
CUCULIFORMES			
Cuculidae			
Eurasian cuckoo	*Cuculus canorus*	Summer visitor	Insectivore
Himalayan cuckoo	*Cuculus saturates*	Summer visitor	Insectivore
Indian cuckoo	*Cuculus micropterus*	Summer visiter	Insectivore
Asian koel	*Eudynamys scolopacea*	Summer visitor	Omnivore
COLUMBIFORMES			
Columbidae			
Oriental turtle dove	*Streptopelia orientalis*	Resident	Granivore
Spotted dove	*Streptopelia chinensis*	Resident	Granivore
Common pigeon	*Columba livia*	Resident	Granivore

PICIFORMES			
Megalaimidae			
Great barbet	*Megalaima virens*	Resident	Frugivore
Blue throated barbet	*Psilopogon asiaticus*	Resident	Frugivore
Golden throated barbet	*Psilopogon franklinii*	Resident	Frugivore
Picidae			
Fulvous breasted woodpecker	*Dendrocopos macei*	Resident	Insectivore
Greater yellownape	*Chrysophlegma flavinucha*	Resident	Insectivore
ACCIPITRIFORMES			
Accipitridae			
Black kite	*Milvus migrans*	Passage migrant	Carnivore
Shikra	*Accipiter badius*	Resident	Carnivore
PSITTACIFORMES			
Psittacidae			
Rose ringed parakeet	*Psittacula krameri*	Resident	Frugivore
PELECANIFORMES			
Ardeidae			
Cattle egret	*Bubulcus ibis*	Resident	Carnivore
STRIGIFORMES			
Strigidae			
Asian barred owlet	*Glaucidium cuculoides*	Resident	Carnivore

Appendix 2. Bird list with scientific name, orders, family, migratory status and feeding guilds in Nagarjun forest

Common name	Scientific name	Migratory status	Feeding guilds
GALLIFORMES			
Phasianidae			
Kalij pheasant	*Lophura leucomelanos*	Resident	Omnivore
PASSERIFORMES			
Pycnonotidae			
Himalayan bulbul	*Pycnonotus leuogenys*	Resident	Omnivore
Mountain bulbul	*Hypsipetes incclellandi*	Resident	Omnivore
Red vented bulbul	*Pycnonotus cafer*	Resident	Omnivore
Black bulbul	*Hypsipetes leucocephalus*	Resident	Omnivore
Striated bulbul	*Pycnonotus striatus*	Resident	Omnivore
Corvidae			
Red billed blue magpie	*Urocissa erythrorhyncha*	Resident	Frugivore
Large billed crow	*Corvus macrorhynchos*	Resident	Omnivore
Yellow billed blue magpie	*Urocissa flavirostris*	Resident	Insectivore
Grey treepie	*Dendrocitta formosae*	Resident	Omnivore
House crow	*Corvus splendens*	Resident	Omnivore
Rufous treepie	*Dendrocitta vagabunda*	Resident	Frugivore
Cisticolidae			
Common tailor bird	*Orthotomus sutorius*	Resident	Insectivore
Striated prinia	*Prinia crinigera*	Resident	Insectivore
Sittidae			
Velvet fronted nuthatch	*Sitta frontalis*	Resident	Insectivore
Chestnut bellied nuthatch	*Sitta cinnamoventris*	Resident	Omnivore
Aegithalidae			
Black throated tit	*Aegithalos concinnus*	Resident	Insectivore
Sylviidae			
Chestnut crowned warbler	*Seicercus castaniceps*	Summer visitor	Omnivore
Hume,s warbler	*Phylloscopus humei*	Resident	Insectivore
Tickell,s leaf warbler	*Phylloscopus affinis*	Passage visitor	Insectivore
Grey hooded warbler	*Phylloscopus xanthoschistos*	Resident	Insectivore
Zosteropidae			
Oriental white eye	*Zosterops palpebrosus*	Resident	Omnivore

Whiskered yuhina	*Yuhina flavicollis*	Resident	Insectivore
Stripe throated yuhina	*Yuhina gularis*	Resident	Omnivore
Muscicapidae			
Common stonechat	*Saxicola torquatus*	Resident	Insectivore
Grey bushchat	*Saxicola ferreus*	Resident	Omnivore
Oriental magpie robin	*Copsychus saularis*	Resident	Insectivore
Slaty backed forktail	*Enicurus schistaceus*	Resident	Insectivore
White capped redstart	*Chaimarrornis leucocephalus*	Summer visitor	Insectivore
Plumbeous water redstart	*Rhyacornis fuliginosa*	Resident	Insectivore
Pied bushchat	*Saxicola caprata*	Resident	Insectivore
Grey headed canary flycatcher	*Culicicapa ceylonensis*	Summer visitor	Insectivore
Verditer flycatcher	*Eumyias thalassina*	Summer visitor	Insectivore
Rufous bellied niltava	*Niltava sundara*	Resident	Insectivore
Slaty blue flycatcher	*Ficedula tricolor*	Resident	Insectivore
Campephagidae			
Long tailed minivet	*Pericrocotus ethologus*	Resident	Insectivore
Scarlet minivet	*Pericrocotus flammeus*	Resident	Insectivore
Paridae			
Black lored tit	*Parus xanthogenys*	Resident	Insectivore
Great tit	*Parus major*	Resident	Insectivore
Green backed tit	*Parus monticolus*	Resident	Insectivore
Turdidae			
Blue whistling thrush	*Myophonus caeruleu*	Resident	Omnivore
White throated laughingthrush	*Garrulax albogularis*	Resident	Insectivore
Rufous sibia	*Heterophasia capistrata*	Resident	Omnivore
Streaked laughing thrush	*Trochalopteron lineatum*	Resident	Insectivore
Black throated thrush	*Turdus atrogularis*	Winter visitor	Insectivore
Scaly thrush	*Zoothera dauma*	Summer visitor	Insectivore
White creasted laughing thrush	*Garrulax leucolophus*	Resident	Insectivore
Orange headed thrush	*Geokichla citrine*	Summer visitor	Insectivore
Timallidae			
Black chinned babbler	*Stachyridopsis pyrrhops*	Resident	Insectivore
Chloropseidae			
Orange bellied leafbird	*Chloropsis hardwickii*	Resident	Omnivore
Passeridae			

Eurasean tree sparrow	*Passer montanus*	Resident	Granivore
House sparrow	*Passer domesticus*	Resident	Granivore
Laniidae			
Long tailed shrike	*Lanius schach*	Resident	Carnivore
Grey backed shrike	*Lanius tephronotus*	Winter visitor	Carnivore
Sturnidae			
Jungle myna	*Acridotheres fuscus*	Resident	Omnivore
Common myna	*Acridotheres tristis*	Resident	Omnivore
Dicruridae			
Ashy drongo	*Dicrurus leucophaeus*	Resident	Insectivore
Black drongo	*Dicrurus macrocercus*	Resident	Insectivore
Rhipiduridae			
White throated fantail	*Rhipidura albicollis*	Resident	Insectivore
Nectariniidae			
Crimson sunbird	*Aethopyga siparaja*	Resident	Frugivore
CUCULIFORMES			
Cuculidae			
Asian koel	*Eudynamys scolopacea*	Summer visitor	Omnivore
Lesserhawk cuckoo	*Cuculus poliocephalus*	Summer visitor	Insectivore
COLUMBIFORMES			
Columbidae			
Ashy wood pigeon	*Columba pulchricollis*	Resident	Frugivore
Spotted dove	*Streptopelia chinensis*	Resident	Granivore
Oriental turtle dove	*Streptopelia orientalis*	Resident	Granivore
PICIFORMES			
Megalaimidae			
Blue throated barbet	*Psilopogon asiaticus*	Resident	Frugivore
Great barbet	*Megalaima virens*	Resident	Frugivore
Golden throated barbet	*Psilopogon franklinii*	Resident	Frugivore
Picidae			
Greater yellownape	*Chrysophlegma flavinucha*	Resident	Insectivore
Lesser yellownape	*Picus chlorolophus*	Resident	Insectivore
Grey headed woodpecker	*Picus canus*	Resident	Omnivore
Rufous woodpecker	*Micropternus brachyurus*	Resident	Insectivore
ACCIPITRIFORMES			
Accipitridae			

Black kite	*Milvus migrans*	Passage migrant	Carnivore
Black eagle	*Ictinaetus malaiensis*	Resident	Carnivore
PSITTACIFORMES			
Psittacidae			
Rose ringed parakeet	*Psittacula krameri*	Resident	Frugivore
PELECANIFORMES			
Ardeidae			
Intermediate egret	*Ardea intermedia*	Resident	Carnivore
Cattle egret	*Bubulcus ibis*	Resident	Carnivore
BUCEROTIFORMES			
Upupidae			
Common hoopoe	*Upupa epops*	Resident	Insectivore
STRIGIFORMES			
Strigidae			
Brown wood owl	*Strix leptogrammica*	Resident	Carnivore

Appendix 3. Codes used in Canonical Correspondence Analysis

S.N	Common Name	Scientific Name	Code	Feeding guild
1	Asian koel	*Eudynamys scolopacea*	B1	Omnivore
2	Ashy drongo	*Dicrurus leucophaeus*	B70	Insectivore
3	Ashy wood pigeon	*Columba pulchricollis*	B72	Frugivore
4	Asian barned owl	*Glaucidium cuculoides*	B95	Carnivore
5	Barn swallow	*Hirundo rustica*	B91	Insectivore
6	Blue capped rock thrush	*Monticola cinclorhynchus*	B99	Insectivore
7	Blue throated barbet	*Psilopogon asiaticus*	B2	Frugivore
8	Blue whistling thrush	*Myophonus caeruleu*	B14	Omnivore
9	Black francolin	*Francolinus francolinus*	B87	Frugivore
10	Black kite	*Milvus migrans*	B8	Carnivore
11	Black throated sunbird	*Aethopyga saturate*	B86	Frugivore
12	Black drongo	*Dicrurus macrocercus*	B16	Insectivore
13	Black throated tit	*Aegithalos concinnus*	B6	Insectivore
14	Blue rock thrush	*Monticola solitaries*	B85	Omnivore
15	Brahminy starling	*Sturnia pagodarum*	B88	Omnivore
16	Bronzed drongo	*Dicrurus aeneus*	B82	Insectivore
17	Brown wood owl	*Strix leptogrammica*	B25	Carnivore
18	Black eagle	*Ictinaetus malaiensis*	B26	Carnivore
19	Black bulbul	*Hypsipetes leucocephalus*	B32	Omnivore
20	Black throated thrush	*Turdus atrogularis*	B34	Insectivore
21	Black lored tit	*Parus xanthogenys*	B42	Insectivore
22	Black chinned babbler	*Stachyridopsis pyrrhops*	B60	Insectivore
23	Crimson sunbird	*Aethopyga siparaja*	B78	Frugivore
24	Chestnut bellied nuthatch	*Sitta cinnamoventris*	B9	Omnivore
25	Chestnut bellied rock thrush	*Monticola rufiventris*	B103	Insectivore
26	Chestnut crowned warbler	*Seicercus castaniceps*	B79	Omnivore
27	Common stonechat	*Saxicola torquatus*	B64	Insectivore
28	Common pigeon	*Columba livia*	B80	Granivore
29	Common tailor bird	*Orthotomus sutorius*	B10	Insectivore
30	Common hoopoe	*Upupa epops*	B50	Insectivore

31	Common myna	*Acridotheres tristis*	B69	Omnivore
32	Cattle egret	*Bubulcus ibis*	B52	Carnivore
33	Eurasean cuckoo	*Cuculus canorus*	B94	Insectivore
34	Eurasean tree sparrow	*Passer montanus*	B49	Granivore
35	Fire tailed sunbird	*Aethopyga ignicauda*	B97	Frugivore
36	Fulvous breasted woodpecker	*Dendrocopos macei*	B92	Insectivore
37	Green backed tit	*Parus monticolus*	B47	Insectivore
38	Green tailed sunbird	*Aethopyga nipalensis*	B93	Frugivore
39	Green shrike babbler	*Pteruthius xanthochlorus*	B83	Frugivore
40	Grey headed canary flycatcher	*Culicicapa ceylonensis*	B66	Insectivore
41	Greater yellownape	*Chrysophlegma flavinucha*	B48	Insectivore
42	Grey backed shrike	*Lanius tephronotus*	B76	Carnivore
43	Grey bushchat	*Saxicola ferreus*	B77	Omnivore
44	Grey headed woodpecker	*Picus canus*	B31	Omnivore
45	Great tit	*Parus major*	B29	Insectivore
46	Grey wagtail	*Motacilla cinerea*	B98	Insectivore
47	Grey treepie	*Dendrocitta formosae*	B23	Omnivore
48	Grey hooded warbler	*Phylloscopus xanthoschistos*	B18	Insectivore
49	Great barbet	*Megalaima virens*	B13	Frugivore
50	Golden throated barbet	*Psilopogon franklinii*	B3	Frugivore
51	Hill partridge	*Arborophila torqueola*	B102	Omnivore
52	Himalayan bulbul	*Pycnonotus leuogenys*	B4	Omnivore
53	Himalayan cuckoo	*Cuculus saturates*	B96	Insectivore
54	Hume's warbler	*Phylloscopus humei*	B5	Insectivore
55	House crow	*Corvus splendens*	B15	Omnivore
56	House sparrow	*Passer domesticus*	B17	Granivore
57	Indian cuckoo	*Cuculus micropterus*	B90	Insectivore
58	Intermediate egret	*Ardea intermedia*	B51	Carnivore
59	Jungle myna	*Acridotheres fuscus*	B35	Omnivore
60	Kalij pheasant	*Lophura leucomelanos*	B28	Omnivore
61	Large billed crow	*Corvus macrorhynchos*	B7	Omnivore
62	Lesser yellownape	*Picus chlorolophus*	B27	Insectivore

63	Lesser hawk cuckoo	*Cuculus poliocephalus*	B55	Insectivore
64	Little pied flycatcher	*Ficedula westermanni*	B84	Insectivore
65	Long tailed shrike	*Lanius schach*	B54	Carnivore
66	Mountain bulbul	*Hypsipetes incclellandi*	B38	Omnivore
67	Long tailed minivet	*Pericrocotus ethologus*	B41	Insectivore
68	Orange headed thrush	*Geokichla citrine*	B22	Insectivore
69	Orange bellied leafbird	*Chloropsis hardwickii*	B46	Omnivore
70	Oriental white eye	*Zosterops palpebrosus*	B59	Omnivore
71	Oriental turtle dove	*Streptopelia orientalis*	B37	Granivore
72	Oriental magpie robin	*Copsychus saularis*	B19	Insectivore
73	Pied bushchat	*Saxicola caprata*	B65	Insectivore
74	Plumbeous water redstart	*Rhyacornis fuliginosa*	B75	Insectivore
75	Red billed blue magpie	*Urocissa erythrorhyncha*	B21	Frugivore
76	Red vented bulbul	*Pycnonotus cafer*	B12	Omnivore
77	Rose ringed parakeet	*Psittacula krameri*	B20	Frugivore
78	Rufous sibia	*Heterophasia capistrata*	B62	Omnivore
79	Rusty cheeked scimitar babbler	*Pomatorhinus erythrogenys*	B89	Omnivore
80	Rufous woodpeker	*Micropternus brachyurus*	B24	Insectivore
81	Rufous treepie	*Dendrocitta vagabunda*	B11	Frugivore
82	Rufous bellied niltava	*Niltava sundara*	B68	Insectivore
83	Scaly laughingthrush	*Zoothera dauma*	B45	Insectivore
84	Scarlet minivet	*Pericrocotus flammeus*	B56	Insectivore
85	Shikra	*Accipiter badius*	B81	Carnivore
86	Slaty backed forktail	*Enicurus schistaceus*	B73	Insectivore
87	Stripe throated yuhina	*Yuhina gularis*	B63	Omnivore
88	Striated prinia	*Prinia crinigera*	B53	Insectivore
89	Slaty blue flycatcher	*Ficedula tricolor*	B40	Insectivore
90	Striated bulbul	*Pycnonotus striatus*	B43	Omnivore
91	Streaked laughingthrush	*Trochalopteron lineatum*	B44	Insectivore
92	Spotted dove	*Streptopelia chinensis*	B36	Granivore
93	Tickell's leaf warbler	*Phylloscopus affinis*	B58	Insectivore
94	Velvet fronted nuthatch	*Sitta frontalis*	B33	Insectivore
95	Verditer flycatcher	*Eumyias thalassina*	B67	Insectivore

96	White capped water redstart	*Chaimarrornis leucocephalus*	B74	Insectivore
97	White throated fantail	*Rhipidura albicollis*	B71	Insectivore
98	Whiskered yuhina	*Yuhina flavicollis*	B39	Insectivore
99	White throated laughing thrush	*Garrulax albogularis*	B61	Insectivore
100	White tailed nuthatch	*Sitta himalayensis*	B101	Insectivore
101	White creasted laughing thrush	*Garrulax leucolophus*	B30	Insectivore
102	Yellow billed blue magpie	*Urocissa flavirostris*	B57	Insectivore
103	Yellow wagtail	*Motacilla flava*	B100	Insectivore

Appendix 4. Photoplates

Photo 1: Green tailed sunbird

Photo 2: Kalij pheasant

Photo 3: Yellow wagtail

Photo 4: Velvet fronted nuthatch

Photo 5: Shikra

Photo 6: Black drongo

Photo 7: Scarlet minivet

Photo 8: Himalayan bulbul

Photo 9: Black-lored tit

Photo 10: Black bulbul

Photo 11: A researcher in field