SEASONAL PATTERN IN HABITAT SELECTION BY BIRDS OF JHILMIL JHEEL CONSERVATION RESERVE, UTTARAKHAND

A Thesis

Submitted by

ANKITA DAS

For the award of the Degree of

DOCTOR OF PHILOSOPHY

IN

WILDLIFE SCIENCE

Under the guidance of

Dr. K. RAMESH

Wildlife Institute of India

Dehradun – 248001, Uttarakhand

Saurashtra University

Rajkot – 360005

December 2022

Poem dedicated to birds-

Dream of being a bird

Listen to me “I am a bird”

and I want to be heard.

I want to fly in the sky

Doing pitter-patter in the water,

Hopping in the bushes and grasses,

forest and on the hills.

Let me live and roam

Because I have a family and a home.

- Ankita Das

भारतीय वन्यजीव संस्थान
Wildlife Institute of India
(An Autonomous Institute under Ministry of Environment, Forest & Climate Change, Govt. of India)
पत्रपेटी सं०/Post Box No. 18, चन्द्रबनी, देहरादून/Chandrabani, Dehradun - 248001, उत्तराखण्ड, भारत/Uttarakhand, INDIA

Azadi Ka Amrit Mahotsav

DECLARATION BY THE CANDIDATE

I hereby declare that the work conducted under the thesis titled "**Seasonal Pattern in Habitat Selection by Birds of Jhilmil Jheel Conservation Reserve, Uttarakhand**", is a record of original research work, done by me and subsequently submitted for the award of the degree of doctor of Philosophy in Wildlife Science to Saurashtra University, Rajkot. This research work has been carried out under the guidance and supervision of Dr.K. Ramesh, Scientist-E, Wildlife Institute of India. The work has not formed the basis for the award of any other degree, diploma or any other qualification. I also declare that the thesis embodies my own work, analysis, observation and understanding and the particulars given in it are true to the best of my knowledge.

Ankita Das

(Ankita Das)

Place: Dehradun

Date: 12/12/2022

(Dr. K. Ramesh)
Supervisor

ई.पी.ए.बी.एक्स/EPABX : +91 135-2640114, 2640115, 2646100; फैक्स/Fax : 0135-2640117 | ई-मेल/Email: wii@wii.gov.in वेब/Website www.wii.gov.in Twitter: @wiiofficial1

भारतीय वन्यजीव संस्थान
Wildlife Institute of India
(An Autonomous Institute under Ministry of Environment, Forest & Climate Change, Govt. of India)
पत्रपेटी सं0/Post Box No. 18, चन्द्रबनी, देहरादून/Chandrabani, Dehradun - 248001, उत्तराखण्ड, भारत/Uttarakhand, INDIA

Azadi Ka Amrit Mahotsav

CERTIFICATE

This is to certify that the thesis by **Ms. Ankita Das** titled **"Seasonal Pattern in Habitat Selection by Birds of Jhilmil Jheel Conservation Reserve, Uttarakhand"** is an original and independent research work submitted to the **Saurashtra University, Rajkot (Gujarat)**, for the award of the degree of **Doctor of Philosophy in Wildlife Science**.

Ms. Ankita Das has put more than six semesters of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

(Dr. K. Ramesh)
Supervisor

YV Jhala

(Dr. Y.V. Jhala)
Dean
Faculty of Wildlife Science

संकायाध्यक्ष / Dean
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

ई.पी.ए.बी.एक्स/EPABX : +91 135 2640114, 2640115, 2646100 फैक्स/ Fax : 0135 2640117 | ई-मेल/Email: wii@wii.gov.in वेब/ Website www.wii.gov.in Twitter: @wiiofficial1

SAURASHTRA UNIVERSITY
P.G.T.R Section
Main Office, First Floor
University Road
Rajkot - 360 005 (Gujarat)
Phone No. : 2578501
Fax : (0281)2856983
www.saurashtrauniversity.edu

Accredited Grade 'A' by NAAC

CERTIFICATE FOR PRE-PH.D. PRESENTATION

This is to certify that **Ms. Ankita Das** has made Pre-Ph.D. Presentation as per UGC Guideline "University Grant Commission (Minimum Standard and Procedure for award of Ph.D. Degree) Regulation-2016" and Saurashtra University Ordinance for Ph.D. Programme (O.Ph.D. 8.3), on her research work titled **"Seasonal Pattern in Habitat Selection by Birds of Jhilmil Jheel Conservation Reserve, Uttarakhand"** at Wildlife Institute of India, Dehradun, Research Centre of Saurashtra University, Rajkot on **26th July, 2022** before all the faculty members and students of the Department for getting feedback and comments.

I certify that the research work was appreciated by all who were present, and the comments made by the faculty and researchers have been appropriately included in the thesis.

(Dr. K. Ramesh)
Supervisor

(Dr. Y.V. Jhala)
Dean
Faculty of Wildlife Science

संकायाध्यक्ष / Dean
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

भारतीय वन्यजीव संस्थान
Wildlife Institute of India
(An Autonomous Institute under Ministry of Environment, Forest & Climate Change, Govt. of India)
पत्रपेटी सं0/ Post Box No. 18, चन्द्रबनी, देहरादून / Chandrabani, Dehradun - 248001, उत्तराखण्ड, भारत / Uttarakhand, INDIA

75 Azadi Ka Amrit Mahotsav

CERTIFICATE OF PLAGIARISM CHECK

It is certified that the Ph.D. thesis titled **"Seasonal Pattern in Habitat Selection by Birds of Jhilmil Jheel Conservation Reserve, Uttarakhand"** submitted by Ms. **Ankita Das** been examined by us for plagiarism check as per UGC (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations. The following inferences are drawn from this check:

a) Thesis has significant new work/knowledge as compared to already published work or work under consideration for publication elsewhere.
b) No sentence, equation, diagram, table, paragraph or section is found to have been copied verbatim from previous work unless it was placed under quotation marks and the source was duly cited.
c) The work presented is original work of the author (i.e., there is no plagiarism) and there is no fabrication of data or result by manipulating research materials, equipment or processes, or by changing or by omitting data or results such that the research is not accurately represented.

Software used is iThenticate® and the similarity index is below accepted norms (i.e 15%).

The report is as follows:

Software used	**Date**	**iThenticate® similarity index**
iThenticate®	1.12.2022	9 %

The similarity index came as -9 %. The report from the plagiarism check is attached with the certificate.

(Dr. K. Ramesh)
Supervisor

(Smt. Sunita Agarwal)
Librarian

(Sunita Agarwal)
Librarian
Wildlife Institute of India
Dehradun

(Dr. Y. V. Jhala)
Dean
Faculty of Wildlife Science

संकायाध्यक्ष / Dean
भारतीय वन्यजीव संस्थान
WILDLIFE INSTITUTE OF INDIA
देहरादून / Dehradun

ई.पी.ए.बी.एक्स/EPABX : +91 135 2640114, 2640115, 2646100 फैक्स/ Fax : 0135 2640117 | ई-मेल/Email: wii@wii.gov.in वेब/ Website www.wii.gov.in Twitter: @wiiofficial1

SEASONAL PATTERN IN HABITAT SELECTION BY BIRDS ...

By: Das Ankita

As of: Dec 1, 2022 3:44:18 PM
25,509 words - 101 matches - 73 sources

Similarity Index

9%

Mode: Summary Report

sources:

64 words / < 1% match - Internet from 18-Jan-2020 12:00AM
bioone.org

12 words / < 1% match - Internet from 21-Feb-2020 12:00AM
bioone.org

44 words / < 1% match - Internet from 21-Jul-2022 12:00AM
www.biorxiv.org

32 words / < 1% match - Internet from 16-Oct-2021 12:00AM
www.biorxiv.org

70 words / < 1% match - Crossref
Venier, L.A.. "Boreal bird community response to jack pine forest succession", Forest Ecology and Management, 20050926

58 words / < 1% match - Crossref
Shiladitya Mukhopadhyay, Subhendu Mazumdar. "Habitat-wise composition and foraging guilds of avian community in a suburban landscape of lower Gangetic plains, West Bengal, India", Biologia, 2019

54 words / < 1% match - Crossref
Tian Gao, Marcus Hedblom, Tobias Emilsson, Anders Busse Nielsen. "The role of forest stand structure as biodiversity indicator", Forest Ecology and Management, 2014

47 words / < 1% match - Internet from 24-Aug-2022 12:00AM
ecologicalprocesses.springeropen.com

43 words / < 1% match - Internet
Baldiviezo, Cristian Daniel Veliz, Passos, Marcela Fortes de Oliveira, Azevedo, Cristiano Schetini. "Bird-plant interaction networks in native forests and eucalyptus plantations within a protected area", Universidade de São Paulo (USP), Museu de Zoologia (MZUSP)., 2021

43 words / < 1% match - Internet from 21-May-2012 12:00AM
www.zoosprint.org

31 words / < 1% match - Internet
Zerihun Girma, Yosef Mamo, Girma Mengesha, Ashok Verma, Tsyon Asfaw. "Seasonal abundance and habitat use of bird species in and around Wondo Genet Forest, south-central Ethiopia", Ecology and Evolution

11 words / < 1% match - Internet
Justus Precious Deikumah, Richard Kwafo, Vida Asieduwaa Konadu. "Land use types influenced avian assemblage structure in a forest–agriculture landscape in Ghana", Ecology and Evolution

37 words / < 1% match - Internet from 24-Dec-2021 12:00AM
www.cifor-icraf.org

37 words / < 1% match - Internet from 13-Jul-2020 12:00AM
www.frontiersin.org

36 words / < 1% match - Internet from 06-Oct-2022 12:00AM
wii.gov.in

19 words / < 1% match - Internet from 21-Jan-2020 12:00AM
www.biodiversitylibrary.org

17 words / < 1% match - Internet from 03-Jan-2020 12:00AM
www.biodiversitylibrary.org

33 words / < 1% match - Crossref
Baral, H.S., and C. Inskipp. "The Birds of Sukla Phanta Wildlife Reserve, Nepal", Our Nature, 2010.

29 words / < 1% match - Crossref
Ankita Sinha, Hima Hariharan, Bhupendra Adhikari, Ramesh Krishnamurthy. "Bird diversity along riverine areas in the Bhagirathi Valley, Uttarakhand, India", Biodiversity Data Journal, 2019

28 words / < 1% match - Crossref
Jayapal, R.. "Importance of forest structure versus floristics to composition of avian assemblages in tropical deciduous forests of Central Highlands, India", Forest Ecology and Management, 20090510

28 words / < 1% match - Internet from 05-Jun-2022 12:00AM
koreascience.or.kr

27 words / < 1% match - Crossref
Masashi Ohsawa. "Beetle families as indicators of Coleopteran diversity in forests: a study using Malaise traps in the central mountainous region of Japan", Journal of Insect Conservation, 02/11/2010

14 words / < 1% match - Internet from 25-Apr-2022 12:00AM
link.springer.com

12 words / < 1% match - Internet from 09-Sep-2022 12:00AM
link.springer.com

26 words / < 1% match - Internet from 01-Jul-2017 12:00AM
okologia.mta.hu

26 words / < 1% match - Internet from 11-May-2009 12:00AM
www.amazon.com

23 words / < 1% match - Crossref
T.I. Simamora, S.D. Purbowo, Y. Laumonier. "Looking for indicator bird species in the context of forest fragmentation and isolation in West Kalimantan, Indonesia", Global Ecology and Conservation, 2021

23 words / < 1% match - Internet from 06-Nov-2013 12:00AM
tigers.missouri.edu

22 words / < 1% match - Internet from 22-Oct-2022 12:00AM
academic.oup.com

21 words / < 1% match - Crossref
Urban, Dean L., and Thomas M. Smith. "Microhabitat Pattern and the Structure of Forest Bird Communities", The American Naturalist, 1989.

20 words / < 1% match - Crossref
Roberge, J.M.. "Indicator species among resident forest birds - A cross-regional evaluation in northern Europe", Biological Conservation, 200606

19 words / < 1% match - Crossref
Jan Douda, Jana Doudová-Kochánková, Karel Boublík, Alena Drašnarová. "Plant species coexistence at local scale in temperate swamp forest: test of habitat heterogeneity hypothesis", Oecologia, 2011

19 words / < 1% match - Internet from 27-Sep-2022 12:00AM
www.sacon.in

18 words / < 1% match - Crossref
Izsak, J.. "Links between the species abundance distribution and the shape of the corresponding rank abundance curve", Ecological Indicators, 201203

18 words / < 1% match - Internet from 20-Jul-2020 12:00AM
www.indiaenvironmentportal.org.in

17 words / < 1% match - Crossref Posted Content
Lorenzo Marini, Ignasi Bartomeus, Romina Rader, Francesco Lami. "Species-habitat networks: Bridging applied ecology and network theory", Cold Spring Harbor Laboratory, 2018

ACKNOWLEDGEMENTS

In the beautiful and challenging journey called ‘Ph.D.’ I came across various people whom I would like to acknowledge. I got the opportunity to be a part of the project ‘Developing Conservation Plan of Jhilmil Jheel Conservation Reserve, Haridwar, Uttarakhand’ under which my Ph.D. thesis was accomplished and in this process I was assisted by my many people without whose help it would not have been possible to achieve this task.

First and foremost, I express my sincere gratitude to my respected guide Dr. K. Ramesh (Scientist-E, Wildlife Institute of India, Dehradun). He guided me throughout and helped me in developing research ideas and objectives and developing this thesis work. He gave me complete freedom of thought. My heartfelt thanks to Dr. V.P. Uniyal (Scientist-G, Wildlife Institute of India, Dehradun) who sorted out various problems which came up in my Ph.D. time period. I would like to thank Dr. Rajah Jayapal, Dr. P.R.Arun, Dr.S.Babu and Dr. H.N. Kumara from Sálim Ali Centre for Ornithology and Natural History, Coimbatore (SACON) who constantly gave me inputs and suggestions regarding the work and encouraged me during the entire period of my study. I am thankful to the Director Dr. Satya Prakash Yadav, Dean Dr. Y.V. Jhala, Registrar Dr. Ruchi Badola and Research Coordinator Dr. Bitapi Sinha for providing the institutional support. My sincere gratitude to former directors Dr. V.B. Mathur and Dr. Dhananjay Mohan (former Directors of WII) and Dr. K. Shankar (former Director of SACON) for their support. I am grateful to Dr. Asad Rahmani (former director of BNHS) for his inputs in my writings. I thank Finance and Administrative departments of SACON and WII. I am also grateful to Shri M.M. Uniyal who helped me in various official work.

I want to thank the Ministry of Environment, Forest and Climate change (MOEFCC) for funding this project, without which it would not have been possible to undertake this research work. I gratefully acknowledge the help of Uttarakhand Forest Department for permitting me to work in the field, providing logistic support for the study and all the necessary assistance and cooperation during the field studies. I want to thank the forest staffs Mr. Sunil Bhadula, Mr. Gopal Negi, Mr. Bhandari for sharing their knowledge about the landscape. I remain indebted to my field assistant Amani, who saved my life from frequent encounters with elephants. With his hard work, it was possible to do the fieldwork. Besides I would like to thank Satendra from Tantwala village who worked as a volunteer and Hiral Gandhi from IISER Mohali who worked as an intern during the initial days of fieldwork.

I want to thank people from Wildlife Institute of India, Dehradun who helped me in my work Dr. Soumya Dasgupta, Dr. Tanveer Ahmed, Dr. Naveen Chandra Joshi, Dr. Ankita Sinha, Dr.Tapajit Bhattacharya, Dr. Vineet Dubey, Dr. Amit, Dr. Upma Manral, Dr. Monica Kaushik and Dr. Aashna Sharma. I owe my deepest gratitude specially to Dr. Soumya Dasgupta for his unwavering support throughout the study period. I want to mention my friends Sameer Gautam, Shrutarshi Paul, Nilanjan Chatterjee, Bhaskar Bhandari, Ashish Jangid, Sohom, Kalsang Dorje, Anoop Singh, Ashish Panda, Priyanka, Meghna, Supratim and Shankarsan from Wildlife Institute of India who helped me in countless ways. My heartfelt thanks to my friends from SACON Babu Rao, Jeevith, Aakriti, Ankit, Asit, Sudhir, Siddesh, Niveditha, Surya and Clince. I would especially like to thank Babu Rao who helped me in the clarification of various concepts and helped in the analysis of my data. I want to mention about one of my good friends Chirantan Sharma who has always mentally supported me in the ups and downfall of my life during my Ph.D. study period, especially uplifting my spirits during family health issues during covid time period. I would also like to thank my best friend, Rajesh Kumar Vishwakarma, from Hydrology Department, IIT Roorkee for boosting my spirits during difficult times.

I am grateful to my family who always showered their love, care and compassion on me. They have always helped me to get through my work easily. They helped me overcome various hindrances which I faced during the study period. I thank my elder sister and niece for cheering me up during stressful situations. Finally I would like to acknowledge my 'determination' which kept me going throughout.

-Ankita Das

CONTENTS

List of plates

List of figures

List of tables

Executive summary

Birds are an essential part of the ecosystem. They act as an effective tool to connect people to biodiversity and conservation. They are one of the best indicators of the environment as they live in almost every type of environment and are vulnerable to various disturbances, thus can be associated with changes in habitat. As birds are primarily diurnal, often conspicuous and wide-ranging, so studies on bird communities have emerged as a significant area of research in community ecology. Bird community ecology can be categorized into 'process' and 'pattern'. 'Process' is the cause and includes interaction within communities such as co-occurrence and competition. 'Pattern' is the effect and it includes structure and organization of communities, species diversity pattern, bird habitat association and habitat selection. Most of the work on bird community structure has been carried out in large-sized protected areas. The present study was initiated to assess seasonal pattern in habitat selection by birds in Jhilmil Jheel Conservation Reserve (JJCR) which is a small-sized Protected Area (PA). This work also focuses on both 'process' and 'pattern' of bird community structure. The work also focusses on how small-sized PAs are equally important in conserving wildlife species such as birds. Understanding the relationship of birds with habitat provides insights into habitat use, which contributes in the conservation of species. Habitat selection of birds is one of the foremost steps to understand the complexity of their community. Some factors influencing habitat selection are habitat heterogeneity, structure and composition of vegetation, seasonality and co-occurrence. Habitat heterogeneity helps in maintaining high bird diversity. Abundance and distribution of species in a community also depends on the physiognomic, floristic composition of the forest vegetation and seasonality.

For the present research work, the study area was stratified into six habitats: plantation, mixed deciduous forest (mixed forest), riverine habitat, scrub forest, grasslands and agriculture fields-human settlement. Habitat-wise point count method (Bibby et al., 2000) was done to collect abundance data of birds covering plantation (28), mixed forest (15), scrub forest (12), riverine (25), grassland (21) and agriculture fields-human settlements (15). Sampling was done in the summer (April-June) and winter seasons (November-mid March) in 2018-2020. Bird sampling was conducted in 116 point count stations, separated by 200 meters from each other to avoid double counting of birds. Sampling was done in the early morning from 5:30 am to 8:30 am during summer and from 8:00 am to 10:30 am during winter season. Birds were recorded for their species, abundance, feeding guild, habitat type and vertical strata. Every point count station was visited 20 times. Surveys were avoided during inclement weather. Birds were identified by referring to field guides (Ali, 2002; Grimmett et al., 2011) whereas birds' call and songs were identified through xeno-canto (2020). For habitat quantification, vegetation plots were laid in the point count stations, with two plots in each point count station, 232 quadrat plots were laid in total. Each tree and shrub was identified to species level with the help of available field guides. Information on trees were collected in quadrat of 10X10 m^2. Tree characteristics such as tree species, abundance, GBH, height, density, basal area and canopy cover were assessed. Information on shrubs was collected in 5x5 m^2 plot nested inside the 10x10 m^2 plot. Herbs and grasses were recorded in 1x1 m^2 nested at the four corners of 10x10 m^2 plot. Disturbance data such as presence of livestock, presence of trail and presence of logged trees were taken in presence/absence form in each quadrat plot. Habitat quantification was done in both summer and winter seasons.

The species accumulation curve showed sampling adequacy in both the summer and winter seasons. In total, 170 species of birds representing 16 orders and 64 families were recorded. The dominant order was Passeriformes, the dominant family was Muscicapidae and the dominant bird species was Red-vented Bulbul. Richness index was found to be 17.7371. It shows JJCR has high species richness. Most of the bird species were resident followed by winter visitors, summer visitors and monsoon visitor. The overall bird species diversity was 4.126. Most of the bird species had clumped distribution. Bird species diversity was found out to be 3.806 and 3.994 in summer and winter season respectively. There were 110 bird species in summer season and 131 bird species in winter season. RAD (Rank abundance) curve showed that there is dominance of some of the birds during winter season. There was significant difference in mean abundance of birds in different habitats in summer and winter season. JJCR harbours ten species of globally threatened avifauna including three Critically Endangered, three Endangered and four Vulnerable species. In addition, the reserve also has eight species of Near Threatened category.

The diversity of bird species and community assemblage depends on the habitat heterogeneity. The seasonal and spatial variations in bird species composition across the six different habitats were assessed and I also investigated the association of different structural and physiognomic characteristics of vegetation with different bird species. I found a significant difference in bird community across the different habitats within the reserve, and the difference was attributed by the difference in abundance of bird species in each community. There was significant variation in bird community assemblage in summer and winter seasons and the overall dissimilarity was 91.17%. In summer season the highest dissimilarity between bird communities was recorded between plantation and grassland habitat, whereas in winter the difference is highest between scrub forest and riverine habitat possibly due to differences in the vegetation composition leading to dissimilar bird community. The lowest difference in bird community was recorded between mixed deciduous and scrub forest in both summer and winter seasons could be attributed to similarity in the vegetation composition leading to similar bird composition. The non-metric multidimensional scaling showed the association of different bird species to different structural and physiognomic characteristics of habitat. The present study shows that small protected areas such as Jhilmil Jheel Conservation Reserve has high potential for conservation of bird diversity and thus emphasize that the protection of different habitats is equally important for conserving biodiversity.

Habitat selection pattern of birds can be understood through resource selection function (RSF). Resource selection function index stated that 48 bird species had 100% selection for a specific habitat in summer and 71 bird species had 100% selection for a specific habitat in winter. The birds were thereafter classified into habitat specialist and generalist based on their specificity to a particular habitat type. The birds were also classified according to their presence in different vertical strata. The potential for bird species to act as indicator species of various habitats in Jhilmil

Jheel Conservation Reserve (JJCR) was also assessed. JJCR comprised 60.59 % as habitat specialists, 37.06 % as generalist species and 2.35 % commensals. Maximum species belonged to middle canopy. Indicator values of all bird species were computed for every habitat type and those species with statistically significant values ($P < 0.001$) were considered as suitable indicators for a particular habitat. In summer season out of 110 species, 60 species were identified as indicator species. Grassland had 11 indicator species, mixed deciduous forest-12, Plantation-12, Riverine habitat-15, Agriculture field-human settlement had 3 indicator species and scrub forest had 7 indicator species. In winter season out of 131 species, 64 species were identified as indicator species. Grassland had 10 indicator species, plantation-12, riverine-16, riverine-16, agriculture field-human settlement-3, mixed and scrub forest had 7 and 16 indicator species respectively. The knowledge of indicator species can be used to monitor habitat and forest status and improve management and conservation strategies.

Finding the relationship between birds and habitat and patterns of species co-occurrence is an important part of community ecology. Network analysis provides visualization of associations between species and defines most processes in terms of nodes and links. This approach links multiple species and habitat resources. It is helpful in quantifying properties of entire habitat networks co-existence among species. Bird species co-occurrence was done using ‘cooccur’ package in R. Birds association with other co-occurring birds were seen. Network analysis was done to assess the network complexity of bird’s community in different habitats using i graph package in R. Species network analysis was used to compare the complexity of the bird communities among the six habitat types. The network analysis was done through igraph R package. Purple Sunbird, Jungle Babbler and Indian Pitta had the highest number of positive interaction. Those with highest number of negative associations were Red-wattled Lapwing, Paddyfield Pipit and River Lapwing. In winter season, Oriental Magpie Robin had the highest number of positive association. Those with the highest number of negative associations were Paddyfield Pipit, Citrine Wagtail and Common Stonechat. Riverine and scrub forest had the highest bird community complexity followed by plantation, mixed forest and grassland. For effective management strategies, it is essential to understand their co-occurrence pattern.

Habitat features also play a key role in determining the composition of bird feeding guild. Bird species were categorized into fine foraging guilds based on their food preferences namely Insectivore, Granivore, Herbivores, Nectarivore, Frugivore, Frugiore-Insectivore, Nectarivore-Insectivore, Frugivore-Insectivore-Nectarivore (FIN), Fruit-Seed-Nectar (FSN), feeding on Fruit-Seed-Nectar and Insects (FSNI), Omnivore and Piscivore. The present study was aimed to investigate the role of habitat and anthropogenic variables on guild structure of bird assemblage in JJCR. Birds were sampled using point count method whereas quadrat plot method was used to characterise the habitat features. Insectivore guild contributed to the most species rich feeding guild. There was significant difference between the bird feeding guild composition in every habitat and season. Majorly feeding guilds showed positive association with GBH stating preference for old growth and negative association with anthropogenic disturbances such as presence of livestock and presence of trails.

Our study emphasized that maintaining functionally diverse bird assemblages in any landscape is an important management goal and recommends conserving vegetation complexity and regulating livestock grazing in JJCR.

The present work is the first detailed study of the bird community in JJCR. It supports diverse bird community, despite being small and the study depicted how habitat heterogeneity, vegetation structure and composition, season and species co-occurrence brings the difference in bird species assemblage. JJCR is an important foraging and resting habitat for migratory and resident birds. Our study highlights the role of habitat variables in determining bird composition. Retention of old-growth forest stands better conserves birds. The indicator species and feeding guild should be included in the management plan as it helps in maintaining functionally diverse bird assemblages in any landscape. It is important to understand how species use resources and their co-occurrence pattern for effective management strategies. Even though the present study area is protected as a conservation reserve still some threat persists such as logging lopping, livestock grazing etc. which might affect the bird community in the long run. For long-term management of this Conservation Reserve, proper management plan and regulation is needed.

CHAPTER 1

INTRODUCTION

"If you take care of birds, you take care of most of the big problems in the world."

-Thomas E. Lovejoy

1.1. Birds community

Birds act as an effective tool to connect people to biodiversity and its conservation (Cox and Gaston, 2015). They are essential ecosystem service providers (Garcia et al., 2010; Donazar et al., 2016; Gaston et al., 2018). They are extremely mobile, wide ranging and live in almost every type of environment and are vulnerable to various disturbances. They are barometers of environmental change (Villiers, 2009; Mekonen, 2017) and are considered as good indicators of environmental quality as they relate to changes in various habitat features (Vallecillo, 2016). Bird community has been considered as a better predictor of habitat quality and health than a single species. Bird community has been defined as individual suites of species co-occurring on the landscape at a given time (Wiens, 1989a; Wiens, 1989 b).

One of the central themes in ecological research is understanding the organization of ecological community (Simberloff, 2004). The number of species in any local assemblage is an important index of community structure (Gotelli and Colwell, 2011). 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 (Mohan, 1997). Community ecology has concentrated on determining patterns in species associations and distributions and identifying processes that lead to these patterns and species co-existence (Lewinsohn and Prado, 2006), the occurrence, co-occurrence and interactions of species with their measurable environment (Wiens, 1989 a; Wiens, 1989 b; Mc Cune and Grace, 2002). 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). Studies on bird communities have emerged as a major area of research in community ecology.

Bird community ecology studies can be categorized into two major priorities i.e. (i) pattern (ii) processes (Wiens, 1989). Pattern characterises the natural assemblage of species, structure and organisation of communities, species diversity pattern and bird habitat association. Processes include interaction within communities such as co-occurrence, competition and factors operating in habitat selection by particular taxa. Jayapal (1997) stated that pattern is the effect and process is the cause. Understanding the relationship of birds with habitat provides insights into habitat use, which contributes in the conservation of species.

1.2. Habitat

Habitat is described as a set of environmental factors which a species needs for survival and reproduction. All organisms use habitat that varies over scale and time. Space and time are defined through hierarchy behaviours such as foraging (patch), dispersal (habitat) and migration (landscape). Bird community patterns result from species composition and distribution across spatial and temporal gradients (Robinson et al., 2000).

1.3. Features of habitat

Based on type of sites, habitat has been described as follows:

Feeding sites: Feeding site can be used as a descriptor for habitat for certain bird species. Species sharing same habitat feed in different sites. For example, many duck species breeding on Lake Myvatn, northern Iceland had distinct foraging sites (Bengtson, 1971).

Perch sites: Another important descriptor is perching site as perch sites might be quite specific for some birds. For instance, Ferruginous Hawks used lower fence posts while Golden Eagles used the highest perch sites (Collins, 1981).

Nest sites: Many bird species have specific nest-site requirements. The nests of Warbling Vireos were opened to the eastern sky and not to the western sky (Walsberg, 1981).

Roosting sites: The roosting sites are judiciously selected which can enhance their survival and reduce predation risks. Starlings select winter roosts where the night time temperature is higher (Yom-Tov et al., 1977).

Social Environment: Both intra and interspecific competition influence habitat selection. American Redstarts show intraspecific competition in habitat selection. Adult plumage birds nest in deciduous forests while first-year birds often nest in coniferous forests (Ficken and Ficken, 1967). Interspecific competition was found between Parula warblers and Golden–crowned Kinglet. Parula Warblers foraged heavily in the tips of spruce foliage. They were found to forage regularly through the interior of the spruce forests if the islands are not occupied by Golden-crowned Kinglet (Morse, 1967).

1.4. Factors responsible for habitat selection

Habitat selection of birds is one of the foremost steps to understand the complexity of their community. Habitat selection is the preference of a particular habitat among various habitats. It is a universal activity and behavioural response which results in disproportionate use of habitat influencing survival of individuals. It involves a series of choices such as general habitat selection, territory selection and nest site selection (Morris, 2017). It might be learned or genetic. It may vary from season to season for individuals or species (Cody, 1985). Different habitat selection helps species to coexist. After general habitat selection, territory acquisition occurs. Some birds select a new territory each year while some return to the same territory each year. After that a bird specifically selects a site within its territory to build a nest. The bird then protects it from predators and various other abiotic factors (Cody, 1985).

Some factors influencing habitat selection are habitat heterogeneity, vegetation structure, vegetation composition (Terborgh, 1985), competition and productivity (Cody, 1981), intraspecific attraction (Hunter et al., 2017), food availability. Habitat heterogeneity helps in maintaining high bird diversity (Ahmed, 2019; Sultana et al., 2021). The bird species assemblage and abundance of species in a community depends on physiognomic and floristic composition of the forest vegetation (Cody, 1985; Rotenberry, 1985; Cody, 1981; Terborgh et al., 1990; Weins, 1992; Morrison et al., 1992; Block and Brennan, 1993). A major role is also played by seasonality in determining the abundance and distribution of birds (Girma et al., 2017). Birds are also affected by landscape structure (Karr and Freemark, 1983; Pulliam and Danielson; 1991; Petit and Petit, 1996) and human-altered landscapes (Thiollay, 1995; Davis et al., 2000; Gardner et al., 2009; Clough et al., 2009; Larsen et al., 2012).

1.5. Literature review

Studies on structure and organization of local avian assemblages have been a major area of research in community ecology since David Lack and Robert MacArthur's works in mid twentieth century (Wiens, 1989). Mac Arthur's work on 'Bird species Diversity' (1961) was the pioneer work on bird community. It established the relationship between bird diversity and foliage density. Some of the studies on community which started thereafter in different biogeographical regions namely Nearctic (Cody, 1968; Karr and Roth, 1971; Willson, 1974; Franzreb and Ohmart, 1978; Stiles, 1978; Stauffer and Best, 1980; Beedy, 1981; Wiens, 1981; James and Rathbun, 1981; Blake and Karr, 1984; Howe, 1984; Monkkonen, 1994; Canterburry, 2000; Stephens et al., 2016), Neotropical (Cody, 1968; Pearson, 1971; Erard, 1989; Aleixo,1999; Karr et al., 1990; Blake, 2007), Australasia (Bell, 1982; Howe, 1984; Watson et al., 2005; Neate-Clegg et al., 2016), Oriental realm (Ali, 1979; Robin et al., 2015; Romanov et al., 2016), Palaearctic region (Ali, 1979; Chhettri et al., 2001; Chhettri et al., 2005; Acharya et al., 2010; Price et al., 2014; Erdelen, 1984; Monkkonen, 1994; Ozkan et al., 2013; Stephens et al., 2016), Afrotropical (Lack, 1987; Erard, 1989; Sekercioglu, 2002; Waltert et al., 2005; Romdal and Rahbek, 2009).

Particular birds are associated with particular habitats (Brawn et al., 2001; Seymour and Simmons, 2008) and thus respond to changing habitat conditions (Siriwardena et al., 1998: Krebs et al., 1999). The composition of avian assemblages and how habitat features influence them has been one of the most common matter of investigation in community ecology (Jayapal et al., 2009). It is important to understand how different bird species select different habitats. There are few avifaunal studies from adjoining landscapes of Jhilmil Jheel Conservation Reserve. Pandey et al. (1994) have worked on birds of Rajaji National Park. Das et al. (2011) have studied on the vultures of RajajiTiger Reserve. Response of migrant and resident bird communities to anthropogenic disturbances in Shiwalik landscape, Uttarakhand was assessed by Kaushik et al. (2012). Mohan (1997) has worked on the birds of New Forest campus, Dehradun. Birds of Asan wetland were compiled by Mohan et al. (2016). Balodi et al. (2018) and Ahmed et al. (2019) studied the diversity, status and distribution of avifauna in Ramnagar, Uttarakhand.

Habitat-selection studies form an important part in conservation planning. There are several studies done on habitat selection of mammals including habitat selection of grizzly bear in the central Canadian Arctic by Mcloughlin et al. (2002, 2004), habitat selection of Giant Panda in Foping Nature Reserve in China (Liu et al., 2005). There are numerous studies done on the resource selection function of insects including a study on ten cricket species which showed 100% selection for a particular microhabitat highlighting the importance of preserving all the components of forest structure of an evergreen forest of Kudremukh National Park (Jain and Balakrishna, 2011). Joern (1982) found that the pattern in microhabitat use depends on biotic interaction in the grasshoppers in Western Texas. Habitat selection study on wood turtles showed that they selected forest edges to maintain thermoregularity and feeding needs (Compton et al., 2002). Numerous studies have examined the relationships between bird species diversity and habitat features such as vegetation structure and composition (Cody, 1985; Rotenberry, 1985; Cody, 1981; Terborgh et al., 1990; Weins, 1992; Morrison et al., 1992; Block and Bremen, 1993) and heterogeneity (MacArthur and MacArthur, 1961; Willson, 1974; James and Wamer, 1982; Terborgh, 1985; Mills et al., 1991; Germaine et al., 1998; Haney and Lydic, 1999; Sekercioglu, 2002; Shirley, 2004) . Most of the habitat selection based studies are focussed on birds. A study was conducted on the microhabitat selection of breeding little Bustards in Central Spain, which emphasised on management measures addressing management measures irrespective of landscape composition (Morales et al., 2008). Prothonotary warblers preferred flooded woodland than dried bottomland due to the availability of natural nest sites and feeding needs (Petit and Petit, 1996).

Environmental heterogeneity is considered one of the prime factors determining species diversity (Tilman and Pacala, 1993; Chase and Leibold, 2009). MacArthur and Wilson (1967), Rosenzweig (1995) and Tews et al. (2004) suggested that habitat heterogeneity could be the most important factor that shapes species–area relationships. Habitat Heterogeneity theory was developed initially by MacArthur and MacArthur (1961). It states that increase in habitat types leades to an increase in species diversity. Habitat heterogeneity enhances diversity when habitats are large enough to support distinct populations. Presence of many habitats leads to presence of many specialists which have distinct habitat preferences. Small-sized habitats and fragmentations might lead to competition among the generalists. Small habitats might also increase quality of the matrix by providing predator free space and complementary resources (Cramer and Willing, 2002). Heterogeneity provides broader niche space and thus supports more biodiversity. The edges between different habitats and favours species co-existence (Hamm and Drossel, 2017). More heterogeneous environment increases the effective species pool by providing more suitable conditions for many species having different ecological requirements (Allouche et al., 2012). This is an essential element of niche-based theories of species diversity and forms the basis of community ecology (Hutchinson, 1957; Chase and Leibold, 2009).

There are numerous literature available on bird habitat association in different habitats. It has been described as follows:

Grassland: There are various studies on grassland bird communities all over the world (Glover, 1969; Wiens, 1973; Caccamise et al., 1996). Little work has been done on the avifauna of subtropical grasslands in north India and in lowland Nepal (Baral, 2001). In Nepal the fertile areas of Terai are densely populated and have been converted to agricultural fields (Gurung, 1983). Studies by Dubey et al. (2015) on avian diversity in the Jaldapara national park, West Bengal, India and Baral and Inskipp (2009) on the birds of Sukla Phanta Wildlife Reserve, Nepal states that such grasslands are important refuge for many grassland birds. Clearance of tall grasslands, harvesting of grasses before they seed out and increasing livestock population has caused decline in the number of Finn's Weaver (*Ploceus megarhynchus*) at various places. In Nepal, Bengal Florican (*Houbaropsis bengalensis*) showed less preference for grasslands close to human settlements due to increased disturbance by cattle grazing (Baral et al., 2003). Encroachment by trees and shrubs in the grassland poses a major threat to the long-term existence of the main Sukla Phanta grasslands and the birds which depend on it (Baral et al., 2003; Inskipp and Inskipp, 1983 and Poudyal et al., 2008a). Population status and habitat ecology of Bristled Grassbird (*Chaetornis striata*) in Chitwan National Park, central Nepal was carried out by Singh and Buckingham (2019). They found that Bristled Grassbird avoided heavily grazed grasslands. *Sachharum spontaneum* grasslands along river courses was preferred by Bristled Grassbird (Baral, 2001; Singh and Buckingham, 2015). He raised the concern that loss of grasslands to scrub in lowlands of grasslands might be a major threat to Bristled Grassbird. Bristled Grassbird prefer densely vegetated medium to tall grasslands in dry and moist areas (Singh and Buckingham, 2019). Its population is declining because of the loss and degradation of grasslands and conversion of grasslands to agriculture (BirdLife International, 2015). Javed and Rahmani (1998) have worked on the conservation of avifauna in Dudhwa National Park, Uttar Pradesh which is a terai grassland and studied the impact of annual grassland burning and other management practices.

Scrub forest: Scrub forests are few isolated shrubs or young trees or dense thickets or it can be natural part of other habitats such as grassland (Mali et al., 2017). Scrub is one of the important forest habitats. In India, few studies have been carried out on scrubland bird species (Gandhi, 1986; 2006; Johnsingh et al., 1987; Santharam, 1989). Shahabuddin and Kumar (2007) worked on how rural biomass extraction can alter vegetation structure which had a significant effect on bird species composition of tropical scrub forest.

Riverine habitat: Riverine forest is an area where there is an interface of land and river. Landscape perspective of streams and rivers i.e. riverscape, has emerged in recent years (Malard et al., 2000). Riverine habitat has a wide range of flora and fauna (Ward et al., 2002; Amitha Bachan, 2003; Capon et al., 2016). The key factors for integrative understanding of riverscape are the abundance, distribution and structure of riverine bird communities (Sullivan et al., 2007). Sinha et al. (2019) have worked on bird diversity along riverine areas in Bhagirathi Valley which is one of the headwaters of the River Ganges. Bashir et al. (2012) prepared an inventory of bird species on the banks of Upper Ganges between Bijnor and Narora barrage in Uttar Pradesh. Dey et al. (2014) have reported major threats to bird conservation in the Vikramshila Gangetic Dolphin Sanctuary which is an IBA and lies in the eastern Gangetic plain. Mishra et al. (2016) have worked on the population structure of waders of River Ganges in Rae Baraeli, Uttar Pradesh. Ghosh (2021) has worked on the avian diversity in different habitats of Gangetic plains in West Bengal. Riverine forests are facing deforestation due to their conversion to agricultural fields and human habitation (Fernandez-Juricic, 2004).

Mixed deciduous forest: Jayapal et al. (2009) emphasized the importance of forest structure versus floristics in the composition of avian assemblages in tropical deciduous forests of Central Highlands, India. Jayson et al. (2003) have worked on vertical stratification and its relation to foliage in tropical forest birds in Western Ghats (India) and Kellner (2018) has worked on local-scale habitat components driving bird abundance in eastern North American deciduous forests.

Agriculture fields: The majority of land in tropical and subtropical regions is used for agriculture. There have been studies of avian diversity in agricultural landscapes in different parts of India. Agricultural fields have been studied for their bird composition and diversity in Punjab (Malhi, 2006), Karnataka (Basavarajappa, 2006), Maharashtra (Abdar, 2014), West Bengal (Hossain and Aditya, 2016), Uttarakhand (Elsen et al., 2016), Odisha (Mukhopadhyay and Mazumdar, 2017), Telangana (Narayana et al., 2019) and Haryana (Kumar and Sahu, 2020). Agriculture has led to over 80% of forest loss globally (FAO, 2010). Agricultural intensification is considered a potential threat to the bird population throughout the developed and developing world (Green et al., 2005). Increased use of fertilizer and pesticide can have deleterious effects on the avian assemblage of agro-ecosystem (Redhead et al., 2018; Dhindsa et al, 1986). It has also been reported that commercial sugarcane plantations favour generalist species while it does not support specialists (Hurst et al., 2013; Reynolds et al., 2018; Smith et al., 2015). Some studies state that agricultural landscapes act as refugia and primary habitat for various species (Ghosh et al., 2021). Properly managed agriculture fields (Rodrigues et al., 2013) and the heterogeneous agricultural landscapes can promote high bird diversity (e.g., Petit et al., 1999; Benton et al., 2003; Bennett et al., 2006; Fahrig et al., 2011). Perfecto and Vandermeer (2008) and Schroth (2004) have also demonstrated the potential of diverse agricultural areas in supporting biological diversity. Norris (2008) stated that agricultural lands can serve as safe corridors for the dispersal of wildlife between patches. There are studies which state how agriculture fields containing both native and exotic agroforestry trees are beneficial for birds as they provide food to birds (Dhindsa, 1994). Managed agricultural areas are equally important as the forest patches they surround (Perfecto and Vandermeer, 2002). Agricultural lands having native tree cover have conservation value (Harvey et al., 2008) as it provides structural heterogeneity while providing habitat and resources for native fauna species (Fahrig et al., 2015).

Plantation: Eucalyptus plantations are widely used in temperate, tropical, and subtropical regions (Richardson and Rejmanek, 2011) because of their fast growth rate, wide adaptability and profitability for paper production (Turnbull, 1999). There are various studies on the association between birds and plantations. The study also stated that both bird species richness and herbs were lower in eucalyptus plantation as compared to native forest and conservation of native forest patches should be the priority. In a study in NW Portugal forest plant richness, diversity and evenness was higher in the oak forest than eucalyptus forest, and also reported higher bird species richness and diversity in oak and pine forest as compared to eucalypt plantation (Proenca et al., 2010). Most of the bird species in the plantation area belonged to non-forest habitats while forest-associated species were more in secondary forest. Eucalyptus plantations have a lower species diversity of plants (Barlow et al., 2007; Proença et al., 2010). In Cerrado (vast ecoregion of tropical savanna in eastern Brazil), the number of bird species was higher than eucalyptus plantation because of lower undergrowth cover in plantations. Eucalyptus monocultures which are non-native tree plantations can replace native vegetation, makes the forest homogeneous and thus can extinguish local species, alter the regional water resources and diminish soil fertility (Marsden et al., 2001; Borsboom et al., 2002; Kanowski et al., 2005; Carnus et al., 2006; Valduga et al., 2016; Bayle, 2019). As plantations are generally man-made habitats, it takes many years for a stable bird community to establish. The study done by (Baldiviezo et al., 2021) showed that the species composition and the importance of the species for the interaction network were similar between native forest and the eucalyptus plantation. This was attributed to lack of anthropogenic activities, well-developed understory, and presence of native surrounding vegetation. The teak plantations were very homogenous habitats and supported a considerable proportion of the local avian species fauna (Daniel, 1989). There are also few studies on the preference of bird species for the Eucalyptus plantation. A study on the bird community in a natural secondary forest and *Lophostemon confertus* plantation in Hong Kong, South China found that there were more bird species in the plantation as compared to secondary forest (Kwok and Corlett, 2000). Species richness of forest-dependent bird species was more in forest site, but their abundance was higher in eucalyptus plantation (John and Kabigumila, 2011). The proper management of eucalyptus plantations through the retention of undergrowth provides hospitable habitat for birds.

Besides the different habitats, the microhabitats also play a major role in structuring bird assemblage. The significance of vertical strata (microhabitats) and the segregation of birds based on these strata has largely remained unexplored or poorly understood (Pearson, 1971; Jayson and Mathew, 2003; Zozaya et al., 2011). To support management of conservation areas, research on bird stratification is needed (Acharya and Vijayan, 2017). Various studies on which stratification has been investigated are insects (Adams, 1941; Bates, 1944; Haddow et al., 1964), mammals (Harrison, 1962; Napier, 1966; Titchenell et al., 2011), birds (Dilger, 1956;

Moynihan, 1962; Kendeigh, 1947; Dunlavy, 1935; Colquhoun and Morley, 1943; Hartley, 1953; Slud, 1960; Kati et al., 2009). The diversity of bird populations serves as a strong indicator of the overall health of an ecosystem (Dendup et al., 2021). Monitoring indicators is assessing sustainability for forest management. Roberge and Angelstam (2006) emphasized that the indicator species approach should constitute one of many complementary tools for conservation management. Niemi et al. (1997) gave a critical analysis on the use of indicator species in management. Various taxa have been used as indicator species such as plants and fungi (Ferris and Humphrey, 1999; Hansson, 2001), insects (Bonebrake et al., 2010; Ohsawa, 2010; Scalercio et al., 2009; Uys et al., 2010; Brereton, 2009; Lomov et al., 2006), mammals (Mathur et al., 2011; Upamanyu and Uniyal, 2008), birds (Mohan, 2007; Hayes et al., 2020). A cross regional evaluation on the indicator species among resident forest birds in northern Europe was done by Roberge and Angelstam (2006). Kremen (1992) assessed the indicator properties of species assemblages for monitoring natural areas. Sinamora et al. (2021) worked on determining indicator bird species in the context of forest fragmentation and isolation in West Kalimantan. It is important to identify the indicator species in heterogeneous habitats to monitor the staus of each habitat.

Heterogeneous environment enhances species richness and helps in species co-existence because of the availability of more partitionable niches (Terborgh, 1977; Palmer, 1994; Vivian-Smith, 1997). The presence of birds in a habitat is also affected by its association with other birds. Bird co-occurrence pattern can provide a framework for understanding the complexity of co-occurrence patterns and can improve bird conservation (Kim et al., 2017). Co-occurrence data defines the diversity of habitats or species niche width (Fridley, 2007; Pannek, 2016). Oberrath and Böhning-Gaese (1999) and Webb et al. (2002) worked on the spatial co-occurrence for both resident and migratory birds. Fournier et al. (2016) have worked on the co-occurrence of orthopteran and plant species in grasslands. Fanfarillo et al. (2020) have worked on co-occurrence patterns of rare and threatened species in winter arable plant communities of Italy. They mentioned that generalist show co-occurrence with many species and show similar co-occurrence pattern. Specialists show co-occurrence with few species. Network analysis for showing various interactions has been done by Montoya-Arango et al., 2019; Kim et al., 2017; Elo et al., 2021; Fournier et al., 2016; Bascompte and Jordano, 2007; Devi et al., 2022). Network has been used in food webs (Cohen, 1978; Cohen et al., 1990; May, 1973; Pimm, 1982). Network analysis has been used to assess the bird occurrence pattern for 10, 422 bird inventories from several countries (Kim et al., 2017).

The assessment of avian habitat preferences and foraging guilds are vital for analysing their response to changing habitat (Lawton et al., 1998) and conservation policy (Jankowski et al., 2013). The guild concept (Grinnel, 1917; Root, 1967) has been helpful in understanding the bird communities as bird guilds are indicators of ecological conditions (O'Connell et al., 2000). The concept of guild has been widely discussed in animals and extensively studied in birds (Blaum et al., 2011; Sabo and Holmes, 1983; Recher et al., 1985; Chettri et al., 2005; Perez-Crespo et al., 2013; González-Salazar et al., 2014; Koli, 2014; Mukhopadhyay, 2019). Numerous studies suggested that avian community structure is closely associated with habitat structure (Mac Arthur and Mac Arthur, 1961; MacArthur, 1964; Karr, 1968; Karr and Roth, 1971; Røv, 1975; Holmes et al., 1979; Menon et al., 2019; Ahmed et al., 2022). There are various studies which state that the extraction of fuelwood, grazing causes changes in the landscape (Chhetri et al., 2005; Singh, 2000; Kaushik et al., 2012; Shahabuddin et al., 2006; Menon et al., 2019) and alters the habitat structure (Martin and Possingham, 2005) and such alteration also affects the bird community. Livestock encroachments also influences bird community (Mengesha et al., 2011) and herbivory and disturbances are the major factors driving the dissimilarities in species composition within a forest community (Dasgupta et al., 2022).

There are several works done stating the significance of different habitats for birds, the threats and the recommendations for habitat management. People are encouraged to plant trees in grazed grasslands as a step towards reforestation but such activities reduce grassland area as trees outcompete grasses growing over there (Baral and Inskipp, 2009). Singh and Buckingham (2015) stated the need for a strategic conservation plan which includes grassland-dependent species in Terai grasslands including the needs of Bristled Grassbird. Scrubland has yet to be given attention for bird studies. Scattered scrub in open sites is often very significant for nest sites and song-posts (Malcome, 2007). River corridors provide important habitats for birds such as riparian, waterbird and upland birds (Sullivan et al., 2007). Bryce et al. (2002) stated that riparian obligate birds are expected to respond to changes in the surrounding habitats of stream corridor before aquatic organisms. Sullivan et al. (2007) proposed that to maintain diverse and abundant bird assemblage there should be intact channel geometry, active floodplains, high-quality aquatic habitat and natural flow regimes which enhances hydrological connectivity across the river corridor. He also specified that the mixture of forested and non-forested riparian vegetation is important for riverine bird communities. Robertson (1931) stated that different bird species have used Eucalyptus trees for shelter, nesting, feeding on the flower, nectar of the flower and seeds. It has been found to provide perches and roost sites for raptors as well. John and Kabigumila (2007) assessed the conservation value of eucalyptus plantations for local avifauna. The older plantations have a greater diversity of birds and a more stable community structure than the younger monocultures (Daniels, 1989; Mehta, 1998; Trivedi, 2006). They recommended the proper management of eucalyptus plantations through retaining undergrowth to provide hospitable habitat for birds. The surrounding matrix near wildlife habitats is also significant (Deikumah et al., 2014; Kennedy et al., 2010; Ruiz-Guerra et al., 2012) as it can be a major source of feeding and breeding for wildlife (Antongiovanni and Metzger, 2005) and it provides corridor for movement of wildlife between habitats (Devictor and Jiguet, 2007). The surrounding agroforest supports wildlife occurrence and movement (Karanth et al., 2016). JJCR is surrounded by agricultural fields and human-modified landscape and has high dependency of local people (Tewari and Rawat, 2013). High dependency and agricultural expansion creates a need for management to conserve biodiversity. One way to manage this could be retaining substantial tree cover within the surrounding agricultural areas, which is known to increase assemblage similarity between forests and agricultural habitats by increasing the vegetation structural complexity (Rocha et al., 2015). Therefore, it is essential to understand the impact of changes in the matrix on the wildlife as many small protected areas in India house many wildlife species and these PAs are embedded in a matrix of agroforestry landscape (Bhagwat et al., 2005; Robbins et al., 2015).

Small forest patches are potential biodiversity islets and might deliver several crucial ecosystem services (Decocq et al., 2016). Gibbon Wildlife Sanctuary named after Hoolock Gibbon which covers an area of (20.98km^2) in Assam, is small, but it has old-growth rainforest and seven species of primates. Small National Parks such as Phawngpui Blue Mountain in Mizoram (55 km^2) and Keibul-Lamjao in Manipur (39km^2) have more than 300 breeding bird species (Ghosh, 2019). There are various adverse effects of small, stand-alone areas as it has resulted in increased human-elephant conflicts (Baskaran et al., 2013), reduced gene flow among populations of tigers (Natesh et al., 2017) and forest understory birds (Robin et al., 2015), and altered species composition in mixed foraging bird flocks (Sridhar and Sankar, 2008). Based on global studies, estimates of bird species loss suggest that isolated tropical fragments 10 km^2 in area will lose their first species within 7 years, while one the size of 500 km^2 will lose its first species within 40 years (Newmark et al., 2017). Connecting smaller protected forests to larger ones can ensure the movement of animals so that there is an exchange of genetic material, which will ensure long-term sustainability of the populations (Ghosh, 2019).

1.6. Research gaps

Based on the literature review, the following research gaps have been identified:

- Absence of detailed investigation on the bird community structure in JJCR.
- Inadequate information on the seasonal flux of the bird species diversity and abundance in different habitats.

- Most of the previous works on bird community structure have been in large sized protected areas. The need for such knowledge in small protected areas which is more vulnerable to various threats has been addressed in this study.
- Habitat heterogeneity hypothesis have been less explored in small-sized forests.
- Very few studies have been conducted on ‘process’ of bird community and there is little work on the co-occurrence pattern of birds in different seasons and the network complexity of birds’ community in different habitats especially in Indian context. This work focusses on both ‘process’ and ‘pattern’ of bird community structure.
- The indicator bird species of various habitat types have not been explored thoroughly.
- The feeding guild structure of bird community has not been well studied in a small-sized PA.

1.7. Rationale for the study

After literature review, it was observed that there have been various studies on birds and their community structure (surrogate for biodiversity) but there is a need for avian community studies especially in small forest areas which is more vulnerable to various threats. So, the present study was initiated to investigate the habitat selection of birds in Jhilmil Jheel Conservation Reserve. As Jhilmil Jheel Conservation Reserve (hereafter JJCR), a small sized PA lies at the interface of agriculture fields and forests in Haridwar, Uttarakhand, it is important to understand the birds which thrive in such conditions. It is also a mosaic of habitat types and therefore it provides an optimum condition to assess the responses of birds to heterogeneity. Moreover, there are not many studies in this landscape that have analyzed the response of faunal communities to the disturbances. So, the present study is really important in the current scenario of human encroachment, agriculture expansion and forest loss. So, I have documented the birds' community structure, distribution pattern of birds and their association with different habitats and vegetation features in JJCR. Considering this, the current study was undertaken to see as to how avian species are influenced by the habitat heterogeneity and anthropogenic disturbances, so that conservation measures can be suggested to ensure better management.

1.8. Objectives

1. To document the avian community structure

2. To study the bird-habitat association with a view to document habitat selection

3. To assess the resource selection function of birds in different habitats

4. To document the bird co-occurrence in different habitats

5. To study the feeding guild structure of bird assemblage

1.9. Organization of thesis

This thesis is organised into eight chapters. The first two chapters are introductory. Third, fourth, fifth, sixth and seventh are technical. The last chapter i.e. eighth, has concluding remarks and proposes recommendations for habitat restoration of JJCR. The **first chapter** deals with the introduction of the research work. It gives a general description of the bird community, the concept of habitat, features and habitat selection. Review of literature on bird habitat association is also provided here. It discusses different factors responsible for habitat selection by birds, emphasizing on habitat heterogeneity. The **second chapter** is about the description of the study area and study design. It describes the geographical features of the area, flora and fauna of JJCR, mainly focussing on the bird community. It also describes the study design of the research work. The **third chapter** provides description of the overall avian community structure of JJCR. It describes about the spatial and temporal pattern of avian community structure in JJCR. It contains description of seasonal variation in bird richness in different habitats. The **fourth chapter** is about the bird-habitat association. This chapter identifies the bird species influencing the differences in bird species composition in different habitats. It also discusses the influence of habitat physiognomy and composition on the bird composition. The **fifth chapter** is about the quantitative description of the habitat selection function using resource selection function index. This chapter also documents the general pattern of bird assemblage in different microhabitats of JJCR and explores the potential indicator bird species in different habitats. It emphasizes the knowledge of the dynamics of indicator species and its use in monitoring habitat and forest status and improve management and conservation strategies. The **sixth chapter** is about the co-occurrence pattern of bird species in summer and winter seasons. It discusses the birds which have positive and negative co-occurrence. It also emphasizes on network complexity of bird communities in different habitats. The **seventh chapter** is about the feeding guild structure of Jhilmil Jheel Conservation Reserve. It documents the various feeding guilds in JJCR and discusses about difference in bird guild composition in different habitats and seasons. The relationship between vegetation parameters and different feeding guilds of birds has also been documented. The last chapter i.e. the **eighth**

chapter is about the conclusion of the research work and focusses on conservation and management recommendations for Jhilmil Jheel Conservation Reserve.

(**The scientific names of all the birds have been mentioned in the appendix**)

CHAPTER 2

STUDY AREA AND STUDY DESIGN

2.1. Overview

Jhilmil Jheel Conservation Reserve (hereafter JJCR) came into the limelight after the discovery of a small population of Swamp Deer and it was declared as a Conservation Reserve in 2005. It is among the first Conservation Reserves of India. JJCR lies at the junction of Terai–arc landscape, Shivalik landscape and upper Gangetic plains representing a very unique and species-rich ecosystem.

Terai-arc landscape stretches from Yamuna river in the west to Valmiki Tiger Reserve, Bihar in the east (Johnsingh et al., 2004) and runs parallel to Himalayan foothills and covers Shivalik hills, Bhabar tract and Terai plains (Rodgers and Panwar, 1988). Known for its fine alluvium and high water table, the Terai is characterized by hygrophilous grasslands and Tropical Moist Deciduous forests (Champion and Seth, 1968). Terai lies south of the Bhabar tract, which is south of the foothills of the Himalayas. JJCR is a remnant Terai habitat in the westernmost part of Terai landscape in India.

The **Shivalik,** also known as Sub-Himalaya, is a system of raised ridges formed from the debris brought down from the main Himalaya. They run along the base of Himalaya. It ranges from 200-1000 m above mean sea level and is extremely fragile. This landscape has high ecological significance due to the intermingling of taxa from the two biogeographic regions, viz. the Himalayas and the Upper Gangetic Plains (Johnsingh et al., 2004). The conservation area is also based at the junction of the

Bhabhar and Terai formations extending up to the **Ganga** (Nandy et al., 2012), characterized by deep sandy loam soils consisting of coarse sand and stones in shallow patches. The Jheel area drains directly into the Ganga (Nandy et al., 2012).

2.2 Location

Jhilmil Jheel Conservation Reserve (N 29^0 32’ to $29^0$50’ and E 78^0 to $78^0$15’) lies in Rasiyabaad Forest Reserve, Haridwar Forest Division, Uttarakhand, India (Figure 2.1a, b). It lies in the buffer area of Rajaji National Park. It covers 3782.50 ha of Reserve Forest and an altitude varying from 200 to 250 meters above mean sea level (Sinha et al., 2011). It is surrounded by Chiriyapur Forest Range on the east and southern side, Shyampur range on northern side and Lakshar range on the western side. It is located between Haridwar–Najibabad Highway (NH 74). Jhilmil Jheel is a saucer-shaped wetland on the left bank of river Ganga (Sinha et al., 2011) and lies at the core of Rasiyabaad forest range and. The Conservation Reserve includes three forest blocks (Table 2.1 and Figure 2.2).

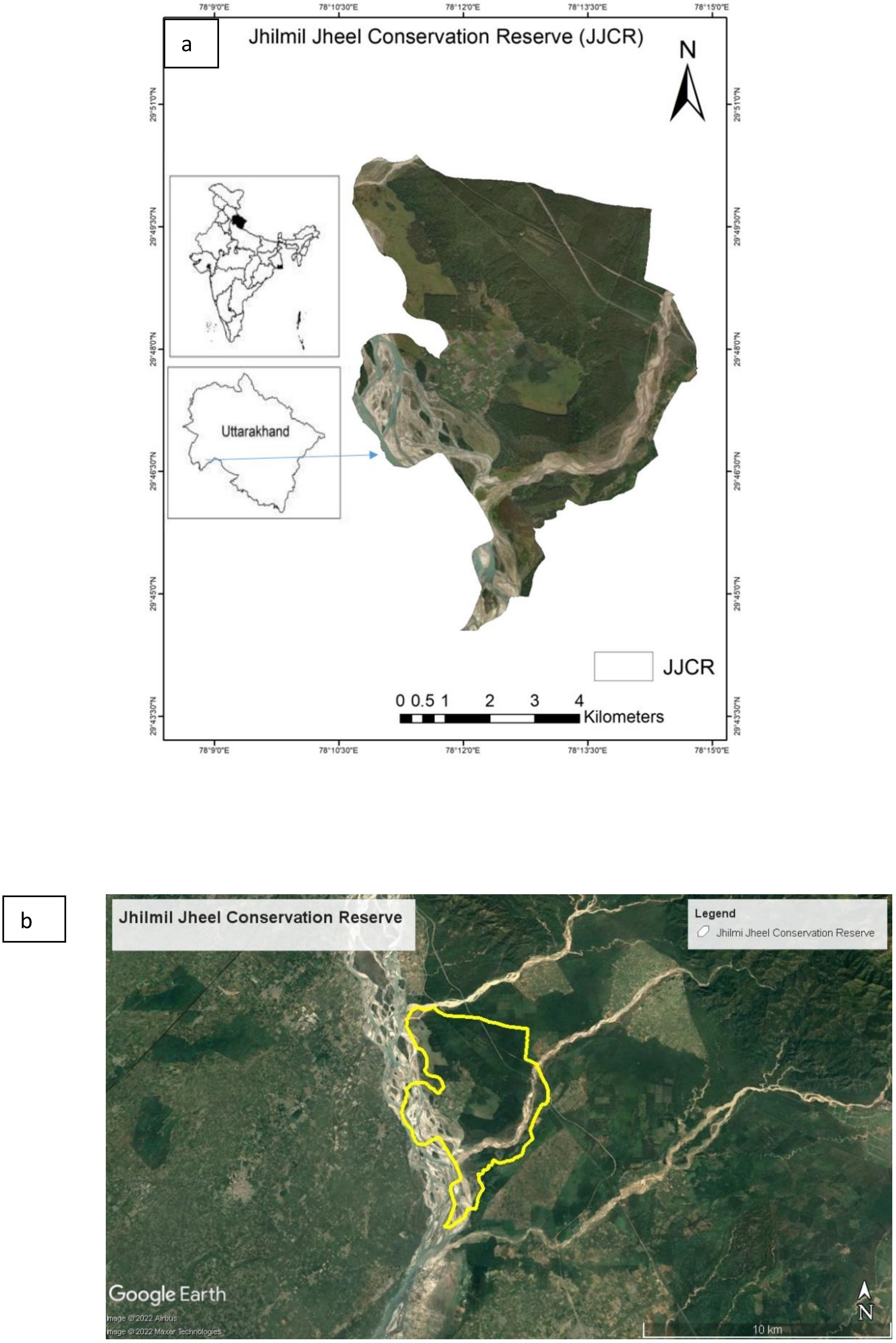


Figure 2.1. (a) Location of Jhilmil Conservation Reserve (Haridwar), Uttarakhand (b) Google earth image of surrounding matrix of Jhilmil Jheel Conservation Reserve

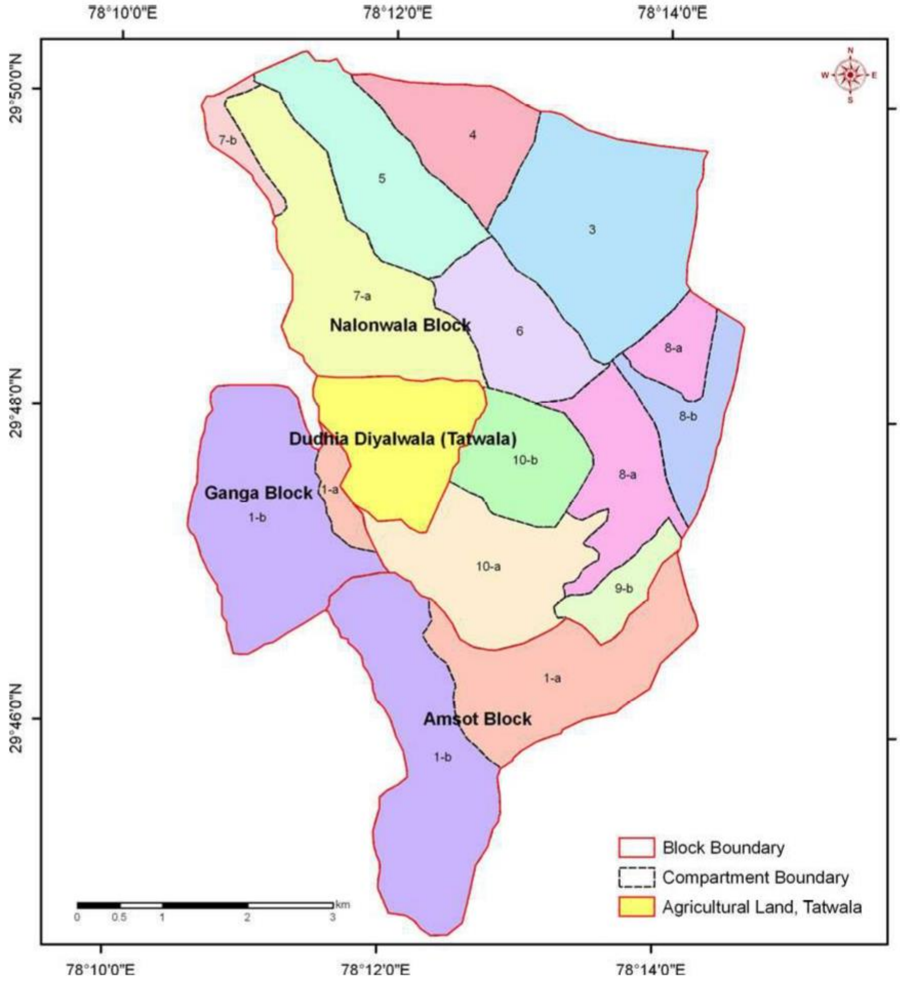


Figure 2.2. Different blocks of JJCR (Source: Nandy et al., 2012)

Table 2.1. Details of the area coverage of different compartments of the blocks of JJCR (source: (Sinha et al., 2011)

Block	**Compartment**	**Area (ha)**
Nalowala	3	450.90
	4	151.90
	5	262.60
	6	201.30
	7-a	339.50
	7-b	216.10
	8-a	87.00
	8-b	148.00
	9-a	163.80
	9-b	102.00
	10-a	259.00
	10-b	148.60
	Total	**2530.70**
Amsot	1-a	337.40
	1-b	493.20
	Total	**830.60**
Ganga	1-a	16.40
	1-b	405.80
	Total	**422.20**
Total		**3783.50**

2.3. Geographical extent

As per the notification, the Jhilmil Jheel Conservation Reserve has the following boundaries:

North: It extends from the junction of Pili River and Haridwar-Najibabad highway, along its southern boundary, up to the junction of this highway and Rawasan river in Nalowala Compartment no.8a.

East: It extends from Nalowala compartment no.8a and 8b up to the point where Nalowala compartment no.8a, 8b and 9b meets in the mid of Rawasan river.

South: The southern boundary starts from the meeting point of Nalowala compartment 8a and 9b in Rawasan river and then passes along the southern boundary of Amsot Compartment no. 1a and 1 b to join the Nalowala 10a and then continues along the western boundary of Nalowala 10a and 10b and then turns west along the southern boundary of Nalowala 7a till the Ganges river. The boundary then turns south along the western margin of Tantwala village up to the eastern boundary of Ganga 1a and then encircles Ganga compartment no 1b to end at the junction of Ganga 1b, Ganga 1a and Tantwala Village.

West: It extends from the meeting point of Ganga 1b, Ganga 1a and Tantwala village the western boundary of Jhilmil Jheel Conservation Reserve proceeds to the south western boundary of Nalowala compartment no 7b, to that point where Nalowala compartment no 7 a, Pili River and the Najibabad Highway meets.

2.4. Physical characteristics

Geology and soil

As mentioned earlier, Jhilmil Jheel area is located at the junction of the Bhabhar and Terai formations extending up to the Ganges. Bhabar is in the northern belt consisting of bouldery detritus and alluvium deposits brought by streams. The south tract belongs to Terai. The hill detritus gradually disappears and the subterranean water oozes leading to waterlogging conditions. The flood plains of the Ganges are characterized by deep sandy loam soils containing coarse sand and stone in shallow patches. Both fine sand and clayey loam soil texture is found here. The central part of the Jhilmil Jheel Conservation Reserve is a wetland and part of the area gets submerged during the monsoon months (Sinha et al., 2011).

Water Sources

Jhilmil Jheel receives water from the northerly formations of the Shivaliks of Chidiyapur Range or even further beyond as underground streams or 'Chhoyas' as well as from the flood of River Ganga. A series of streams emerge from the forest area and flow into the Jhilmil Jheel, which eventually flows into the Ganges. Hence most of the cultivable land around Jhilmil Jheel has a high water table (Sinha et al., 2011).

2.5. Climate

The area experiences sub-tropical climate. There are three distinct seasons in JJCR: Summer, monsoon and winter season. Summer season extends from April till June. Summer is very hot and humid. Temperature soars up to 44^0 C during summer. The area experiences monsoon by end June and rains continue till September. Average rainfall in the area is 1300 mm per annum. During monsoon period, hot humid conditions prevail. The relative humidity is maximum in July-August and minimum in April-May (Kumar and Natiyal, 2013). Winter begins from mid October and remains till March. Temperature goes as low as 2^0 C during winter season. It also experiences winter rains which dips the temperature even further. Subsequent heavy fog are also prevalent in the area.

2.6. Biological attributes

Jhilmil Jheel Conservation Reserve is endowed with variety of flora and fauna. It has a cluster of habitats that contribute to its rich biodiversity.

2.6.1. Flora

According to the classification done by Champion and Seth, eight types of forest are found in Jhilmil Jheel Conservation Reserve (Table 2.2). The vegetation of the area, as per the study (Tewari, 2009), can be categorized into following types: (i) Moist deciduous forest (mixed forest) (ii) Riverine forest (iii) Secondary scrub (iv) Grasslands (v) Plantation (Plate 2.1). The characteristic species in different habitats have been mentiond in table 2.3. *Zizyphus mauritiana* dominates the scrub forest. *Acacia catechu* is dominant in riverine habitat. Mixed Deciduous Forest is dominated by *Helicteres isora* whereas Grasslands were dominated by *Phragmites karka* and *Typha Augustifolia.* Top canopy is occupied by plantation of *Eucalyptus* and *Tectona grandis, Schleichera oleosa, Mitragyna parviflora, Ficus benghalensis, Holoptelia integrifolia* and *Bombax ceiba*. The second layer is occupied by tree species such as *Aegle mermelos, Mallotus philippensis, Syzygium cuminii* and *Trewia nudiflora*. The third layer is occupied by shrubs like *Clerodendrum infortunatum, Murraya koenigii, Pogostemon benghalensis* and invasive species like *Lantana camara*. There are 53 medicinal plants including 20 trees, 7 shrubs and 26 herbs. Some of these species are of high tradable nature such as *Bacopa sp.*, *Adhatoda sp.*, *Centella asiatica*, *Terminalia arjuna*, *Oroxylum indicum* etc. (Kumar and Natiyal, 2013).

Table 2.2: Forest types of JJCR

	Serial No.	**Forest Type**	**Champion and Seth classification**
A- Climax Types	1	Northern Dry mixed Deciduous forest	4b/C1
B- Edapic Types	2	Butea forest	D Tr E5
	3	Aegle forest	D Tr E7
	4	Dry Bamboo	D Tr E12
C- Seral Types	5	Khair-sissoo Riverine Forest	D Tr 1S/2
	6	Deciduous scrub Forest	D Tr 2S/2
	7	North Indian upper and lower Alluvial savannah forest	M Tr 2S/7aand7b
	8	Riverine Grasslands	

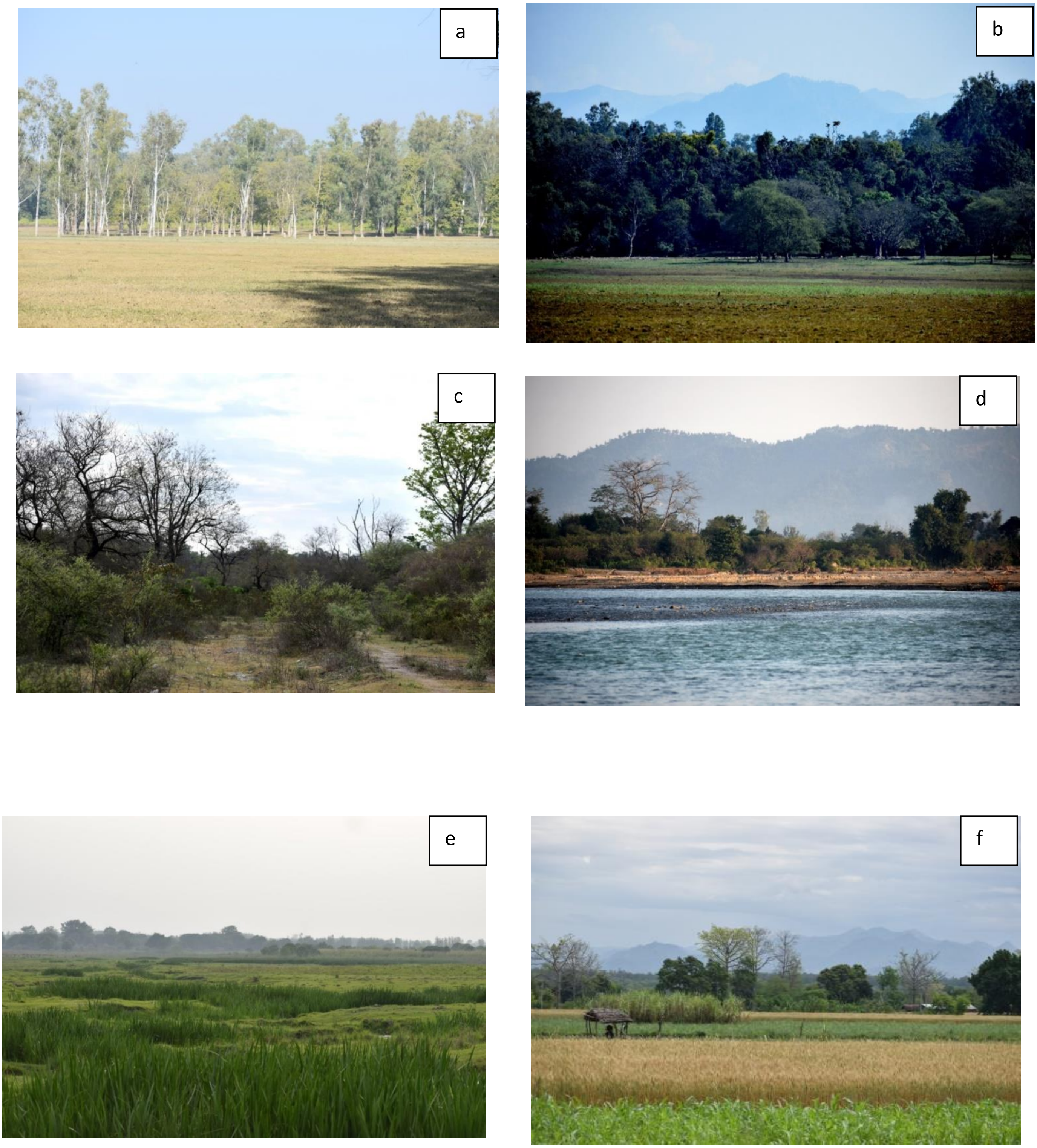


Plate 2.1. Different vegetation types of JJCR (a) Eucalyptus plantation (b) Mixed deciduous forest (c) Scrub forest (d) Riverine habitat (e) Grasslands (f) Agriculture field-human settlements (Photo credits: Ankita Das)

Table 2.3. The characteristic plant species in different habitats are as follows:

Forest Types	**Characteristic Tree species**	**Characteristic Shrub species**	**Characteristic Herb species**	**Grass species**
Mixed Deciduous Forest	*Alangium salvifolium, Albizia lebbeck, A. procera, Anogeissus latifolia, Bauhinia malabarica, Butea monosperma, Crataevia religiosa, Diospyros Montana, Ehretia laevis, Ficus benghalensis, Grewia tilifolia, Adina cordifolia, Holoptelia integrifolia, Mitragyna parvifolia, Terminalia belerica,* Aegle *marmelos, Cassia fistula, Cordia dichotoma, Emblica officinalis, Ficus racemosa, Melia azeadarach, Mallotus philippensis, and Pongamia pinnata.*	*Adhatoda Zeylanica, Calotropis procera, Carissa opaca, Cassia occidentalis, Catunaregam spinosa, Clerodendron viscosum, Helicteres isora, Limonia acidissima, and Murraya koenigii*	*Aerva lanata, Curcuma aromatica, Dicliptera roxburghiana, Evolvulus nummularius, Hemigraphis rupestris, Perilepta auriculata, Rungia pectinata, Sida rhombifolia, Tephrosia purpuriea, and Vernonia cinerea*	*Brachiaria bipinnata, Hemarthria compressa, Ischaemum indicum, Oplismenus compositus*
Riverine Forest	*Acacia catechu, Bombax ceiba, Ficus palmate, Gmelina arborea,*		*Bacopa procumbens, Boertheavia. diffusa,*	*Eragrostis gangetica, Paspalum scrobiculatum,*

	Morus alba, Oroxylum indicum, Syzygium cumini and Trewia nudiflora		*Centella asiatica, Chenopodium ambrosoides, Desmodium veluntium, Ipomoea pes-tigridis, Launaea procumbens, Scoparia dulcis, Solanum xanthocarpum, and Youngia japonica*	*Saccharum bengalense, S. spontaneum, Sporobolus diander and Themeda species* and sedges *Cyperus iria, C. niveus, C. nutans and C.rotundus*
Secondary Scrub	*Acacia nilotica, Broussonetia papyrifera*,and *zizyphus mauritina*	*lantana camara* and *Rubus ellipticus*	*cannabis sativa, Desmodium gangeticum, Medicago lupulina, Solanum viarum, Uraria rufescens, Urena lobata,* and *Viola betonicifolia*	*Apluda mutica, Chrysopogon fulvus, Cymbopogon sp., Cynoglossum sp*
Grassland				*Coix lacrymajobi, Eragrostis stenophylla, Phragmites karka, Cynodon dactylon, Imperata cylindrical, Pennisetum glaucum,*

				Vetiveria zizanioides, Echinochloa colonum, Eleusine indica, Paspalum conjugatum and Polypogon fugax
Plantation	Teak (*Tectona grandis*), Eucalyptus (*hybrid*), Sheesham (*Dalbergia sissoo*), Khair (*Acacia catechu*)			

2.6.2. Fauna

Owing to JJCR's location at the meeting point of Bhabar and terai and situated on the left bank of river Ganga with vast Indo-Gangetic plains supports a rich array of faunal diversity. JJCR represents a habitat island that is a refuge for threatened Swamp Deer and associated faunal species typical of the terai belt.

Mammals

24 species of mammals are found in JJCR (Plate 2.2), including Elephant (*Elephas maximus*), Common Leopard (*Panthera Pardus*), Nilgai (*Boselaphus tragocamelus*), deer species like Spotted Deer (*Axis axis*), Sambar (*Rusa unicolor*) and Swamp deer

(*Rucervus duvauceliii duvaucelii)* (ZSI, 2014). *Panthera tigris* and *Elephas maximus* are endangered, whereas *Rucervus duvaucelii* and *Panthera pardus* are vulnerable.

Swamp Deer is the flagship species of this conservation Reserve. It lives in swampy grassland and the floodplains. Its distribution is there only in three regions: central, north-east and northern India. They migrate to Banganga wetland during monsoon period. There is occasional visit by Tiger. They have been mainly reported in the Mixed Deciduous forest. Thus JJCR serves as satellite habitat of the wildlife of Rajaji Tiger Reserve. JJCR is also an elephant corridor and a good spot for sighting Elephant. They are mainly seen in Dasowala area. During summer they can be seen near river Ganges and in canal.

Reptiles

20 species of reptiles are found here. Four species are vulnerable: *Crocodylus palaustris, Hardella thurjii*, *Pangshura tentoria circumdata, Melanochelys tricarinata* (ZSI, 2014).

Amphibia

7 species of amphibans are present in this conservation reserve (ZSI, 2014). A new species of frog *Minervarya jhilmilensis* was found from Jhilmil in 2017.

Pisces

35 species of fish representing 25 genera, 12 families and 5 orders have been recorded from JJCR (ZSI, 2014). *Tor putitora* is endangered and *Ompok pabda* is near threatened.

Entomofauna

67 species of butterfly have been reported (ZSI, 2014). 6 species of Dragonfly and 2 species of damselfly are seen. Common Pierrot is schedule I of Wildlife (Protection) Act, 1972.

Avifauna

JJCR is home to various bird species (Plate 2.3., 2.4.) including threatened species and thus, it was declared an Important Bird and Biodiversity Area (IBA) in 2016. JJCR qualifies the IBA criteria of threatened species (Rahmani et al., 2016). It has three critically endangered species, three endangered species, four vulnerable species and eight near threatened species.

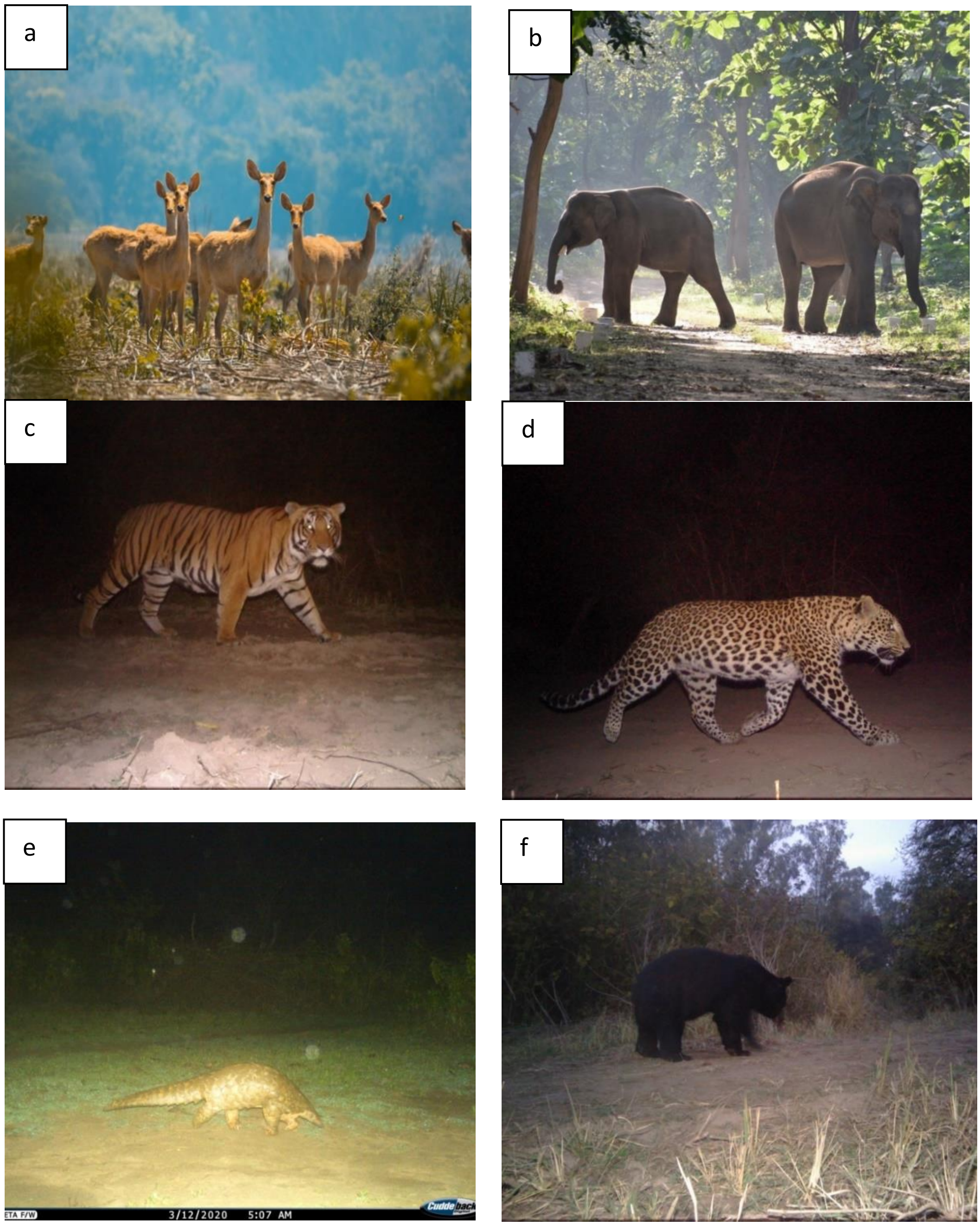


Plate 2.2 Mammals of JJCR (a) Swamp deer (*Rucervus duvauceliii duvaucelii)* (b)Elephant (*Elephas maximus*) (c) Tiger *(Panthera tigris)* (d) Leopard (*Panthera pardus)* (e) Pangolin (*Manis crassicaudata*) (f) Sloth Bear (*Melursus ursinus*)

(Photo credits: Haridwar Forest Division; Shrutarshi Paul (Swamp Deer); Ankita Das (Elephant))

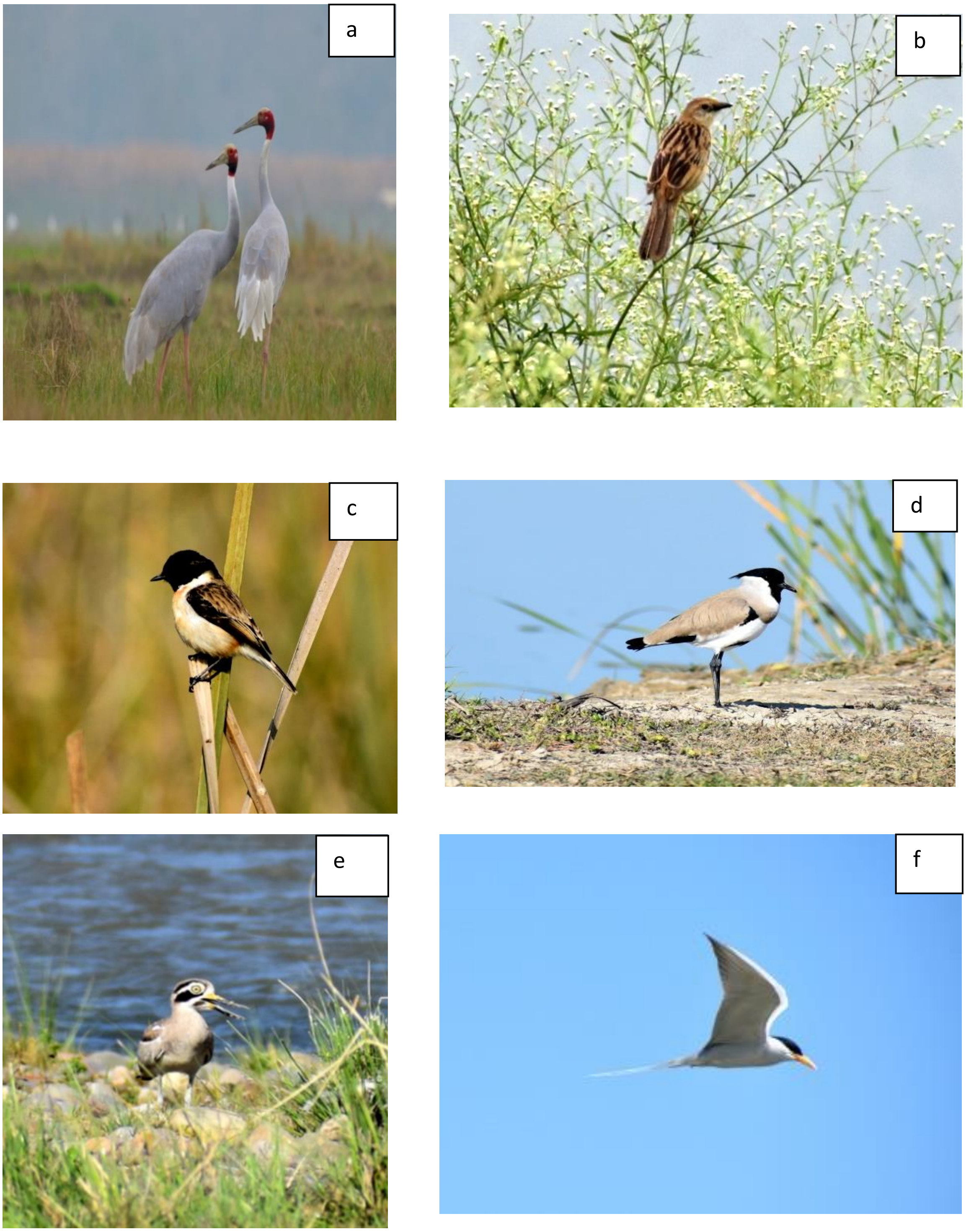


Plate 2.3. Birds of JJCR (a) Sarus Crane (*Antigone Antigone*) (b) Bristled Grassbird (*Chaestornis striata*) (c) White-tailed Stonechat(*Saxicola leucurus*) (d) River Lapwing (*Vanellus duvaucelii*) (e) Great Thick-knee (*Esacus recurvirostris*) (f) River Tern (*Sterna aurantia*) (Photo credits:Ankita Das; Nilanjan Chatterjee (Sarus Crane))

Plate 2.4 Birds of JJCR (g) Black necked Stork (*Ephippiorhynchus asiaticus*) (h) Woolly-necked Stork (*Ciconia episcopus*) (i) Egyptian Vulture (*Neophron percnopterus*) (j) Slender-billed Vulture (*Gyps tenuirostris*) (k) Oriental Pied Hornbill (*Anthracoceros albirostris*) (l) Indian Pitta (*Pitta brachyura*) (Photo credits: Ankita Das)

2.7. Human settlements and anthropogenic disturbances

Around fifty years ago, the terai landscape stretched across the greater part of the Indo-Gangetic Plains and had rich forests and tall grasslands. Since then, the exploitation and unsustainable management of forest resources have led to fragmentation and degradation of natural habitat. As agriculture and human settlements have ravaged the terai ecosystem, these unique habitats have been fragmented, shrinked, and degraded at a large scale (Sankaran, 1990). Fifty percent of the people living in this landscape are below poverty line, who depend on its resources for their livelihood. Moreover, it is the only wetland in the area of its size that remains green and productive throughout the year, attracting graziers from neighbouring areas and being intensively grazed (Sinha et al., 2011).

As one of the country's most productive areas and one of the most populated in India's northern region (Cincotta et al., 2000)**,** this landscape suffers high human disturbance (Johnsingh et al., 2004; Wikramanayake et al., 2004). There are five settlements in and around this conservation reserve namely Taantwaala, Gujjar deras, Naurangabad, Lakkadghat and Gendikhata. Taantwala and Gujjar deras lies inside the conservation Reserve. People residing in Taantwala have migrated from various places such as Punjab, Himachal Pradesh, Garhwal part of Uttarakhand. They are mainly agrarian. They mainly grow sugarcane. They also grow crops such as paddy, wheat, bajra, jowar, oats, maize and vegetables such as carrots, gram seeds, onion, potato and tomato. They are also involved in animal husbandry. They rear cow, buffalo and goat.

Gujjars are semi-nomadic pastoral communities that have inhabited various parts of the entire Shiwalik landscape for at least 110 years (Gooch, 2009). They practice pastoralism and raise buffalo and cattle and earn through selling milk. They practised transhumance in the past in which they stayed in the Himalayan foothills in winter and migrated to alpine meadows during summer. Most of the Gujjars have abandoned this traditional migration due to socio-economic changes in their community and unwillingness of the local community in the the Himalaya to share the resources with Gujjars (WII, 2005). This has resulted in more resource dependency in the landscape and waste disposal in the forest. People from Gujjar deras, Tantwala village, Gendikhata village and Lakkadghat village depend on this conservation reserve for fodder, grass and fuelwood collection and indulge in various other activities such as fishing and honey collection (Plate 2.5). There is unregulated livestock grazing in JJCR (Plate 2.5). Few people have got the permits for livestock grazing, but more cattle are seen grazing in the conservation reserve compared to the permits given. There is no alternative field in the village for livestock grazing.

Plate 2.5 Disturbances in JJCR (a) Human settlement (Gujjar deras) (b) Fuelwood collection (c) Grass collection (d) Livestock grazing (e) Fishing activity (f) Waste disposal. (Photo credits : Ankita Das)

2.8. Management plan of Jhilmil Jheel Conservation Reserve

Until when wildlife shooting was permitted, licensed hunters were allowed for a limited shoot. Rasiyabad Forest Rest House (1889) of the Conservation Reserve, is still an evidence of being used in the past by the hunters. Jhilmil Conservation Reserve is state-owned and managed under Haridwar Forest Division, Uttarakhand Forest Department. It was managed under Chidiapur Forest Range, Haridwar Forest Division until 2005. Thereafter it came under Rasiyabaad Forest Range, Haridwar Forest Division. Jhilmil Jheel Conservation Reserve came into existence on 14th August 2005, when Hon. President of India, Prof. APJ Abdul Kalam, declared the area as Jhilmil Jheel Conservation Reserve for the conservation and protection of Swamp deer. It was declared a Conservation Reserve due to its ecological, faunal, floral, geo-morphological, natural, and zoological significance to protect wildlife and develop its environment. Sinha et al. (2011) made the first management plan of Jhilmil Jheel Conservation Reserve with special reference to conservation of flagship species of the area Swamp deer (*Rucervus duvauceli duvauceli*).

2.9. Study design

The study area was stratified into six habitats: plantation, mixed deciduous forest, riverine habitat, scrub forest, grasslands and agriculture fields-human settlement. In total 116 point count stations were laid. Sampling was done in summer (April-June) and winter seasons (November-mid March) in 2018-2020. Every point count station was visited 20 times. Habitat-wise point count method (Bibby et al. 2000) was used to collect abundance data of birds covering plantation (28), mixed forest (15), scrub forest (12), riverine (25), grassland (21) and agriculture-human settlement (15) (Table 2.4, Figure 2.3). Each point count station was 200 meters away from each other. The habitat's physiognomic and species composition variability was assessed through vegetation plots at the point count locations. Habitat quantification was done in both summer and winter season. Total 232 quadrat plots were sampled with two quadrat plots in each point count station. We laid nested quadrats with the largest quadrat of 10 x10 m^2 to get data on the tree characteristics like tree species richness, abundance, girth at breast height (GBH), height and canopy cover. All woody vegetation of 20cm (GBH) or more was considered as trees. Shrub characteristics such as shrub species, shrub abundance, and shrub cover were assessed in 5x5 m^2. All woody vegetation less than 20cm GBH were considered as shrubs. Ground cover such as herb cover, grass cover, leaf litter, bare ground was assessed in 1x1 m^2. Disturbance data such as presence of livestock, presence of trail and presence of logged trees were taken in presence/absence form in each quadrat plot. Habitat quantification was done in both summer and winter season.

Table 2.4. Details of point counts in every habitat

Habitat	**Area (km^2)**	**No. of point count stations**
Plantation	14.59	28
Riverine	6.95	25
Grassland	6.23	21
Mixed forest	5.06	15
Agriculture fields-human settlement	2.55	15
Scrub forest	2.46	12

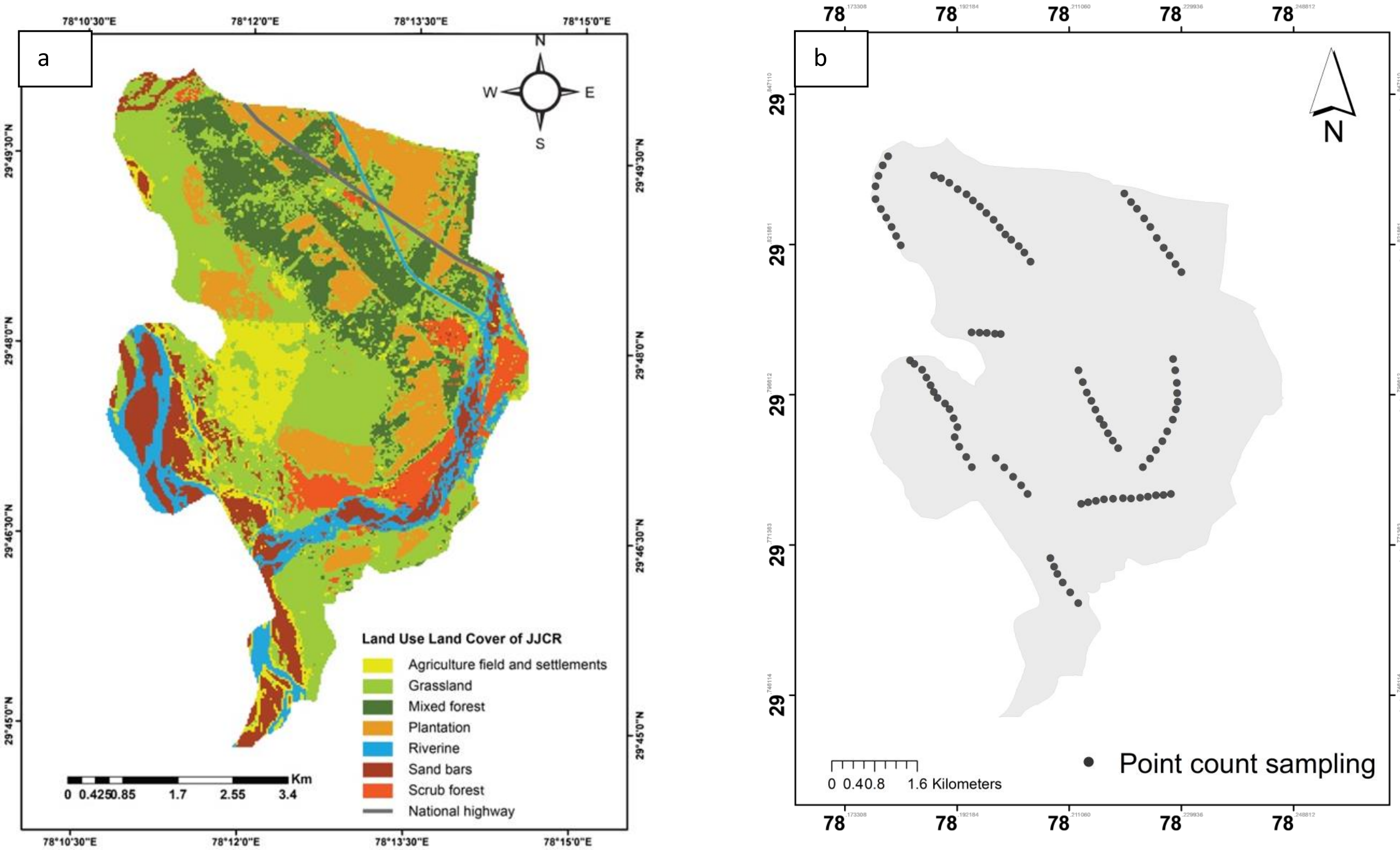


Figure 2. 3. (a) Land use land cover map (overall accuracy =91.72%) (b) Study map with locations of point count stations

CHAPTER 3

AVIAN COMMUNITY STRUCTURE

3.1. Introduction

The structural, functional, and compositional status of ecosystems is reflected in the state of bird communities in the region (O'Connell, 2000) and it is important to identify the most important sites for bird conservation to ensure that birds and other animals can thrive and survive. As a result, BirdLife developed the concept of Important Bird and Biodiversity Areas (IBAs) to identify the most important bird habitat areas.

IBAs are exceptionally rich in birds and other taxa and hold significant populations of rare, endemic, and threatened species. These are places of International significance for the conservation of birds and other biodiversity. This identifies and conserves a network of sites critical for the long term survival of bird species that are threatened (Rahmani et al., 2016). There are 554 IBAs in India and the state of Uttarakhand has 15 IBA sites, including the Jhilmil Jheel Conservation Reserve (JJCR) of Haridwar Forest Division. This IBA is a wetland in the terai landscape and represents one of the most productive and threatened ecosystems (Sinha et al., 2011). Jhilmil Jheel was designated as a conservation reserve for its remnant patches of riverine grasslands and for the protection of the westernmost population of the globally vulnerable Swamp Deer (*Rucervus duvaucelii duvaucelii).* These riverine habitats are also rich in grassland avifauna. The present study focuses on the avian community structure and status of avifauna in JJCR.

The diversity of bird populations serves as a strong indicator of the overall health of an ecosystem (Dendup et al., 2021). Bird community pattern is a result of composition and distribution across spatial and temporal gradients (Robinson et al., 2000; Malizia, 2001). The number of species in any local assemblage is an important index of community structure (Gotelli and Colwell, 2011). There are many factors which influences bird community such as climatic factors , habitat structure, vegetation strata (Pitelka, 1941; Recher, 1969; Rotenberry and Wiens, 1980; Emlen et al., 1986; Gentilli, 1992; Telleria et al., 1992, Cueto and de Casenave , 1999), variation in seasonal factors (Canterbury et al., 2000) patch size, the nature of the surrounding habitat and the proximity of other similar patches, season, deforestation and livestock encroachments (Mengesha et al., 2011). The avifaunal assemblage of any particular location remains dynamic (Sinha, 2019). A major role is played by seasonality in determining the abundance and distribution of birds (Lee and Kang, 2019). The seasonal variation in temperature and rainfall, spatial and temporal microhabitat conditions affects the availability of food for birds (Mengesha et al., 2011), cover availability which affects the breeding success and survival of bird species (Mengesha and Bekele; 2008). Newton (2008) revealed that processes acting in breeding and wintering grounds determine the patterns and habitat occupancy and seasonal abundance in migratory bird species. Wilson and Mac Arthur (1967) reported that bird diversity is affected by habitat diversity among various other factors. The current study is the first systematic account of the birds of JJCR with particular focus on the community structure of this IBA's avifauna and their conservation status. In the present study, I have assessed the bird diversity in the heterogenous habitat within the Jhilmil Jheel Conservation Reserve, a small conservation reserve situated in the middle of human modified landscape in India.

The research questions addressed in this chapter are:

(i) What is the status of the overall bird community?

(ii) Is there any spatial and temporal pattern of bird species?

3.2. Methods

Fieldwork was carried out between March 2018 to March 2020. Bird sampling was done in six habitats, found in the IBA: plantation, mixed deciduous forest (mixed forest), riverine habitat, scrub forest, grasslands and agriculture fields-human settlements in summer (April-June) and winter season (November-mid March). Bird sampling was done through point count method (Bibby et al., 2000). I executed habitat-wise point count (Bibby et al., 2000) to collect abundance data of birds covering plantation (28), mixed forest (15), scrub forest (12), riverine (25), grassland (21) and agriculture fields-human settlements (15). Each point count station was 200 metres away from the other. Birds were observed for 10 minutes in each point count station. All the birds seen or heard during this time were recorded. Birds were surveyed from 5:30 am to 8:30 am during summer and from 8:00 am to 10:30 am during winter. Surveys during days of inclement weather were avoided. Twenty replications of sampling were done per point count station.

3.3. Data analysis

Species accumulation curve was done in R-Studio software (version R 3.6.3) to determine the sampling adequacy.

Status of overall bird community

Species richness

The survey data was used to find out the population trend of bird species in JJCR (IUCN, 2022). The Richness index was computed as Margalef richness index following Margalef (1958).

$$R = (S-1)/Ln(N)$$

Where: R: index of species richness.

S: number of species observed.

N: number of individuals (all species observed).

Ln: natural logarithm value.

There are three classifications of Margalef richness index values, namely low species richness ($R < 2.5$), medium species richness ($2.5 > R < 4$) and high species richness ($R > 4$).

Bird species diversity

Bird species diversity was computed using Shannon-Weiner index as follows:

$$(H) = -\sum_{k=1}^{s} (P_i * \ln P_i)$$

H = Species diversity

Pi = Proportion of abundance of species i

S =Total number of species in the habitat

Relative diversity of family

The relative diversity index (RDI) of families was calculated following Torre-Cuadros et al. (2007).

$$RDI = \frac{\text{Number of bird species in a family}}{\text{Total number of species}} \times 100$$

Frequency of sighting

The frequency of sighting of each bird species was categorized as follows: high (>51 sightings), medium (26-50 sightings), low (6-25 sightings), very low (1-5 sightings).

Residential-migratory status

To determine the residential-migratory status, the avian species were categorized into residents, winter visitors, summer visitors and monsoon visitor.

Similarity index

The similarity of different habitats with respect to their bird composition was calculated using Sorensen index as follows:

= 2C/A+B, where,

A = Total number of species in habitat A

B = Total number of species in habitat B

C = Total number of species common to the habitats A and B

The common bird species based on their number of sightings were plotted in different habitats.

Spatial and temporal pattern of bird species

Distribution pattern

Distribution pattern of bird species in different habitats were classified following Khan et al. (2013). Birds distributed in only one habitat were considered having clumped distribution, those bird species present in two habitats were considered having aggregate distribution, birds having distribution in three habitats were randomly distributed and which were present in more than three habitats had hyperdispersal distribution.

Beta diversity

Beta diversity was calculated using Vegan Package of R-Studio software (version R 3.6.3).

Mean abundance

Mean abundance of bird species in different seasons and habitats was done through violin plots in R.

Rank abundance and Relative abundance

Rank abundance and relative abundance of bird species was found out in MS excel.

The relative abundance was determined using the equation:

Relative abundance (%) = n/N ×100

Where,

n= numbers of individuals of particular recorded species

N= total number of individuals of recorded species

Relative abundance of threatened species was also determined.

3.4. Results

Species accumulation curve showed the adequacy of the sampling in both summer and winter season (Figure 3.1).

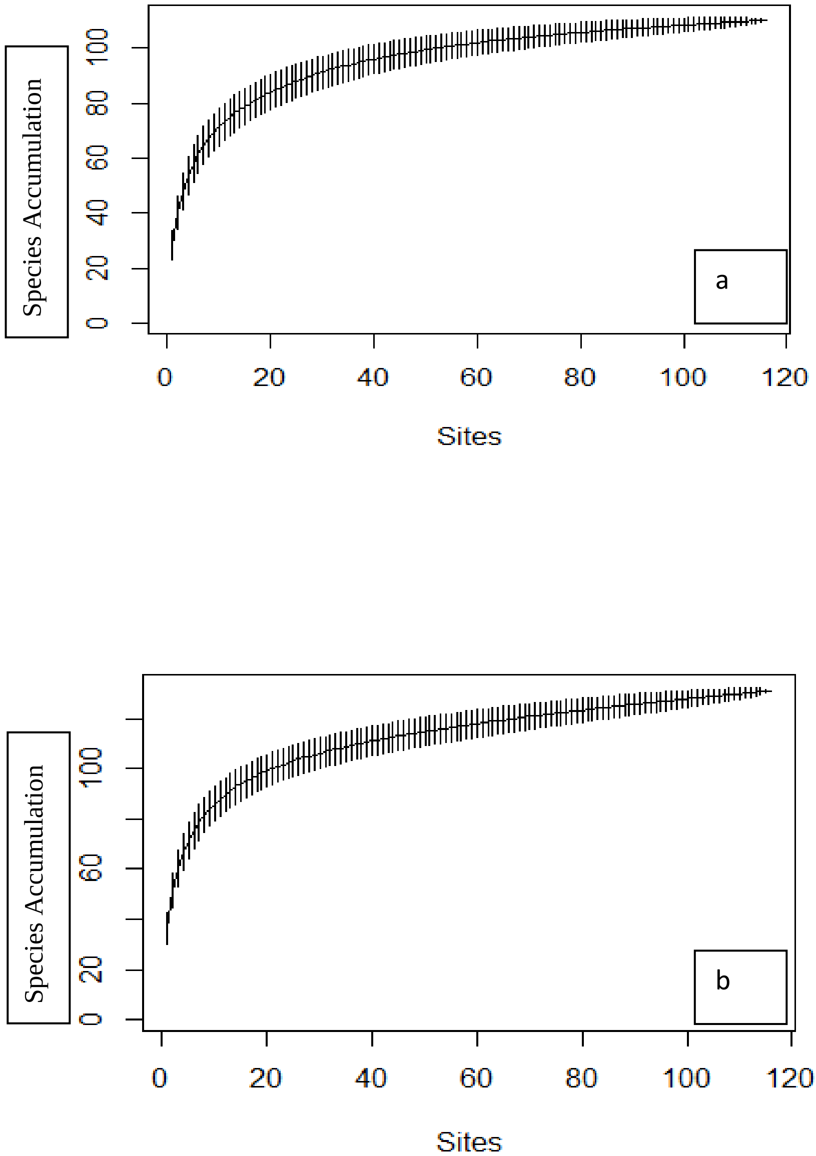


Figure 3.1. (a): Species accumulation curve during summer and (b) during winter season

Status of the overall bird community

170 species were recorded in the point count sampling, representing 64 families and 16 orders (Appendix 1). The dominant order was Passeriformes (92 species), followed by Charadriiformes (13 species) and Accipitriformes (12 species) (Figure 3.2). The dominant family was Muscicapidae (15 species), followed by Accipitridae (12 species) and Cuculidae (9 species).

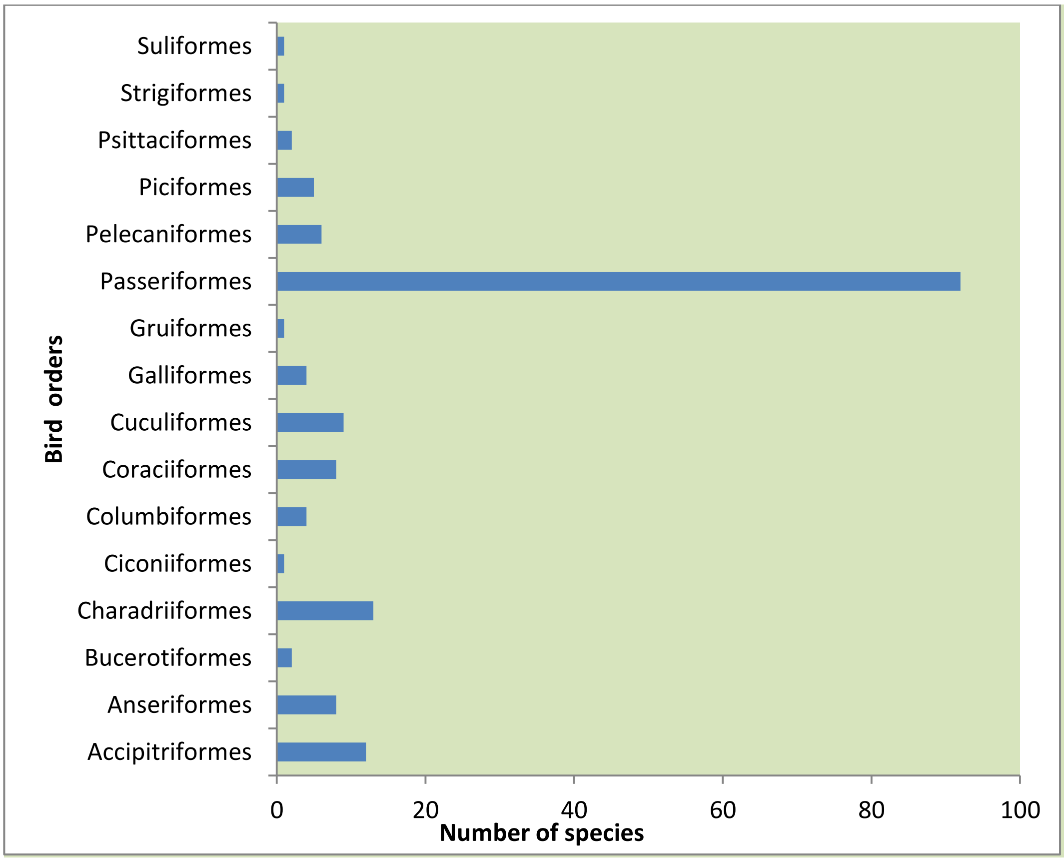


Figure 3.2. Avian community composition of Jhilmil Jheel Conservation Reserve, Uttarakhand

The richness index was calculated as 17.7371. It shows that JJCR has high species richness. Red-vented Bulbul (*Pycnonotus cafer)* was the most abundant bird species.

Red-vented Bulbuls are generalist species and thus able to survive in a wide variety of conditions.

The overall bird species diversity was 4.126. The diversity is high as JJCR is supported by cluster of various habitats. It has also been seen that different kinds of habitat support large number of avifauna (Balodi et al., 2018, Ahmed, 2019; Sultana et al., 2021). Muscicapidae family also had the highest relative diversity (Table 3.1).

Table 3.1. Relative diversity of families

Family	Number of species	Relative diversity of families
Accipitridae	12	7.06
Acrocephalidae	1	0.59
Aegithinidae	1	0.59
Alaudidae	4	2.35
Alcedinidae	4	2.35
Anatidae	8	4.71
Ardeidae	5	2.94
Bucerotidae	2	1.18
Campephagidae	2	1.18
Charadriidae	1	0.59
Charadriidae	3	1.76
Ciconiidae	1	0.59
Cisticolidae	6	3.53
Cloropseidae	1	0.59

Columbidae	4	2.35
Coraciidae	2	1.18
Corvidae	3	1.76
Cuculidae	9	5.29
Dicaeidae	2	1.18
Dicruridae	5	2.94
Estrildidae	2	1.18
Fringillidae	1	0.59
Glareolidae	1	0.59
Gruidae	1	0.59
Hirundinidae	2	1.18
Laniidae	2	1.18
Laridae	4	2.35
Leiothrichidae	2	1.18
Locustellidae	2	1.18
Megalaimidae	3	1.76
Meropidae	2	1.18
Monarchidae	2	1.18
Motacillidae	5	2.94
Muscicapidae	15	8.82
Nectariniidae	2	1.18
Oriolidae	2	1.18

Pandionidae	1	0.59
Paridae	1	0.59
Passeridae	2	1.18
Phalacrocoracidae	3	1.76
Phasianidae	4	2.35
Phylloscopidae	4	2.35
Picidae	2	1.18
Pittidae	1	0.59
Ploceidae	2	1.18
Psittaculidae	2	1.18
Pycnonotidae	4	2.35
Rhipiduridae	1	0.59
Scolopacidae	4	2.35
Sittidae	1	0.59
Stenostiridae	1	0.59
Strigidae	1	0.59
Sturnidae	5	2.94
Sylviidae	1	0.59
Threskiornithidae	1	0.59
Timaliidae	3	1.76
Turdidae	1	0.59
Zosteropidae	1	0.59

Out of all the bird species of JJCR, 45% are stable while 25 % is constituted by bird species whose population is decreasing and 14.7 % of bird species are increasing. Bird species whose global population trend status is unknown constituted 14% of the total bird species (Figure 3.3.)

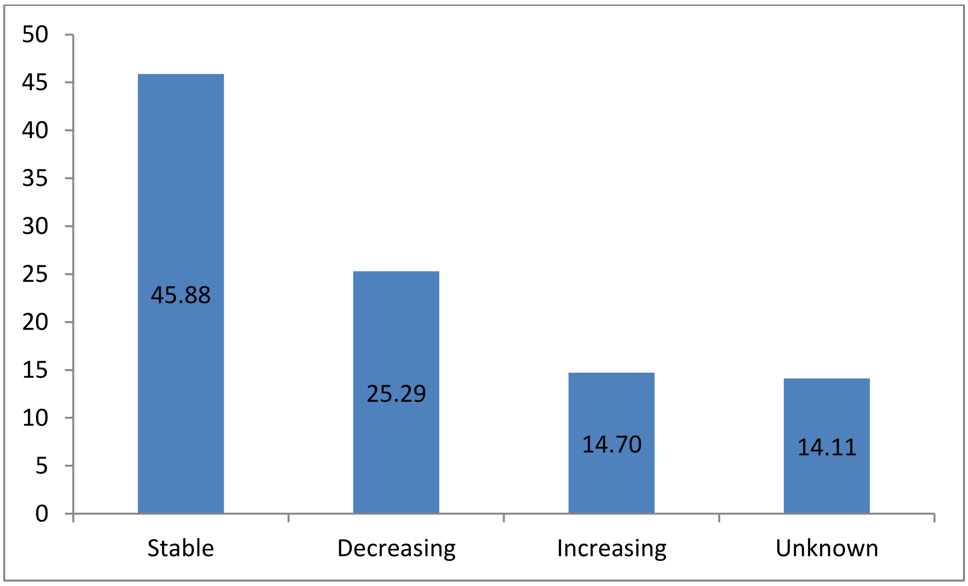


Figure 3.3. Global population trend of bird species in JJCR

Of the total bird species observed, 71 species had very low number of sightings, 42 species had low number of sightings, 18 species had medium number of sightings and 39 species had high number of sightings (Figure. 3.4).

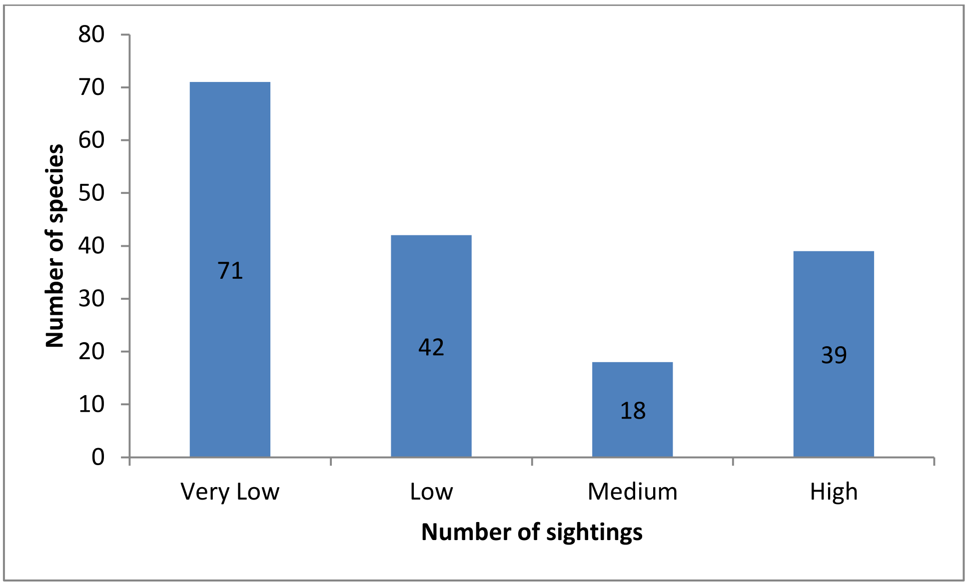


Figure 3.4. Status of avifauna based on the frequency of sightings.

To determine the migratory-residential status, the avian species were categorized into residents, winter visitors, summer visitors and monsoon visitor. Majority of species are residents followed by winter visitors, summer visitors and monsoon visitors. There were 112 resident species, 46 winter visitors, 11 summer visitors and 1 monsoon visitor (Figure 3.5). This trend is supported by study done by Ahmed et al. (2019).

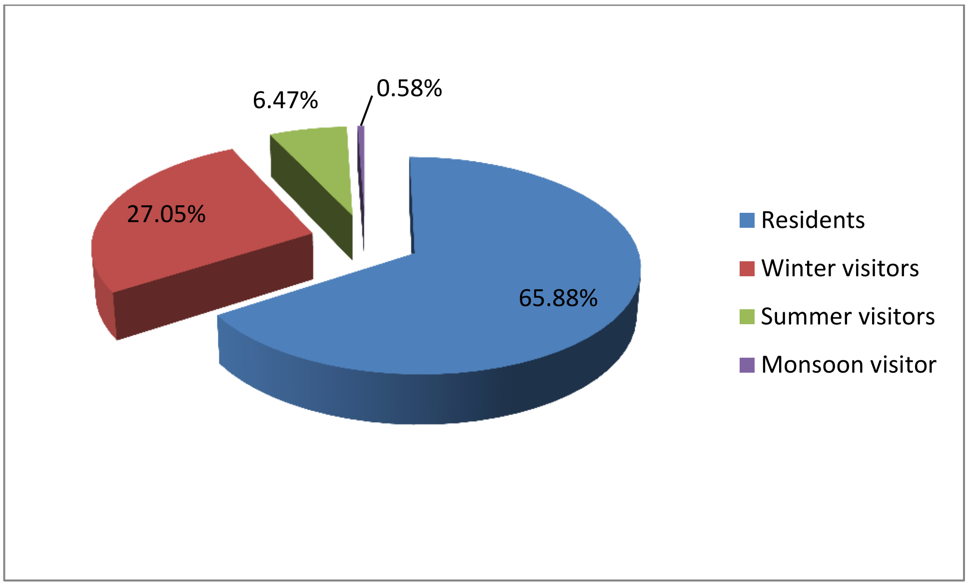


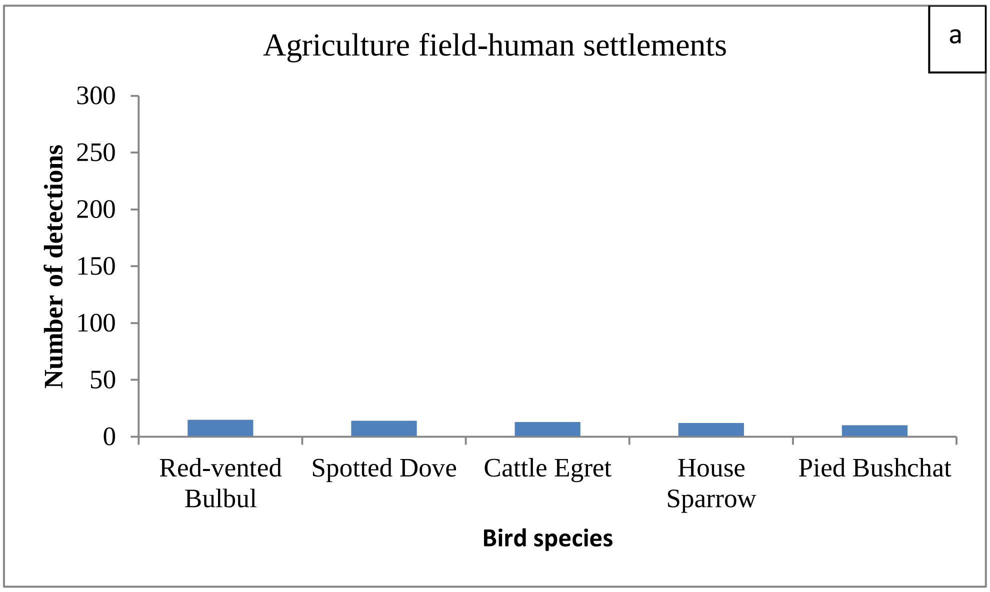
Figure 3.5. Migratory-residential status of birds of Jhilmil Jheel Conservation Reserve, Uttarakhand

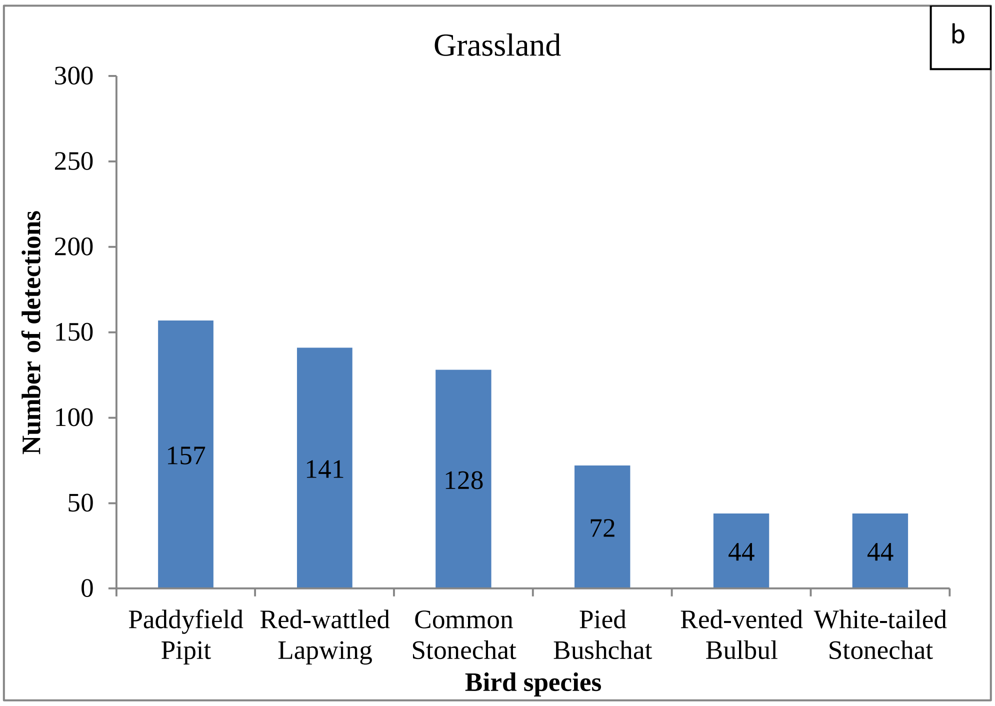
Similarity index

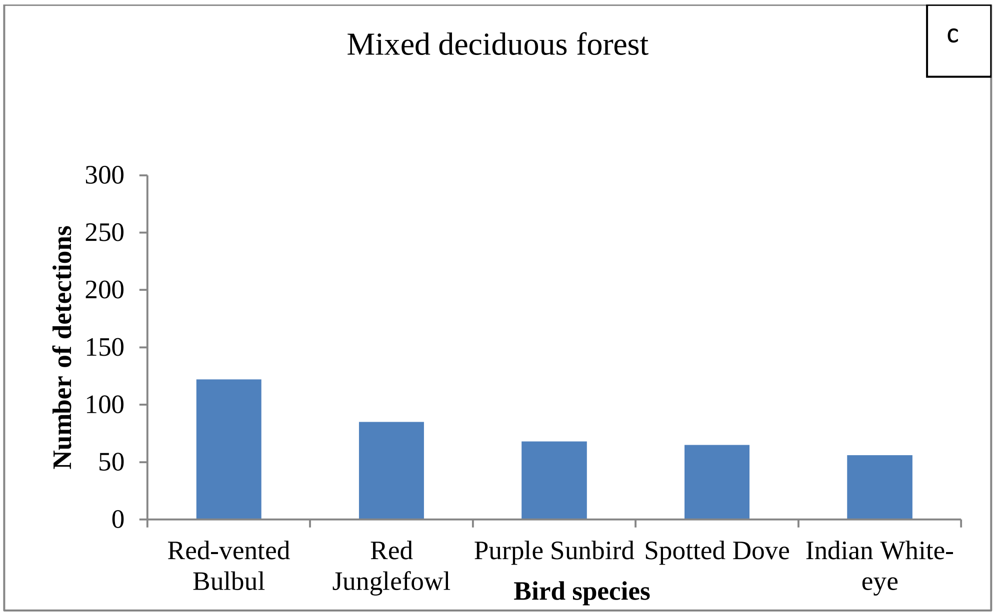
The result of Sorensen similarity index showed that the highest similarity (68%) of bird composition was between scrub forest and mixed forest whereas the least similarity (25%) was between agriculture field and riverine habitat (Table 3.2). The common species of each habitat based on the number of detections has been presented in Figure 3.6.

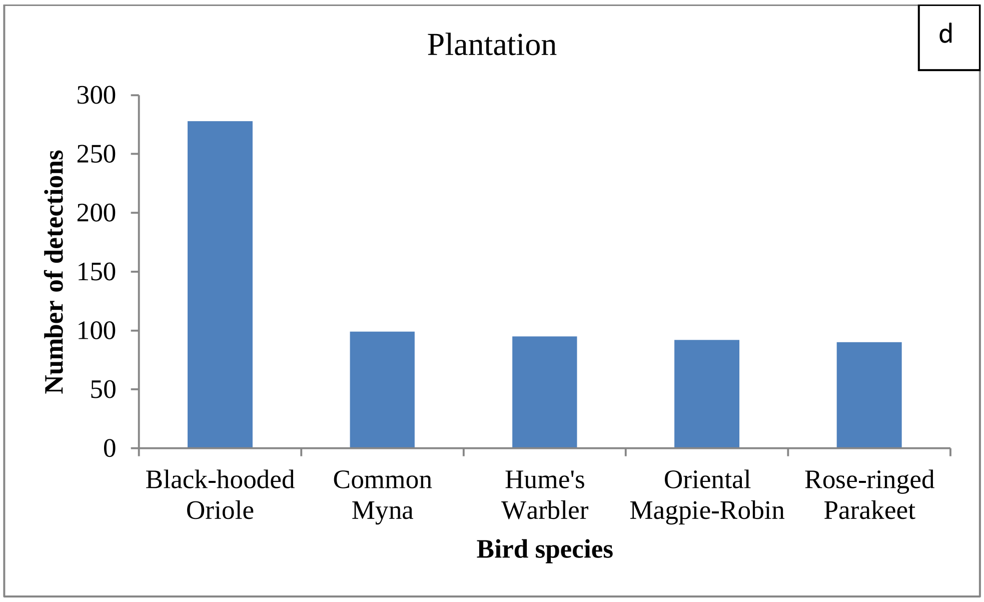
Table 3.2. Sorensen similarity index value between different habitats

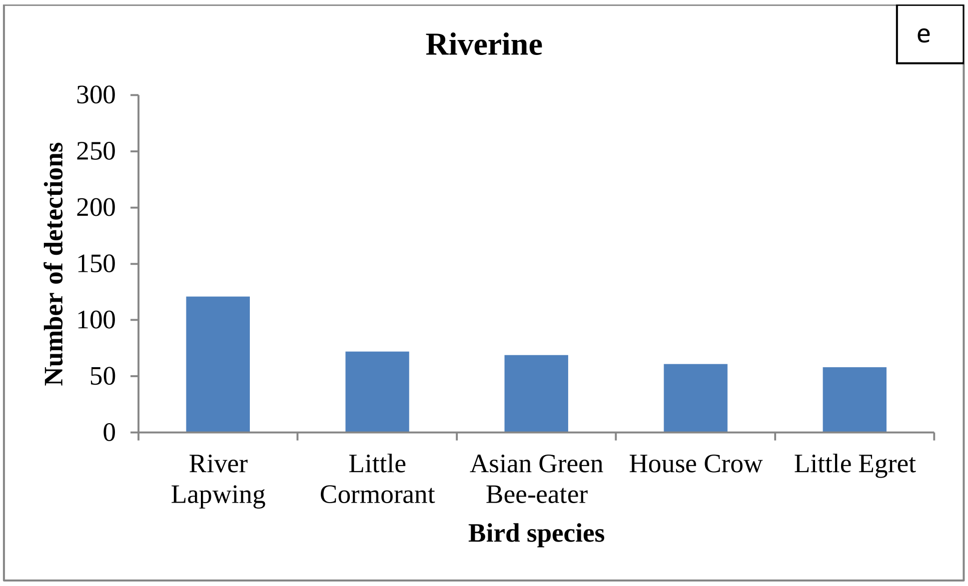
	Eucalyptus	**Mixed**	**Scrub forest**	**Riverine**	**Grassland**	**Agriculture**
Eucalyptus	0					
Mixed	0.655738	0				
Scrub forest	0.507692	0.683333	0			
Riverine	0.364865	0.304348	0.287671	0		
Grassland	0.267606	0.327586	0.354839	0.450704	0	
Agriculture	0.273684	0.258824	0.27957	0.252252	0.269663	0


a
Agriculture field-human settlements
Number of detections
300
250
200
150
100
50
0
Red-vented Bulbul
Spotted Dove
Cattle Egret
House Sparrow
Pied Bushchat
Bird species


b
Grassland
Number of detections
300
250
200
150
100
50
0
157
141
128
72
44
44
Paddyfield Pipit
Red-wattled Lapwing
Common Stonechat
Pied Bushchat
Red-vented Bulbul
White-tailed Stonechat
Bird species


c
Mixed deciduous forest
Number of detections
300
250
200
150
100
50
0
Red-vented Bulbul
Red Junglefowl
Purple Sunbird
Spotted Dove
Indian White-eye
Bird species


d
Plantation
Number of detections
300
250
200
150
100
50
0
Black-hooded Oriole
Common Myna
Hume's Warbler
Oriental Magpie-Robin
Rose-ringed Parakeet
Bird species



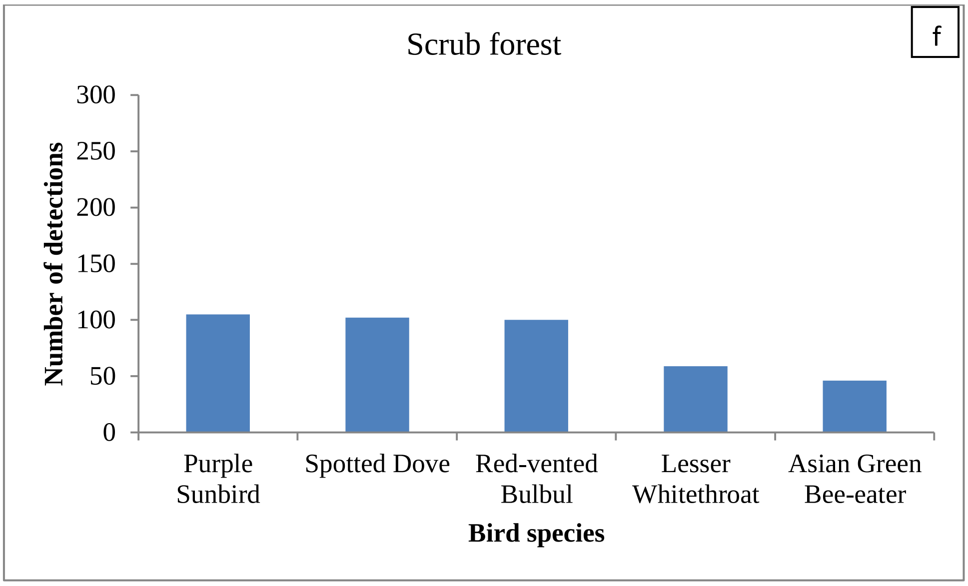


Figure 3.6. Common bird species in different habitats (a) Agriculture field-human settlement (b) Grassland (c) Mixed deciduous forest (d) Plantation (e) Riverine (f) Scrub forest

Spatial and temporal pattern of bird species

There were 110 bird species in summer and 131 bird species in season. Bird species diversity was found out to be 3.806 and 3.994 in the summer and winter seasons respectively. Habitat-wise bird species richness and diversity have been given in Figure 3.7.

In summer season, 47 species showed clumped distribution, 26 species had aggregate distribution and random and hyperdispersal distribution were shown by 17 and 20 species respectively. In winter season, 72 species showed clumped distribution, 23 species had aggregate distribution and random and hyperdispersal distribution were shown by 16 and 20 species respectively (Figure 3.8).

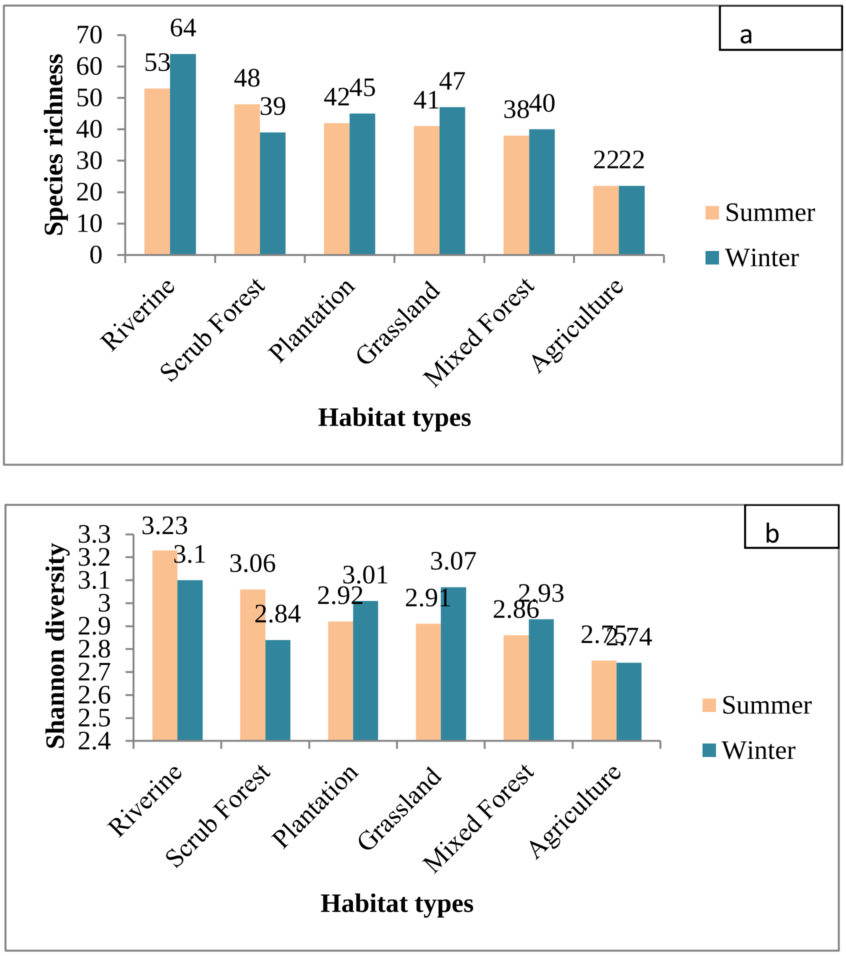


Figure 3.7. (a) Bird species richness and (b) Bird species diversity in summer and winter season in different habitats

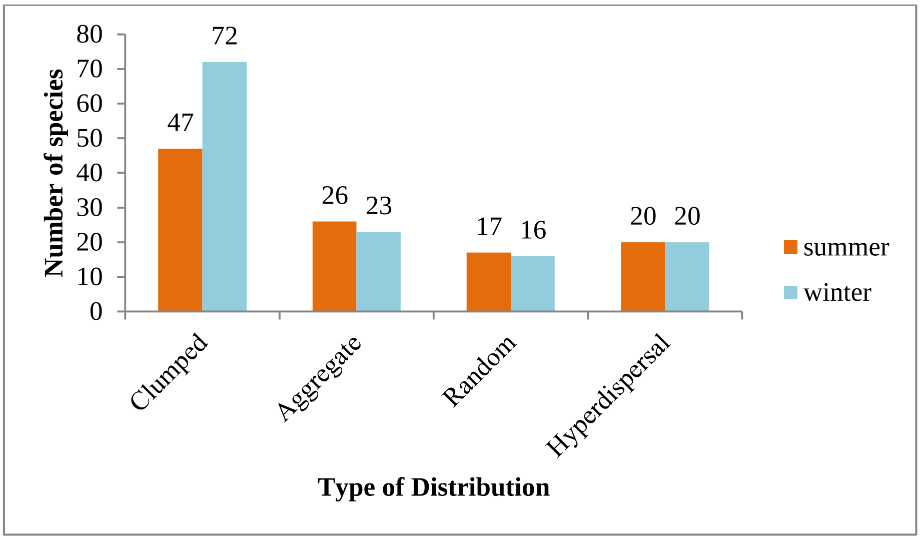


Figure 3.8. Distribution of bird species in Jhilmil Jheel Conservation Reserve, Uttarakhand

Beta diversity

Overall beta diversity was found to be 0.980 in summer season, whereas the value of turnover and nestedness was found to be 0.972 and 0.007 respectively. In winter season, overall beta diversity was found to be 0.981, while value of turnover was found to be 0.974 and value of nestedness was found to be 0.007. This shows that the species turnover rate was high, implying that both species assemblage and the number of individuals of different species varies in different habitats.

Rank abundance

RAD is a fundamental quantity of the community and has been used in various studies (Wilson, 1991; Beck, 2006; McGill et al., 2007). Rank abundance curves are self-supporting ecological indicators. It tells about the ecological status of the living environment and features the dominant abundances. Individuals belonging to the few most abundant species represent the overwhelming proportion of individuals in the multispecies community (Izsák, and Pavoine, 2012). The RAD curve showed that the bird abundance is the same till 400 in both seasons but there is a rise in abundance after 400 in the winter season (Figure 3.9).

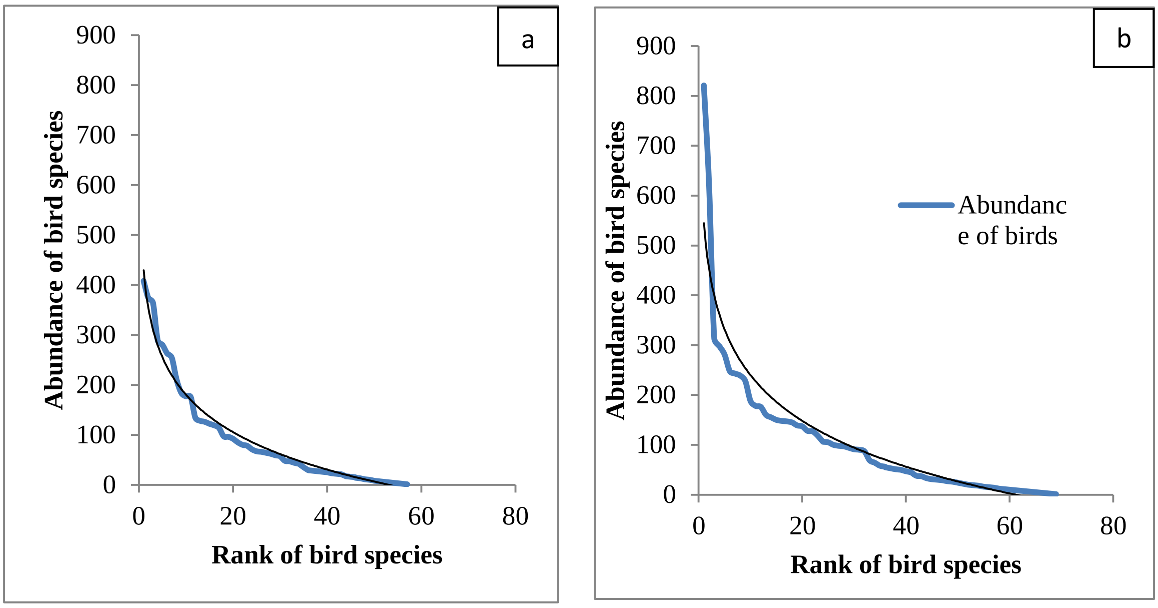


Figure 3.9. Rank abundance curve of bird species in (a) summer and (b) winter season.

Mean abundance

Violin plots showed a significant difference in the mean abundance of birds in different habitats in summer season as shown by Kruskal Wallis test. The mean abundance was highest in mixed deciduous forest. There was a significant difference in the mean abundance of birds in different habitats in winter. The mean abundance was highest in the riverine habitat (Figure 3.10).

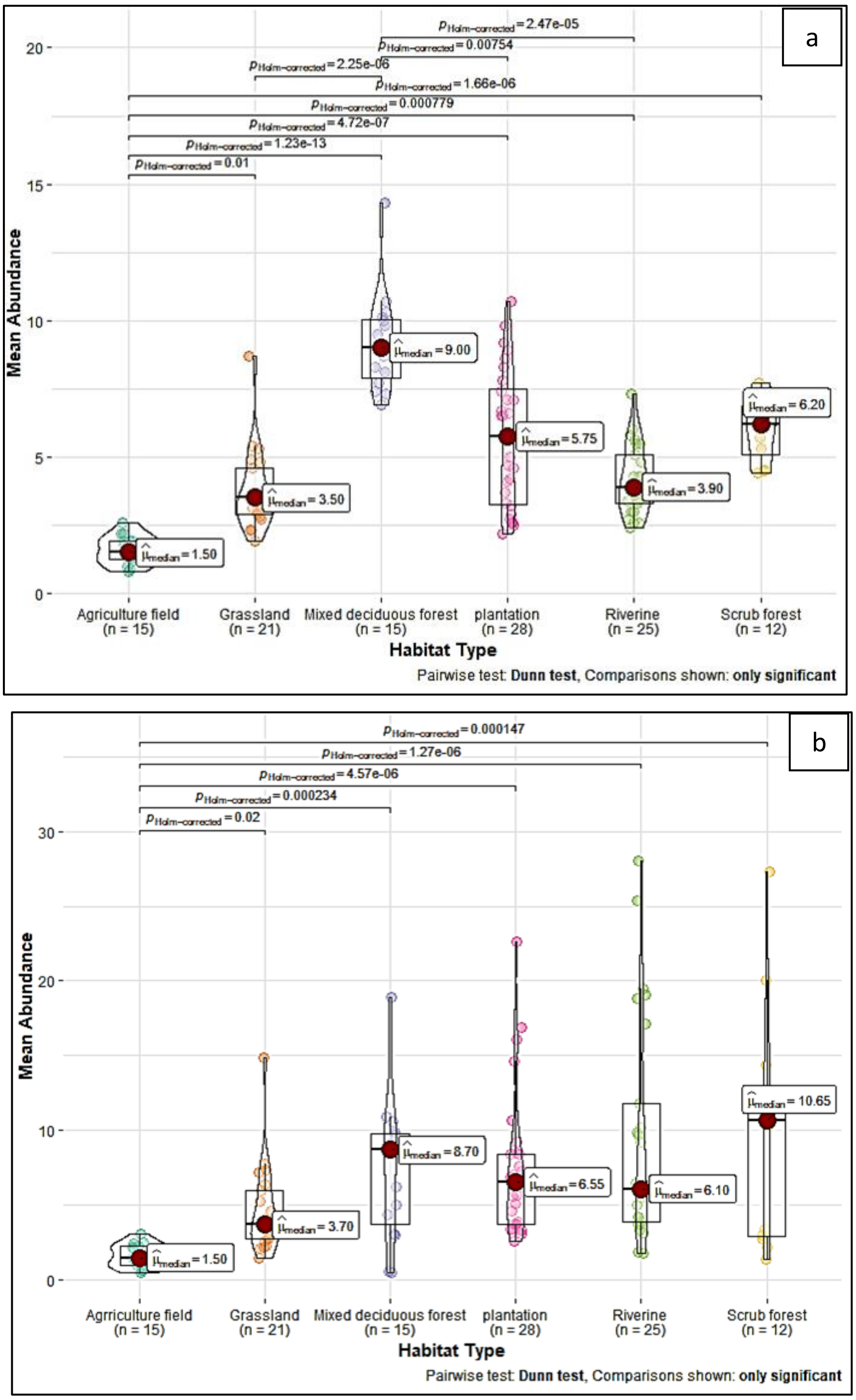


Figure 3.10. Mean abundance of bird species in (a) summer and (b) winter seasons.

Relative abundance

In summer, the relative abundance of River Lapwing was higher (11.16%) in riverine habitat, Paddyfield pipit (15.99%) in grassland habitat, Baya Weaver (24.91%) in mixed deciduous forest, Jungle babbler in plantation (14.92%), Purple Sunbird (13.16%) in scrub forest and Red-vented Bulbul (15.48%) in agriculture field (Table 3.3).

In winter, Red-wattled Lapwing (13.41%), Red-vented Bulbul (19.03%), Black Bulbul (11.62%), Ruddy Shelduck (25.77%), Red-vented Bulbul (27.72%), Cattle Egret (17.48%) were relatively abundant in grassland, mixed forest, plantation, riverine, scrub forest and agricultural areas respectively (Table 3.4).

Table 3.3. Relative abundance of birds in summer season

Bird species	Agriculture	Grassland	Mixed Forest	Plantation	Riverine	Scrub Forest
Ashy-crowned Sparrow-Lark	0.00	0.00	0.00	0.00	0.29	0.00
Ashy Prinia	2.09	2.92	0.87	0.00	1.35	1.66
Asian Koel	1.26	0.00	0.51	0.63	0.48	0.55
Indian Pied Starling	1.67	1.52	0.00	0.00	0.00	0.00
Barn Swallow	0.00	12.31	2.10	0.00	0.00	0.00
Bay-backed Shrike	0.00	0.00	0.00	0.00	0.00	0.14
Baya Weaver	10.04	1.40	24.91	0.00	0.00	4.02
Black-breasted Weaver	0.00	0.38	0.00	0.00	0.00	0.00
Black-chinned Babbler	0.00	0.00	2.17	0.44	0.00	1.39
Black Drongo	0.00	0.76	0.00	2.63	1.64	0.83
Black Francolin	0.00	0.38	0.00	0.00	0.48	0.00
Black-hooded Oriole	0.00	0.00	0.58	10.72	0.48	0.00
Black Kite	0.00	0.00	0.00	0.00	0.29	0.00
Blue-tailed Bee-eater	0.00	0.00	1.52	0.00	0.00	0.55
Brahminy Starling	0.00	0.00	0.36	0.00	0.00	1.25
Bristled Grassbird	0.00	0.51	0.00	0.00	0.00	0.00
Brown-headed Barbet	0.00	0.00	0.00	1.69	0.00	0.14

Cattle Egret	6.28	0.89	0.00	3.26	0.58	0.00
Changeable-Hawk Eagle	0.00	0.00	0.00	0.06	0.00	0.14
Chestnut-bellied Nuthatch	0.00	0.00	0.00	0.00	0.00	0.28
Chestnut-shouldered Petronia	0.00	0.00	3.19	0.50	0.29	1.52
Common Cuckoo	0.00	0.00	0.00	0.06	0.00	0.00
Common-Hawk Cuckoo	0.00	0.00	0.43	1.25	0.00	0.00
Common Iora	0.00	0.00	2.10	0.31	0.00	3.46
Common Kingfisher	0.00	0.38	0.00	0.00	0.29	0.00
Common Myna	2.51	3.43	0.00	9.40	2.21	0.69
Common Stonechat	0.00	7.74	0.00	0.00	0.58	0.00
Common Tailorbird	0.00	0.00	2.68	0.50	1.54	4.99
Coppersmith Barbet	0.00	0.00	0.14	0.31	0.00	0.55
Crested Lark	0.00	0.00	0.00	0.00	0.10	0.00
Crested Serpent-Eagle	0.00	0.00	0.14	0.19	0.00	0.00
Drongo Cuckoo	0.00	0.00	0.00	0.06	0.00	0.00
Eurasian Collared-Dove	0.00	0.00	0.72	0.00	1.25	0.69
Great Cormorant	0.00	0.00	0.00	0.00	0.48	0.00
Green Bee-eater	5.86	4.57	1.74	0.00	10.11	11.63
Grey-bellied Cuckoo	0.00	0.25	0.00	0.00	0.10	0.00
Grey-breasted Prinia	0.00	0.00	0.87	0.13	0.00	0.97
Grey Bushchat	0.42	0.76	0.00	0.00	0.00	0.00
Grey Francolin	0.00	0.13	0.00	0.00	0.19	0.00
Grey Heron	0.00	0.00	0.00	0.00	0.38	0.00
Grey-hooded Warbler	0.00	0.00	0.00	0.06	0.00	0.00
Gray Wagtail	0.00	0.00	0.00	0.00	0.58	0.00
Himalayan Griffon	0.00	0.00	0.00	0.00	0.00	0.14
House Crow	7.11	1.27	0.00	0.00	5.58	0.00
House Sparrow	9.62	0.00	0.00	0.00	0.00	0.00
Indian Cuckoo	0.42	0.00	0.22	1.00	0.00	0.28
Indian Grey Hornbill	0.00	0.00	0.58	1.82	0.48	0.00
Indian Paradise-Flycatcher	0.00	0.00	1.45	9.78	0.00	0.00
Indian Peafowl	0.00	0.38	2.61	0.31	0.00	2.77
Indian Pitta	0.00	0.00	2.32	4.64	0.00	1.11
Indian Robin	0.00	0.00	0.00	0.00	0.19	3.46
Indian Roller	0.00	0.13	0.72	0.69	1.54	0.55
Intermediate Egret	0.00	0.00	0.00	0.00	0.58	0.00
Pied Cuckoo	0.00	0.00	0.00	0.00	0.00	0.28

Jungle Babbler	0.00	0.00	7.31	14.92	0.00	4.85
Jungle Myna	0.00	0.00	0.58	0.00	0.00	0.00
Jungle Owlet	0.00	0.00	0.00	0.31	0.00	0.00
Large-billed Crow	0.00	0.51	0.22	0.13	1.83	0.00
Laughing Dove	0.00	0.76	0.00	0.00	0.00	1.25
Lesser Goldenback	0.00	0.00	0.00	0.25	0.00	0.42
Lesser Whitethroat	0.00	0.00	0.00	0.00	0.00	0.28
Little Cormorant	0.00	0.00	0.00	0.00	9.24	0.00
Little Egret	0.00	0.00	0.00	0.00	8.85	0.00
Little-ringed Plover	0.00	0.00	0.00	0.00	0.67	0.00
Little Tern	0.00	0.00	0.00	0.00	0.38	0.00
Long-tailed Shrike	0.00	0.00	0.00	0.00	0.00	0.28
Oriental Honey-buzzard	0.00	0.00	0.07	0.00	0.00	0.00
Oriental Magpie-Robin	0.00	0.38	1.30	5.33	0.67	2.91
Oriental Skylark	0.00	2.79	0.00	0.00	0.29	0.00
Oriental White-eye	0.00	0.00	1.67	1.44	0.00	2.22
Paddyfield Pipit	0.00	15.99	0.00	0.00	0.19	0.00
Pale-billed Flowerpecker	0.00	0.00	0.00	0.00	0.00	0.28
Pied Bushchat	5.44	5.33	0.00	0.00	0.00	0.28
Pied Kingfisher	0.00	0.00	0.00	0.00	1.64	0.00
Plain Prinia	1.26	2.03	0.00	0.25	0.38	1.11
Plum-headed Parakeet	0.00	0.00	0.36	0.00	0.00	0.28
Pond Heron	2.51	0.00	0.00	0.00	0.10	0.00
Purple Sunbird	0.00	0.25	4.20	3.70	3.85	13.16
Red Junglefowl	0.00	0.00	5.58	1.38	0.00	2.77
Red-naped Ibis	0.00	0.00	0.00	0.00	0.38	0.00
Red-vented Bulbul	15.48	3.93	7.82	5.83	1.92	10.39
Red-wattled Lapwing	2.51	15.61	0.00	0.00	4.62	0.00
Red-whiskered Bulbul	1.26	0.63	0.87	0.88	0.00	1.11
Blyth’s Reed Warbler	0.00	0.00	0.00	0.00	0.38	0.00
River Lapwing	0.00	0.76	0.00	0.00	11.16	0.00
River Tern	0.00	0.00	0.00	0.00	4.62	0.00
Rock Pigeon	8.79	0.00	0.00	0.00	0.00	0.00
Rose-ringed Parakeet	6.28	0.13	10.43	7.90	0.00	0.42
Ruddy Shelduck	0.00	0.00	0.00	0.00	7.51	0.00
Rufous Treepie	2.09	0.00	1.16	1.44	0.00	0.00
Sarus Crane	0.84	0.00	0.00	0.00	0.58	0.00
Shikra	0.00	0.00	0.00	0.50	0.00	0.28
Short-toed Snake-Eagle	0.00	0.13	0.00	0.00	0.00	0.00

Small Minivet	0.00	0.00	0.22	0.06	0.00	0.42
Small Pratincole	0.00	0.00	0.00	0.00	2.79	0.00
Indian Spot-billed Duck	0.00	0.00	0.00	0.00	2.12	0.00
Spotted Dove	6.28	0.38	5.29	4.95	1.73	12.74
Streak-throated Woodpecker	0.00	0.00	0.00	0.00	0.00	0.28
Striated Babbler	0.00	0.63	0.00	0.00	0.00	0.00
Striated Grassbird	0.00	3.55	0.00	0.00	0.00	0.00
Tawny-bellied Babbler	0.00	0.00	0.00	0.00	0.00	0.14
White-bellied Drongo	0.00	0.00	0.00	0.13	0.58	0.00
White-browed Wagtail	0.00	0.00	0.00	0.00	0.77	0.00
White-eyed Buzzard	0.00	0.00	0.00	0.00	0.00	0.14
White-tailed Stonechat	0.00	0.38	0.00	0.00	0.00	0.00
White-throated Kingfisher	0.00	0.63	0.00	0.13	0.58	0.00
White Wagtail	0.00	0.00	0.00	0.00	0.10	0.00
Yellow-bellied Prinia	0.00	2.16	0.00	0.00	0.00	0.00
Yellow-wattled Lapwing	0.00	2.03	0.00	0.00	0.00	0.00
Zitting Cisticola	0.00	0.89	0.00	0.00	0.00	0.00

Table 3.4. Relative abundance of birds in winter season

Bird species	**Agriculture**	**Grassland**	**mixed Forest**	**Plantation**	**Riverine**	**Scrub forest**
Ashy Drongo	0.00	0.10	0.00	0.00	0.00	0.00
Ashy Prinia	0.00	0.00	0.09	0.00	0.29	1.34
Asian Brown Flycatcher	0.00	0.00	0.18	0.05	0.00	0.00
Indian Pied Starling	0.00	1.84	0.00	0.00	0.00	0.00
Bank Myna	0.00	0.00	0.00	0.00	0.13	0.00
Bar-headed Goose	0.00	0.00	0.00	0.00	4.20	0.00
Barn Swallow	0.00	2.05	13.02	0.14	6.22	0.00
Bay-backed Shrike	0.00	0.00	0.00	0.00	0.00	0.08
Black-bellied Tern	0.00	0.00	0.00	0.00	0.29	0.00
Black Bulbul	0.00	0.00	0.00	11.62	0.00	0.00
Black Drongo	0.00	1.33	0.27	2.44	0.55	1.51
Black-hooded Oriole	0.00	0.00	2.73	7.41	0.13	0.00
Black-naped Monarch	0.00	0.00	0.00	0.05	0.00	0.00
Brahminy Starling	0.00	0.00	0.00	0.00	0.59	0.00

Bronze Drongo	0.00	0.10	0.00	0.00	0.00	0.00
Brown-headed Barbet	0.00	0.00	0.18	0.48	0.00	0.17
Brown Rock Chat	0.81	0.41	0.00	0.00	0.00	0.00
Cattle Egret	17.48	0.41	0.00	0.00	0.13	0.00
Chestnut-bellied Rockthrush	0.00	0.00	0.00	0.05	0.00	0.00
Cinereous Vulture	0.00	0.00	0.00	0.00	0.04	0.00
Citrine Wagtail	0.00	2.05	0.00	0.00	2.98	0.00
Common Greenshank	0.00	0.00	0.00	0.00	0.13	0.00
Common Kingfisher	0.00	0.20	0.00	0.00	0.25	0.00
Common Myna	4.07	0.31	0.00	4.35	0.08	0.00
Common Sandpiper	0.00	0.00	0.00	0.00	0.25	0.00
Common Stonechat	0.00	11.77	0.00	0.00	0.50	0.00
Common Tailorbird	1.63	0.00	0.73	0.00	0.21	0.25
Crested Serpent-Eagle	0.00	0.10	0.27	0.29	0.17	0.00
Crimson Sunbird	0.00	0.00	0.82	0.00	0.00	0.59
Egyptian Vulture	0.00	0.00	0.00	0.00	0.04	0.00
Eurasian Collared-Dove	0.00	0.00	0.00	0.00	0.59	0.00
Eurasian Sparrowhawk	0.00	0.00	0.09	0.00	0.00	0.00
Gadwall	0.00	0.00	0.00	0.00	0.63	0.00
Golden-fronted Leafbird	0.00	0.00	0.27	0.00	0.00	0.00
Goosander	0.00	0.00	0.00	0.00	1.22	0.00
Great Barbet	0.00	0.00	0.00	0.00	0.00	0.08
Great Cormorant	0.00	0.00	0.00	0.00	3.66	0.00
Great Egret	0.00	0.00	0.00	0.00	0.17	0.00
Great Tit	0.00	0.00	1.37	1.77	0.00	0.25
Greater Coucal	0.41	0.00	0.00	0.00	0.00	0.34
Green Bee-eater	0.00	0.00	1.28	0.29	0.00	0.17
Greenish warbler	0.00	0.20	0.91	3.30	0.21	2.68
Grey Bushchat	0.00	0.00	0.00	0.00	0.00	0.08
Grey-headed Canary-Flycatcher	0.00	0.00	0.00	0.53	0.00	0.00
Grey-hooded Warbler	0.00	0.00	0.27	0.00	0.00	0.00
Gray Wagtail	6.91	0.72	0.00	0.00	1.35	0.00
Himalayan Bulbul	0.00	0.41	1.73	3.11	0.00	5.61
Himalayan Griffon	0.00	0.00	0.00	0.00	0.08	0.00
House Crow	3.25	0.00	0.00	3.20	1.30	0.00
House Sparrow	9.76	0.00	0.00	0.00	0.00	0.00
Humes Warbler	0.41	0.10	4.74	6.50	2.40	2.85
Indian Grey Hornbill	0.00	0.00	2.46	0.00	0.00	0.34
Indian Peafowl	0.00	0.41	1.82	0.00	0.00	1.93
Indian Robin	0.00	0.00	0.00	0.00	0.00	1.84
Indian Roller	0.00	1.74	0.00	0.05	0.80	0.00

Indian Silverbill	0.00	0.20	0.00	0.00	0.00	0.59
Intermediate Egret	0.00	0.00	0.00	0.00	1.60	0.00
Jungle Babbler	2.44	0.00	5.56	8.37	0.00	4.69
Jungle Owlet	0.00	0.00	0.09	0.38	0.00	0.00
Large-billed Crow	0.00	2.35	0.82	4.50	0.63	0.59
Laughing Dove	0.00	0.92	0.00	0.00	0.00	0.00
Lemon-rumped Warbler	0.00	0.00	0.00	0.10	0.00	0.00
Lesser Goldenback	0.00	0.00	0.00	0.62	0.00	0.59
Lesser Whistling Duck	0.00	0.00	0.00	0.00	0.04	0.00
Lesser Whitethroat	0.00	0.00	4.46	0.00	0.00	7.54
Little Cormorant	0.00	0.00	0.00	0.00	9.58	0.00
Little Egret	0.00	0.00	0.00	0.00	1.09	0.00
Little-ringed Plover	0.00	0.00	0.00	0.00	2.90	0.00
Little Stint	0.00	0.00	0.00	0.00	0.17	0.00
Long-tailed Shrike	0.00	0.51	0.00	0.00	0.00	0.00
Maroon Oriole	0.00	0.00	0.00	0.05	0.00	0.00
Northern Pintail	0.00	0.00	0.00	0.00	5.38	0.00
Oriental Magpie-Robin	0.00	0.00	1.46	1.00	0.00	1.09
Oriental Pied hornbill	0.00	0.00	0.36	0.00	0.00	0.00
Oriental Skylark	0.00	1.23	0.00	0.00	0.88	0.00
Oriental White-eye	0.00	0.00	8.56	0.62	0.00	5.78
Osprey	0.00	0.00	0.00	0.00	0.04	0.00
Paddyfield Pipit	0.00	9.83	0.00	0.00	1.72	0.00
Pallas Gull	0.00	0.00	0.00	0.00	0.76	0.00
Pied Bushchat	5.28	4.30	0.00	0.00	0.13	0.00
Pied Kingfisher	0.00	0.20	0.00	0.00	1.18	0.00
Plain Martin	0.00	0.00	0.00	0.00	0.67	0.00
Plain Prinia	2.44	2.56	0.27	0.00	0.21	5.53
Plum-headed Parakeet	0.00	0.00	2.55	0.86	0.17	1.17
Pond Heron	2.44	0.20	0.00	0.24	0.59	0.00
Purple Sunbird	0.00	0.00	3.64	0.14	0.00	4.52
Red Avadavat	0.00	0.61	0.00	0.00	0.00	0.00
Red breasted Flycatcher	0.00	0.00	0.91	0.00	0.00	0.75
Red-crested Pochardr	0.00	0.00	0.00	0.00	0.67	0.00
Red Junglefowl	0.00	0.00	3.19	0.00	0.00	0.84
Red-naped Ibis	0.00	5.42	0.00	5.98	0.00	0.00
Red-vented Bulbul	6.91	8.50	19.03	6.36	2.02	27.72
Red-wattled Lapwing	2.44	13.41	0.00	0.38	0.00	0.00
Red-whiskered Bulbul	4.88	0.51	7.10	0.00	0.00	5.44
River Lapwing	0.00	5.63	0.00	0.00	3.99	0.00
River Tern	0.00	0.10	0.00	0.00	0.46	0.00
Rock Pigeon	4.88	0.00	0.00	0.00	0.00	0.00
Rose-ringed Parakeet	7.72	0.00	3.01	8.56	0.63	0.17

Ruddy Shelduck	0.81	0.82	0.00	0.00	25.77	0.00
Rufous-gorgeted Flycatcher	0.00	0.00	0.09	0.00	0.00	0.00
Rufous Treepie	2.85	0.00	3.10	2.77	1.18	1.68
Rusty-cheeked Scimitar-Babbler	0.00	0.00	0.00	0.05	0.00	0.00
Sarus Crane	1.63	1.02	0.00	0.00	0.00	0.00
Shikra	0.00	0.00	0.00	0.10	0.00	0.00
Sirkeer Malkoha	0.00	0.00	0.00	0.00	0.04	0.00
Slender-billed Vulture	0.00	0.00	0.00	0.00	0.04	0.00
Small Minivet	0.00	0.00	0.00	0.00	0.00	0.84
Small Niltava	0.00	0.00	0.09	0.00	0.00	0.00
Small Pratincole	0.00	0.00	0.00	0.00	2.31	0.00
Spangled Drongo	0.00	0.20	1.37	9.13	0.00	2.60
Spotted Dove	10.57	0.00	0.91	0.81	0.00	3.10
Stork-billed Kingfisher	0.00	0.00	0.00	0.00	0.04	0.00
Striated Grassbird	0.00	0.92	0.00	0.00	0.00	0.00
Taiga Flycatcher	0.00	0.00	0.00	1.43	0.00	0.00
Temminck Stint	0.00	0.00	0.00	0.00	0.42	0.00
Thick-billed Flowerpecker	0.00	0.00	0.00	0.05	0.00	0.00
Tickell's Blue Flycatcher	0.00	0.00	0.00	0.05	0.00	0.00
Tickell's Thrush	0.00	0.31	0.00	0.00	0.00	0.00
Velvet-fronted Nuthatch	0.00	0.00	0.00	0.05	0.00	0.00
Verditer Flycatcher	0.00	0.00	0.00	0.00	0.00	0.17
White-browed Wagtail	0.00	0.00	0.00	0.00	0.42	0.00
White-rumped Vulture	0.00	0.10	0.00	0.00	0.00	0.00
White-tailed Stonechat	0.00	5.42	0.00	0.00	0.00	0.00
White-throated Fantail	0.00	0.41	0.18	1.39	0.29	0.75
White-throated Kingfisher	0.00	1.43	0.00	0.00	0.63	0.00
White Wagtail	0.00	0.00	0.00	0.24	3.74	0.00
Woolly-necked Stork	0.00	0.00	0.00	0.14	0.00	0.00
Yellow-bellied Prinia	0.00	1.02	0.00	0.00	0.00	0.00
Yellow-footed Green-Pigeon	0.00	0.00	0.00	0.00	0.00	3.77
Yellow-wattled Lapwing	0.00	1.94	0.00	0.00	0.00	0.00
Yellow-breasted Greenfinch	0.00	5.63	0.00	0.00	0.00	0.00

JJCR qualifies the IBA criteria of threatened species (Rahmani et al., 2016). It has 3 critically endangered species, 3 endangered species, 4 vulnerable species and 8 near-threatened species (Table 3.5). Out of all the threatened bird species observed, Sarus Crane had the highest relative abundance followed by Black-bellied Tern, Bristled Grassbird, Woolly–necked Stork, Egyptian Vulture, Slender-billed Vulture and White-rumped Vulture (Figure 3.11).

Table 3.5. Threatened bird species of JJCR

Threatened category (IUCN status)	Bird species
Critically Endangered	Slender-billed Vulture, White-rumped Vulture, Red-headed Vulture
Endangered	Black-bellied Tern, Egyptian Vulture, Steppe Eagle
Vulnerable	Sarus Crane, Woolly-necked Stork, Greater Spotted Eagle, Bristled Grassbird
Near Threatened	Black-necked Stork, Northern Lapwing, River Lapwing, River Tern, Great Hornbill, Alexandrine Parakeet, Cinereous Vulture, Himalayan Vulture

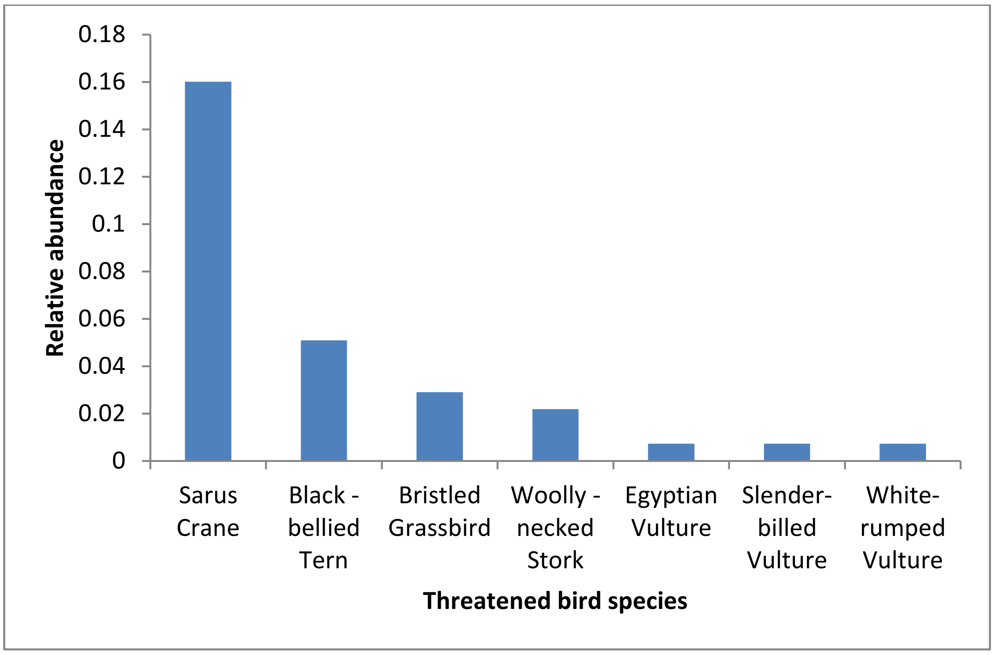


Figure 3.11. Relative abundance of threatened bird species of JJCR

3.5. Discussion

Smaller forest patches might receive less attention than larger forest patches (Decocq et al., 2016) as small reserves do not preserve the same set of species as large reserves (Diamond, 1976; Terborgh, 1976; Whitcomb et al., 1976; Cole, 1981). Smaller forested areas still hold high levels of biodiversity (Ghosh, 2019), are potential biodiversity islets and might deliver several crucial ecosystem services (Decocq et al., 2016). Various small-sized PAs such as JJCR, Asan Conservation Reserve and Pawalgarh Conservation Reserve, have a considerable good number of bird species (Rahmani et al., 2016). JJCR which lies in the Himalayan foothills, in the upper Gangetic plains and at the junction of Bhabar-Terai area has river meanders, riparian habitats and plantation areas along with the natural woodland and grassland. A total of 170 bird species were encountered during the survey period, constituting 24.53% of the total number of species (693) reported from the state of Uttrakhand (Mohan and Sondhi, 2015). The maximum numbers of species recorded were terrestrial. The bird diversity is almost same in the summer and winter seasons because JJCR lies in Himalayan foothills so there is influx of bird species in both the seasons. JJCR has higher bird diversity compared to the studies conducted in the Himalayan foothills by Joshi and Rautela (2014) and Mohan (2007). Our study is in line with various studies which states that habitat heterogeneity helps in maintaining high bird diversity (Ahmed, 2019; Sultana et al., 2021). JJCR provides a range of habitats required for different species. The habitat heterogeneity in small forest reserves creates edge effect which leads to diversity of birds. Besides, JJCR is three storied forest catering to the needs of birds belonging to different foraging strata. In our study we found that the beta diversity and species turnover rate was high and the value of nestedness component was less which implies that the bird species composition and abundance changes in different habitats and very few species were commonly found in every habitat. During summer only Red-vented Bulbul and Spotted Doves were found in all the six habitats while Humes Warbler and Red-vented Bulbuls were observed in all the six habitats in winter. More bird species were found in winter season because of arrival of many winter visitors. We found the highest diversity in riverine habitat as it is the transition between terrestrial and wetland environment having unique riparian vegetation. The river-created habitats such as water–edge and sandbars, sandbar scrub, river-edge forests leads to more diversity of birds (Remsen and Parker, 1983). Diversity was lowest in agriculture field-human settlements probably due to disturbances such as the use of pesticides or chemical fertilisers, unfriendly agricultural practices, semi-natural habitats (Boatman et al., 2004; Sundar and Kittur, 2013; Stanton et al., 2018). It was expected that birds would be using multiple habitats as the area is small. However, the distribution of birds were mostly observed to be in single habitat in both summer and winter season, which shows that birds are preferring specialised habitat despite the small size of this conservation reserve. RAD curve shows that the bird abundance is the same till 400 in both the seasons but there is rise in abundance after 400 in winter season because there is dominance of some of the birds during winter season which is because of the arrival of several winter migratory birds. Highest similarity (68%) in bird composition was between scrub forest and mixed forest which could be because of similarity of vegetation composition resulting in similarity in bird species. Least similarity (25%) was between agriculture field and riverine habitat, possibly because of the difference in vegetation composition resulting in different bird species. The mean abundance was highest in mixed deciduous forest in the summer season which could be because of the presence of many food supplies and the provision of shade during scorching heat. The mean abundance was highest in riverine habitat in winter, possibly due to the presence of many microhabitats in this habitat, this habitat supports both terrestrial and waterbirds and also riverine habitat attracts many winter birds (Remsen and Parker, 1983). In summer season River Lapwing, Paddyfield pipit, Baya Weaver, Jungle babbler, Purple Sunbird, Red-vented Bulbul had the highest relative abundance in riverine habitat, grassland, mixed habitat, plantation, scrub forest and agriculture field respectively, whereas in winter season Red-wattled Lapwing, Red-vented Bulbul, Jungle Babbler, Ruddy Shelduck, Cattle Egret had the highest relative abundance in grassland, mixed forest, plantation, riverine area, scrub forest and agricultural field respectively. The highest relative abundance of these birds was probably due to the availability of the habitat patch that provides its nesting and foraging requirements. The global population trend of 25% of the bird species in JJCR is decreasing. So, JJCR houses bird species experiencing population decline as well as 18 threatened and near-threatened species. It reveals the importance of JJCR to serve as critical habitat for birds. So the significance and importance of the conservation reserve for birdlife conservation is extensive.

CHAPTER 4

BIRD-HABITAT ASSOCIATION

4.1. Introduction

The animal-habitat interaction is the cornerstone of many ecological inquiries that provides insights to many theoretical and applied dimensions (Montgomery et al., 2018; Morris, 2003). Whether generalist or specialist the dependency of animals on its habitat based on the structural and compositional characteristics were well established for different group of animals (Pardini et al., 2005; Tews et al., 2004; Hanioka et al., 2018; Raman, 2006; Menon et al., 2019). Habitat selection is a behavioural response which results in disproportionate use of habitat influencing the survival of individuals (Hutto, 1985; Block and Brennan, 1993). Morris (2003) defined habitat selection as an evolutionary game that serves as a mechanism for regulating populations in space, including source-sink dynamics and a process that underlies the distributions and relative abundances of species.

In a mutualistic manner forest vegetation influence the bird species assemblage and abundance of species in a community depends on physiognomic and floristic composition of the forest vegetation (Cody, 1985; Rotenberry, 1985; Terborgh et al., 1990; Weins, 1992; Morrison et al., 1992; Block and Bremen, 1993; Pomara et al., 2012). Birds are potential predictors of habitat (Mukhopadhyaya and Mazumdar, 2019) and ecosystem health (Jarvinen and Vaisaunen, 1979). As birds are sensitive towards environmental changes, they are suitable for monitoring environmental health (Gregory et al., 2003). They are considered as good predictors of environmental quality as they relate to changes in various habitat features (Chhetri et al., 2005). Studies on avifaunal assemblages and environment relationship have shown that local habitat configuration has a greater effect on the relationship than the regional factors (Evans et al., 2009). Change in vegetation along different gradients influence the abundance and distribution of a particular species or guild. Birds as habitat indicators and assemblage differences were well documented for decades (Weins et al., 1987; Rottenbery, 1981; Thinh, 2006; Gould and Mackey, 2015; Naniwadekar et al., 2019). Bird species richness and diversity are directly correlated with the physiognomic characters (MacArthur and MacArthur, 1961; Balda, 1969; Karr and Roth, 1971). Rice (1983) and Dauglas et al. (1992) reported that the abundance of some tree species or a group of species can influence the distribution of certain bird species or bird guilds. The assessment of vegetation structure thus is important to understand habitat characteristics and the impact of change of habitat on birds (Rajpar and Zakaria, 2011).

Intense use of land and other natural resources with population growth resulted in the loss of forest cover and natural vegetation (Vitousek, 1994; Matson et al., 1997; Chapman and Reich, 2007). The land use intensification creates a wildland urban interphase with a continuum of environmental condition from wildlands to rural, suburban and urban lands (Marzluff et al, 2001, Bar-Massada et al., 2014). Regional biota is influenced by land-use intensification in several ways (Chapman and Reich, 2007). Introduction of roads, buildings, pastures, croplands, clear cuts into wilderness increases heterogeneity in a landscape and might increase species richness and diversity (Mellink, 1991; Blair, 1996; Jobin et al., 1996; Blair and

Launer, 1997; Cam et al., 2000; Drapeau et al., 2000; Soderstrom and Part, 2000; Glennon and Porter, 2005). The introduction of tree or shrub plantings, lawns and buildings can also influence the species richness (Geis, 1974; Sodhi, 1992; Petit et al., 1999; Crooks et al., 2004). In countries with high population densities like India, small protected areas that house viable source populations of many wildlife species are surrounded by human- dominated landscapes, such as agroforests and cultivated landscapes (Bhagwat et al., 2005; Robbins et al., 2015). Agroforests and cultivated areas are now globally recognized as important habitats for biodiversity (Balmford et al., 2005; Fischer et al., 2008; Beaudrot et al., 2016). Along with these associated landscapes the small protected areas often nurture high diversity (Baldwin and Fouch, 2018).

Although large Protected Areas are important to conserve the diversity and ecological processes but small Protected Areas have high significance in fragmented landscape and help in environmental restoration (Brambilla et al., 2020). The small isolated protected forest patches within the heavily modified landscape contributes to conservation of local faunal assemblage (Lindenmayer, 2019; Baldwin and Fouch, 2018). There are few studies done which shows small forested areas can support greater number of species (Blake and Karr, 1984). Parks and reserves form islands of natural habitat and help in the preservation of many species which depend on them. MacArthur and Wilson (1967) emphasized the importance of small islands as they act as stepping stones between large islands and thus increases the probabilities of biotic exchange. For example, small patches of the temperate woodlands of Southeast Australia are species-rich (Lindenmayer, 2019). Small reserves such as the remnant bushland in sub-humid Tasmania supports many rare plants (Kirkpatrick and Gilfedder, 1995). Similarly, the small patches of remnant native vegetation in New Zealand are vital for the conservation of native land snails (Ogle, 1987).

The objective of the study was to assess change in species assemblage in summer and winter season. I also explored the association between the vegetation structures and the bird species composition along the habitat and the seasonal differences in bird assemblage also.

The research questions addressed in this chapter are:

(i) Is the bird composition different in summer and winter seasons?

(ii) How different bird species are associated with the vegetation structures?

4.2. Methods

Bird sampling

The diversity and assemblage of avifauna was assessed through stratified random sampling from March 2018 to March 2020. We executed habitat-wise point count (Bibby et al. 2000) to collect abundance data of birds covering plantation (28), mixed forest (15), scrub forest (12), riverine (25) and grassland (21) and agriculture fields-human settlements (15). Each point count station was 200 meters away from each other (Figure.2). Birds were observed for 10 minutes at each point count station. All the birds visually encountered and calls recorded were entered in a prescribed dataset. Every point count station was visited 20 times to assess the variability of species abundance and species turnover. Birds were counted from 5:30 am to 8:30 am during summer and from 8:00 am to 10:30 am during winter season. Surveys during inclement weather were avoided.

Habitat quantification

The physiognomic and species composition variability of the habitat was assessed through vegetation plots at the point count locations. Total 232 quadrat plots were sampled with two quadrat plots in each point count station. I laid nested quadrats with the largest quadrat of 10X10 m^2 to get data on the tree characteristics like tree species richness, tree abundance, girth at breast height (GBH), tree height, and canopy cover. All woody vegetation of 20cm (GBH) or more were considered as trees. I collected information on abundance of shrub in 5x5 m^2 plot nested inside the 10x10 m^2 plot. Herbs and grasses were recorded in 1x1 m^2 nested at the four corners of 10x10 m^2 plot. Tree cover (Canopy cover), shrub cover and ground cover were estimated following the line intercept method (Canfield, 1941). I estimated the parameters such as tree species richness, tree abundance, average girth at breast height (GBH), average height, and canopy cover % shrub species abundance, richness, shrub cover for further analysis (Table 4.1).

4.3. Data analysis

Similarity Percentages (SIMPER) and Permutational multivariate analysis of variance (PERMANOVA) test (Anderson, 2001) were performed to assess the difference in bird community in different habitats and to identify the bird species responsible for the community dissimilarity based on the abundance value. We also assessed the difference in bird community in summer and winter seasons. We considered bird species which were responsible for more than 50 % dissimilarities (from SIMPER result) between the bird communities in different seasons for ordination analysis. The physiognomic characteristics of the habitat collected during the vegetation sampling were quantified to understand the dependency of the bird species on habitat heterogeneity. We performed the Nonmetric Multidimensional Scaling (NMDS) using 'Bray Curtis' distance to assess the association between different bird species and the habitats. The vegetation structures like tree abundance, shrub cover, grass cover etc., were plotted against the bird community to assess the association of different bird species with the vegetation structure in different habitats.

4.4. Results

Major structural and compositional parameters calculated from the vegetation plots are given in Table 4.1. Major tree species is Eucalyptus whereas major shrub species are *Murraya koenigii* and *Helicteres isora.* The major grasses which are observed here are *Phragmites karka* and *Imperata cylindrica.*

Compositional differences in Bird community

SIMPER analysis showed that the overall dissimilarity between the bird composition in summer and winter season was 91.17%. The PERMANOVA results also showed significant differences in bird composition in both seasons (p=0.0001). The major birds influencing the differences in the community in the summer and winter seasons were Red-vented Bulbul, Jungle Babbler, Ruddy Shelduck, Rose-ringed Parakeet and Little Cormorant (Table 4.2). We found significant difference in the bird community in different habitat in summer and winter (PERMANOVA p= 0.0001 for both summer and winter). SIMPER analysis showed that in summer season, the overall dissimilarity within the bird community in different habitats was 89.11%. The highest dissimilarity was found between plantation and grassland (96.13%), whereas the lowest was found between mixed deciduous forest and scrub forest (67.01%) (Table 4.3). In winter season, the overall dissimilarity was 92.84 %. The highest dissimilarity was found between scrub forest and riverine as 96.71%, whereas the lowest dissimilarity was found between mixed deciduous forest and scrub forest as 80.23% (Table 4.3). The difference in abundance of the bird species like Baya Weaver, Rose-ringed parakeet, Jungle babbler, Red-vented Bulbul, Spotted dove, Red-wattled Lapwing, Green Bee-eater etc. caused the dissimilarities within the bird communities in summer season. A complete list of bird species which were influencing the differences in the community in summer has been given in Table 4.4 and between different habitats in summer season has been given in Table 4.5. The difference in abundance of the bird species like Red-vented Bulbul, Ruddy Shelduck, Jungle Babbler, Little Cormorant, Black Bulbul, Humes Warbler, Barn Swallow, Spangled Drongo, Rose-ringed parakeet, Black-hooded Oriole etc. caused the dissimilarities within the bird communities in winter season. A complete list of bird species which were influencing the differences in the community in winter has been given in Table 4.6 and different habitats in the winter season has been given in Table 4.7.

Table 4.1. Attributes of vegetation in JJCR (based on two plots – 200 m^2)

	Mean	
	Statistic	**Std. Error**
Tree abundance	3.36	0.32
Tree species richness	1.33	0.12
Canopy cover(%)	17.73	1.43
GBH(cm)	47.18	3.70
Tree height(m)	10.44	1.06
Shrub species richness	1.32	0.16
Shrub abundance	13.53	1.78
Shrub cover(%)	15.30	2.25
Invasive species cover	3.07	0.75
Herb(%)	23.87	1.76
Grass(%)	54.11	2.69
Leaf litter(%)	14.73	2.47
Bareground(%)	7.29	2.35

Table 4.2. Result of SIMPER analysis for both the seasons

Taxon	Average dissimilarity	Percentage Contribution	Cumulative percentage	Mean of bird abundance in summer	Mean of bird abundance in winter
Red-vented Bulbul	5.97	6.55	6.55	3.24	7.96
Jungle Babbler	4.30	4.72	11.27	3.70	2.89
Ruddy Shelduck	3.36	3.69	14.96	0.77	6.15
Rose-ringed Parakeet	3.14	3.44	18.40	2.71	2.27
Little Cormorant	2.61	2.87	21.27	0.95	2.26
Baya Weaver	2.54	2.79	24.06	3.80	0.00
Red-wattled Lapwing	2.53	2.78	26.83	1.69	1.38
Black-hooded Oriole	2.42	2.65	29.49	1.82	1.86
Barn Swallow	2.41	2.65	32.13	1.25	3.11
Green Bee-eater	2.35	2.58	34.71	2.47	0.22
Purple Sunbird	2.31	2.54	37.24	2.51	0.96

Paddyfield Pipit	2.22	2.44	39.68	1.27	1.36
Spotted Dove	2.20	2.42	42.10	2.62	0.63
River Lapwing	2.20	2.41	44.51	1.21	1.49
Common Myna	2.16	2.37	46.89	2.03	0.95
Humes Warbler	2.09	2.29	49.18	0.00	2.77
Common Stonechat	1.76	1.93	51.11	0.66	1.26
Black Bulbul	1.75	1.92	53.03	0.00	2.41
Spangled Drongo	1.68	1.84	54.87	0.00	2.37
Oriental White-eye	1.47	1.61	56.49	0.61	1.74
Indian Paradise-Flycatcher	1.39	1.53	58.01	1.74	0.00
Black Drongo	1.29	1.41	59.42	0.70	0.97
Rufous Treepie	1.25	1.38	60.80	0.39	1.39
Oriental Magpie-Robin	1.23	1.35	62.14	1.33	0.50
House Crow	1.19	1.30	63.44	0.67	0.97
Red-whiskered Bulbul	1.17	1.28	64.73	0.39	1.47
Large-billed Crow	1.15	1.26	65.99	0.28	1.47
Greenish Warbler	1.07	1.17	67.16	0.00	1.12
Red Junglefowl	1.07	1.17	68.33	1.18	0.45
Little Egret	1.03	1.13	69.45	0.91	0.26
Lesser Whitethroat	1.02	1.12	70.57	0.02	1.38
Plain Prinia	0.95	1.05	71.61	0.32	0.98
Indian Pitta	0.92	1.01	72.63	1.13	0.00
Pied Bushchat	0.90	0.99	73.61	0.44	0.45
Red-naped Ibis	0.88	0.97	74.58	0.04	1.76
Common Tailorbird	0.85	0.93	75.51	0.96	0.16
Himalayan Bulbul	0.83	0.91	76.42	0.00	1.53
Northern Pintail	0.76	0.83	77.25	0.00	1.27
Ashy Prinia	0.73	0.80	78.05	0.60	0.24
Indian Peafowl	0.68	0.74	78.79	0.63	0.47
Citrine Wagtail	0.67	0.74	79.53	0.00	0.90
Bar-headed Goose	0.66	0.73	80.26	0.00	0.99
White-tailed Stonechat	0.60	0.66	80.92	0.03	0.53
White Wagtail	0.60	0.66	81.58	0.01	0.93
Indian Roller	0.58	0.64	82.22	0.42	0.37
Cattle Egret	0.58	0.63	82.85	0.64	0.07
River Tern	0.57	0.63	83.48	0.48	0.12
Oriental Skylark	0.57	0.63	84.11	0.25	0.33
Indian Grey Hornbill	0.55	0.60	84.71	0.42	0.31
Plum-headed Parakeet	0.52	0.57	85.27	0.07	0.63
Chestnut-shouldered Petronia	0.46	0.50	85.77	0.65	0.00
Great Tit	0.45	0.49	86.26	0.00	0.55

White-throated Fantail	0.44	0.48	86.74	0.00	0.51
Small Pratincole	0.44	0.48	87.22	0.29	0.55
Yellow-wattled Lapwing	0.43	0.47	87.69	0.16	0.19
Common Iora	0.42	0.46	88.15	0.58	0.00
Pied Kingfisher	0.41	0.45	88.60	0.17	0.30
Gray Wagtail	0.39	0.42	89.03	0.06	0.39
Little-ringed Plover	0.36	0.40	89.42	0.07	0.68
Indian Robin	0.36	0.40	89.82	0.27	0.22
White-throated Kingfisher	0.36	0.39	90.21	0.13	0.29
Brown-headed Barbet	0.34	0.38	90.59	0.28	0.14
Striated Grassbird	0.34	0.38	90.96	0.28	0.09
Great Cormorant	0.33	0.36	91.33	0.05	0.86
Black-chinned Babbler	0.33	0.36	91.69	0.47	0.00
Eurasian Collared-Dove	0.30	0.33	92.02	0.28	0.14
Indian Pied Starling	0.28	0.31	92.33	0.12	0.18
Yellow-bellied Prinia	0.28	0.31	92.64	0.17	0.10
Yellow-breasted Greenfinch	0.28	0.31	92.95	0.00	0.55
Yellow-footed Green-Pigeon	0.25	0.28	93.22	0.00	0.45
Taiga Flycatcher	0.25	0.27	93.49	0.00	0.30
Laughing Dove	0.23	0.25	93.74	0.15	0.09
Indian Spot-billed Duck	0.22	0.24	93.98	0.22	0.00
Intermediate Egret	0.21	0.23	94.22	0.06	0.38
Asian Koel	0.21	0.23	94.45	0.26	0.00
Brahminy Starling	0.21	0.23	94.67	0.14	0.14
Red-crested Pochard	0.20	0.22	94.89	0.00	0.16
Common Hawk-Cuckoo	0.20	0.22	95.11	0.26	0.00
Blue-tailed Bee-eater	0.17	0.18	95.29	0.25	0.00
Indian Cuckoo	0.16	0.18	95.47	0.21	0.00
Lesser Goldenback	0.16	0.18	95.65	0.07	0.20
White-browed Wagtail	0.16	0.18	95.83	0.08	0.10
Goosander	0.16	0.18	96.00	0.00	0.29
Crested Serpent-Eagle	0.16	0.17	96.18	0.05	0.14
Pond Heron	0.15	0.17	96.34	0.01	0.21
Grey-breasted Prinia	0.15	0.17	96.51	0.21	0.00
Plain Martin	0.14	0.16	96.67	0.00	0.16
Gadwall	0.13	0.15	96.82	0.00	0.15
Sarus Crane	0.13	0.14	96.96	0.06	0.10
Common Kingfisher	0.13	0.14	97.10	0.06	0.08
Red-breasted Flycatcher	0.13	0.14	97.24	0.00	0.19

Crimson Sunbird	0.12	0.13	97.37	0.00	0.16
Small Minivet	0.11	0.12	97.48	0.07	0.10
Shikra	0.10	0.11	97.59	0.10	0.02
Indian Silverbill	0.10	0.11	97.70	0.00	0.09
Jungle Owlet	0.10	0.11	97.81	0.05	0.09
Grey-headed Canary-Flycatcher	0.09	0.10	97.91	0.00	0.11
Black Francolin	0.09	0.09	98.01	0.08	0.00
Zitting Cisticola	0.08	0.09	98.10	0.07	0.00
Temminck Stint	0.08	0.09	98.19	0.00	0.10
Coppersmith Barbet	0.08	0.09	98.27	0.11	0.00
White-bellied Drongo	0.08	0.09	98.36	0.08	0.00
Grey Bushchat	0.07	0.08	98.44	0.06	0.01
Black-bellied Tern	0.07	0.08	98.52	0.00	0.07
Red Avadavat	0.07	0.08	98.59	0.00	0.06
Pallas Gull	0.06	0.07	98.66	0.00	0.18
Long-tailed Shrike	0.06	0.06	98.72	0.02	0.05
Striated Babbler	0.06	0.06	98.79	0.05	0.00
Brown Rock Chat	0.05	0.05	98.84	0.00	0.04
Bristled Grassbird	0.05	0.05	98.89	0.04	0.00
Great Egret	0.05	0.05	98.94	0.00	0.04
Bank Myna	0.04	0.05	98.99	0.00	0.03
Little Tern	0.04	0.05	99.04	0.04	0.00
Grey Heron	0.04	0.05	99.09	0.04	0.00
Jungle Myna	0.04	0.05	99.13	0.08	0.00
Black Kite	0.04	0.04	99.17	0.03	0.00
Ashy-crowned Sparrow-Lark	0.03	0.04	99.21	0.03	0.00
Grey Francolin	0.03	0.04	99.25	0.03	0.00
Black-breasted Weaver	0.03	0.04	99.29	0.03	0.00
Blyth’s Reed Warbler	0.03	0.04	99.32	0.04	0.00
Grey-hooded Warbler	0.03	0.03	99.36	0.01	0.03
Common Greenshank	0.03	0.03	99.39	0.00	0.03
Oriental Pied-Hornbill	0.03	0.03	99.42	0.00	0.04
Grey-bellied Cuckoo	0.03	0.03	99.45	0.03	0.00
Tickell's Thrush	0.03	0.03	99.48	0.00	0.03
Common Sandpiper	0.03	0.03	99.51	0.00	0.06
Lemon-rumped Warbler	0.02	0.03	99.54	0.00	0.02
Golden-fronted Leafbird	0.02	0.02	99.56	0.00	0.03
Greater Coucal	0.02	0.02	99.58	0.00	0.04
Asian Brown Flycatcher	0.02	0.02	99.60	0.00	0.03
Pale-billed Flowerpecker	0.02	0.02	99.62	0.02	0.00

Pied Cuckoo	0.02	0.02	99.64	0.02	0.00
Himalayan Griffon	0.02	0.02	99.66	0.01	0.02
Little Stint	0.02	0.02	99.67	0.00	0.04
Changeable Hawk-Eagle	0.02	0.02	99.69	0.02	0.00
Chestnut-bellied Nuthatch	0.02	0.02	99.71	0.02	0.00
Streak-throated Woodpecker	0.02	0.02	99.73	0.02	0.00
Bay-backed Shrike	0.01	0.02	99.74	0.01	0.01
White-rumped Vulture	0.01	0.01	99.76	0.00	0.01
Crested Lark	0.01	0.01	99.77	0.01	0.00
Osprey	0.01	0.01	99.78	0.00	0.01
Bronze Drongo	0.01	0.01	99.79	0.00	0.01
Ashy Drongo	0.01	0.01	99.81	0.00	0.01
Asian Woolly-necked Stork	0.01	0.01	99.82	0.00	0.03
Verditer Flycatcher	0.01	0.01	99.83	0.00	0.02
White-eyed Buzzard	0.01	0.01	99.84	0.01	0.00
Slender-billed Vulture	0.01	0.01	99.85	0.00	0.01
Drongo Cuckoo	0.01	0.01	99.86	0.01	0.00
Black-naped Monarch	0.01	0.01	99.87	0.00	0.01
Oriental Honey-buzzard	0.01	0.01	99.87	0.01	0.00
Chestnut-bellied Rock-Thrush	0.01	0.01	99.88	0.00	0.01
Velvet-fronted Nuthatch	0.01	0.01	99.89	0.00	0.01
Rusty-cheeked Scimitar-Babbler	0.01	0.01	99.90	0.00	0.01
Tawny-bellied Babbler	0.01	0.01	99.91	0.01	0.00
Eurasian Sparrowhawk	0.01	0.01	99.91	0.00	0.01
Small Niltava	0.01	0.01	99.92	0.00	0.01
Maroon Oriole	0.01	0.01	99.93	0.00	0.01
Sirkeer Malkoha	0.01	0.01	99.94	0.00	0.01
Common Cuckoo	0.01	0.01	99.94	0.01	0.00
Short-toed Snake-Eagle	0.01	0.01	99.95	0.01	0.00
Lesser Whistling-Duck	0.01	0.01	99.96	0.00	0.01
Stork-billed Kingfisher	0.01	0.01	99.97	0.00	0.01
Great Barbet	0.01	0.01	99.97	0.00	0.01
Rufous-gorgeted flycatcher	0.01	0.01	99.98	0.00	0.01
Tickell's Blue Flycatcher	0.00	0.01	99.99	0.00	0.01
Thick-billed Flowerpecker	0.00	0.01	99.99	0.00	0.01

Cinereous Vulture	0.00	0.00	100.00	0.00	0.01
Egyptian Vulture	0.00	0.00	100.00	0.00	0.01

Table 4.3. Dissimilarity (%) between different habitats in both summer and winter season

summer	Plantation	Mixed Deciduous forest	Scrub forest	Riverine	Grassland
Plantation	0	77.83	81.04	94.29	96.13
Mixed Deciduous forest		0	67.01	93.24	95.14
Scrub forest			0	86.25	92.03
Riverine				0	89.74
Grassland					0

winter	Plantation	Mixed Deciduous forest	Scrub forest	Riverine	Grassland
Plantation	0	83.8	86.99	94.23	96.43
Mixed Deciduous forest		0	80.23	95.25	95.93
Scrub forest			0	96.71	96.05
Riverine				0	94.97
Grassland					0

Table 4.4. Result of SIMPER analysis during summer season in all the habitats

Taxon	Average dissimilarity	Contribution %	Cumulative %	Mean of bird abundance in Plantation	Mean of bird abundance in Mixed deciduous forest	Mean of bird abundance in Scrub forest	Mean of bird abundance in Riverine	Mean of bird abundance in Grassland
Baya Weaver	5.92	6.64	6.64	0.00	22.90	2.42	0.00	0.52
Jungle Babbler	5.61	6.29	12.93	8.50	6.73	2.92	0.00	0.00
Red-vented Bulbul	4.10	4.60	17.53	3.32	7.20	6.25	0.80	1.48
Rose-ringed Parakeet	4.05	4.54	22.08	4.50	9.60	0.25	0.00	0.05
Green Bee- eater	3.69	4.15	26.22	0.00	1.60	7.00	4.20	1.71
Spotted Dove	3.57	4.00	30.23	2.82	4.87	7.67	0.72	0.14
Purple Sunbird	3.33	3.74	33.96	2.11	3.87	7.92	1.60	0.10
Red-wattled Lapwing	3.21	3.60	37.56	0.00	0.00	0.00	1.92	5.86
Common Myna	2.96	3.32	40.88	5.36	0.00	0.42	0.92	1.29
Black-hooded Oriole	2.91	3.26	44.14	6.11	0.53	0.00	0.20	0.00
Paddyfield Pipit	2.82	3.16	47.30	0.00	0.00	0.00	0.08	6.00
Indian Paradise-Flycatcher	2.72	3.05	50.35	5.57	1.33	0.00	0.00	0.00
River Lapwing	2.44	2.74	53.08	0.00	0.00	0.00	4.64	0.29
Barn Swallow	2.04	2.29	55.37	0.00	1.93	0.00	0.00	4.62
Oriental Magpie-Robin	1.87	2.10	57.47	3.04	1.20	1.75	0.28	0.14
Little Cormorant	1.79	2.01	59.48	0.00	0.00	0.00	3.84	0.00
Little Egret	1.77	1.98	61.47	0.00	0.00	0.00	3.68	0.00
Red JungleFowl	1.72	1.93	63.40	0.79	5.13	1.67	0.00	0.00

Indian Pitta	1.66	1.87	65.26	2.64	2.13	0.67	0.00	0.00
Ruddy Shelduck	1.64	1.84	67.11	0.00	0.00	0.00	3.12	0.00
Common Tailorbird	1.47	1.65	68.76	0.29	2.47	3.00	0.64	0.00
Common Stonechat	1.43	1.60	70.36	0.00	0.00	0.00	0.24	2.90
House Crow	1.31	1.46	71.82	0.00	0.00	0.00	2.32	0.48
Black Drongo	1.17	1.31	73.13	1.50	0.00	0.50	0.68	0.29
Ashy Prinia	1.11	1.25	74.38	0.00	0.80	1.00	0.56	1.10
Cattle Egret	1.02	1.14	75.52	1.86	0.00	0.00	0.24	0.33
Chestnut- shouldered Petronia	1.01	1.13	76.65	0.29	2.93	0.92	0.12	0.00
Indian Peafowl	1.01	1.13	77.78	0.18	2.40	1.67	0.00	0.14
Pied Bushchat	0.98	1.10	78.89	0.00	0.00	0.17	0.00	2.00
Oriental White-eye	0.98	1.10	79.99	0.82	1.53	1.33	0.00	0.00
River Tern	0.96	1.08	81.07	0.00	0.00	0.00	1.92	0.00
Common Iora	0.94	1.05	82.12	0.18	1.93	2.08	0.00	0.00
Black-chinned Babbler	0.72	0.81	82.93	0.25	2.00	0.83	0.00	0.00
Indian Grey Hornbill	0.67	0.75	83.68	1.04	0.53	0.00	0.20	0.00
Indian Roller	0.67	0.75	84.43	0.39	0.67	0.33	0.64	0.05
Red-whiskered Bulbul	0.60	0.68	85.11	0.50	0.80	0.67	0.00	0.24
Plain Prinia	0.60	0.67	85.78	0.14	0.00	0.67	0.16	0.76
Rufous Treepie	0.59	0.67	86.45	0.82	1.07	0.00	0.00	0.00
Striated Grassbird	0.58	0.65	87.09	0.00	0.00	0.00	0.00	1.33
Indian Robin	0.55	0.62	87.71	0.00	0.00	2.08	0.08	0.00
Oriental Skylark	0.53	0.59	88.31	0.00	0.00	0.00	0.12	1.05
Small Pratincole	0.52	0.59	88.90	0.00	0.00	0.00	1.16	0.00
Large-billed Crow	0.47	0.53	89.43	0.07	0.20	0.00	0.76	0.19
Brown-headed Barbet	0.47	0.53	89.95	0.96	0.00	0.08	0.00	0.00

Eurasian Collared-Dove	0.46	0.51	90.46	0.00	0.67	0.42	0.52	0.00
Indian Spot-billed Duck	0.44	0.49	90.96	0.00	0.00	0.00	0.88	0.00
Asian Koel	0.41	0.46	91.42	0.36	0.47	0.33	0.20	0.00
Yellow- bellied Prinia	0.41	0.46	91.88	0.00	0.00	0.00	0.00	0.81
Blue-tailed Bee-eater	0.40	0.45	92.32	0.00	1.40	0.33	0.00	0.00
Common Hawk-Cuckoo	0.39	0.44	92.77	0.71	0.40	0.00	0.00	0.00
Yellow-wattled Lapwing	0.38	0.43	93.20	0.00	0.00	0.00	0.00	0.76
Grey-breasted Prinia	0.35	0.39	93.59	0.07	0.80	0.58	0.00	0.00
Indian Cuckoo	0.34	0.38	93.97	0.57	0.20	0.17	0.00	0.00
Laughing Dove	0.32	0.36	94.33	0.00	0.00	0.75	0.00	0.29
Pied Kingfisher	0.32	0.36	94.69	0.00	0.00	0.00	0.68	0.00
Brahminy Starling	0.29	0.32	95.01	0.00	0.33	0.75	0.00	0.00
White-throated Kingfisher	0.25	0.28	95.29	0.07	0.00	0.00	0.24	0.24
Indian Pied Starling	0.24	0.27	95.56	0.00	0.00	0.00	0.00	0.57
Shikra	0.19	0.21	95.77	0.29	0.00	0.17	0.00	0.00
Coppersmith Barbet	0.18	0.20	95.97	0.18	0.13	0.33	0.00	0.00
White-browed Wagtail	0.17	0.19	96.16	0.00	0.00	0.00	0.32	0.00
Zitting Cisticola	0.17	0.19	96.35	0.00	0.00	0.00	0.00	0.33
Black Francolin	0.17	0.19	96.54	0.00	0.00	0.00	0.20	0.14
Little-ringed Plover	0.16	0.18	96.71	0.00	0.00	0.00	0.28	0.00
White-bellied Drongo	0.15	0.17	96.89	0.07	0.00	0.00	0.24	0.00
Grey Bushchat	0.14	0.16	97.05	0.00	0.00	0.00	0.00	0.29
Sarus Crane	0.13	0.15	97.19	0.00	0.00	0.00	0.24	0.00
Gray Wagtail	0.13	0.14	97.34	0.00	0.00	0.00	0.24	0.00
Small Minivet	0.12	0.14	97.47	0.04	0.20	0.25	0.00	0.00
Striated Babbler	0.12	0.13	97.61	0.00	0.00	0.00	0.00	0.24

Common Kingfisher	0.12	0.13	97.74	0.00	0.00	0.00	0.12	0.14
Intermediate Egret	0.12	0.13	97.87	0.00	0.00	0.00	0.24	0.00
Lesser Goldenback	0.11	0.12	97.99	0.14	0.00	0.25	0.00	0.00
Plum-headed Parakeet	0.11	0.12	98.11	0.00	0.33	0.17	0.00	0.00
Great Cormorant	0.10	0.12	98.23	0.00	0.00	0.00	0.20	0.00
Jungle Myna	0.10	0.11	98.35	0.00	0.53	0.00	0.00	0.00
Bristled Grassbird	0.10	0.11	98.46	0.00	0.00	0.00	0.00	0.19
Little Tern	0.09	0.10	98.56	0.00	0.00	0.00	0.16	0.00
Grey Heron	0.09	0.10	98.65	0.00	0.00	0.00	0.16	0.00
Jungle Owlet	0.08	0.09	98.74	0.18	0.00	0.00	0.00	0.00
Crested Serpent-Eagle	0.07	0.08	98.82	0.11	0.13	0.00	0.00	0.00
Red-naped Ibis	0.07	0.08	98.90	0.00	0.00	0.00	0.16	0.00
Black-breasted Weaver	0.07	0.08	98.98	0.00	0.00	0.00	0.00	0.14
Black Kite	0.07	0.08	99.06	0.00	0.00	0.00	0.12	0.00
Ashy-crowned Sparrow-Lark	0.07	0.08	99.14	0.00	0.00	0.00	0.12	0.00
Grey Francolin	0.07	0.08	99.22	0.00	0.00	0.00	0.08	0.05
Blyth’s Reed Warbler	0.07	0.08	99.29	0.00	0.00	0.00	0.16	0.00
White-tailed Stonechat	0.06	0.07	99.36	0.00	0.00	0.00	0.00	0.14
Grey-bellied Cuckoo	0.06	0.07	99.42	0.00	0.00	0.00	0.04	0.10
Long-tailed Shrike	0.05	0.05	99.48	0.00	0.00	0.17	0.00	0.00
Lesser Whitethroat	0.04	0.05	99.53	0.00	0.00	0.17	0.00	0.00
Pied Cuckoo	0.04	0.05	99.57	0.00	0.00	0.17	0.00	0.00
Pale-billed Flowerpecker	0.04	0.05	99.62	0.00	0.00	0.17	0.00	0.00
Streak-throated Woodpecker	0.04	0.04	99.66	0.00	0.00	0.17	0.00	0.00
Chestnut-bellied Nuthatch	0.04	0.04	99.70	0.00	0.00	0.17	0.00	0.00
Changeable Hawk-Eagle	0.03	0.04	99.74	0.04	0.00	0.08	0.00	0.00

Crested Lark	0.02	0.03	99.77	0.00	0.00	0.00	0.04	0.00
White-eyed Buzzard	0.02	0.03	99.80	0.00	0.00	0.08	0.00	0.00
White Wagtail	0.02	0.02	99.82	0.00	0.00	0.00	0.04	0.00
Pond Heron	0.02	0.02	99.85	0.00	0.00	0.00	0.04	0.00
Bay-backed Shrike	0.02	0.02	99.87	0.00	0.00	0.08	0.00	0.00
Himalayan Griffon	0.02	0.02	99.89	0.00	0.00	0.08	0.00	0.00
Oriental Honey-buzzard	0.02	0.02	99.91	0.00	0.07	0.00	0.00	0.00
Tawny-bellied Babbler	0.02	0.02	99.93	0.00	0.00	0.08	0.00	0.00
Grey-hooded Warbler	0.02	0.02	99.95	0.04	0.00	0.00	0.00	0.00
Drongo Cuckoo	0.02	0.02	99.97	0.04	0.00	0.00	0.00	0.00
Short-toed Snake-Eagle	0.01	0.02	99.98	0.00	0.00	0.00	0.00	0.05
Common Cuckoo	0.01	0.02	100.00	0.04	0.00	0.00	0.00	0.00

Table 4.5. SIMPER analysis for summer season between different habitats (pairwise comparison)

Plantation and Mixed deciduous forest					
Taxon	**Average dissimilarity**	**Contribution%**	**Cumulative %**	**Mean of bird abundance in Plantation**	**Mean of bird abundance in Mixed deciduous forest**
Baya Weaver	15.64	20.09	20.09	0.00	22.90
Rose-ringed Parakeet	6.43	8.26	28.35	4.50	9.60
Jungle Babbler	6.15	7.91	36.26	8.50	6.73
Red-vented Bulbul	3.88	4.99	41.25	3.32	7.20
Black-hooded Oriole	3.73	4.79	46.03	6.11	0.53
Indian Paradise-Flycatcher	3.33	4.28	50.31	5.57	1.33
Common Myna	3.30	4.24	54.55	5.36	0.00
Red Junglefowl	3.27	4.21	58.76	0.79	5.13
Spotted Dove	3.16	4.07	62.83	2.82	4.87
Purple Sunbird	2.05	2.63	65.46	2.11	3.87
Chestnut-shouldered Petronia	2.00	2.57	68.02	0.29	2.93
Oriental Magpie-Robin	1.66	2.13	70.15	3.04	1.20
Common Tailorbird	1.65	2.12	72.27	0.29	2.47
Indian Peafowl	1.63	2.09	74.37	0.18	2.40
Barn Swallow	1.49	1.92	76.29	0.00	1.93
Indian Pitta	1.37	1.75	78.04	2.64	2.13
Black-chinned Babbler	1.34	1.72	79.77	0.25	2.00
Common Iora	1.34	1.72	81.48	0.18	1.93
Oriental White-eye	1.19	1.53	83.02	0.82	1.53
Green Bee-eater	1.09	1.40	84.42	0.00	1.60
Cattle Egret	1.07	1.38	85.80	1.86	0.00
Black Drongo	1.03	1.33	87.12	1.50	0.00
Rufous Treepie	1.02	1.32	88.44	0.82	1.07
Blue-tailed Bee-eater	0.97	1.24	89.68	0.00	1.40
Indian Grey Hornbill	0.86	1.11	90.79	1.04	0.53
Red-whiskered Bulbul	0.74	0.96	91.74	0.50	0.80
Brown-headed Barbet	0.64	0.82	92.56	0.96	0.00
Grey-breasted Prinia	0.60	0.77	93.33	0.07	0.80
Indian Roller	0.59	0.76	94.09	0.39	0.67
Common Hawk-Cuckoo	0.58	0.75	94.84	0.71	0.40
Ashy Prinia	0.57	0.73	95.57	0.00	0.80
Asian Koel	0.46	0.60	96.16	0.36	0.47

Indian Cuckoo	0.45	0.57	96.74	0.57	0.20
Eurasian Collared-Dove	0.43	0.55	97.29	0.00	0.67
Jungle Myna	0.30	0.39	97.68	0.00	0.53
Brahminy Starling	0.22	0.29	97.97	0.00	0.33
Plum-headed Parakeet	0.22	0.28	98.24	0.00	0.33
Shikra	0.20	0.25	98.50	0.29	0.00
Coppersmith Barbet	0.18	0.23	98.73	0.18	0.13
Large-billed Crow	0.18	0.23	98.95	0.07	0.20
Crested Serpent-Eagle	0.16	0.20	99.15	0.11	0.13
Small Minivet	0.15	0.19	99.35	0.04	0.20
Jungle Owlet	0.11	0.14	99.49	0.18	0.00
Plain Prinia	0.09	0.11	99.60	0.14	0.00
Lesser Goldenback	0.08	0.11	99.71	0.14	0.00
Oriental Honey-buzzard	0.06	0.07	99.78	0.00	0.07
White-throated Kingfisher	0.05	0.06	99.83	0.07	0.00
White-bellied Drongo	0.04	0.05	99.88	0.07	0.00
Grey-hooded Warbler	0.02	0.03	99.91	0.04	0.00
Changeable Hawk-Eagle	0.02	0.03	99.94	0.04	0.00
Drongo Cuckoo	0.02	0.03	99.97	0.04	0.00
Common Cuckoo	0.02	0.03	100.00	0.04	0.00

Plantation and Scrub forest					
Taxon	**Average dissimilarity**	**Contribution%**	**Cumulative %**	**Mean of bird abundance in Plantation**	**Mean of bird abundance in Scrub forest**
Jungle Babbler	6.90	8.51	8.51	8.50	2.92
Green Bee-eater	6.28	7.75	16.27	0.00	7.00
Purple Sunbird	5.46	6.73	23.00	2.11	7.92
Spotted Dove	5.27	6.50	29.50	2.82	7.67
Black-hooded Oriole	5.01	6.18	35.68	6.11	0.00
Red-vented Bulbul	4.66	5.74	41.43	3.32	6.25
Indian Paradise-Flycatcher	4.49	5.55	46.97	5.57	0.00
Common Myna	4.15	5.13	52.10	5.36	0.42
Rose-ringed Parakeet	3.93	4.85	56.95	4.50	0.25
Oriental Magpie-Robin	2.58	3.18	60.12	3.04	1.75
Common Tailorbird	2.53	3.12	63.24	0.29	3.00
Baya Weaver	2.11	2.61	65.85	0.00	2.42

Indian Pitta	1.98	2.45	68.30	2.64	0.67
Indian Robin	1.85	2.29	70.58	0.00	2.08
Common Iora	1.74	2.15	72.73	0.18	2.08
Red Junglefowl	1.70	2.10	74.83	0.79	1.67
Indian Peafowl	1.43	1.77	76.60	0.18	1.67
Black Drongo	1.43	1.76	78.37	1.50	0.50
Oriental White-eye	1.41	1.74	80.11	0.82	1.33
Cattle Egret	1.30	1.61	81.72	1.86	0.00
Chestnut-shouldered Petronia	0.94	1.16	82.88	0.29	0.92
Indian Grey Hornbill	0.90	1.11	83.99	1.04	0.00
Ashy Prinia	0.90	1.11	85.09	0.00	1.00
Red-whiskered Bulbul	0.87	1.08	86.17	0.50	0.67
Brown-headed Barbet	0.84	1.03	87.20	0.96	0.08
Black-chinned Babbler	0.81	1.00	88.20	0.25	0.83
Brahminy Starling	0.79	0.97	89.17	0.00	0.75
Laughing Dove	0.69	0.85	90.02	0.00	0.75
Plain Prinia	0.69	0.85	90.87	0.14	0.67
Rufous Treepie	0.66	0.82	91.69	0.82	0.00
Common Hawk-Cuckoo	0.58	0.72	92.40	0.71	0.00
Indian Cuckoo	0.55	0.68	93.08	0.57	0.17
Indian Roller	0.55	0.68	93.76	0.39	0.33
Grey-breasted Prinia	0.51	0.63	94.39	0.07	0.58
Asian Koel	0.49	0.60	94.99	0.36	0.33
Eurasian Collared-Dove	0.41	0.50	95.49	0.00	0.42
Shikra	0.38	0.47	95.97	0.29	0.17
Coppersmith Barbet	0.38	0.47	96.44	0.18	0.33
Lesser Goldenback	0.29	0.36	96.80	0.14	0.25
Blue-tailed Bee-eater	0.28	0.35	97.15	0.00	0.33
Small Minivet	0.25	0.31	97.46	0.04	0.25
Long-tailed Shrike	0.18	0.22	97.67	0.00	0.17
Pied Bushchat	0.17	0.21	97.89	0.00	0.17
Lesser Whitethroat	0.15	0.19	98.08	0.00	0.17
Pale-billed Flowerpecker	0.15	0.18	98.26	0.00	0.17
Pied Cuckoo	0.15	0.18	98.44	0.00	0.17
Jungle Owlet	0.14	0.17	98.61	0.18	0.00
Streak-throated Woodpecker	0.14	0.17	98.79	0.00	0.17
Chestnut-bellied Nuthatch	0.14	0.17	98.96	0.00	0.17
Plum-headed Parakeet	0.14	0.17	99.13	0.00	0.17

Changeable Hawk-Eagle	0.09	0.12	99.25	0.04	0.08
White-eyed Buzzard	0.09	0.11	99.35	0.00	0.08
Bay-backed Shrike	0.08	0.09	99.45	0.00	0.08
Himalayan Griffon	0.07	0.09	99.54	0.00	0.08
Crested Serpent-Eagle	0.07	0.08	99.62	0.11	0.00
Tawny-bellied Babbler	0.06	0.08	99.70	0.00	0.08
White-throated Kingfisher	0.06	0.07	99.77	0.07	0.00
Large-billed Crow	0.05	0.07	99.84	0.07	0.00
White-bellied Drongo	0.05	0.06	99.90	0.07	0.00
Grey-hooded Warbler	0.03	0.04	99.93	0.04	0.00
Drongo Cuckoo	0.03	0.04	99.97	0.04	0.00
Common Cuckoo	0.03	0.03	100.00	0.04	0.00

Plantation and Riverine habitat					
Taxon	**Average dissimilarity**	**Contribution%**	**Cumulative %**	**Mean of bird abundance in Plantation**	**Mean of bird abundance in Riverine**
Jungle Babbler	8.84	9.38	9.38	8.50	0.00
Black-hooded Oriole	5.84	6.20	15.57	6.11	0.20
Indian Paradise-Flycatcher	5.36	5.68	21.26	5.57	0.00
River Lapwing	5.11	5.42	26.67	0.00	4.64
Common Myna	4.89	5.19	31.86	5.36	0.92
Rose-ringed Parakeet	4.68	4.97	36.82	4.50	0.00
Green Bee-eater	4.41	4.68	41.50	0.00	4.20
Little Cormorant	3.82	4.06	45.56	0.00	3.84
Little Egret	3.78	4.00	49.56	0.00	3.68
Ruddy Shelduck	3.51	3.72	53.29	0.00	3.12
Red-vented Bulbul	3.46	3.67	56.96	3.32	0.80
Oriental Magpie-Robin	2.79	2.96	59.92	3.04	0.28
Indian Pitta	2.78	2.95	62.87	2.64	0.00
Spotted Dove	2.69	2.85	65.72	2.82	0.72
House Crow	2.43	2.58	68.30	0.00	2.32
Purple Sunbird	2.33	2.48	70.77	2.11	1.60
Red-wattled Lapwing	2.06	2.19	72.96	0.00	1.92
River Tern	2.06	2.18	75.14	0.00	1.92
Black Drongo	1.83	1.94	77.08	1.50	0.68

Cattle Egret	1.78	1.89	78.97	1.86	0.24
Indian Grey Hornbill	1.18	1.25	80.22	1.04	0.20
Small Pratincole	1.12	1.19	81.40	0.00	1.16
Brown-headed Barbet	0.97	1.03	82.43	0.96	0.00
Indian Spot-billed Duck	0.94	0.99	83.42	0.00	0.88
Indian Roller	0.89	0.95	84.37	0.39	0.64
Oriental White-eye	0.88	0.93	85.30	0.82	0.00
Common Tailorbird	0.82	0.87	86.17	0.29	0.64
Large-billed Crow	0.80	0.84	87.01	0.07	0.76
Rufous Treepie	0.79	0.84	87.85	0.82	0.00
Red Junglefowl	0.69	0.74	88.58	0.79	0.00
Common Hawk-Cuckoo	0.69	0.73	89.31	0.71	0.00
Pied Kingfisher	0.68	0.72	90.04	0.00	0.68
Ashy Prinia	0.67	0.71	90.75	0.00	0.56
Indian Cuckoo	0.53	0.56	91.31	0.57	0.00
Asian Koel	0.51	0.54	91.85	0.36	0.20
Eurasian Collared-Dove	0.48	0.51	92.37	0.00	0.52
Red-whiskered Bulbul	0.41	0.43	92.80	0.50	0.00
White-browed Wagtail	0.37	0.39	93.18	0.00	0.32
Chestnut-shouldered Petronia	0.36	0.38	93.57	0.29	0.12
Little-ringed Plover	0.34	0.36	93.92	0.00	0.28
White-throated Kingfisher	0.32	0.34	94.26	0.07	0.24
White-bellied Drongo	0.32	0.34	94.60	0.07	0.24
Shikra	0.31	0.33	94.92	0.29	0.00
Plain Prinia	0.28	0.30	95.22	0.14	0.16
Sarus Crane	0.28	0.30	95.52	0.00	0.24
Gray Wagtail	0.27	0.29	95.81	0.00	0.24
Common Stonechat	0.26	0.28	96.09	0.00	0.24
Intermediate Egret	0.25	0.26	96.35	0.00	0.24
Black Francolin	0.23	0.24	96.59	0.00	0.20
Great Cormorant	0.22	0.24	96.83	0.00	0.20
Black-chinned Babbler	0.21	0.22	97.05	0.25	0.00
Little Tern	0.19	0.20	97.25	0.00	0.16
Grey Heron	0.19	0.20	97.45	0.00	0.16
Jungle Owlet	0.17	0.18	97.63	0.18	0.00
Common Iora	0.16	0.17	97.80	0.18	0.00
Red-naped Ibis	0.15	0.16	97.96	0.00	0.16
Black Kite	0.15	0.16	98.12	0.00	0.12
Indian Peafowl	0.15	0.16	98.28	0.18	0.00
Ashy-crowned Sparrow-Lark	0.15	0.16	98.43	0.00	0.12

Coppersmith Barbet	0.15	0.16	98.59	0.18	0.00
Blyth’s Reed Warbler	0.15	0.15	98.74	0.00	0.16
Oriental Skylark	0.13	0.14	98.88	0.00	0.12
Lesser Goldenback	0.11	0.12	99.00	0.14	0.00
Common Kingfisher	0.11	0.12	99.12	0.00	0.12
Indian Robin	0.11	0.12	99.24	0.00	0.08
Grey Francolin	0.11	0.12	99.35	0.00	0.08
Paddyfield Pipit	0.10	0.11	99.46	0.00	0.08
Grey-breasted Prinia	0.08	0.08	99.54	0.07	0.00
Crested Serpent-Eagle	0.08	0.08	99.62	0.11	0.00
Crested Lark	0.05	0.06	99.68	0.00	0.04
White Wagtail	0.05	0.05	99.73	0.00	0.04
Pond Heron	0.05	0.05	99.78	0.00	0.04
Grey-bellied Cuckoo	0.05	0.05	99.83	0.00	0.04
Grey-hooded Warbler	0.03	0.04	99.86	0.04	0.00
Changeable Hawk-Eagle	0.03	0.04	99.90	0.04	0.00
Drongo Cuckoo	0.03	0.04	99.93	0.04	0.00
Small Minivet	0.03	0.04	99.97	0.04	0.00
Common Cuckoo	0.03	0.03	100.00	0.04	0.00

Plantation and Grassland					
Taxon	**Average dissimilarity**	**Contribution%**	**Cumulative %**	**Mean of bird abundance in Plantation**	**Mean of bird abundance in Grassland**
Jungle Babbler	9.31	9.69	9.69	8.50	0.00
Paddyfield Pipit	6.85	7.12	16.81	0.00	6.00
Red-wattled Lapwing	6.68	6.95	23.76	0.00	5.86
Black-hooded Oriole	6.28	6.54	30.29	6.11	0.00
Indian Paradise-Flycatcher	5.61	5.84	36.13	5.57	0.00
Common Myna	5.25	5.46	41.59	5.36	1.29
Rose-ringed Parakeet	4.94	5.13	46.73	4.50	0.05
Red-vented Bulbul	3.82	3.97	50.70	3.32	1.48
Barn Swallow	3.76	3.91	54.61	0.00	4.62
Common Stonechat	3.30	3.44	58.04	0.00	2.90
Oriental Magpie-Robin	3.01	3.13	61.18	3.04	0.14

Indian Pitta	2.93	3.05	64.22	2.64	0.00
Spotted Dove	2.69	2.80	67.02	2.82	0.14
Pied Bushchat	2.33	2.43	69.45	0.00	2.00
Purple Sunbird	2.28	2.37	71.82	2.11	0.10
Green Bee-eater	2.01	2.09	73.90	0.00	1.71
Cattle Egret	1.95	2.03	75.94	1.86	0.33
Black Drongo	1.79	1.86	77.80	1.50	0.29
Striated Grassbird	1.41	1.47	79.27	0.00	1.33
Ashy Prinia	1.23	1.28	80.54	0.00	1.10
Oriental Skylark	1.18	1.23	81.77	0.00	1.05
Indian Grey Hornbill	1.15	1.20	82.97	1.04	0.00
Brown-headed Barbet	1.02	1.06	84.02	0.96	0.00
Yellow-bellied Prinia	1.00	1.04	85.06	0.00	0.81
Yellow-wattled Lapwing	0.94	0.98	86.05	0.00	0.76
Oriental White-eye	0.93	0.96	87.01	0.82	0.00
Plain Prinia	0.90	0.93	87.94	0.14	0.76
Rufous Treepie	0.82	0.86	88.80	0.82	0.00
Common Hawk-Cuckoo	0.72	0.75	89.55	0.71	0.00
Red Junglefowl	0.72	0.75	90.30	0.79	0.00
Red-whiskered Bulbul	0.62	0.64	90.94	0.50	0.24
Baya Weaver	0.59	0.61	91.55	0.00	0.52
Indian Pied Starling	0.58	0.60	92.15	0.00	0.57
Indian Cuckoo	0.55	0.57	92.72	0.57	0.00
House Crow	0.48	0.50	93.22	0.00	0.48
Zitting Cisticola	0.42	0.43	93.66	0.00	0.33
Indian Roller	0.39	0.41	94.07	0.39	0.05
Asian Koel	0.39	0.41	94.47	0.36	0.00
Grey Bushchat	0.35	0.36	94.84	0.00	0.29
Laughing Dove	0.35	0.36	95.20	0.00	0.29
Indian Peafowl	0.34	0.35	95.54	0.18	0.14
Shikra	0.32	0.34	95.88	0.29	0.00
White-throated Kingfisher	0.32	0.33	96.21	0.07	0.24
Common Tailorbird	0.31	0.32	96.53	0.29	0.00
River Lapwing	0.30	0.31	96.85	0.00	0.29
Striated Babbler	0.29	0.30	97.15	0.00	0.24
Chestnut-shouldered Petronia	0.27	0.28	97.43	0.29	0.00
Bristled Grassbird	0.24	0.25	97.68	0.00	0.19
Black-chinned Babbler	0.22	0.23	97.91	0.25	0.00
Large-billed Crow	0.20	0.21	98.11	0.07	0.19
Jungle Owlet	0.17	0.18	98.29	0.18	0.00
Black-breasted Weaver	0.17	0.18	98.47	0.00	0.14

Common Iora	0.17	0.17	98.65	0.18	0.00
Common Kingfisher	0.16	0.17	98.82	0.00	0.14
Black Francolin	0.16	0.17	98.99	0.00	0.14
Coppersmith Barbet	0.15	0.16	99.14	0.18	0.00
White-tailed Stonechat	0.14	0.15	99.29	0.00	0.14
Lesser Goldenback	0.12	0.12	99.42	0.14	0.00
Grey-bellied Cuckoo	0.09	0.09	99.51	0.00	0.10
Grey-breasted Prinia	0.08	0.09	99.60	0.07	0.00
Crested Serpent-Eagle	0.08	0.08	99.68	0.11	0.00
White-bellied Drongo	0.06	0.06	99.74	0.07	0.00
Grey Francolin	0.05	0.05	99.79	0.00	0.05
Grey-hooded Warbler	0.04	0.04	99.82	0.04	0.00
Changeable Hawk-Eagle	0.04	0.04	99.86	0.04	0.00
Drongo Cuckoo	0.04	0.04	99.90	0.04	0.00
Small Minivet	0.04	0.04	99.93	0.04	0.00
Short-toed Snake-Eagle	0.03	0.04	99.97	0.00	0.05
Common Cuckoo	0.03	0.03	100.00	0.04	0.00

Mixed deciduous forest and Scrub forest					
Taxon	**Average dissimilarity**	**Contribution%**	**Cumulative %**	**Mean of bird abundance in Mixed deciduous forest**	**Mean of bird abundance in Scrub forest**
Baya Weaver	13.3 9	19.98	19.98	22.90	2.42
Rose-ringed Parakeet	5.88	8.77	28.76	9.60	0.25
Jungle Babbler	4.33	6.46	35.22	6.73	2.92
Green Bee-eater	3.94	5.87	41.09	1.60	7.00
Spotted Dove	3.31	4.93	46.03	4.87	7.67
Purple Sunbird	3.27	4.88	50.91	3.87	7.92
Red-vented Bulbul	3.10	4.63	55.53	7.20	6.25
Red Junglefowl	2.46	3.66	59.20	5.13	1.67
Chestnut-shouldered Petronia	1.94	2.90	62.10	2.93	0.92
Common Tailorbird	1.69	2.52	64.62	2.47	3.00

Indian Peafowl	1.57	2.34	66.95	2.40	1.67
Common Iora	1.49	2.22	69.18	1.93	2.08
Oriental Magpie-Robin	1.43	2.13	71.31	1.20	1.75
Barn Swallow	1.42	2.12	73.43	1.93	0.00
Indian Robin	1.38	2.06	75.48	0.00	2.08
Indian Pitta	1.24	1.86	77.34	2.13	0.67
Oriental White-eye	1.22	1.83	79.17	1.53	1.33
Black-chinned Babbler	1.16	1.73	80.90	2.00	0.83
Blue-tailed Bee-eater	0.99	1.47	82.37	1.40	0.33
Ashy Prinia	0.91	1.36	83.74	0.80	1.00
Indian Paradise-Flycatcher	0.90	1.35	85.08	1.33	0.00
Red-whiskered Bulbul	0.82	1.23	86.31	0.80	0.67
Grey-breasted Prinia	0.70	1.04	87.35	0.80	0.58
Rufous Treepie	0.69	1.04	88.39	1.07	0.00
Brahminy Starling	0.69	1.03	89.42	0.33	0.75
Eurasian Collared-Dove	0.58	0.86	90.28	0.67	0.42
Indian Roller	0.56	0.83	91.11	0.67	0.33
Laughing Dove	0.51	0.76	91.87	0.00	0.75
Plain Prinia	0.47	0.70	92.57	0.00	0.67
Asian Koel	0.44	0.65	93.22	0.47	0.33
Black-hooded Oriole	0.37	0.55	93.77	0.53	0.00
Black Drongo	0.34	0.50	94.27	0.00	0.50
Jungle Myna	0.29	0.44	94.71	0.53	0.00
Indian Grey Hornbill	0.29	0.44	95.15	0.53	0.00
Plum-headed Parakeet	0.29	0.43	95.57	0.33	0.17
Coppersmith Barbet	0.28	0.42	95.99	0.13	0.33
Small Minivet	0.27	0.41	96.40	0.20	0.25
Common Myna	0.25	0.37	96.77	0.00	0.42
Indian Cuckoo	0.24	0.36	97.13	0.20	0.17
Common Hawk-Cuckoo	0.23	0.35	97.48	0.40	0.00
Lesser Goldenback	0.16	0.24	97.72	0.00	0.25
Large-billed Crow	0.14	0.20	97.92	0.20	0.00
Long-tailed Shrike	0.12	0.19	98.11	0.00	0.17
Shikra	0.12	0.18	98.29	0.00	0.17
Pied Bushchat	0.12	0.18	98.47	0.00	0.17
Lesser Whitethroat	0.11	0.17	98.64	0.00	0.17
Pale-billed Flowerpecker	0.11	0.16	98.81	0.00	0.17
Pied Cuckoo	0.11	0.16	98.97	0.00	0.17

Streak-throated Woodpecker	0.11	0.16	99.13	0.00	0.17
Chestnut-bellied Nuthatch	0.11	0.16	99.29	0.00	0.17
Crested Serpent-Eagle	0.10	0.15	99.44	0.13	0.00
White-eyed Buzzard	0.06	0.09	99.53	0.00	0.08
Bay-backed Shrike	0.06	0.08	99.61	0.00	0.08
Himalayan Griffon	0.05	0.08	99.69	0.00	0.08
Changeable Hawk-Eagle	0.05	0.08	99.77	0.00	0.08
Oriental Honey-buzzard	0.05	0.08	99.85	0.07	0.00
Tawny-bellied Babbler	0.05	0.07	99.93	0.00	0.08
Brown-headed Barbet	0.05	0.07	100.00	0.00	0.08

Mixed deciduous forest and Riverine habitat					
Taxon	**Average dissimilarity**	**Contribution%**	**Cumulative %**	**Mean of bird abundance in Mixed deciduous forest**	**Mean of bird abundance in Riverine**
Baya Weaver	17.09	18.33	18.33	22.90	0.00
Rose-ringed Parakeet	6.78	7.28	25.61	9.60	0.00
Jungle Babbler	5.01	5.37	30.98	6.73	0.00
Red-vented Bulbul	5.00	5.37	36.34	7.20	0.80
Red Junglefowl	3.77	4.05	40.39	5.13	0.00
Spotted Dove	3.61	3.87	44.26	4.87	0.72
River Lapwing	3.55	3.80	48.06	0.00	4.64
Little Cormorant	2.74	2.94	51.00	0.00	3.84
Green Bee-eater	2.69	2.88	53.88	1.60	4.20
Little Egret	2.68	2.88	56.75	0.00	3.68
Purple Sunbird	2.49	2.67	59.42	3.87	1.60
Ruddy Shelduck	2.43	2.61	62.03	0.00	3.12
Chestnut-shouldered Petronia	2.18	2.33	64.36	2.93	0.12
Indian Peafowl	1.83	1.96	66.32	2.40	0.00
House Crow	1.72	1.84	68.17	0.00	2.32
Common Tailorbird	1.71	1.83	70.00	2.47	0.64
Indian Pitta	1.66	1.78	71.78	2.13	0.00
Barn Swallow	1.65	1.77	73.54	1.93	0.00
Black-chinned Babbler	1.54	1.66	75.20	2.00	0.00
Common Iora	1.47	1.57	76.77	1.93	0.00
Red-wattled Lapwing	1.44	1.55	78.32	0.00	1.92
River Tern	1.44	1.55	79.86	0.00	1.92
Oriental White-eye	1.15	1.23	81.09	1.53	0.00
Blue-tailed Bee-eater	1.06	1.13	82.23	1.40	0.00
Indian Paradise-Flycatcher	1.04	1.11	83.34	1.33	0.00
Oriental Magpie-Robin	0.91	0.97	84.31	1.20	0.28
Ashy Prinia	0.90	0.97	85.28	0.80	0.56
Small Pratincole	0.81	0.87	86.15	0.00	1.16
Indian Roller	0.80	0.86	87.01	0.67	0.64
Rufous Treepie	0.79	0.85	87.86	1.07	0.00
Eurasian Collared-Dove	0.68	0.72	88.59	0.67	0.52

Indian Spot-billed Duck	0.66	0.71	89.29	0.00	0.88
Common Myna	0.65	0.69	89.99	0.00	0.92
Grey-breasted Prinia	0.64	0.68	90.67	0.80	0.00
Large-billed Crow	0.63	0.68	91.35	0.20	0.76
Red-whiskered Bulbul	0.59	0.63	91.98	0.80	0.00
Black-hooded Oriole	0.52	0.56	92.54	0.53	0.20
Black Drongo	0.50	0.54	93.08	0.00	0.68
Pied Kingfisher	0.49	0.53	93.60	0.00	0.68
Asian Koel	0.45	0.48	94.09	0.47	0.20
Indian Grey Hornbill	0.44	0.48	94.56	0.53	0.20
Jungle Myna	0.33	0.35	94.91	0.53	0.00
Common Hawk-Cuckoo	0.26	0.28	95.20	0.40	0.00
White-browed Wagtail	0.25	0.27	95.47	0.00	0.32
Brahminy Starling	0.24	0.26	95.73	0.33	0.00
Plum-headed Parakeet	0.23	0.25	95.98	0.33	0.00
Little-ringed Plover	0.23	0.25	96.22	0.00	0.28
Cattle Egret	0.20	0.22	96.44	0.00	0.24
Sarus Crane	0.19	0.20	96.65	0.00	0.24
White-bellied Drongo	0.19	0.20	96.85	0.00	0.24
Gray Wagtail	0.19	0.20	97.05	0.00	0.24
White-throated Kingfisher	0.19	0.20	97.25	0.00	0.24
Common Stonechat	0.18	0.20	97.45	0.00	0.24
Intermediate Egret	0.18	0.19	97.64	0.00	0.24
Indian Cuckoo	0.17	0.18	97.82	0.20	0.00
Black Francolin	0.16	0.17	97.99	0.00	0.20
Great Cormorant	0.15	0.17	98.15	0.00	0.20
Small Minivet	0.14	0.15	98.30	0.20	0.00
Little Tern	0.13	0.14	98.44	0.00	0.16
Grey Heron	0.13	0.14	98.58	0.00	0.16
Plain Prinia	0.12	0.13	98.71	0.00	0.16
Crested Serpent-Eagle	0.12	0.13	98.84	0.13	0.00
Red-naped Ibis	0.11	0.12	98.96	0.00	0.16
Blyth's Reed Warbler	0.11	0.12	99.07	0.00	0.16
Black Kite	0.10	0.11	99.18	0.00	0.12
Ashy-crowned Sparrow-Lark	0.10	0.11	99.29	0.00	0.12
Coppersmith Barbet	0.10	0.10	99.39	0.13	0.00
Oriental Skylark	0.09	0.10	99.49	0.00	0.12
Common Kingfisher	0.08	0.09	99.57	0.00	0.12
Indian Robin	0.07	0.08	99.65	0.00	0.08

Grey Francolin	0.07	0.08	99.72	0.00	0.08
Paddyfield Pipit	0.07	0.07	99.80	0.00	0.08
Oriental Honey-buzzard	0.06	0.07	99.86	0.07	0.00
Crested Lark	0.03	0.04	99.90	0.00	0.04
White Wagtail	0.03	0.03	99.93	0.00	0.04
Pond Heron	0.03	0.03	99.97	0.00	0.04
Grey-bellied Cuckoo	0.03	0.03	100.00	0.00	0.04

Mixed deciduous forest and Grassland					
Taxon	**Average dissimilarity**	**Contribution%**	**Cumulative %**	**Mean abundance in Mixed deciduous forest**	**Mean of bird abundance in Grassland**
Baya Weaver	17.27	18.15	18.15	22.90	0.52
Rose-ringed Parakeet	6.97	7.33	25.48	9.60	0.05
Jungle Babbler	5.18	5.44	30.92	6.73	0.00
Red-vented Bulbul	4.82	5.06	35.98	7.20	1.48
Paddyfield Pipit	4.69	4.93	40.91	0.00	6.00
Red-wattled Lapwing	4.59	4.83	45.74	0.00	5.86
Barn Swallow	4.29	4.51	50.25	1.93	4.62
Spotted Dove	3.91	4.11	54.36	4.87	0.14
Red Junglefowl	3.90	4.10	58.46	5.13	0.00
Purple Sunbird	3.02	3.17	61.63	3.87	0.10
Common Stonechat	2.27	2.38	64.01	0.00	2.90
Chestnut-shouldered Petronia	2.25	2.37	66.38	2.93	0.00
Common Tailorbird	1.98	2.08	68.46	2.47	0.00
Indian Peafowl	1.85	1.95	70.41	2.40	0.14
Green Bee-eater	1.77	1.86	72.27	1.60	1.71
Indian Pitta	1.71	1.80	74.07	2.13	0.00
Black-chinned Babbler	1.60	1.68	75.75	2.00	0.00
Pied Bushchat	1.59	1.67	77.42	0.00	2.00
Common Iora	1.52	1.59	79.01	1.93	0.00
Ashy Prinia	1.23	1.30	80.31	0.80	1.10
Oriental White-eye	1.19	1.25	81.55	1.53	0.00
Blue-tailed Bee-eater	1.09	1.15	82.70	1.40	0.00
Indian Paradise-Flycatcher	1.07	1.13	83.83	1.33	0.00
Common Myna	1.05	1.10	84.93	0.00	1.29
Striated Grassbird	0.99	1.04	85.97	0.00	1.33

Oriental Magpie-Robin	0.94	0.99	86.97	1.20	0.14
Rufous Treepie	0.82	0.86	87.83	1.07	0.00
Oriental Skylark	0.81	0.85	88.68	0.00	1.05
Red-whiskered Bulbul	0.73	0.76	89.44	0.80	0.24
Yellow-bellied Prinia	0.67	0.70	90.14	0.00	0.81
Grey-breasted Prinia	0.66	0.69	90.84	0.80	0.00
Yellow-wattled Lapwing	0.63	0.66	91.50	0.00	0.76
Plain Prinia	0.58	0.61	92.11	0.00	0.76
Indian Roller	0.56	0.59	92.70	0.67	0.05
Eurasian Collared-Dove	0.48	0.51	93.21	0.67	0.00
Black-hooded Oriole	0.44	0.46	93.68	0.53	0.00
Indian Pied Starling	0.41	0.44	94.11	0.00	0.57
Asian Koel	0.37	0.39	94.50	0.47	0.00
House Crow	0.35	0.36	94.86	0.00	0.48
Jungle Myna	0.33	0.35	95.22	0.53	0.00
Indian Grey Hornbill	0.33	0.35	95.57	0.53	0.00
Cattle Egret	0.29	0.30	95.87	0.00	0.33
Zitting Cisticola	0.28	0.29	96.16	0.00	0.33
Common Hawk-Cuckoo	0.27	0.28	96.44	0.40	0.00
Large-billed Crow	0.26	0.27	96.72	0.20	0.19
Brahminy Starling	0.25	0.26	96.98	0.33	0.00
Plum-headed Parakeet	0.24	0.25	97.23	0.33	0.00
Black Drongo	0.24	0.25	97.48	0.00	0.29
Grey Bushchat	0.24	0.25	97.73	0.00	0.29
Laughing Dove	0.23	0.24	97.97	0.00	0.29
River Lapwing	0.21	0.22	98.20	0.00	0.29
Striated Babbler	0.19	0.20	98.40	0.00	0.24
White-throated Kingfisher	0.19	0.20	98.60	0.00	0.24
Indian Cuckoo	0.18	0.18	98.78	0.20	0.00
Bristled Grassbird	0.16	0.17	98.95	0.00	0.19
Small Minivet	0.15	0.15	99.10	0.20	0.00
Crested Serpent-Eagle	0.12	0.13	99.23	0.13	0.00
Black-breasted Weaver	0.12	0.12	99.35	0.00	0.14
Common Kingfisher	0.11	0.12	99.47	0.00	0.14
Black Francolin	0.11	0.12	99.59	0.00	0.14
White-tailed Stonechat	0.10	0.11	99.70	0.00	0.14
Coppersmith Barbet	0.10	0.10	99.80	0.13	0.00
Grey-bellied Cuckoo	0.07	0.07	99.87	0.00	0.10
Oriental Honey-buzzard	0.06	0.07	99.94	0.07	0.00
Grey Francolin	0.03	0.03	99.97	0.00	0.05
Short-toed Snake-Eagle	0.03	0.03	100.00	0.00	0.05

Scrub forest and Riverine habitat					
Taxon	**Average dissimilarity**	**Contribution%**	**Cumulative %**	**Mean of bird abundance in Scrub forest**	**Mean of bird abundance in Riverine**
Spotted Dove	6.74	7.81	7.81	7.67	0.72
Purple Sunbird	6.58	7.63	15.45	7.92	1.60
Red-vented Bulbul	5.86	6.79	22.24	6.25	0.80
Green Bee-eater	5.15	5.97	28.20	7.00	4.20
River Lapwing	4.66	5.41	33.61	0.00	4.64
Little Cormorant	3.53	4.10	37.70	0.00	3.84
Little Egret	3.48	4.03	41.74	0.00	3.68
Ruddy Shelduck	3.21	3.72	45.45	0.00	3.12
Common Tailorbird	2.73	3.16	48.62	3.00	0.64
Jungle Babbler	2.70	3.13	51.75	2.92	0.00
Baya Weaver	2.36	2.73	54.48	2.42	0.00
House Crow	2.24	2.59	57.07	0.00	2.32
Indian Robin	2.05	2.38	59.45	2.08	0.08
Common Iora	1.94	2.25	61.70	2.08	0.00
Red-wattled Lapwing	1.89	2.19	63.89	0.00	1.92
River Tern	1.89	2.19	66.08	0.00	1.92
Oriental Magpie-Robin	1.81	2.10	68.17	1.75	0.28
Red Junglefowl	1.64	1.90	70.07	1.67	0.00
Indian Peafowl	1.56	1.81	71.88	1.67	0.00
Oriental White-eye	1.34	1.55	73.43	1.33	0.00
Ashy Prinia	1.29	1.50	74.93	1.00	0.56
Common Myna	1.07	1.24	76.17	0.42	0.92
Small Pratincole	1.04	1.21	77.37	0.00	1.16
Black Drongo	0.99	1.15	78.52	0.50	0.68
Chestnut-shouldered Petronia	0.95	1.10	79.62	0.92	0.12
Brahminy Starling	0.89	1.03	80.65	0.75	0.00
Indian Spot-billed Duck	0.86	1.00	81.65	0.00	0.88
Indian Roller	0.86	1.00	82.64	0.33	0.64
Black-chinned Babbler	0.82	0.96	83.60	0.83	0.00
Plain Prinia	0.78	0.91	84.51	0.67	0.16
Eurasian Collared-Dove	0.77	0.90	85.41	0.42	0.52

Laughing Dove	0.77	0.89	86.30	0.75	0.00
Large-billed Crow	0.70	0.82	87.11	0.00	0.76
Red-whiskered Bulbul	0.69	0.80	87.91	0.67	0.00
Pied Kingfisher	0.63	0.73	88.64	0.00	0.68
Indian Pitta	0.61	0.70	89.35	0.67	0.00
Grey-breasted Prinia	0.52	0.61	89.95	0.58	0.00
Asian Koel	0.44	0.51	90.46	0.33	0.20
Coppersmith Barbet	0.33	0.39	90.85	0.33	0.00
White-browed Wagtail	0.33	0.39	91.23	0.00	0.32
Blue-tailed Bee-eater	0.31	0.36	91.60	0.33	0.00
Little-ringed Plover	0.31	0.35	91.95	0.00	0.28
Cattle Egret	0.28	0.32	92.27	0.00	0.24
Small Minivet	0.26	0.30	92.57	0.25	0.00
Sarus Crane	0.25	0.29	92.87	0.00	0.24
White-bellied Drongo	0.25	0.29	93.16	0.00	0.24
Gray Wagtail	0.25	0.29	93.45	0.00	0.24
White-throated Kingfisher	0.25	0.29	93.74	0.00	0.24
Common Stonechat	0.24	0.28	94.01	0.00	0.24
Lesser Goldenback	0.24	0.27	94.29	0.25	0.00
Intermediate Egret	0.23	0.26	94.55	0.00	0.24
Rose-ringed Parakeet	0.21	0.25	94.80	0.25	0.00
Black Francolin	0.21	0.24	95.04	0.00	0.20
Great Cormorant	0.20	0.24	95.28	0.00	0.20
Long-tailed Shrike	0.20	0.23	95.51	0.17	0.00
Indian Grey Hornbill	0.20	0.23	95.74	0.00	0.20
Indian Cuckoo	0.20	0.23	95.96	0.17	0.00
Shikra	0.20	0.23	96.19	0.17	0.00
Pied Bushchat	0.20	0.23	96.42	0.17	0.00
Little Tern	0.17	0.20	96.62	0.00	0.16
Lesser Whitethroat	0.17	0.20	96.82	0.17	0.00
Black-hooded Oriole	0.17	0.20	97.01	0.00	0.20
Grey Heron	0.17	0.20	97.21	0.00	0.16
Pale-billed Flowerpecker	0.16	0.19	97.40	0.17	0.00
Pied Cuckoo	0.16	0.19	97.59	0.17	0.00
Streak-throated Woodpecker	0.16	0.18	97.77	0.17	0.00
Chestnut-bellied Nuthatch	0.16	0.18	97.95	0.17	0.00
Plum-headed Parakeet	0.16	0.18	98.13	0.17	0.00
Red-naped Ibis	0.14	0.17	98.29	0.00	0.16
Blyth’s Reed Warbler	0.14	0.16	98.45	0.00	0.16

Black Kite	0.14	0.16	98.61	0.00	0.12
Ashy-crowned Sparrow-Lark	0.13	0.15	98.76	0.00	0.12
Oriental Skylark	0.12	0.14	98.90	0.00	0.12
Common Kingfisher	0.10	0.12	99.02	0.00	0.12
White-eyed Buzzard	0.10	0.11	99.13	0.08	0.00
Grey Francolin	0.10	0.11	99.25	0.00	0.08
Paddyfield Pipit	0.09	0.10	99.35	0.00	0.08
Bay-backed Shrike	0.09	0.10	99.45	0.08	0.00
Himalayan Griffon	0.08	0.09	99.54	0.08	0.00
Changeable Hawk-Eagle	0.08	0.09	99.64	0.08	0.00
Tawny-bellied Babbler	0.07	0.08	99.72	0.08	0.00
Brown-headed Barbet	0.07	0.08	99.80	0.08	0.00
Crested Lark	0.05	0.05	99.85	0.00	0.04
White Wagtail	0.04	0.05	99.90	0.00	0.04
Pond Heron	0.04	0.05	99.95	0.00	0.04
Grey-bellied Cuckoo	0.04	0.05	100.00	0.00	0.04

Scrub forest and Grassland					
Taxon	**Average dissimilarity**	**Contribution%**	**Cumulative %**	**Mean of bird abundance in Scrub forest**	**Mean of bird abundance in Grassland**
Purple Sunbird	8.32	9.04	9.04	7.92	0.10
Spotted Dove	7.58	8.24	17.28	7.67	0.14
Green Bee-eater	6.31	6.86	24.14	7.00	1.71
Paddyfield Pipit	6.22	6.75	30.89	0.00	6.00
Red-wattled Lapwing	6.08	6.60	37.50	0.00	5.86
Red-vented Bulbul	5.76	6.26	43.76	6.25	1.48
Barn Swallow	3.54	3.85	47.60	0.00	4.62
Common Tailorbird	3.02	3.28	50.88	3.00	0.00
Common Stonechat	3.00	3.26	54.14	0.00	2.90
Jungle Babbler	2.81	3.06	57.20	2.92	0.00
Baya Weaver	2.67	2.90	60.10	2.42	0.52
Indian Robin	2.16	2.35	62.45	2.08	0.00
Pied Bushchat	2.05	2.23	64.68	0.17	2.00
Common Iora	2.02	2.20	66.88	2.08	0.00
Oriental Magpie-Robin	1.85	2.01	68.89	1.75	0.14
Red Junglefowl	1.71	1.86	70.75	1.67	0.00

Ashy Prinia	1.69	1.83	72.58	1.00	1.10
Indian Peafowl	1.67	1.82	74.40	1.67	0.14
Common Myna	1.59	1.73	76.12	0.42	1.29
Oriental White-eye	1.40	1.52	77.65	1.33	0.00
Striated Grassbird	1.30	1.41	79.06	0.00	1.33
Plain Prinia	1.13	1.23	80.29	0.67	0.76
Oriental Skylark	1.07	1.16	81.45	0.00	1.05
Laughing Dove	1.01	1.10	82.54	0.75	0.29
Brahminy Starling	0.94	1.02	83.56	0.75	0.00
Chestnut-shouldered Petronia	0.93	1.01	84.57	0.92	0.00
Yellow-bellied Prinia	0.90	0.98	85.55	0.00	0.81
Red-whiskered Bulbul	0.87	0.95	86.50	0.67	0.24
Black-chinned Babbler	0.86	0.94	87.44	0.83	0.00
Yellow-wattled Lapwing	0.85	0.92	88.36	0.00	0.76
Black Drongo	0.77	0.83	89.20	0.50	0.29
Indian Pitta	0.63	0.69	89.88	0.67	0.00
Grey-breasted Prinia	0.54	0.59	90.47	0.58	0.00
Indian Pied Starling	0.53	0.58	91.05	0.00	0.57
Eurasian Collared-Dove	0.48	0.52	91.58	0.42	0.00
Indian Roller	0.45	0.49	92.06	0.33	0.05
House Crow	0.45	0.48	92.55	0.00	0.48
Cattle Egret	0.39	0.42	92.97	0.00	0.33
Zitting Cisticola	0.37	0.41	93.38	0.00	0.33
Coppersmith Barbet	0.35	0.38	93.76	0.33	0.00
Blue-tailed Bee-eater	0.32	0.35	94.11	0.33	0.00
Grey Bushchat	0.32	0.34	94.45	0.00	0.29
Asian Koel	0.31	0.34	94.80	0.33	0.00
River Lapwing	0.28	0.30	95.10	0.00	0.29
Small Minivet	0.27	0.30	95.39	0.25	0.00
Striated Babbler	0.26	0.28	95.68	0.00	0.24
Rose-ringed Parakeet	0.26	0.28	95.96	0.25	0.05
White-throated Kingfisher	0.25	0.27	96.23	0.00	0.24
Lesser Goldenback	0.25	0.27	96.49	0.25	0.00
Bristled Grassbird	0.21	0.23	96.72	0.00	0.19
Long-tailed Shrike	0.21	0.23	96.95	0.17	0.00
Indian Cuckoo	0.21	0.23	97.18	0.17	0.00
Shikra	0.21	0.23	97.40	0.17	0.00
Lesser Whitethroat	0.18	0.20	97.60	0.17	0.00
Pied Cuckoo	0.17	0.19	97.78	0.17	0.00
Pale-billed Flowerpecker	0.17	0.19	97.97	0.17	0.00
Streak-throated Woodpecker	0.16	0.18	98.15	0.17	0.00
Chestnut-bellied Nuthatch	0.16	0.18	98.32	0.17	0.00

Plum-headed Parakeet	0.16	0.18	98.50	0.17	0.00
Black-breasted Weaver	0.16	0.17	98.67	0.00	0.14
Common Kingfisher	0.15	0.16	98.83	0.00	0.14
Black Francolin	0.15	0.16	98.99	0.00	0.14
White-tailed Stonechat	0.13	0.14	99.13	0.00	0.14
Large-billed Crow	0.13	0.14	99.28	0.00	0.19
White-eyed Buzzard	0.10	0.11	99.39	0.08	0.00
Bay-backed Shrike	0.09	0.10	99.49	0.08	0.00
Himalayan Griffon	0.09	0.09	99.58	0.08	0.00
Grey-bellied Cuckoo	0.08	0.09	99.67	0.00	0.10
Changeable Hawk-Eagle	0.08	0.09	99.76	0.08	0.00
Tawny-bellied Babbler	0.07	0.08	99.84	0.08	0.00
Brown-headed Barbet	0.07	0.08	99.92	0.08	0.00
Grey Francolin	0.04	0.05	99.96	0.00	0.05
Short-toed Snake-Eagle	0.03	0.04	100.00	0.00	0.05

Riverine habitat and Grassland					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Riverine**	**Mean of bird abundance in Grassland**
Paddyfield Pipit	7.70	8.58	8.58	0.08	6.00
Red-wattled Lapwing	6.38	7.10	15.68	1.92	5.86
River Lapwing	5.93	6.60	22.29	4.64	0.29
Green Bee-eater	4.75	5.30	27.58	4.20	1.71
Little Cormorant	4.54	5.06	32.64	3.84	0.00
Little Egret	4.50	5.02	37.66	3.68	0.00
Ruddy Shelduck	4.24	4.72	42.38	3.12	0.00
Barn Swallow	4.17	4.65	47.03	0.00	4.62
Common Stonechat	3.73	4.16	51.18	0.24	2.90
House Crow	3.21	3.58	54.76	2.32	0.48
Pied Bushchat	2.66	2.97	57.73	0.00	2.00
Red-vented Bulbul	2.57	2.87	60.59	0.80	1.48
River Tern	2.47	2.75	63.34	1.92	0.00
Common Myna	2.21	2.47	65.81	0.92	1.29
Purple Sunbird	2.04	2.28	68.09	1.60	0.10
Ashy Prinia	1.89	2.11	70.20	0.56	1.10
Striated Grassbird	1.59	1.78	71.97	0.00	1.33

Oriental Skylark	1.41	1.57	73.55	0.12	1.05
Small Pratincole	1.32	1.47	75.01	1.16	0.00
Yellow-bellied Prinia	1.15	1.28	76.29	0.00	0.81
Indian Spot-billed Duck	1.13	1.25	77.55	0.88	0.00
Black Drongo	1.12	1.25	78.80	0.68	0.29
Yellow-wattled Lapwing	1.08	1.20	80.00	0.00	0.76
Spotted Dove	1.07	1.19	81.20	0.72	0.14
Plain Prinia	1.05	1.17	82.37	0.16	0.76
Large-billed Crow	1.01	1.12	83.49	0.76	0.19
Indian Roller	0.84	0.94	84.43	0.64	0.05
Common Tailorbird	0.82	0.91	85.34	0.64	0.00
Pied Kingfisher	0.81	0.90	86.24	0.68	0.00
Cattle Egret	0.80	0.89	87.13	0.24	0.33
Baya Weaver	0.67	0.74	87.87	0.00	0.52
Indian Pied Starling	0.65	0.72	88.60	0.00	0.57
Eurasian Collared-Dove	0.57	0.63	89.23	0.52	0.00
White-throated Kingfisher	0.55	0.61	89.84	0.24	0.24
Oriental Magpie-Robin	0.52	0.58	90.43	0.28	0.14
Zitting Cisticola	0.48	0.54	90.96	0.00	0.33
White-browed Wagtail	0.44	0.49	91.45	0.32	0.00
Little-ringed Plover	0.41	0.46	91.91	0.28	0.00
Grey Bushchat	0.40	0.45	92.36	0.00	0.29
Black Francolin	0.40	0.45	92.81	0.20	0.14
Laughing Dove	0.40	0.44	93.25	0.00	0.29
Sarus Crane	0.34	0.38	93.63	0.24	0.00
White-bellied Drongo	0.34	0.37	94.00	0.24	0.00
Striated Babbler	0.33	0.37	94.37	0.00	0.24
Gray Wagtail	0.33	0.37	94.74	0.24	0.00
Common Kingfisher	0.30	0.33	95.07	0.12	0.14
Intermediate Egret	0.29	0.33	95.40	0.24	0.00
Bristled Grassbird	0.27	0.30	95.70	0.00	0.19
Great Cormorant	0.27	0.30	96.00	0.20	0.00
Indian Grey Hornbill	0.26	0.29	96.29	0.20	0.00
Red-whiskered Bulbul	0.25	0.28	96.57	0.00	0.24
Little Tern	0.23	0.26	96.83	0.16	0.00
Asian Koel	0.23	0.26	97.09	0.20	0.00
Indian Peafowl	0.23	0.26	97.34	0.00	0.14
Grey Heron	0.23	0.25	97.59	0.16	0.00
Black-hooded Oriole	0.21	0.24	97.83	0.20	0.00

Black-breasted Weaver	0.20	0.22	98.05	0.00	0.14
Black Kite	0.18	0.21	98.26	0.12	0.00
Grey Francolin	0.18	0.20	98.46	0.08	0.05
Ashy-crowned Sparrow-Lark	0.18	0.20	98.66	0.12	0.00
Red-naped Ibis	0.18	0.20	98.86	0.16	0.00
Blyth’s Reed Warbler	0.17	0.19	99.05	0.16	0.00
White-tailed Stonechat	0.16	0.18	99.23	0.00	0.14
Grey-bellied Cuckoo	0.15	0.17	99.40	0.04	0.10
Indian Robin	0.14	0.15	99.56	0.08	0.00
Chestnut-shouldered Petronia	0.13	0.15	99.70	0.12	0.00
Crested Lark	0.06	0.07	99.77	0.04	0.00
White Wagtail	0.06	0.06	99.84	0.04	0.00
Pond Heron	0.06	0.06	99.90	0.04	0.00
Rose-ringed Parakeet	0.05	0.06	99.96	0.00	0.05
Short-toed Snake-Eagle	0.04	0.04	100.00	0.00	0.05

Table 4.6. Results of SIMPER analysis during winter season in all the habitats

Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Plantation**	**Mean of bird abundance in Mixed deciduous forest**	**Mean of bird abundance in Scrub forest**	**Mean of bird abundance in Riverine**	**Mean of bird abundance in Grassland**
Red-vented Bulbul	8.07	8.69	8.69	4.75	13.90	27.60	1.92	3.95
Ruddy Shelduck	4.82	5.19	13.87	0.00	0.00	0.00	24.50	0.38
Jungle Babbler	3.49	3.76	17.63	6.25	4.07	4.67	0.00	0.00
Little Cormorant	3.48	3.75	21.38	0.00	0.00	0.00	9.12	0.00
Black Bulbul	3.05	3.29	24.66	8.68	0.00	0.00	0.00	0.00
Humes Warbler	3.00	3.23	27.89	4.86	3.47	2.83	2.28	0.05
Barn Swallow	2.86	3.09	30.98	0.11	9.53	0.00	5.92	0.95
Spangled Drongo	2.82	3.04	34.02	6.82	1.00	2.58	0.00	0.10
Rose-ringed Parakeet	2.65	2.86	36.88	6.39	2.20	0.17	0.60	0.00
Black-hooded Oriole	2.39	2.58	39.45	5.54	2.00	0.00	0.12	0.00
Paddyfield Pipit	2.27	2.45	41.90	0.00	0.00	0.00	1.64	4.57
Common Stonechat	2.25	2.42	44.32	0.00	0.00	0.00	0.48	5.48
River Lapwing	2.17	2.34	46.66	0.00	0.00	0.00	3.80	2.62
Oriental White-eye	2.16	2.32	48.98	0.46	6.27	5.75	0.00	0.00
Red-wattled Lapwing	2.12	2.29	51.27	0.29	0.00	0.00	0.00	6.24
Lesser Whitethroat	2.01	2.16	53.43	0.00	3.27	7.50	0.00	0.00
Red-whiskered Bulbul	1.85	2.00	55.42	0.00	5.20	5.42	0.00	0.24
Greenish Warbler	1.73	1.86	57.28	2.46	0.33	2.67	0.20	0.10

Rufous Treepie	1.70	1.83	59.11	2.07	2.27	1.67	1.12	0.00
Large-billed Crow	1.64	1.76	60.87	3.36	0.60	0.58	0.60	1.10
Himalayan Bulbul	1.51	1.63	62.50	2.32	1.27	5.58	0.00	0.19
Red-naped Ibis	1.48	1.59	64.09	4.46	0.00	0.00	0.00	2.52
Northern Pintail	1.39	1.50	65.59	0.00	0.00	0.00	5.12	0.00
Black Drongo	1.38	1.48	67.07	1.82	0.20	1.50	0.52	0.62
Plain Prinia	1.34	1.44	68.51	0.00	0.20	5.50	0.20	1.19
Purple Sunbird	1.31	1.41	69.93	0.11	2.67	4.50	0.00	0.00
Bar-headed Goose	1.22	1.31	71.24	0.00	0.00	0.00	4.00	0.00
Common Myna	1.21	1.30	72.54	3.25	0.00	0.00	0.08	0.14
Citrine Wagtail	1.15	1.24	73.77	0.00	0.00	0.00	2.84	0.95
House Crow	1.07	1.16	74.93	2.39	0.00	0.00	1.24	0.00
White Wagtail	1.07	1.15	76.08	0.18	0.00	0.00	3.56	0.00
White-tailed Stonechat	1.04	1.12	77.20	0.00	0.00	0.00	0.00	2.52
Pied Bushchat	0.95	1.02	78.22	0.00	0.00	0.00	0.12	2.00
Plum-headed Parakeet	0.88	0.95	79.17	0.64	1.87	1.17	0.16	0.00
Spotted Dove	0.88	0.95	80.12	0.61	0.67	3.08	0.00	0.00
Great Tit	0.78	0.84	80.96	1.32	1.00	0.25	0.00	0.00
Red Junglefowl	0.74	0.80	81.75	0.00	2.33	0.83	0.00	0.00
White-throated Fantail	0.68	0.74	82.49	1.04	0.13	0.75	0.28	0.19
Oriental Magpie-Robin	0.66	0.71	83.20	0.75	1.07	1.08	0.00	0.00
Oriental Skylark	0.61	0.65	83.86	0.00	0.00	0.00	0.84	0.57
Gray Wagtail	0.60	0.64	84.50	0.00	0.00	0.00	1.28	0.33
Yellow-footed Green-Pigeon	0.54	0.58	85.08	0.00	0.00	3.75	0.00	0.00
Little-ringed Plover	0.52	0.56	85.64	0.00	0.00	0.00	2.76	0.00
Great Cormorant	0.52	0.56	86.21	0.00	0.00	0.00	3.48	0.00

Yellow-breasted Greenfinch	0.52	0.55	86.76	0.00	0.00	0.00	0.00	2.62
Indian Roller	0.50	0.54	87.30	0.04	0.00	0.00	0.76	0.81
Indian Peafowl	0.50	0.54	87.84	0.00	1.33	1.92	0.00	0.19
Pied Kingfisher	0.49	0.53	88.37	0.00	0.00	0.00	1.12	0.10
Indian Grey Hornbill	0.49	0.53	88.90	0.00	1.80	0.33	0.00	0.00
Yellow-wattled Lapwing	0.45	0.49	89.38	0.00	0.00	0.00	0.00	0.91
White-throated Kingfisher	0.43	0.47	89.85	0.00	0.00	0.00	0.60	0.67
Taiga Flycatcher	0.43	0.46	90.31	1.07	0.00	0.00	0.00	0.00
Ashy Prinia	0.41	0.45	90.75	0.00	0.07	1.33	0.28	0.00
Red-crested Pochard	0.37	0.40	91.16	0.00	0.00	0.00	0.64	0.00
Green Bee-eater	0.34	0.37	91.53	0.21	0.93	0.17	0.00	0.00
Little Egret	0.34	0.37	91.90	0.00	0.00	0.00	1.04	0.00
Small Pratincole	0.33	0.36	92.25	0.00	0.00	0.00	2.20	0.00
Indian Pied Starling	0.31	0.33	92.58	0.00	0.00	0.00	0.00	0.86
Indian Robin	0.31	0.33	92.91	0.00	0.00	1.83	0.00	0.00
Goosander	0.30	0.32	93.23	0.00	0.00	0.00	1.16	0.00
Intermediate Egret	0.29	0.31	93.54	0.00	0.00	0.00	1.52	0.00
Common Tailorbird	0.27	0.30	93.83	0.00	0.53	0.25	0.20	0.00
Plain Martin	0.26	0.28	94.11	0.00	0.00	0.00	0.64	0.00
Pond Heron	0.25	0.27	94.39	0.18	0.00	0.00	0.56	0.10
Red-breasted Flycatcher	0.25	0.27	94.66	0.00	0.67	0.75	0.00	0.00
Gadwall	0.25	0.26	94.92	0.00	0.00	0.00	0.60	0.00
Crimson Sunbird	0.24	0.25	95.18	0.00	0.60	0.58	0.00	0.00
River Tern	0.23	0.25	95.42	0.00	0.00	0.00	0.44	0.05
Crested Serpent-Eagle	0.22	0.24	95.66	0.21	0.20	0.00	0.16	0.05
Brown-headed Barbet	0.22	0.24	95.90	0.36	0.13	0.17	0.00	0.00

Lesser Goldenback	0.21	0.23	96.13	0.46	0.00	0.58	0.00	0.00
Indian Silverbill	0.20	0.22	96.35	0.00	0.00	0.58	0.00	0.10
Eurasian Collared-Dove	0.18	0.20	96.54	0.00	0.00	0.00	0.56	0.00
Brahminy Starling	0.17	0.18	96.73	0.00	0.00	0.00	0.56	0.00
Yellow-bellied Prinia	0.16	0.18	96.90	0.00	0.00	0.00	0.00	0.48
Grey-headed Canary-Flycatcher	0.16	0.17	97.08	0.39	0.00	0.00	0.00	0.00
Laughing Dove	0.16	0.17	97.25	0.00	0.00	0.00	0.00	0.43
Temminck Stint	0.15	0.16	97.41	0.00	0.00	0.00	0.40	0.00
White-browed Wagtail	0.15	0.16	97.57	0.00	0.00	0.00	0.40	0.00
Common Kingfisher	0.13	0.14	97.71	0.00	0.00	0.00	0.24	0.10
Striated Grassbird	0.13	0.14	97.85	0.00	0.00	0.00	0.00	0.43
Black-bellied Tern	0.13	0.14	97.99	0.00	0.00	0.00	0.28	0.00
Small Minivet	0.12	0.13	98.12	0.00	0.00	0.83	0.00	0.00
Sarus Crane	0.12	0.13	98.25	0.00	0.00	0.00	0.00	0.48
Red Avadavat	0.12	0.13	98.38	0.00	0.00	0.00	0.00	0.29
Cattle Egret	0.12	0.13	98.51	0.00	0.00	0.00	0.12	0.19
Pallas Gull	0.11	0.12	98.64	0.00	0.00	0.00	0.72	0.00
Jungle Owlet	0.11	0.12	98.75	0.29	0.07	0.00	0.00	0.00
Brown Rock Chat	0.09	0.09	98.85	0.00	0.00	0.00	0.00	0.19
Great Egret	0.09	0.09	98.94	0.00	0.00	0.00	0.16	0.00
Bank Myna	0.08	0.09	99.03	0.00	0.00	0.00	0.12	0.00
Long-tailed Shrike	0.07	0.08	99.11	0.00	0.00	0.00	0.00	0.24
Oriental Pied-Hornbill	0.06	0.06	99.17	0.00	0.27	0.00	0.00	0.00
Common Greenshank	0.05	0.06	99.23	0.00	0.00	0.00	0.12	0.00
Common Sandpiper	0.05	0.05	99.28	0.00	0.00	0.00	0.24	0.00
Tickell's Thrush	0.05	0.05	99.33	0.00	0.00	0.00	0.00	0.14

Greater Coucal	0.04	0.05	99.38	0.00	0.00	0.33	0.00	0.00
Golden-fronted Leafbird	0.04	0.05	99.43	0.00	0.20	0.00	0.00	0.00
Grey-hooded Warbler	0.04	0.05	99.47	0.00	0.20	0.00	0.00	0.00
Lemon-rumped Warbler	0.04	0.05	99.52	0.07	0.00	0.00	0.00	0.00
Asian Brown Flycatcher	0.03	0.04	99.55	0.04	0.13	0.00	0.00	0.00
Little Stint	0.03	0.03	99.59	0.00	0.00	0.00	0.16	0.00
White-rumped Vulture	0.02	0.03	99.61	0.00	0.00	0.00	0.00	0.05
Verditer Flycatcher	0.02	0.02	99.64	0.00	0.00	0.17	0.00	0.00
Osprey	0.02	0.02	99.66	0.00	0.00	0.00	0.04	0.00
Bronze Drongo	0.02	0.02	99.68	0.00	0.00	0.00	0.00	0.05
Ashy Drongo	0.02	0.02	99.70	0.00	0.00	0.00	0.00	0.05
Asian Woolly-necked Stork	0.02	0.02	99.72	0.11	0.00	0.00	0.00	0.00
Shikra	0.02	0.02	99.74	0.07	0.00	0.00	0.00	0.00
Himalayan Griffon	0.02	0.02	99.76	0.00	0.00	0.00	0.08	0.00
Slender-billed Vulture	0.01	0.02	99.77	0.00	0.00	0.00	0.00	0.05
Eurasian Sparrowhawk	0.01	0.02	99.79	0.00	0.07	0.00	0.00	0.00
Small Niltava	0.01	0.02	99.80	0.00	0.07	0.00	0.00	0.00
Great Barbet	0.01	0.01	99.82	0.00	0.00	0.08	0.00	0.00
Black-naped Monarch	0.01	0.01	99.83	0.04	0.00	0.00	0.00	0.00
Velvet-fronted Nuthatch	0.01	0.01	99.85	0.04	0.00	0.00	0.00	0.00
Rusty-cheeked Scimitar-Babbler	0.01	0.01	99.86	0.04	0.00	0.00	0.00	0.00
Chestnut-bellied Rock-Thrush	0.01	0.01	99.87	0.04	0.00	0.00	0.00	0.00
Sirkeer Malkoha	0.01	0.01	99.89	0.00	0.00	0.00	0.04	0.00
Rufous-gorgeted flycatcher	0.01	0.01	99.90	0.00	0.07	0.00	0.00	0.00
Grey Bushchat	0.01	0.01	99.91	0.00	0.00	0.08	0.00	0.00
Bay-backed Shrike	0.01	0.01	99.93	0.00	0.00	0.08	0.00	0.00

Lesser Whistling-Duck	0.01	0.01	99.94	0.00	0.00	0.00	0.04	0.00
Stork-billed Kingfisher	0.01	0.01	99.95	0.00	0.00	0.00	0.04	0.00
Maroon Oriole	0.01	0.01	99.97	0.04	0.00	0.00	0.00	0.00
Cinereous Vulture	0.01	0.01	99.97	0.00	0.00	0.00	0.04	0.00
Tickell's Blue Flycatcher	0.01	0.01	99.98	0.04	0.00	0.00	0.00	0.00
Thick-billed Flowerpecker	0.01	0.01	99.99	0.04	0.00	0.00	0.00	0.00
Egyptian Vulture	0.01	0.01	100.00	0.00	0.00	0.00	0.04	0.00

Table 4.7. SIMPER analysis for winter season between different habitats (pairwise comparisons)

Plantation and mixed deciduous forest					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Plantation**	**Mean of bird abundance in Mixed deciduous forest**
Red-vented Bulbul	8.51	10.15	10.15	4.75	13.90
Black Bulbul	5.99	7.15	17.29	8.68	0.00
Jungle Babbler	5.54	6.61	23.90	6.25	4.07
Spangled Drongo	4.50	5.37	29.27	6.82	1.00
Rose-ringed Parakeet	4.29	5.12	34.39	6.39	2.20
Oriental White-eye	4.19	4.99	39.39	0.46	6.27
Barn Swallow	3.78	4.51	43.89	0.11	9.53
Humes Warbler	3.73	4.45	48.34	4.86	3.47
Red-whiskered Bulbul	3.53	4.21	52.55	0.00	5.20
Black-hooded Oriole	3.40	4.05	56.60	5.54	2.00
Lesser Whitethroat	2.56	3.05	59.66	0.00	3.27
Rufous Treepie	2.43	2.91	62.56	2.07	2.27
Common Myna	2.28	2.72	65.28	3.25	0.00
Large-billed Crow	2.26	2.70	67.98	3.36	0.60
Purple Sunbird	2.05	2.45	70.43	0.11	2.67
Himalayan Bulbul	2.02	2.41	72.84	2.32	1.27
Greenish Warbler	1.95	2.33	75.17	2.46	0.33
Red Junglefowl	1.94	2.32	77.48	0.00	2.33
Red-naped Ibis	1.83	2.18	79.66	4.46	0.00
Plum-headed Parakeet	1.78	2.12	81.78	0.64	1.87
Black Drongo	1.50	1.79	83.57	1.82	0.20
House Crow	1.48	1.77	85.33	2.39	0.00
Great Tit	1.43	1.70	87.03	1.32	1.00
Indian Grey Hornbill	1.28	1.52	88.56	0.00	1.80
Oriental Magpie-Robin	1.01	1.20	89.75	0.75	1.07
White-throated Fantail	0.89	1.06	90.82	1.04	0.13
Taiga Flycatcher	0.84	1.01	91.82	1.07	0.00
Green Bee-eater	0.83	0.99	92.81	0.21	0.93
Indian Peafowl	0.81	0.96	93.78	0.00	1.33
Spotted Dove	0.76	0.91	94.68	0.61	0.67

Crimson Sunbird	0.44	0.53	95.21	0.00	0.60
Red-breasted Flycatcher	0.43	0.52	95.73	0.00	0.67
Brown-headed Barbet	0.40	0.48	96.21	0.36	0.13
Common Tailorbird	0.36	0.43	96.64	0.00	0.53
Crested Serpent-Eagle	0.32	0.38	97.02	0.21	0.20
Grey-headed Canary-Flycatcher	0.32	0.38	97.40	0.39	0.00
Lesser Goldenback	0.31	0.36	97.76	0.46	0.00
Jungle Owlet	0.22	0.26	98.02	0.29	0.07
Plain Prinia	0.20	0.24	98.26	0.00	0.20
Oriental Pied-Hornbill	0.18	0.21	98.47	0.00	0.27
White Wagtail	0.14	0.17	98.63	0.18	0.00
Golden-fronted Leafbird	0.13	0.16	98.79	0.00	0.20
Red-wattled Lapwing	0.13	0.15	98.95	0.29	0.00
Grey-hooded Warbler	0.13	0.15	99.10	0.00	0.20
Ashy Prinia	0.11	0.13	99.23	0.00	0.07
Pond Heron	0.09	0.11	99.34	0.18	0.00
Asian Brown Flycatcher	0.09	0.11	99.45	0.04	0.13
Lemon-rumped Warbler	0.08	0.10	99.55	0.07	0.00
Eurasian Sparrowhawk	0.04	0.05	99.60	0.00	0.07
Small Niltava	0.04	0.05	99.65	0.00	0.07
Rufous-gorgeted flycatcher	0.04	0.05	99.70	0.00	0.07
Asian Woolly-necked Stork	0.04	0.04	99.74	0.11	0.00
Shikra	0.03	0.04	99.78	0.07	0.00
Indian Roller	0.03	0.03	99.81	0.04	0.00
Black-naped Monarch	0.03	0.03	99.85	0.04	0.00
Velvet-fronted Nuthatch	0.02	0.03	99.87	0.04	0.00
Rusty-cheeked Scimitar-Babbler	0.02	0.03	99.90	0.04	0.00
Chestnut-bellied Rock-Thrush	0.02	0.03	99.93	0.04	0.00
Maroon Oriole	0.02	0.03	99.96	0.04	0.00
Thick-billed Flowerpecker	0.02	0.02	99.98	0.04	0.00
Tickell's Blue Flycatcher	0.02	0.02	100.00	0.04	0.00

Plantation and scrub forest					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Plantation**	**Mean of bird abundance in Scrub forest**
Red-vented Bulbul	13.11	15.08	15.08	4.75	27.60
Black Bulbul	5.49	6.31	21.39	8.68	0.00
Jungle Babbler	5.17	5.95	27.33	6.25	4.67
Lesser Whitethroat	4.39	5.04	32.38	0.00	7.50
Spangled Drongo	4.38	5.03	37.41	6.82	2.58
Black-hooded Oriole	3.81	4.38	41.79	5.54	0.00
Rose-ringed Parakeet	3.77	4.33	46.12	6.39	0.17
Humes Warbler	3.55	4.08	50.20	4.86	2.83
Himalayan Bulbul	2.93	3.37	53.57	2.32	5.58
Oriental White-eye	2.81	3.23	56.81	0.46	5.75
Plain Prinia	2.64	3.03	59.83	0.00	5.50
Greenish Warbler	2.62	3.01	62.84	2.46	2.67
Red-whiskered Bulbul	2.56	2.94	65.79	0.00	5.42
Purple Sunbird	2.46	2.83	68.62	0.11	4.50
Common Myna	2.09	2.40	71.02	3.25	0.00
Large-billed Crow	2.04	2.34	73.36	3.36	0.58
Spotted Dove	1.98	2.27	75.63	0.61	3.08
Yellow-footed Green-Pigeon	1.96	2.26	77.88	0.00	3.75
Black Drongo	1.78	2.04	79.93	1.82	1.50
Rufous Treepie	1.73	1.99	81.91	2.07	1.67
Red-naped Ibis	1.71	1.97	83.88	4.46	0.00
House Crow	1.36	1.57	85.45	2.39	0.00
Great Tit	1.13	1.30	86.75	1.32	0.25
Indian Robin	1.09	1.26	88.01	0.00	1.83
Ashy Prinia	0.94	1.08	89.09	0.00	1.33
White-throated Fantail	0.91	1.05	90.14	1.04	0.75
Oriental Magpie-Robin	0.89	1.03	91.16	0.75	1.08
Plum-headed Parakeet	0.78	0.90	92.06	0.64	1.17
Taiga Flycatcher	0.77	0.88	92.95	1.07	0.00
Indian Peafowl	0.68	0.78	93.73	0.00	1.92
Indian Silverbill	0.57	0.65	94.38	0.00	0.58
Small Minivet	0.45	0.51	94.90	0.00	0.83

Lesser Goldenback	0.43	0.50	95.39	0.46	0.58
Red-breasted Flycatcher	0.42	0.48	95.88	0.00	0.75
Red Junglefowl	0.38	0.43	96.31	0.00	0.83
Brown-headed Barbet	0.34	0.39	96.70	0.36	0.17
Crimson Sunbird	0.34	0.39	97.09	0.00	0.58
Grey-headed Canary-Flycatcher	0.29	0.33	97.42	0.39	0.00
Common Tailorbird	0.28	0.32	97.74	0.00	0.25
Green Bee-eater	0.26	0.30	98.04	0.21	0.17
Indian Grey Hornbill	0.26	0.30	98.34	0.00	0.33
Jungle Owlet	0.18	0.20	98.54	0.29	0.00
Crested Serpent-Eagle	0.17	0.19	98.73	0.21	0.00
Greater Coucal	0.16	0.19	98.91	0.00	0.33
White Wagtail	0.13	0.15	99.06	0.18	0.00
Red-wattled Lapwing	0.12	0.14	99.20	0.29	0.00
Pond Heron	0.09	0.10	99.30	0.18	0.00
Verditer Flycatcher	0.08	0.09	99.39	0.00	0.17
Lemon-rumped Warbler	0.07	0.09	99.48	0.07	0.00
Barn Swallow	0.06	0.07	99.55	0.11	0.00
Great Barbet	0.05	0.06	99.61	0.00	0.08
Grey Bushchat	0.04	0.05	99.66	0.00	0.08
Bay-backed Shrike	0.04	0.05	99.71	0.00	0.08
Asian Woolly-necked Stork	0.03	0.04	99.75	0.11	0.00
Shikra	0.03	0.04	99.79	0.07	0.00
Indian Roller	0.03	0.03	99.82	0.04	0.00
Black-naped Monarch	0.02	0.03	99.84	0.04	0.00
Velvet-fronted Nuthatch	0.02	0.03	99.87	0.04	0.00
Rusty-cheeked Scimitar-Babbler	0.02	0.03	99.90	0.04	0.00
Chestnut-bellied Rock-Thrush	0.02	0.03	99.92	0.04	0.00
Maroon Oriole	0.02	0.02	99.95	0.04	0.00
Asian Brown Flycatcher	0.02	0.02	99.97	0.04	0.00
Thick-billed Flowerpecker	0.01	0.02	99.98	0.04	0.00
Tickell's Blue Flycatcher	0.01	0.02	100.00	0.04	0.00

Plantation and Riverine habitat					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Plantation**	**Mean of bird abundance in Riverine**
Ruddy Shelduck	9.60	10.19	10.19	0.00	24.50
Little Cormorant	6.86	7.28	17.46	0.00	9.12
Black Bulbul	5.43	5.77	23.23	8.68	0.00
Jungle Babbler	4.09	4.34	27.57	6.25	0.00
Spangled Drongo	4.02	4.26	31.84	6.82	0.00
Rose-ringed Parakeet	3.93	4.17	36.01	6.39	0.60
Black-hooded Oriole	3.71	3.94	39.95	5.54	0.12
Red-vented Bulbul	3.52	3.73	43.68	4.75	1.92
Humes Warbler	3.31	3.51	47.19	4.86	2.28
Northern Pintail	2.82	2.99	50.18	0.00	5.12
Barn Swallow	2.65	2.81	52.99	0.11	5.92
River Lapwing	2.48	2.63	55.62	0.00	3.80
Bar-headed Goose	2.46	2.61	58.23	0.00	4.00
Common Myna	2.07	2.19	60.42	3.25	0.08
Large-billed Crow	2.05	2.17	62.59	3.36	0.60
White Wagtail	2.04	2.17	64.76	0.18	3.56
House Crow	1.80	1.91	66.67	2.39	1.24
Greenish Warbler	1.76	1.87	68.54	2.46	0.20
Citrine Wagtail	1.75	1.86	70.39	0.00	2.84
Red-naped Ibis	1.72	1.83	72.22	4.46	0.00
Rufous Treepie	1.72	1.83	74.05	2.07	1.12
Black Drongo	1.50	1.59	75.64	1.82	0.52
Himalayan Bulbul	1.37	1.45	77.09	2.32	0.00
Great Cormorant	1.08	1.14	78.23	0.00	3.48
Little-ringed Plover	1.08	1.14	79.38	0.00	2.76
Gray Wagtail	1.01	1.07	80.44	0.00	1.28
Great Tit	0.93	0.99	81.43	1.32	0.00
Pied Kingfisher	0.91	0.96	82.40	0.00	1.12
White-throated Fantail	0.83	0.88	83.27	1.04	0.28
Taiga Flycatcher	0.75	0.80	84.07	1.07	0.00
Red-crested Pochard	0.70	0.75	84.82	0.00	0.64

Small Pratincole	0.68	0.72	85.54	0.00	2.20
Little Egret	0.67	0.71	86.25	0.00	1.04
Oriental Skylark	0.66	0.70	86.96	0.00	0.84
Paddyfield Pipit	0.63	0.67	87.63	0.00	1.64
Goosander	0.59	0.63	88.26	0.00	1.16
Intermediate Egret	0.59	0.62	88.89	0.00	1.52
Plum-headed Parakeet	0.59	0.62	89.51	0.64	0.16
Oriental Magpie-Robin	0.57	0.61	90.11	0.75	0.00
Plain Martin	0.52	0.55	90.66	0.00	0.64
Indian Roller	0.49	0.52	91.18	0.04	0.76
Gadwall	0.48	0.51	91.70	0.00	0.60
Pond Heron	0.44	0.47	92.17	0.18	0.56
White-throated Kingfisher	0.44	0.47	92.64	0.00	0.60
Spotted Dove	0.42	0.44	93.08	0.61	0.00
River Tern	0.41	0.43	93.51	0.00	0.44
Eurasian Collared-Dove	0.36	0.38	93.90	0.00	0.56
Brahminy Starling	0.34	0.36	94.25	0.00	0.56
Oriental White-eye	0.31	0.33	94.58	0.46	0.00
Temminck Stint	0.29	0.31	94.89	0.00	0.40
White-browed Wagtail	0.29	0.31	95.20	0.00	0.40
Grey-headed Canary-Flycatcher	0.28	0.30	95.50	0.39	0.00
Lesser Goldenback	0.28	0.30	95.80	0.46	0.00
Crested Serpent-Eagle	0.28	0.29	96.09	0.21	0.16
Common Stonechat	0.27	0.29	96.38	0.00	0.48
Brown-headed Barbet	0.27	0.29	96.67	0.36	0.00
Ashy Prinia	0.25	0.26	96.94	0.00	0.28
Black-bellied Tern	0.25	0.26	97.20	0.00	0.28
Pallas Gull	0.23	0.25	97.45	0.00	0.72
Common Kingfisher	0.20	0.22	97.66	0.00	0.24
Plain Prinia	0.20	0.21	97.88	0.00	0.20
Jungle Owlet	0.18	0.19	98.06	0.29	0.00
Green Bee-eater	0.17	0.18	98.24	0.21	0.00
Common Tailorbird	0.16	0.17	98.42	0.00	0.20
Great Egret	0.16	0.17	98.59	0.00	0.16
Bank Myna	0.15	0.16	98.75	0.00	0.12
Pied Bushchat	0.12	0.13	98.88	0.00	0.12
Cattle Egret	0.12	0.13	99.01	0.00	0.12
Red-wattled Lapwing	0.12	0.13	99.14	0.29	0.00

Common Greenshank	0.10	0.11	99.25	0.00	0.12
Common Sandpiper	0.10	0.11	99.36	0.00	0.24
Lemon-rumped Warbler	0.07	0.08	99.44	0.07	0.00
Purple Sunbird	0.06	0.07	99.50	0.11	0.00
Little Stint	0.06	0.07	99.57	0.00	0.16
Osprey	0.04	0.04	99.61	0.00	0.04
Asian Woolly-necked Stork	0.03	0.04	99.65	0.11	0.00
Himalayan Griffon	0.03	0.03	99.68	0.00	0.08
Shikra	0.03	0.03	99.72	0.07	0.00
Sirkeer Malkoha	0.03	0.03	99.74	0.00	0.04
Stork-billed Kingfisher	0.02	0.03	99.77	0.00	0.04
Lesser Whistling-Duck	0.02	0.03	99.80	0.00	0.04
Black-naped Monarch	0.02	0.03	99.82	0.04	0.00
Velvet-fronted Nuthatch	0.02	0.02	99.85	0.04	0.00
Rusty-cheeked Scimitar-Babbler	0.02	0.02	99.87	0.04	0.00
Chestnut-bellied Rock-Thrush	0.02	0.02	99.89	0.04	0.00
Maroon Oriole	0.02	0.02	99.92	0.04	0.00
Cinereous Vulture	0.02	0.02	99.93	0.00	0.04
Asian Brown Flycatcher	0.02	0.02	99.95	0.04	0.00
Egyptian Vulture	0.02	0.02	99.97	0.00	0.04
Tickell's Blue Flycatcher	0.01	0.02	99.98	0.04	0.00
Thick-billed Flowerpecker	0.01	0.02	100.00	0.04	0.00

Plantation and Grassland					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Plantation**	**Mean of bird abundance in Grassland**
Black Bulbul	6.83	7.09	7.09	8.68	0.00
Red-vented Bulbul	5.83	6.05	13.13	4.75	3.95
Common Stonechat	5.15	5.34	18.48	0.00	5.48
Jungle Babbler	5.14	5.33	23.81	6.25	0.00
Spangled Drongo	5.00	5.19	28.99	6.82	0.10
Red-wattled Lapwing	4.94	5.12	34.12	0.29	6.24
Black-hooded Oriole	4.79	4.97	39.08	5.54	0.00

Paddyfield Pipit	4.72	4.90	43.98	0.00	4.57
Rose-ringed Parakeet	4.70	4.88	48.85	6.39	0.00
Humes Warbler	4.06	4.21	53.06	4.86	0.05
Red-naped Ibis	3.18	3.30	56.35	4.46	2.52
Large-billed Crow	2.92	3.02	59.38	3.36	1.10
Common Myna	2.65	2.75	62.12	3.25	0.14
River Lapwing	2.49	2.58	64.70	0.00	2.62
White-tailed Stonechat	2.46	2.56	67.26	0.00	2.52
Greenish Warbler	2.26	2.35	69.60	2.46	0.10
Pied Bushchat	2.14	2.22	71.82	0.00	2.00
Rufous Treepie	2.07	2.14	73.96	2.07	0.00
Black Drongo	1.89	1.96	75.92	1.82	0.62
Himalayan Bulbul	1.77	1.84	77.76	2.32	0.19
House Crow	1.68	1.75	79.50	2.39	0.00
Plain Prinia	1.36	1.41	80.92	0.00	1.19
Yellow-breasted Greenfinch	1.25	1.30	82.21	0.00	2.62
Great Tit	1.18	1.23	83.44	1.32	0.00
Yellow-wattled Lapwing	1.06	1.10	84.54	0.00	0.91
White-throated Fantail	1.03	1.07	85.61	1.04	0.19
Barn Swallow	1.01	1.05	86.65	0.11	0.95
Taiga Flycatcher	0.97	1.01	87.66	1.07	0.00
Citrine Wagtail	0.82	0.85	88.50	0.00	0.95
Oriental Magpie-Robin	0.74	0.77	89.27	0.75	0.00
Indian Pied Starling	0.73	0.76	90.03	0.00	0.86
Oriental Skylark	0.70	0.72	90.75	0.00	0.57
Indian Roller	0.68	0.71	91.46	0.04	0.81
Plum-headed Parakeet	0.60	0.62	92.08	0.64	0.00
White-throated Kingfisher	0.57	0.59	92.67	0.00	0.67
Spotted Dove	0.53	0.55	93.22	0.61	0.00
Yellow-bellied Prinia	0.40	0.41	93.63	0.00	0.48
Oriental White-eye	0.39	0.40	94.03	0.46	0.00
Laughing Dove	0.37	0.39	94.42	0.00	0.43
Grey-headed Canary-Flycatcher	0.36	0.38	94.80	0.39	0.00
Lesser Goldenback	0.35	0.36	95.16	0.46	0.00
Brown-headed Barbet	0.35	0.36	95.52	0.36	0.00
Striated Grassbird	0.31	0.33	95.84	0.00	0.43
Ruddy Shelduck	0.30	0.31	96.16	0.00	0.38
Sarus Crane	0.30	0.31	96.46	0.00	0.48

Red Avadavat	0.29	0.30	96.76	0.00	0.29
Gray Wagtail	0.25	0.26	97.02	0.00	0.33
Crested Serpent-Eagle	0.23	0.24	97.27	0.21	0.05
Green Bee-eater	0.22	0.23	97.49	0.21	0.00
Jungle Owlet	0.22	0.23	97.72	0.29	0.00
Brown Rock Chat	0.21	0.21	97.93	0.00	0.19
Red-whiskered Bulbul	0.18	0.18	98.12	0.00	0.24
Long-tailed Shrike	0.17	0.18	98.30	0.00	0.24
White Wagtail	0.16	0.17	98.46	0.18	0.00
Indian Peafowl	0.16	0.16	98.62	0.00	0.19
Pond Heron	0.14	0.15	98.77	0.18	0.10
Cattle Egret	0.14	0.15	98.92	0.00	0.19
Tickell's Thrush	0.12	0.12	99.04	0.00	0.14
Lemon-rumped Warbler	0.10	0.10	99.14	0.07	0.00
Indian Silverbill	0.09	0.10	99.24	0.00	0.10
Purple Sunbird	0.08	0.08	99.32	0.11	0.00
Common Kingfisher	0.07	0.08	99.40	0.00	0.10
Pied Kingfisher	0.07	0.08	99.48	0.00	0.10
White-rumped Vulture	0.06	0.06	99.54	0.00	0.05
Bronze Drongo	0.05	0.05	99.58	0.00	0.05
Ashy Drongo	0.05	0.05	99.63	0.00	0.05
River Tern	0.05	0.05	99.68	0.00	0.05
Asian Woolly-necked Stork	0.04	0.04	99.72	0.11	0.00
Shikra	0.04	0.04	99.76	0.07	0.00
Slender-billed Vulture	0.04	0.04	99.80	0.00	0.05
Black-naped Monarch	0.03	0.03	99.83	0.04	0.00
Velvet-fronted Nuthatch	0.03	0.03	99.86	0.04	0.00
Rusty-cheeked Scimitar-Babbler	0.03	0.03	99.89	0.04	0.00
Chestnut-bellied Rock-Thrush	0.03	0.03	99.92	0.04	0.00
Maroon Oriole	0.03	0.03	99.94	0.04	0.00
Asian Brown Flycatcher	0.02	0.02	99.96	0.04	0.00
Thick-billed Flowerpecker	0.02	0.02	99.98	0.04	0.00
Tickell's Blue Flycatcher	0.02	0.02	100.00	0.04	0.00

Mixed deciduous forest and Scrub forest					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Mixed deciduous forest**	**Mean of bird abundance in Scrub forest**
Red-vented Bulbul	14.85	18.51	18.51	13.90	27.60
Lesser Whitethroat	5.28	6.58	25.10	3.27	7.50
Oriental White-eye	4.71	5.87	30.97	6.27	5.75
Red-whiskered Bulbul	4.46	5.56	36.53	5.20	5.42
Jungle Babbler	4.03	5.02	41.55	4.07	4.67
Barn Swallow	3.52	4.39	45.94	9.53	0.00
Greenish Warbler	3.10	3.86	49.80	0.33	2.67
Humes Warbler	2.88	3.59	53.39	3.47	2.83
Plain Prinia	2.70	3.37	56.76	0.20	5.50
Purple Sunbird	2.65	3.30	60.06	2.67	4.50
Himalayan Bulbul	2.45	3.06	63.11	1.27	5.58
Spangled Drongo	2.40	2.99	66.10	1.00	2.58
Spotted Dove	2.20	2.74	68.84	0.67	3.08
Rufous Treepie	2.01	2.51	71.35	2.27	1.67
Yellow-footed Green-Pigeon	2.00	2.49	73.84	0.00	3.75
Red Junglefowl	1.88	2.34	76.18	2.33	0.83
Plum-headed Parakeet	1.66	2.07	78.24	1.87	1.17
Black-hooded Oriole	1.44	1.80	80.04	2.00	0.00
Black Drongo	1.44	1.79	81.83	0.20	1.50
Rose-ringed Parakeet	1.39	1.73	83.57	2.20	0.17
Indian Grey Hornbill	1.30	1.62	85.19	1.80	0.33
Indian Peafowl	1.29	1.61	86.79	1.33	1.92
Indian Robin	1.16	1.44	88.23	0.00	1.83
Ashy Prinia	1.04	1.29	89.53	0.07	1.33
Oriental Magpie-Robin	0.99	1.23	90.76	1.07	1.08
Great Tit	0.83	1.04	91.79	1.00	0.25
Green Bee-eater	0.73	0.91	92.70	0.93	0.17
Large-billed Crow	0.70	0.87	93.57	0.60	0.58
Red-breasted Flycatcher	0.69	0.86	94.43	0.67	0.75
Crimson Sunbird	0.66	0.83	95.26	0.60	0.58

Indian Silverbill	0.63	0.79	96.05	0.00	0.58
Common Tailorbird	0.60	0.75	96.80	0.53	0.25
Small Minivet	0.47	0.59	97.39	0.00	0.83
White-throated Fantail	0.45	0.56	97.95	0.13	0.75
Lesser Goldenback	0.23	0.29	98.23	0.00	0.58
Brown-headed Barbet	0.23	0.29	98.52	0.13	0.17
Oriental Pied-Hornbill	0.17	0.21	98.73	0.27	0.00
Greater Coucal	0.16	0.20	98.93	0.00	0.33
Crested Serpent-Eagle	0.15	0.19	99.12	0.20	0.00
Golden-fronted Leafbird	0.13	0.16	99.28	0.20	0.00
Grey-hooded Warbler	0.12	0.15	99.43	0.20	0.00
Verditer Flycatcher	0.08	0.10	99.53	0.00	0.17
Asian Brown Flycatcher	0.07	0.09	99.62	0.13	0.00
Great Barbet	0.05	0.06	99.69	0.00	0.08
Grey Bushchat	0.05	0.06	99.74	0.00	0.08
Bay-backed Shrike	0.05	0.06	99.80	0.00	0.08
Jungle Owlet	0.04	0.05	99.85	0.07	0.00
Eurasian Sparrowhawk	0.04	0.05	99.90	0.07	0.00
Small Niltava	0.04	0.05	99.95	0.07	0.00
Rufous-gorgeted flycatcher	0.04	0.05	100.00	0.07	0.00

Mixed deciduous forest and Riverine habitat					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Mixed deciduous forest**	**Mean of bird abundance in Riverine**
Ruddy Shelduck	9.78	10.26	10.26	0.00	24.50
Red-vented Bulbul	8.48	8.91	19.17	13.90	1.92
Little Cormorant	7.25	7.61	26.77	0.00	9.12
Barn Swallow	5.97	6.27	33.04	9.53	5.92
Oriental White-eye	3.96	4.16	37.20	6.27	0.00
Red-whiskered Bulbul	3.35	3.52	40.72	5.20	0.00
Northern Pintail	2.87	3.02	43.74	0.00	5.12
River Lapwing	2.62	2.75	46.49	0.00	3.80

Bar-headed Goose	2.52	2.65	49.13	0.00	4.00
Humes Warbler	2.46	2.58	51.72	3.47	2.28
Lesser Whitethroat	2.43	2.56	54.27	3.27	0.00
Jungle Babbler	2.23	2.34	56.61	4.07	0.00
White Wagtail	2.12	2.22	58.84	0.00	3.56
Purple Sunbird	1.96	2.06	60.90	2.67	0.00
Citrine Wagtail	1.86	1.95	62.85	0.00	2.84
Red Junglefowl	1.85	1.94	64.79	2.33	0.00
Rufous Treepie	1.83	1.92	66.71	2.27	1.12
Rose-ringed Parakeet	1.77	1.86	68.57	2.20	0.60
Plum-headed Parakeet	1.49	1.56	70.14	1.87	0.16
Black-hooded Oriole	1.42	1.49	71.62	2.00	0.12
Indian Grey Hornbill	1.21	1.27	72.89	1.80	0.00
Little-ringed Plover	1.09	1.14	74.03	0.00	2.76
Great Cormorant	1.09	1.14	75.17	0.00	3.48
Gray Wagtail	1.08	1.13	76.31	0.00	1.28
Pied Kingfisher	0.98	1.03	77.34	0.00	1.12
Red-crested Pochard	0.81	0.85	78.19	0.00	0.64
Indian Peafowl	0.77	0.80	78.99	1.33	0.00
House Crow	0.76	0.80	79.79	0.00	1.24
Himalayan Bulbul	0.74	0.78	80.57	1.27	0.00
Little Egret	0.72	0.75	81.33	0.00	1.04
Black Drongo	0.72	0.75	82.08	0.20	0.52
Oriental Skylark	0.70	0.73	82.81	0.00	0.84
Small Pratincole	0.69	0.72	83.53	0.00	2.20
Spangled Drongo	0.67	0.70	84.23	1.00	0.00
Oriental Magpie-Robin	0.66	0.69	84.92	1.07	0.00
Green Bee-eater	0.65	0.68	85.61	0.93	0.00
Large-billed Crow	0.65	0.68	86.29	0.60	0.60
Paddyfield Pipit	0.64	0.67	86.96	0.00	1.64
Goosander	0.61	0.64	87.61	0.00	1.16
Intermediate Egret	0.59	0.62	88.23	0.00	1.52
Great Tit	0.58	0.61	88.84	1.00	0.00
Plain Martin	0.54	0.57	89.41	0.00	0.64
Gadwall	0.51	0.53	89.94	0.00	0.60
Indian Roller	0.50	0.52	90.47	0.00	0.76
Common Tailorbird	0.48	0.50	90.97	0.53	0.20
White-throated Kingfisher	0.47	0.49	91.46	0.00	0.60
River Tern	0.45	0.47	91.93	0.00	0.44

Crimson Sunbird	0.42	0.44	92.37	0.60	0.00
White-throated Fantail	0.41	0.43	92.81	0.13	0.28
Red-breasted Flycatcher	0.41	0.43	93.24	0.67	0.00
Pond Heron	0.41	0.43	93.67	0.00	0.56
Spotted Dove	0.39	0.41	94.09	0.67	0.00
Eurasian Collared-Dove	0.38	0.40	94.49	0.00	0.56
Plain Prinia	0.37	0.39	94.88	0.20	0.20
Brahminy Starling	0.35	0.37	95.25	0.00	0.56
Ashy Prinia	0.35	0.37	95.62	0.07	0.28
Greenish Warbler	0.35	0.37	95.99	0.33	0.20
Temminck Stint	0.31	0.33	96.32	0.00	0.40
White-browed Wagtail	0.31	0.33	96.64	0.00	0.40
Crested Serpent-Eagle	0.29	0.30	96.94	0.20	0.16
Common Stonechat	0.29	0.30	97.24	0.00	0.48
Black-bellied Tern	0.27	0.28	97.52	0.00	0.28
Pallas Gull	0.23	0.25	97.77	0.00	0.72
Common Kingfisher	0.21	0.23	97.99	0.00	0.24
Bank Myna	0.18	0.19	98.19	0.00	0.12
Great Egret	0.18	0.19	98.37	0.00	0.16
Oriental Pied-Hornbill	0.17	0.18	98.55	0.27	0.00
Brown-headed Barbet	0.14	0.15	98.70	0.13	0.00
Pied Bushchat	0.13	0.14	98.84	0.00	0.12
Cattle Egret	0.13	0.14	98.98	0.00	0.12
Golden-fronted Leafbird	0.13	0.13	99.11	0.20	0.00
Grey-hooded Warbler	0.12	0.13	99.24	0.20	0.00
Common Greenshank	0.11	0.12	99.36	0.00	0.12
Common Sandpiper	0.10	0.11	99.46	0.00	0.24
Asian Brown Flycatcher	0.07	0.08	99.54	0.13	0.00
Little Stint	0.06	0.07	99.60	0.00	0.16
Osprey	0.04	0.05	99.65	0.00	0.04
Jungle Owlet	0.04	0.04	99.69	0.07	0.00
Eurasian Sparrowhawk	0.04	0.04	99.74	0.07	0.00
Small Niltava	0.04	0.04	99.78	0.07	0.00
Rufous-gorgeted flycatcher	0.04	0.04	99.82	0.07	0.00
Himalayan Griffon	0.03	0.03	99.85	0.00	0.08
Common Myna	0.03	0.03	99.89	0.00	0.08
Sirkeer Malkoha	0.03	0.03	99.91	0.00	0.04
Stork-billed Kingfisher	0.03	0.03	99.94	0.00	0.04
Lesser Whistling-Duck	0.03	0.03	99.97	0.00	0.04

Cinereous Vulture	0.02	0.02	99.98	0.00	0.04
Egyptian Vulture	0.02	0.02	100.00	0.00	0.04

Mixed deciduous forest and Grassland					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Mixed deciduous forest**	**Mean of bird abundance in Grassland**
Red-vented Bulbul	11.06	11.53	11.53	13.90	3.95
Common Stonechat	5.63	5.87	17.40	0.00	5.48
Red-wattled Lapwing	5.34	5.56	22.96	0.00	6.24
Paddyfield Pipit	5.26	5.49	28.45	0.00	4.57
Barn Swallow	5.08	5.29	33.74	9.53	0.95
Oriental White-eye	4.97	5.18	38.92	6.27	0.00
Red-whiskered Bulbul	4.22	4.39	43.31	5.20	0.24
Lesser Whitethroat	3.14	3.27	46.59	3.27	0.00
Humes Warbler	3.00	3.13	49.72	3.47	0.05
Jungle Babbler	2.72	2.84	52.56	4.07	0.00
White-tailed Stonechat	2.69	2.81	55.36	0.00	2.52
River Lapwing	2.69	2.80	58.16	0.00	2.62
Purple Sunbird	2.53	2.64	60.80	2.67	0.00
Red Junglefowl	2.42	2.52	63.32	2.33	0.00
Pied Bushchat	2.38	2.48	65.81	0.00	2.00
Rufous Treepie	1.89	1.97	67.78	2.27	0.00
Black-hooded Oriole	1.81	1.89	69.67	2.00	0.00
Plum-headed Parakeet	1.78	1.86	71.52	1.87	0.00
Rose-ringed Parakeet	1.68	1.75	73.27	2.20	0.00
Plain Prinia	1.61	1.68	74.95	0.20	1.19
Indian Grey Hornbill	1.52	1.59	76.54	1.80	0.00
Red-naped Ibis	1.42	1.48	78.02	0.00	2.52
Large-billed Crow	1.32	1.38	79.40	0.60	1.10
Yellow-breasted Greenfinch	1.27	1.32	80.73	0.00	2.62
Yellow-wattled Lapwing	1.21	1.26	81.99	0.00	0.91
Indian Peafowl	1.06	1.11	83.09	1.33	0.19
Himalayan Bulbul	1.03	1.07	84.16	1.27	0.19

Citrine Wagtail	0.88	0.91	85.08	0.00	0.95
Spangled Drongo	0.87	0.91	85.98	1.00	0.10
Green Bee-eater	0.83	0.86	86.84	0.93	0.00
Oriental Skylark	0.82	0.85	87.70	0.00	0.57
Oriental Magpie-Robin	0.82	0.85	88.55	1.07	0.00
Indian Pied Starling	0.79	0.83	89.38	0.00	0.86
Indian Roller	0.72	0.75	90.13	0.00	0.81
Great Tit	0.71	0.74	90.87	1.00	0.00
Black Drongo	0.64	0.67	91.53	0.20	0.62
White-throated Kingfisher	0.61	0.64	92.17	0.00	0.67
Crimson Sunbird	0.53	0.56	92.73	0.60	0.00
Red-breasted Flycatcher	0.51	0.54	93.27	0.67	0.00
Spotted Dove	0.48	0.50	93.77	0.67	0.00
Common Tailorbird	0.43	0.45	94.22	0.53	0.00
Yellow-bellied Prinia	0.42	0.44	94.65	0.00	0.48
Laughing Dove	0.39	0.41	95.07	0.00	0.43
Striated Grassbird	0.33	0.34	95.41	0.00	0.43
Red Avadavat	0.32	0.33	95.74	0.00	0.29
Ruddy Shelduck	0.31	0.33	96.06	0.00	0.38
Sarus Crane	0.31	0.32	96.38	0.00	0.48
Gray Wagtail	0.27	0.28	96.67	0.00	0.33
Greenish Warbler	0.27	0.28	96.95	0.33	0.10
Crested Serpent-Eagle	0.23	0.24	97.19	0.20	0.05
Brown Rock Chat	0.23	0.24	97.43	0.00	0.19
Oriental Pied-Hornbill	0.21	0.22	97.65	0.27	0.00
White-throated Fantail	0.20	0.21	97.86	0.13	0.19
Brown-headed Barbet	0.19	0.20	98.06	0.13	0.00
Long-tailed Shrike	0.18	0.19	98.25	0.00	0.24
Ashy Prinia	0.16	0.16	98.41	0.07	0.00
Golden-fronted Leafbird	0.16	0.16	98.57	0.20	0.00
Grey-hooded Warbler	0.15	0.16	98.73	0.20	0.00
Cattle Egret	0.15	0.15	98.88	0.00	0.19
Tickell's Thrush	0.12	0.13	99.01	0.00	0.14
Common Myna	0.11	0.11	99.12	0.00	0.14
Indian Silverbill	0.10	0.11	99.23	0.00	0.10
Asian Brown Flycatcher	0.09	0.09	99.32	0.13	0.00
Common Kingfisher	0.08	0.08	99.40	0.00	0.10
Pied Kingfisher	0.08	0.08	99.48	0.00	0.10
White-rumped Vulture	0.06	0.07	99.55	0.00	0.05

Jungle Owlet	0.05	0.05	99.60	0.07	0.00
Eurasian Sparrowhawk	0.05	0.05	99.66	0.07	0.00
Bronze Drongo	0.05	0.05	99.71	0.00	0.05
Ashy Drongo	0.05	0.05	99.76	0.00	0.05
River Tern	0.05	0.05	99.82	0.00	0.05
Small Niltava	0.05	0.05	99.87	0.07	0.00
Pond Heron	0.04	0.05	99.92	0.00	0.10
Rufous-gorgeted flycatcher	0.04	0.05	99.96	0.07	0.00
Slender-billed Vulture	0.04	0.04	100.00	0.00	0.05

Scrub forest and Riverine habitat					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Scrub forest**	**Mean of bird abundance in Riverine**
Red-vented Bulbul	11.65	12.04	12.04	27.60	1.92
Ruddy Shelduck	9.15	9.46	21.51	0.00	24.50
Little Cormorant	6.61	6.84	28.35	0.00	9.12
Lesser Whitethroat	4.20	4.35	32.69	7.50	0.00
Northern Pintail	2.67	2.76	35.45	0.00	5.12
Greenish Warbler	2.60	2.69	38.13	2.67	0.20
Oriental White-eye	2.59	2.68	40.81	5.75	0.00
Jungle Babbler	2.55	2.63	43.45	4.67	0.00
Plain Prinia	2.50	2.59	46.03	5.50	0.20
Barn Swallow	2.47	2.55	48.59	0.00	5.92
Red-whiskered Bulbul	2.44	2.52	51.11	5.42	0.00
River Lapwing	2.39	2.48	53.58	0.00	3.80
Purple Sunbird	2.36	2.44	56.02	4.50	0.00
Bar-headed Goose	2.33	2.41	58.43	0.00	4.00
Humes Warbler	2.27	2.34	60.77	2.83	2.28
Spotted Dove	1.97	2.04	62.80	3.08	0.00
White Wagtail	1.95	2.01	64.82	0.00	3.56
Yellow-footed Green-Pigeon	1.87	1.93	66.75	3.75	0.00
Spangled Drongo	1.86	1.92	68.67	2.58	0.00
Himalayan Bulbul	1.79	1.85	70.52	5.58	0.00

Citrine Wagtail	1.70	1.76	72.28	0.00	2.84
Rufous Treepie	1.28	1.32	73.60	1.67	1.12
Black Drongo	1.26	1.30	74.90	1.50	0.52
Indian Robin	1.04	1.08	75.98	1.83	0.00
Great Cormorant	1.03	1.06	77.04	0.00	3.48
Little-ringed Plover	1.02	1.05	78.10	0.00	2.76
Ashy Prinia	0.98	1.01	79.11	1.33	0.28
Gray Wagtail	0.98	1.01	80.12	0.00	1.28
Pied Kingfisher	0.89	0.92	81.04	0.00	1.12
Red-crested Pochard	0.71	0.74	81.78	0.00	0.64
House Crow	0.70	0.72	82.50	0.00	1.24
Oriental Magpie-Robin	0.66	0.68	83.18	1.08	0.00
Little Egret	0.65	0.68	83.86	0.00	1.04
Indian Peafowl	0.65	0.67	84.53	1.92	0.00
Small Pratincole	0.65	0.67	85.20	0.00	2.20
Oriental Skylark	0.64	0.66	85.86	0.00	0.84
Paddyfield Pipit	0.60	0.62	86.49	0.00	1.64
Rose-ringed Parakeet	0.60	0.62	87.11	0.17	0.60
White-throated Fantail	0.59	0.61	87.72	0.75	0.28
Goosander	0.57	0.59	88.31	0.00	1.16
Intermediate Egret	0.56	0.58	88.88	0.00	1.52
Indian Silverbill	0.54	0.56	89.44	0.58	0.00
Large-billed Crow	0.53	0.54	89.99	0.58	0.60
Plain Martin	0.50	0.51	90.50	0.00	0.64
Plum-headed Parakeet	0.47	0.49	90.99	1.17	0.16
Gadwall	0.46	0.48	91.47	0.00	0.60
Indian Roller	0.46	0.47	91.94	0.00	0.76
White-throated Kingfisher	0.43	0.44	92.38	0.00	0.60
Small Minivet	0.43	0.44	92.83	0.83	0.00
River Tern	0.40	0.42	93.24	0.00	0.44
Red-breasted Flycatcher	0.40	0.41	93.66	0.75	0.00
Common Tailorbird	0.39	0.40	94.06	0.25	0.20
Pond Heron	0.38	0.39	94.44	0.00	0.56
Red Junglefowl	0.36	0.37	94.82	0.83	0.00
Eurasian Collared-Dove	0.35	0.36	95.18	0.00	0.56
Brahminy Starling	0.32	0.34	95.51	0.00	0.56
Crimson Sunbird	0.32	0.33	95.84	0.58	0.00
Great Tit	0.30	0.31	96.15	0.25	0.00
Temminck Stint	0.29	0.30	96.45	0.00	0.40

White-browed Wagtail	0.28	0.29	96.74	0.00	0.40
Common Stonechat	0.26	0.27	97.01	0.00	0.48
Indian Grey Hornbill	0.25	0.26	97.27	0.33	0.00
Black-bellied Tern	0.24	0.25	97.52	0.00	0.28
Pallas Gull	0.22	0.23	97.75	0.00	0.72
Lesser Goldenback	0.22	0.22	97.97	0.58	0.00
Common Kingfisher	0.20	0.20	98.17	0.00	0.24
Great Egret	0.16	0.17	98.34	0.00	0.16
Bank Myna	0.16	0.17	98.50	0.00	0.12
Greater Coucal	0.15	0.16	98.66	0.33	0.00
Crested Serpent-Eagle	0.14	0.15	98.81	0.00	0.16
Pied Bushchat	0.12	0.12	98.93	0.00	0.12
Cattle Egret	0.12	0.12	99.06	0.00	0.12
Common Greenshank	0.10	0.10	99.16	0.00	0.12
Common Sandpiper	0.10	0.10	99.26	0.00	0.24
Green Bee-eater	0.09	0.09	99.35	0.17	0.00
Brown-headed Barbet	0.09	0.09	99.45	0.17	0.00
Verditer Flycatcher	0.08	0.08	99.52	0.17	0.00
Black-hooded Oriole	0.07	0.07	99.60	0.00	0.12
Little Stint	0.06	0.06	99.66	0.00	0.16
Great Barbet	0.05	0.05	99.70	0.08	0.00
Grey Bushchat	0.04	0.04	99.75	0.08	0.00
Bay-backed Shrike	0.04	0.04	99.79	0.08	0.00
Osprey	0.04	0.04	99.83	0.00	0.04
Common Myna	0.03	0.03	99.86	0.00	0.08
Himalayan Griffon	0.03	0.03	99.90	0.00	0.08
Sirkeer Malkoha	0.02	0.03	99.92	0.00	0.04
Stork-billed Kingfisher	0.02	0.02	99.94	0.00	0.04
Lesser Whistling-Duck	0.02	0.02	99.97	0.00	0.04
Cinereous Vulture	0.02	0.02	99.98	0.00	0.04
Egyptian Vulture	0.01	0.02	100.00	0.00	0.04

Scrub forest and Grassland					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Scrub forest**	**Mean of bird abundance in Grassland**
Red-vented Bulbul	14.15	14.74	14.74	27.60	3.95
Lesser Whitethroat	5.33	5.55	20.29	7.50	0.00
Common Stonechat	5.06	5.27	25.56	0.00	5.48
Red-wattled Lapwing	4.84	5.04	30.60	0.00	6.24
Paddyfield Pipit	4.70	4.89	35.49	0.00	4.57
Greenish Warbler	3.61	3.75	39.24	2.67	0.10
Plain Prinia	3.29	3.43	42.67	5.50	1.19
Oriental White-eye	3.13	3.26	45.93	5.75	0.00
Jungle Babbler	3.13	3.26	49.18	4.67	0.00
Red-whiskered Bulbul	2.96	3.08	52.26	5.42	0.24
Purple Sunbird	2.91	3.03	55.30	4.50	0.00
Spotted Dove	2.54	2.64	57.94	3.08	0.00
River Lapwing	2.43	2.53	60.47	0.00	2.62
White-tailed Stonechat	2.42	2.52	62.99	0.00	2.52
Spangled Drongo	2.42	2.52	65.51	2.58	0.10
Yellow-footed Green-Pigeon	2.24	2.33	67.83	3.75	0.00
Himalayan Bulbul	2.14	2.23	70.06	5.58	0.19
Pied Bushchat	2.13	2.22	72.28	0.00	2.00
Black Drongo	1.77	1.85	74.12	1.50	0.62
Humes Warbler	1.50	1.56	75.69	2.83	0.05
Red-naped Ibis	1.32	1.37	77.06	0.00	2.52
Indian Robin	1.31	1.36	78.42	1.83	0.00
Rufous Treepie	1.28	1.33	79.75	1.67	0.00
Yellow-breasted Greenfinch	1.18	1.23	80.98	0.00	2.62
Ashy Prinia	1.15	1.19	82.17	1.33	0.00
Large-billed Crow	1.10	1.15	83.32	0.58	1.10
Yellow-wattled Lapwing	1.07	1.11	84.43	0.00	0.91
Barn Swallow	0.93	0.97	85.40	0.00	0.95
Indian Peafowl	0.86	0.89	86.30	1.92	0.19
Oriental Magpie-Robin	0.83	0.86	87.16	1.08	0.00
Citrine Wagtail	0.79	0.83	87.99	0.00	0.95
Indian Silverbill	0.79	0.82	88.81	0.58	0.10

Indian Pied Starling	0.71	0.74	89.55	0.00	0.86
Oriental Skylark	0.71	0.74	90.30	0.00	0.57
Indian Roller	0.65	0.68	90.97	0.00	0.81
White-throated Kingfisher	0.56	0.58	91.55	0.00	0.67
Small Minivet	0.53	0.55	92.11	0.83	0.00
White-throated Fantail	0.52	0.54	92.65	0.75	0.19
Red-breasted Flycatcher	0.48	0.50	93.15	0.75	0.00
Red Junglefowl	0.42	0.44	93.59	0.83	0.00
Great Tit	0.41	0.43	94.02	0.25	0.00
Crimson Sunbird	0.39	0.40	94.43	0.58	0.00
Yellow-bellied Prinia	0.38	0.40	94.82	0.00	0.48
Plum-headed Parakeet	0.37	0.38	95.21	1.17	0.00
Common Tailorbird	0.36	0.38	95.58	0.25	0.00
Laughing Dove	0.36	0.37	95.96	0.00	0.43
Indian Grey Hornbill	0.33	0.34	96.30	0.33	0.00
Striated Grassbird	0.30	0.31	96.61	0.00	0.43
Ruddy Shelduck	0.29	0.30	96.91	0.00	0.38
Red Avadavat	0.28	0.30	97.20	0.00	0.29
Sarus Crane	0.28	0.29	97.50	0.00	0.48
Lesser Goldenback	0.25	0.26	97.76	0.58	0.00
Gray Wagtail	0.25	0.26	98.02	0.00	0.33
Brown Rock Chat	0.21	0.21	98.23	0.00	0.19
Greater Coucal	0.18	0.19	98.42	0.33	0.00
Long-tailed Shrike	0.17	0.17	98.59	0.00	0.24
Cattle Egret	0.13	0.14	98.73	0.00	0.19
Tickell's Thrush	0.11	0.12	98.85	0.00	0.14
Green Bee-eater	0.11	0.11	98.96	0.17	0.00
Brown-headed Barbet	0.11	0.11	99.08	0.17	0.00
Common Myna	0.10	0.10	99.18	0.00	0.14
Rose-ringed Parakeet	0.09	0.09	99.27	0.17	0.00
Verditer Flycatcher	0.09	0.09	99.37	0.17	0.00
Common Kingfisher	0.07	0.07	99.44	0.00	0.10
Pied Kingfisher	0.07	0.07	99.52	0.00	0.10
Great Barbet	0.06	0.06	99.57	0.08	0.00
White-rumped Vulture	0.06	0.06	99.63	0.00	0.05
Grey Bushchat	0.05	0.05	99.69	0.08	0.00
Bay-backed Shrike	0.05	0.05	99.74	0.08	0.00
Bronze Drongo	0.05	0.05	99.79	0.00	0.05
Ashy Drongo	0.05	0.05	99.84	0.00	0.05

River Tern	0.05	0.05	99.88	0.00	0.05
Pond Heron	0.04	0.04	99.93	0.00	0.10
Crested Serpent-Eagle	0.04	0.04	99.97	0.00	0.05
Slender-billed Vulture	0.03	0.03	100.00	0.00	0.05

Riverine habitat and Grassland					
Taxon	**Average dissimilarity**	**Contribution %**	**Cumulative %**	**Mean of bird abundance in Riverine**	**Mean of bird abundance in Grassland**
Ruddy Shelduck	10.93	11.51	11.51	24.50	0.38
Little Cormorant	8.34	8.79	20.29	9.12	0.00
Paddyfield Pipit	4.92	5.18	25.47	1.64	4.57
Common Stonechat	4.77	5.03	30.50	0.48	5.48
Red-wattled Lapwing	4.74	4.99	35.49	0.00	6.24
River Lapwing	4.39	4.62	40.11	3.80	2.62
Red-vented Bulbul	3.67	3.87	43.98	1.92	3.95
Barn Swallow	3.67	3.87	47.84	5.92	0.95
Northern Pintail	3.23	3.40	51.24	5.12	0.00
Bar-headed Goose	2.86	3.01	54.25	4.00	0.00
White Wagtail	2.39	2.52	56.77	3.56	0.00
White-tailed Stonechat	2.35	2.47	59.24	0.00	2.52
Citrine Wagtail	2.29	2.41	61.65	2.84	0.95
Pied Bushchat	2.05	2.15	63.80	0.12	2.00
Humes Warbler	2.02	2.13	65.93	2.28	0.05
Plain Prinia	1.39	1.46	67.39	0.20	1.19
Red-naped Ibis	1.32	1.39	68.78	0.00	2.52
Gray Wagtail	1.30	1.37	70.14	1.28	0.33
Oriental Skylark	1.26	1.32	71.47	0.84	0.57
Yellow-breasted Greenfinch	1.19	1.25	72.72	0.00	2.62
Little-ringed Plover	1.19	1.25	73.97	2.76	0.00
Great Cormorant	1.17	1.23	75.20	3.48	0.00
Pied Kingfisher	1.13	1.19	76.39	1.12	0.10
Black Drongo	1.07	1.13	77.52	0.52	0.62
Yellow-wattled Lapwing	1.02	1.07	78.59	0.00	0.91
Indian Roller	1.01	1.07	79.65	0.76	0.81
Large-billed Crow	1.00	1.05	80.70	0.60	1.10

Red-crested Pochard	0.92	0.97	81.67	0.64	0.00
House Crow	0.87	0.91	82.59	1.24	0.00
White-throated Kingfisher	0.84	0.88	83.47	0.60	0.67
Little Egret	0.82	0.86	84.33	1.04	0.00
Rufous Treepie	0.78	0.82	85.15	1.12	0.00
Small Pratincole	0.74	0.78	85.93	2.20	0.00
Indian Pied Starling	0.70	0.73	86.66	0.00	0.86
Rose-ringed Parakeet	0.69	0.73	87.39	0.60	0.00
Goosander	0.69	0.73	88.12	1.16	0.00
Intermediate Egret	0.65	0.68	88.80	1.52	0.00
Plain Martin	0.63	0.66	89.46	0.64	0.00
Gadwall	0.59	0.62	90.08	0.60	0.00
River Tern	0.54	0.57	90.65	0.44	0.05
Pond Heron	0.50	0.52	91.17	0.56	0.10
White-throated Fantail	0.48	0.51	91.68	0.28	0.19
Eurasian Collared-Dove	0.44	0.46	92.15	0.56	0.00
Brahminy Starling	0.40	0.42	92.57	0.56	0.00
Yellow-bellied Prinia	0.38	0.40	92.97	0.00	0.48
Temminck Stint	0.36	0.38	93.35	0.40	0.00
White-browed Wagtail	0.36	0.38	93.72	0.40	0.00
Laughing Dove	0.35	0.37	94.09	0.00	0.43
Greenish Warbler	0.32	0.33	94.43	0.20	0.10
Ashy Prinia	0.31	0.33	94.75	0.28	0.00
Black-bellied Tern	0.31	0.32	95.08	0.28	0.00
Common Kingfisher	0.30	0.32	95.40	0.24	0.10
Striated Grassbird	0.30	0.31	95.71	0.00	0.43
Sarus Crane	0.28	0.30	96.01	0.00	0.48
Cattle Egret	0.28	0.29	96.30	0.12	0.19
Red Avadavat	0.27	0.29	96.59	0.00	0.29
Pallas Gull	0.25	0.27	96.86	0.72	0.00
Bank Myna	0.21	0.22	97.08	0.12	0.00
Crested Serpent-Eagle	0.21	0.22	97.30	0.16	0.05
Great Egret	0.21	0.22	97.52	0.16	0.00
Common Tailorbird	0.20	0.21	97.73	0.20	0.00
Brown Rock Chat	0.20	0.21	97.94	0.00	0.19
Plum-headed Parakeet	0.20	0.21	98.15	0.16	0.00
Red-whiskered Bulbul	0.17	0.18	98.32	0.00	0.24
Long-tailed Shrike	0.16	0.17	98.49	0.00	0.24
Indian Peafowl	0.15	0.16	98.65	0.00	0.19

Himalayan Bulbul	0.13	0.14	98.79	0.00	0.19
Common Myna	0.13	0.14	98.93	0.08	0.14
Common Greenshank	0.13	0.13	99.06	0.12	0.00
Common Sandpiper	0.11	0.12	99.18	0.24	0.00
Tickell's Thrush	0.11	0.12	99.30	0.00	0.14
Indian Silverbill	0.09	0.09	99.39	0.00	0.10
Black-hooded Oriole	0.09	0.09	99.48	0.12	0.00
Little Stint	0.07	0.07	99.55	0.16	0.00
White-rumped Vulture	0.05	0.06	99.61	0.00	0.05
Osprey	0.05	0.05	99.66	0.04	0.00
Bronze Drongo	0.04	0.05	99.71	0.00	0.05
Ashy Drongo	0.04	0.05	99.76	0.00	0.05
Spangled Drongo	0.04	0.04	99.80	0.00	0.10
Himalayan Griffon	0.03	0.04	99.84	0.08	0.00
Slender-billed Vulture	0.03	0.04	99.87	0.00	0.05
Sirkeer Malkoha	0.03	0.03	99.90	0.04	0.00
Stork-billed Kingfisher	0.03	0.03	99.93	0.04	0.00
Lesser Whistling-Duck	0.03	0.03	99.96	0.04	0.00
Cinereous Vulture	0.02	0.02	99.98	0.04	0.00
Egyptian Vulture	0.02	0.02	100.00	0.04	0.00

Association between bird species and habitat structural features

The result of NMDS in the summer season (stress value= 0.184) showed that Black-hooded Oriole and Jungle Babbler were positively associated with areas dominated by trees. The abundance of Baya Weaver was positively associated with tree richness. Black-hooded Oriole and Jungle Babbler were positively associated with areas dominated by trees. Red-vented Bulbul, Spotted Dove and Purple Sunbird were positively associated with shrub richness, shrub abundance, shrub cover, and invasive species. Red-wattled Lapwing and Green Bee-eater were positively associated with areas dominated by bareground and open grassland respectively. Common Myna was associated with leaf litter (Figure 4.1a).

The result of NMDS in the winter season (stress value= 0.136) showed that Spangled Drongo and Black-hooded Oriole were associated with the tree parameters such as tree height. Jungle Babbler was associated with tree variables. Humes Warbler was associated with tree richness. Red-vented Bulbul was associated with invasive species cover. Rose-ringed parakeet was associated with shrub variables. Black Bulbul was associated with open forest areas and forest edges represented by shrubs. Barn Swallow was associated with open areas dominated by herbs and tree species richness. Little cormorant and Ruddy Shelduck were associated to bareground near waterbody (Figure 4.1 b).

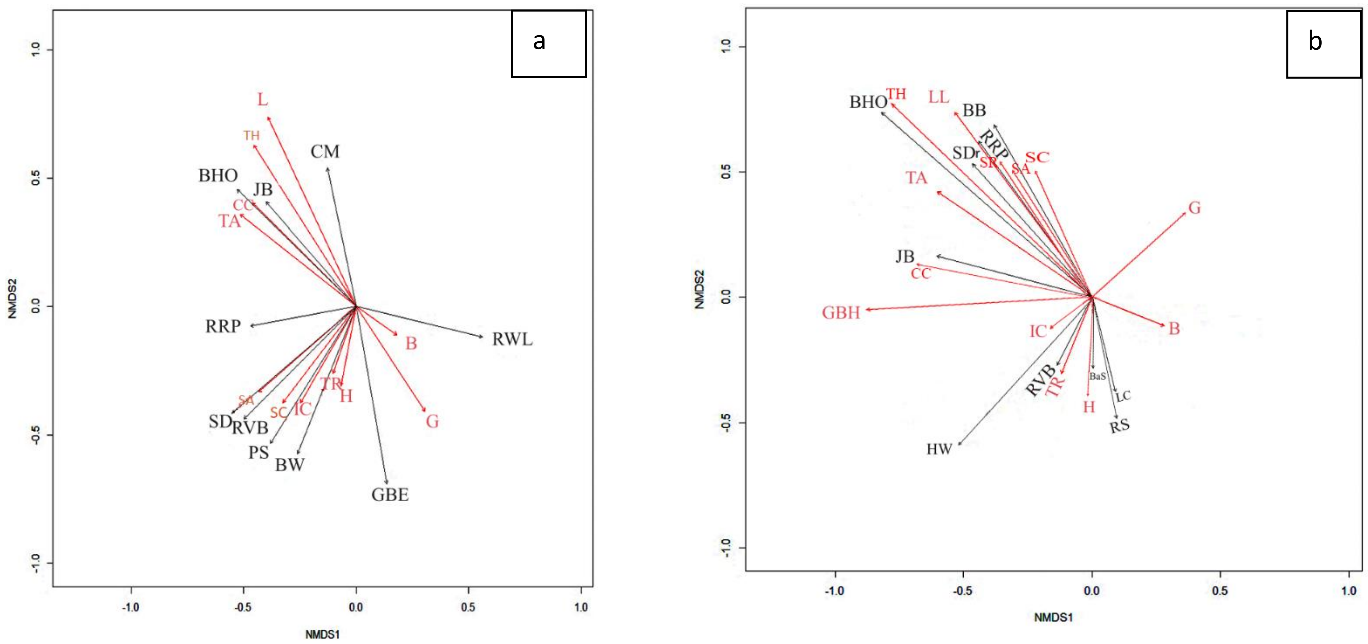


Figure 4.1. NMDS showing association of bird species and vegetation structure variables in (a) summer (b) winter

Vegetation variables: TR=Tree species richness, TA=Tree species abundance, CC=Canopy cover, GBH=Girth at breast height, TH=Tree height, SR=Shrub species richness, SA=Shrub abundance, SC=Shrub Cover, IC=Invasive species cover, H=Herb, G=Grass, B=Bareground, L=Leaf litter.Bird species: CM=Common Myna, JB=Jungle Babbler, BHO=Black-hooded Oriole, RRP=Rose-ringed parakeet, SD=Spotted Dove, RVB=Red-vented Bulbul, PS=Purple Sunbird, BW=Baya Weaver, GBE=Green Bee-eater, HW=Humes Warbler, BB=Black Bulbul, LC=Little Cormorant, RS=Ruddy Shelduck, BaS =Barn Swallow, SDr=Spangled Drongo

4.5. Discussion

JJCR being a small-sized protected area is having a considerable diversity of bird species along the heterogeneous landform gradient. The difference in bird community assemblage between the heterogeneous habitat was also significant. Island biogeography theory by MacArthur and Wilson (1967) illustrated the importance of small areas for biodiversity conservation. Small isolated patches are important for local and regional biodiversity conservation, as they are the only remaining patches within highly human modified landscapes and can be important areas for natural regeneration of modified ecosystems (Lindemeyer, 2019). Mohan (1997) has highlighted the importance of small forests such as New forest campus, Dehradun as hotspots of birds and emphasized on its conservation. The present study has yielded valuable information on the avian community organization in relation to habitat structure in general and overall functioning of the ecosystem in particular. It showed the structural and functional association of birds with different habitats of JJCR. The structural complexity of the habitat types increases the diversity of bird community (Verschuyl et al., 2008; Tu Fan and Ko, 2020). More heterogeneous habitats provide shelter and refuge to many birds and other vertebrates (Seto et al., 2004; Kallimanis et al., 2010; Fjeldsa et al., 2012; Cooke, 2020).

The seasonal difference in bird abundance was quite common in the literature (Neupane et al., 2020; Girma et al., 2017). I found that the seasonal variation in bird species assemblage was mostly attributed by the differed abundance of species like Red-vented Bulbul and Jungle Babbler and the presence of winter visitors such as Ruddy Shelduck and Humes Warbler. The study also revealed the variation of bird community assemblage in JJCR along the different land use land cover. The abundance of different bird species like Baya Weaver, Jungle Babbler, Red-vented Bulbul, Rose-ringed Parakeet etc., in summer season and Red-vented Bulbul, Ruddy Shelduck, Jungle Babbler, Little Cormorant etc., in winter season have contributed to difference in bird community assemblage in different habitats. The result suggested that the generalists' species utilize the entire area of the JJCR irrespective of the habitat type, while habitat specialists are restricted to a particular habitat and not distributed in the entire reserve even though the small size of entire JJCR. The study has further looked into the association of these birds with different habitat variables. The role of habitat, both the physiognomy and the floristics are important for bird species assemblages (Wiens and Rotenberry, 1981; Müller et al., 2010; Rotenberry, 1985). I found the association of different species to particular habitats imparting the difference in bird assemblage along the structural variation of the vegetation cover. Black-hooded Oriole is an upper canopy bird and thus was associated with areas dominated by trees as also evident in other studies (Rajpar and Zakaria, 2011). Humes Warbler is a winter visitor and was associated with tree species richness. During winter it is found in riverine woods and forests, plantations and woodland (Clement, 2020). Black Bulbul and Spangled Drongos were associated with both tree and shrub variables. Black Bulbul and Spangled Drongo were observed in trees and found to be involved in aerial sallies in order to catch insects in open forested patches and forest edges dominated with shrubs. Black Bulbul is a winter visitor and prefers open forests in winter (Fishpool and Tobias, 2020) and Spangled Drongo also prefers open parts of the forest, clearings and forest edges (Rocamora et al., 2020). Rose-ringed Parakeets were found to feed on the flowers of *Helicteres isora* and thus showed association with the shrubs. Association between Rose-ringed Parakeet and *Helicteres isora* plant has also been reported by Manikandan and Kunhikannan (2016). Red-vented Bulbul and Purple Sunbird usually prefer bushes and shrubs. Invasive species are now important determinants of bird species assemblages (Grzędzicka and Reif, 2020). In our study we found that the fruits of invasive species like *Lantana camara* attracts bulbuls (Taneja et al., 2022) and the flowers are visited for nectar by Purple Sunbird. Baya Weaver was associated with tree richness as they were found to involve in nesting activity in particular tree species (*Ziziphus mauritiana*) during the summer season (Sohi and Kler, 2017). Green Bee-eater prefers open areas, so was found to be associated with areas dominated by grass (Wasnik et al., 2014). Barn Swallow prefers open areas and was also reported to be roosting on power lines passing through the mixed forest. Barn Swallows have often been observed roosting on power lines (Medvin and Beecher, 1986; Gorenzel and Salmon, 1994) and need open habitat for foraging (Gorenzel and Salmon, 1994). So it was associated with open areas dominated by herbs and also forested habitat. Jungle Babbler was more associated with areas dominated by trees, possibly because of the presence of more leaf litter in the areas with high canopy cover. Common Myna which is a human commensal (Lim et al., 2003; Hart et al., 2020) was associated with leaf litter probably because it was found in Eucalyptus plantation and other habitats nearby human settlements, which had lot of leaf litter. Red-wattled Lapwing was associated towards herbs and grasses as it is a ground bird (Wiersma and Kirwan, 2020). Little Cormorant and Ruddy Shelduck being waterbirds were associated with bareground near waterbody.

The small protected areas having habitat heterogeneity can harbour good biodiversity of lifeforms irrespective of anthropogenic disturbances. If conservation efforts are only focussed on larger areas and smaller patches are ignored, then the loss of many species in small and isolated patches of remnant habitats will be there and will remain un-noticed (Wintle et al., 2019; Borgelt et al., 2022). The small habitat patches act as stepple stones between two bigger forest patches. Thus, small protected areas should be recognized equally to its large counterparts in present conservation scenarios.

CHAPTER 5

RESOURCE SELECTION FUNCTION OF BIRDS IN DIFFERENT HABITATS

5.1. Introduction

Habitat selection is the preference for a particular habitat among various habitats. It may vary from season to season for individuals or species (Cody, 1985). Habitat selection helps species to co-exist (Rosenzweig, 1981). Habitat selection pattern can be understood through resource selection function (RSF).

Resource selection function (RSF)

RSFs are used to determine which habitat characteristics are important to a specific organism. It requires ‘used’ and ‘available habitat’. Manly et al. (2002) have described RSF as any function that is proportional to the probability of use. RSF can be used to determine distribution, abundance and species diversity (Boyce and McDonald, 1999; Manly et al., 2002; Nielsen et al., 2005, Nielsen et al., 2003). Determining which resources are selected over other helps in getting information about the nature of the animal and its requirements for survival (Manly et al., 2007). Resource selection helps in the co-existence of species (Rosenzweig, 1981).

Understanding habitat structure and its relationship with birds provides insights on habitat use, which contributes in the conservation of species (Cody, 2001; Gillespie and Walter, 2001; Okes et al., 2008; Wood et al., 2013). Habitat structure has both vertical (stratification) and horizontal (spatial) components and these components create ecological niches. Both horizontal and vertical heterogeneity provide habitat for a variety of plant and animal species (Lindenmayer et al., 2000). Vertical segregation helps in maintaining species diversity (Roth, 1976; Robin and Davidar, 2002; Naka, 2004), provides niche partitioning and helps in co-existing of species, thus reducing competition (Gutzwiller et al., 1998; Recher and Davis, 1998; Vieira and Monteiro-Filho, 2003; Walther, 2002; Styring and Zakaria, 2004; Carvalho et al., 2013, Mohd-Azlan et al., 2015). Activity of forest birds is influenced by height of the forests (Miranda and Pasinelli, 2001; Naka, 2003). Vertical stratification thus provides resources and microhabitat for wildlife, especially birds (Pearson, 1971; Whitehurst et al., 2013). Microhabitat is one of the central focus of community ecology (Hilden, 1965; Cody, 1968, 1981, 1985; Wiens, 1969, 1974; James, 1971; Karr, 1971; Anderson and Shugart, 1974; Willson, 1974). It helps in buffering climate, thus reducing animal’s exposure to extreme climate events (Scheffers et al., 2014).

The diverse habitats and microhabitats of forest ecosystems are home to the majority of the world's terrestrial species (Ozanne et al., 2003). But these biologically diverse systems are increasingly threatened by deforestation and forest degradation (Singh et al., 2001; Dirzo and Raven, 2003). Biodiversity conservation is an important goal of forest management (Hunter, 1999; Nakashizuka, 2004). Although biodiversity has broad, multi-dimensional, and multi-scale characteristics, full assessment at a large scale is difficult and extremely expensive (Gaston, 1996; Green et al., 2005). To monitor changes in forest biodiversity, indicators, which are surrogate measures of other components of forest biodiversity, are increasingly used (Boutin et al., 2009). The use and the application of the concept of indicators of biodiversity have been recommended as it is not possible to monitor each and every species (e.g., Beccaloni and Gaston, 1995; Duelli and Obrist, 1998; Cassola and Pearson, 2000; Ranius, 2002; Maleque et al., 2006; Halme et al., 2009). The term ‘indicator species’ can have different interpretations (Butler et al., 2012; Lindenmayer et al., 2000) and selecting suitable indicator species depends on several criteria. Indicator species are sensitive to environmental changes and their abundance in a given area indicates certain environmental conditions (Lindenmayer et al., 2000; Miller et al., 1998; Simberloff, 1998; Thompson et al., 2013). An effective indicator needs to be present in large numbers, be easily recognizable, as well as sensitive to environmental variables (Scoble, 1995; Holloway, 1985). Indicator species are used to assess the efficacy of environmental management, pollution, monitoring forest disturbance and population management (Morrison et al., 2002). Indicator species can also be used for determining the habitat quality of specific vegetation, which relate to specific vegetation types or with particular habitat preference, indicators of habitat degradation. The indicator species can also be habitat specialists. They have been also described as the ecological indicators of community or habitat types or indicators of environmental conditions or environmental changes.

Birds are one of the best-studied taxonomic groups (Roberge and Angelstam, 2006) and they are considered one of the very good indicators of biodiversity as they are present in almost all types of environment and sensitive to any changes. Management of many bird species can be eased by considering only a group of indicator species. Monitoring the status of all species is difficult (Baldi, 2003), so many natural resource managers want to monitor any focal species (Lambeck, 1997) so that the impact of management can be understood. Habitat specialists reflect fast changes in a habitat than generalists and resident species can also be used for year-round monitoring (Hilty and Merenlender, 2000). Resident birds have greater potential to become indicator species than migratory birds because they stay throughout the year and are more vulnerable to changes in the landscape (Imbeau et al., 2001; Schmiegelow and Mo¨nkko¨ nen, 2002) and are considered good indicators of biodiversity. They indicate the biological condition of the environment, thus considered as Ecological Disturbance Indicator Species (EDIS) as they have strong association with their habitat.

The research questions addressed in this chapter are:

(i) What is the resource selection function of birds in different habitats?

(ii) What is the general pattern of bird assemblage in different microhabitats?

(iii) Is there any difference in the bird composition of different vertical strata in different habitats?

(iv) Which are the indicator bird species of different habitats in summer and winter season?

5.2. Methods

Bird sampling

Bird sampling was carried out in each habitat during the summer and winter seasons from March 2018 to March 2020. Point count method (Bibby et al., 2000) was used to count the birds in all habitats. Every point count station was visited 20 times. Birds were counted from 5:30 am to 8:30 am during summer and from 8:00 am to 10:30 am during winter. All birds seen or heard on every point count station during 10 minutes were noted down. Birds seen flying was not included. Surveys were not conducted during inclement weather conditions. Individual birds were identified following field guides Ali and Ripley (1987) and Grimmett et al. (2011).

5.3. Data analysis

Resource selection function index (RSF)

RSF was calculated following Jain and Balakrishnan (2011):

- Proportional use of habitat by species = number of individuals of species found in habitat /total number of individuals of species sampled
- Proportional availability of habitat = average surface area contributed by habitat / total area available (summed across all habitats)
- Resource selection function = Proportion used / Proportion available
- The standardisation is carried out as follows:

$$b_{h,s} = w_{h,s} / \Sigma_{h=1 \text{ to } H}(w_{h,s})$$

for s = 1to S, where S is the total number of species and H is the total number of habitats.

Based on RSF, birds were classified into habitat specialist if bird species were specifically preferring one or two habitats, habitat generalist if they were present in more than two habitats and human commensal i.e. the birds which live in close proximity to human habitation.

Birds were classified based on their perching and feeding height into vertical strata such as upper canopy, middle canopy, lower canopy, understorey and terrestrial. The classification was based on the information given by Ali and Ripley (2001) and supplemented by our field observations. Bird species which were either waterbirds or water-dependent were categorized as ‘aquatic’, while those which are adept in the air were categorized as ‘aerial’. The diversity of different vertical strata was calculated through Shannon diversity. PERMANOVA test (Anderson 2001) was performed to assess the difference in bird species in different strata in different seasons and habitat.

Indicator species analysis was done in R software using the package Indval, which measures the importance of habitat for a particular bird species. It is a non-parametric, intuitive technique to examine the specificity of the use of the habitats by individual species (Jayapal, 2006). The indicator value index is the product of two components, called `A' and `B' (Dufrêne and Legendre, 1997; Cáceres and Legendre, 2009). (1) Component `A' is sample estimate of the probability that the surveyed site belongs to the target site group given the fact that the species has been found. This conditional probability is called the specificity or positive predictive value of the species as indicator of the site group. (2) Component `B' is sample estimate of the probability of finding the species in sites belonging to the site group. This second conditional probability is called the fidelity or sensitivity of the species as indicator of the target site group. 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 the importance of that habitat to the species. Indicator value lies from 0-1, where 1 means 100% indicator of a particular habitat.

5.4. Results

Resource selection function

The proportional availability of plantation, mixed deciduous forest, scrub forest, riverine habitat, grassland and agriculture field-human settlement are 0.39 %, 0.13 %, 0.07 %, 0.18 %, 0.16% and 0.07 % respectively (Figure 5.1).

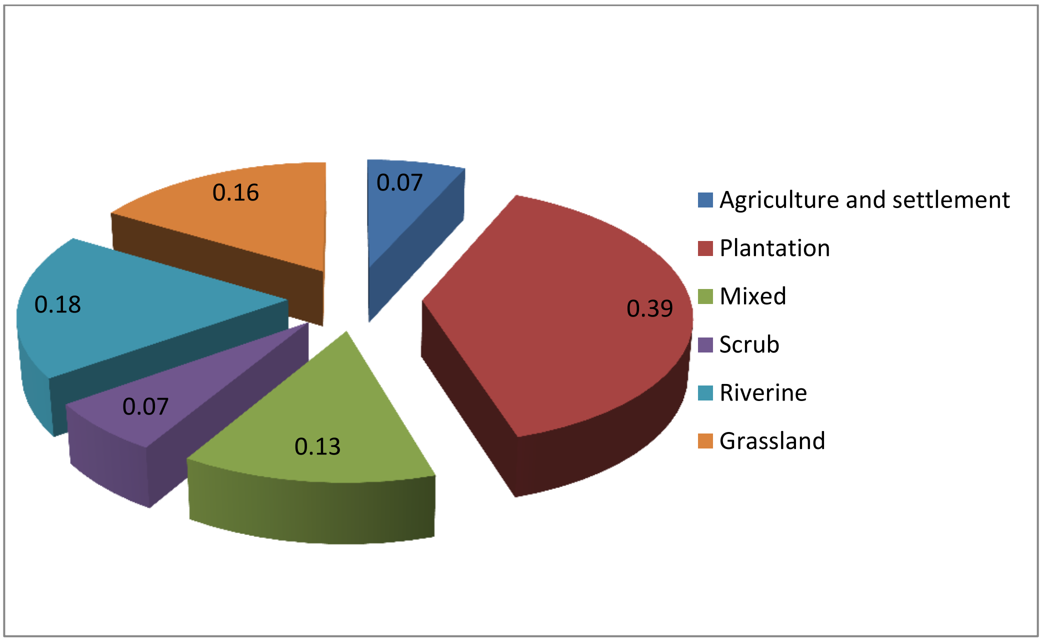


Figure 5.1. Proportional availability (%) of habitats of JJCR

In total, 20 bird species had 100% selection for riverine habitat during summer and 30 bird species during the winter. In grassland 10 and 13 species had 100% RSF during the summer and winter, 4 and 13 bird species had 100 % RSF for plantation in summer and winter respectively. 2 and 6 bird species had 100 % RSF for mixed forest in summer and winter respectively. 10 species had 100% RSF for scrub forest in summer and 7 had 100 % RSF in winter. 2 species had 100% RSF for agriculture field-human settlement in both summer and winter. Riverine habitat had the highest RSF. So, in total 48 bird species had 100% selection for a particular habitat in summer (Table 5.1) and 71 bird species had 100% selection for particular habitat in winter (Table 5.2).

Table 5.1. Resource Selection Function during summer season

Bird species	**Agriculture**	**Grassland**	**Mixed Forest**	**Plantation**	**Riverine**	**Scrub Forest**
Ashy-crowned Sparrow-Lark	0.00	0.00	0.00	0.00	1.00	0.00
Ashy Prinia	0.13	0.26	0.17	0.00	0.14	0.31
Asian Koel	0.21	0.00	0.26	0.12	0.13	0.28
Indian Pied Starling	0.43	0.57	0.00	0.00	0.00	0.00
Barn Swallow	0.00	0.73	0.27	0.00	0.00	0.00
Bay-backed Shrike	0.00	0.00	0.00	0.00	0.00	1.00
Baya Weaver	0.10	0.02	0.76	0.00	0.00	0.12
Black-breasted Weaver	0.00	1.00	0.00	0.00	0.00	0.00
Black-chinned Babbler	0.00	0.00	0.59	0.05	0.00	0.36
Black Drongo	0.00	0.12	0.00	0.33	0.29	0.26
Black Francolin	0.00	0.40	0.00	0.00	0.60	0.00
Black-hooded Oriole	0.00	0.00	0.12	0.83	0.05	0.00
Black Kite	0.00	0.00	0.00	0.00	1.00	0.00
Blue tailed Bee eater	0.00	0.00	0.74	0.00	0.00	0.26
Brahminy Starling	0.00	0.00	0.23	0.00	0.00	0.77
Bristled Grassbird	0.00	1.00	0.00	0.00	0.00	0.00
Brown-headed Barbet	0.00	0.00	0.00	0.83	0.00	0.17
Cattle Egret	0.50	0.10	0.00	0.31	0.08	0.00
Changeable-Hawk Eagle	0.00	0.00	0.00	0.15	0.00	0.85
Chestnut-bellied Nuthatch	0.00	0.00	0.00	0.00	0.00	1.00
Chestnut-shouldered Petronia	0.00	0.00	0.64	0.04	0.03	0.29
Common Cuckoo	0.00	0.00	0.00	1.00	0.00	0.00
Common-Hawk Cuckoo	0.00	0.00	0.47	0.53	0.00	0.00
Common Iora	0.00	0.00	0.38	0.02	0.00	0.60

Common Kingfisher	0.00	0.53	0.00	0.00	0.47	0.00
Common Myna	0.10	0.20	0.00	0.46	0.15	0.09
Common Stonechat	0.00	0.92	0.00	0.00	0.08	0.00
Common Tailorbird	0.00	0.00	0.31	0.02	0.10	0.57
Coppersmith Barbet	0.00	0.00	0.18	0.15	0.00	0.67
Crested Lark	0.00	0.00	0.00	0.00	1.00	0.00
Crested Serpent-Eagle	0.00	0.00	0.67	0.33	0.00	0.00
Drongo Cuckoo	0.00	0.00	0.00	1.00	0.00	0.00
Eurasian Collared-Dove	0.00	0.00	0.35	0.00	0.33	0.32
Great Cormorant	0.00	0.00	0.00	0.00	1.00	0.00
Green Bee-eater	0.08	0.09	0.08	0.00	0.24	0.50
Grey-bellied Cuckoo	0.00	0.69	0.00	0.00	0.31	0.00
Grey-breasted Prinia	0.00	0.00	0.47	0.03	0.00	0.51
Grey Bushchat	0.28	0.72	0.00	0.00	0.00	0.00
Grey Francolin	0.00	0.36	0.00	0.00	0.64	0.00
Grey Heron	0.00	0.00	0.00	0.00	1.00	0.00
Grey-hooded Warbler	0.00	0.00	0.00	1.00	0.00	0.00
Gray Wagtail	0.00	0.00	0.00	0.00	1.00	0.00
Himalayan Griffon	0.00	0.00	0.00	0.00	0.00	1.00
House Crow	0.39	0.10	0.00	0.00	0.51	0.00
House Sparrow	1.00	0.00	0.00	0.00	0.00	0.00
Indian Cuckoo	0.13	0.00	0.22	0.38	0.00	0.27
Indian Grey Hornbill	0.00	0.00	0.38	0.45	0.17	0.00
Indian Paradise- Flycatcher	0.00	0.00	0.28	0.72	0.00	0.00
Indian Peafowl	0.00	0.03	0.47	0.02	0.00	0.48
Indian Pitta	0.00	0.00	0.45	0.34	0.00	0.21
Indian Robin	0.00	0.00	0.00	0.00	0.03	0.97
Indian Roller	0.00	0.02	0.30	0.11	0.35	0.22
Intermediate Egret	0.00	0.00	0.00	0.00	1.00	0.00
Pied Cuckoo	0.00	0.00	0.00	0.00	0.00	1.00
Jungle Babbler	0.00	0.00	0.41	0.32	0.00	0.26
Jungle Myna	0.00	0.00	1.00	0.00	0.00	0.00
Jungle Owlet	0.00	0.00	0.00	1.00	0.00	0.00
Large-billed Crow	0.00	0.16	0.15	0.03	0.66	0.00
Laughing Dove	0.00	0.23	0.00	0.00	0.00	0.77
Lesser Goldenback	0.00	0.00	0.00	0.19	0.00	0.81
Lesser Whitethroat	0.00	0.00	0.00	0.00	0.00	1.00
Little Cormorant	0.00	0.00	0.00	0.00	1.00	0.00
Little Egret	0.00	0.00	0.00	0.00	1.00	0.00
Little-ringed Plover	0.00	0.00	0.00	0.00	1.00	0.00
Little Tern	0.00	0.00	0.00	0.00	1.00	0.00
Long-tailed Shrike	0.00	0.00	0.00	0.00	0.00	1.00

Oriental Honey- buzzard	0.00	0.00	1.00	0.00	0.00	0.00
Oriental Magpie-Robin	0.00	0.03	0.19	0.31	0.05	0.42
Oriental Skylark	0.00	0.89	0.00	0.00	0.11	0.00
Oriental White-eye	0.00	0.00	0.38	0.13	0.00	0.49
Paddyfield Pipit	0.00	0.99	0.00	0.00	0.01	0.00
Pale-billed Flowerpecker	0.00	0.00	0.00	0.00	0.00	1.00
Pied Bushchat	0.39	0.55	0.00	0.00	0.00	0.06
Pied Kingfisher	0.00	0.00	0.00	0.00	1.00	0.00
Plain Prinia	0.15	0.35	0.00	0.04	0.08	0.39
Plum-headed Parakeet	0.00	0.00	0.57	0.00	0.00	0.43
Pond Heron	0.94	0.00	0.00	0.00	0.06	0.00
Purple Sunbird	0.00	0.01	0.20	0.07	0.10	0.62
Red Junglefowl	0.00	0.00	0.63	0.06	0.00	0.31
Red-naped Ibis	0.00	0.00	0.00	0.00	1.00	0.00
Red-vented Bulbul	0.18	0.07	0.28	0.08	0.04	0.36
Red-wattled Lapwing	0.08	0.69	0.00	0.00	0.24	0.00
Red-whiskered Bulbul	0.14	0.10	0.29	0.11	0.00	0.36
Blyth’s Reed Warbler	0.00	0.00	0.00	0.00	1.00	0.00
River Lapwing	0.00	0.05	0.00	0.00	0.95	0.00
River Tern	0.00	0.00	0.00	0.00	1.00	0.00
Rock Pigeon	1.00	0.00	0.00	0.00	0.00	0.00
Rose-ringed Parakeet	0.13	0.00	0.65	0.19	0.00	0.03
Ruddy Shelduck	0.00	0.00	0.00	0.00	1.00	0.00
Rufous Treepie	0.28	0.00	0.49	0.23	0.00	0.00
Sarus Crane	0.46	0.00	0.00	0.00	0.54	0.00
Shikra	0.00	0.00	0.00	0.42	0.00	0.58
Short-toed Snake-Eagle	0.00	1.00	0.00	0.00	0.00	0.00
Small Minivet	0.00	0.00	0.34	0.04	0.00	0.63
Small Pratincole	0.00	0.00	0.00	0.00	1.00	0.00
Indian Spot-billed Duck	0.00	0.00	0.00	0.00	1.00	0.00
Spotted Dove	0.09	0.01	0.23	0.08	0.04	0.55
Streak-throated Woodpecker	0.00	0.00	0.00	0.00	0.00	1.00
Striated Babbler	0.00	1.00	0.00	0.00	0.00	0.00
Striated Grassbird	0.00	1.00	0.00	0.00	0.00	0.00
Tawny-bellied Babbler	0.00	0.00	0.00	0.00	0.00	1.00
White-bellied Drongo	0.00	0.00	0.00	0.13	0.87	0.00
White-browed Wagtail	0.00	0.00	0.00	0.00	1.00	0.00
White-eyed Buzzard	0.00	0.00	0.00	0.00	0.00	1.00
White-tailed Stonechat	0.00	1.00	0.00	0.00	0.00	0.00
White-throated Kingfisher	0.00	0.45	0.00	0.07	0.48	0.00
White Wagtail	0.00	0.00	0.00	0.00	1.00	0.00
Yellow-bellied Prinia	0.00	1.00	0.00	0.00	0.00	0.00

Yellow-wattled Lapwing	0.00	1.00	0.00	0.00	0.00	0.00
Zitting Cisticola	0.00	1.00	0.00	0.00	0.00	0.00

Table 5.2. Resource selection function during winter season

Bird species	Agriculture	Grassland	mixed Forest	Plantation	Riverine	Scrub forest
Ashy Drongo	0.00	1.00	0.00	0.00	0.00	0.00
Ashy Prinia	0.00	0.00	0.03	0.00	0.14	0.83
Asian Brown Flycatcher	0.00	0.00	0.86	0.14	0.00	0.00
Indian Pied Starling	0.00	1.00	0.00	0.00	0.00	0.00
Bank Myna	0.00	0.00	0.00	0.00	1.00	0.00
Bar-headed Goose	0.00	0.00	0.00	0.00	1.00	0.00
Barn Swallow	0.00	0.06	0.54	0.00	0.40	0.00
Bay-backed Shrike	0.00	0.00	0.00	0.00	0.00	1.00
Black-bellied Tern	0.00	0.00	0.00	0.00	1.00	0.00
Black Bulbul	0.00	0.00	0.00	1.00	0.00	0.00
Black Drongo	0.00	0.14	0.04	0.23	0.13	0.46
Black-hooded Oriole	0.00	0.00	0.36	0.62	0.03	0.00
Black-naped Monarch	0.00	0.00	0.00	1.00	0.00	0.00
Brahminy Starling	0.00	0.00	0.00	0.00	1.00	0.00
Bronze Drongo	0.00	1.00	0.00	0.00	0.00	0.00
Brown-headed Barbet	0.00	0.00	0.22	0.37	0.00	0.41
Brown Rock Chat	0.53	0.47	0.00	0.00	0.00	0.00
Cattle Egret	0.94	0.04	0.00	0.00	0.03	0.00
Chestnut-bellied Rockthrush	0.00	0.00	0.00	1.00	0.00	0.00
Cinereous Vulture	0.00	0.00	0.00	0.00	1.00	0.00
Citrine Wagtail	0.00	0.24	0.00	0.00	0.76	0.00
Common Greenshank	0.00	0.00	0.00	0.00	1.00	0.00
Common Kingfisher	0.00	0.27	0.00	0.00	0.73	0.00
Common Myna	0.35	0.05	0.00	0.57	0.03	0.00
Common Sandpiper	0.00	0.00	0.00	0.00	1.00	0.00
Common Stonechat	0.00	0.92	0.00	0.00	0.08	0.00
Common Tailorbird	0.30	0.00	0.33	0.00	0.15	0.23
Crested Serpent-Eagle	0.00	0.09	0.34	0.23	0.33	0.00
Crimson Sunbird	0.00	0.00	0.41	0.00	0.00	0.59

Egyptian Vulture	0.00	0.00	0.00	0.00	1.00	0.00
Eurasian Collared-Dove	0.00	0.00	0.00	0.00	1.00	0.00
Eurasian Sparrowhawk	0.00	0.00	1.00	0.00	0.00	0.00
Gadwall	0.00	0.00	0.00	0.00	1.00	0.00
Golden-fronted Leafbird	0.00	0.00	1.00	0.00	0.00	0.00
Goosander	0.00	0.00	0.00	0.00	1.00	0.00
Great Barbet	0.00	0.00	0.00	0.00	0.00	1.00
Great Cormorant	0.00	0.00	0.00	0.00	1.00	0.00
Great Egret	0.00	0.00	0.00	0.00	1.00	0.00
Great Tit	0.00	0.00	0.46	0.37	0.00	0.17
Greater Coucal	0.20	0.00	0.00	0.00	0.00	0.80
Green Bee-eater	0.00	0.00	0.71	0.10	0.00	0.19
Greenish Warbler	0.00	0.02	0.10	0.24	0.04	0.61
Grey Bushchat	0.00	0.00	0.00	0.00	0.00	1.00
Grey-headed Canary-Flycatcher	0.00	0.00	0.00	1.00	0.00	0.00
Grey-hooded Warbler	0.00	0.00	1.00	0.00	0.00	0.00
Gray Wagtail	0.52	0.09	0.00	0.00	0.38	0.00
Himalayan Bulbul	0.00	0.02	0.11	0.13	0.00	0.74
Himalayan Griffon	0.00	0.00	0.00	0.00	1.00	0.00
House Crow	0.25	0.00	0.00	0.37	0.38	0.00
House Sparrow	1.00	0.00	0.00	0.00	0.00	0.00
Humes Warbler	0.01	0.00	0.25	0.22	0.20	0.31
Indian Grey Hornbill	0.00	0.00	0.78	0.00	0.00	0.22
Indian Peafowl	0.00	0.05	0.30	0.00	0.00	0.65
Indian Robin	0.00	0.00	0.00	0.00	0.00	1.00
Indian Roller	0.00	0.50	0.00	0.01	0.49	0.00
Indian Silverbill	0.00	0.11	0.00	0.00	0.00	0.89
Intermediate Egret	0.00	0.00	0.00	0.00	1.00	0.00
Jungle Babbler	0.05	0.00	0.26	0.25	0.00	0.44
Jungle Owlet	0.00	0.00	0.27	0.73	0.00	0.00
Large-billed Crow	0.00	0.23	0.11	0.38	0.13	0.16
Laughing Dove	0.00	1.00	0.00	0.00	0.00	0.00
Lemon-rumped Warbler	0.00	0.00	0.00	1.00	0.00	0.00
Lesser Goldenback	0.00	0.00	0.00	0.25	0.00	0.75
Lesser Whistling Duck	0.00	0.00	0.00	0.00	1.00	0.00
Lesser Whitethroat	0.00	0.00	0.23	0.00	0.00	0.77
Little Cormorant	0.00	0.00	0.00	0.00	1.00	0.00
Little Egret	0.00	0.00	0.00	0.00	1.00	0.00
Little-ringed Plover	0.00	0.00	0.00	0.00	1.00	0.00
Little Stint	0.00	0.00	0.00	0.00	1.00	0.00
Long-tailed Shrike	0.00	1.00	0.00	0.00	0.00	0.00
Maroon Oriole	0.00	0.00	0.00	1.00	0.00	0.00

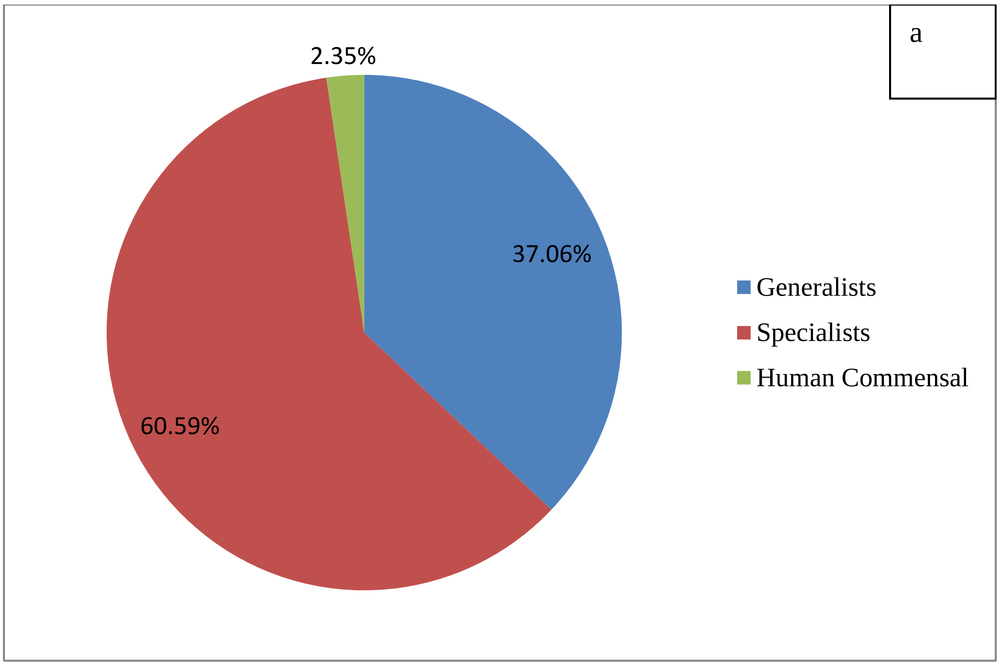
Northern Pintail	0.00	0.00	0.00	0.00	1.00	0.00
Oriental Magpie-Robin	0.00	0.00	0.34	0.15	0.00	0.51
Oriental Pied hornbill	0.00	0.00	1.00	0.00	0.00	0.00
Oriental Skylark	0.00	0.39	0.00	0.00	0.61	0.00
Oriental White-eye	0.00	0.00	0.42	0.02	0.00	0.57
Osprey	0.00	0.00	0.00	0.00	1.00	0.00
Paddyfield Pipit	0.00	0.72	0.00	0.00	0.28	0.00
Pallas Gull	0.00	0.00	0.00	0.00	1.00	0.00
Pied Bushchat	0.40	0.56	0.00	0.00	0.04	0.00
Pied Kingfisher	0.00	0.07	0.00	0.00	0.93	0.00
Plain Martin	0.00	0.00	0.00	0.00	1.00	0.00
Plain Prinia	0.07	0.13	0.02	0.00	0.02	0.76
Plum-headed Parakeet	0.00	0.00	0.45	0.10	0.05	0.41
Pond Heron	0.45	0.07	0.00	0.07	0.41	0.00
Purple Sunbird	0.00	0.00	0.28	0.01	0.00	0.71
Red Avadavat	0.00	1.00	0.00	0.00	0.00	0.00
Red breasted Flycatcher	0.00	0.00	0.37	0.00	0.00	0.63
Red-crested Pochardr	0.00	0.00	0.00	0.00	1.00	0.00
Red Junglefowl	0.00	0.00	0.65	0.00	0.00	0.35
Red-naped Ibis	0.00	0.51	0.00	0.49	0.00	0.00
Red-vented Bulbul	0.03	0.07	0.21	0.04	0.03	0.61
Red-wattled Lapwing	0.09	0.89	0.00	0.02	0.00	0.00
Red-whiskered Bulbul	0.10	0.02	0.35	0.00	0.00	0.54
River Lapwing	0.00	0.39	0.00	0.00	0.61	0.00
River Tern	0.00	0.09	0.00	0.00	0.91	0.00
Rock Pigeon	1.00	0.00	0.00	0.00	0.00	0.00
Rose-ringed Parakeet	0.25	0.00	0.23	0.42	0.08	0.03
Ruddy Shelduck	0.01	0.01	0.00	0.00	0.98	0.00
Rufous-gorgeted Flycatcher	0.00	0.00	1.00	0.00	0.00	0.00
Rufous Treepie	0.11	0.00	0.27	0.16	0.16	0.30
Rusty-cheeked Scimitar-Babbler	0.00	0.00	0.00	1.00	0.00	0.00
Sarus Crane	0.48	0.52	0.00	0.00	0.00	0.00
Shikra	0.00	0.00	0.00	1.00	0.00	0.00
Sirkeer Malkoha	0.00	0.00	0.00	0.00	1.00	0.00
Slender-billed Vulture	0.00	0.00	0.00	0.00	1.00	0.00
Small Minivet	0.00	0.00	0.00	0.00	0.00	1.00
Small Niltava	0.00	0.00	1.00	0.00	0.00	0.00
Small Pratincole	0.00	0.00	0.00	0.00	1.00	0.00
Spangled Drongo	0.00	0.01	0.11	0.46	0.00	0.42
Spotted Dove	0.36	0.00	0.08	0.04	0.00	0.52
Stork-billed Kingfisher	0.00	0.00	0.00	0.00	1.00	0.00
Striated Grassbird	0.00	1.00	0.00	0.00	0.00	0.00

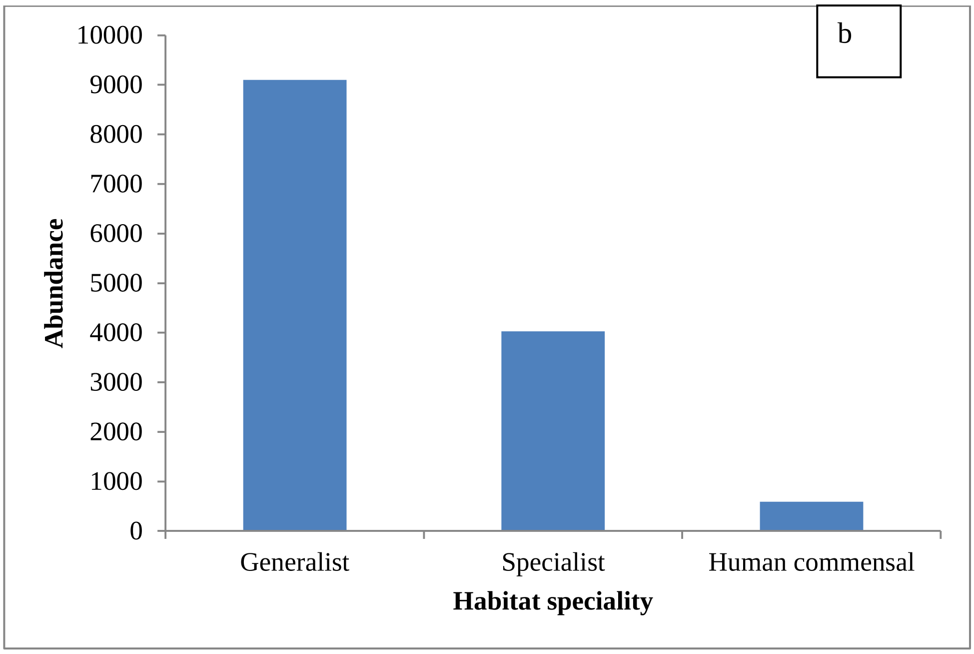
Taiga Flycatcher	0.00	0.00	0.00	1.00	0.00	0.00
Temminck Stint	0.00	0.00	0.00	0.00	1.00	0.00
Thick-billed Flowerpecker	0.00	0.00	0.00	1.00	0.00	0.00
Tickell's Blue Flycatcher	0.00	0.00	0.00	1.00	0.00	0.00
Tickell's Thrush	0.00	1.00	0.00	0.00	0.00	0.00
Velvet-fronted Nuthatch	0.00	0.00	0.00	1.00	0.00	0.00
Verditer Flycatcher	0.00	0.00	0.00	0.00	0.00	1.00
White-browed Wagtail	0.00	0.00	0.00	0.00	1.00	0.00
White-rumped Vulture	0.00	1.00	0.00	0.00	0.00	0.00
White-tailed Stonechat	0.00	1.00	0.00	0.00	0.00	0.00
White-throated Fantail	0.00	0.09	0.05	0.26	0.14	0.46
White-throated Kingfisher	0.00	0.51	0.00	0.00	0.49	0.00
White Wagtail	0.00	0.00	0.00	0.03	0.97	0.00
Woolly-necked Stork	0.00	0.00	0.00	1.00	0.00	0.00
Yellow-bellied Prinia	0.00	1.00	0.00	0.00	0.00	0.00
Yellow-footed Green-Pigeon	0.00	0.00	0.00	0.00	0.00	1.00
Yellow-wattled Lapwing	0.00	1.00	0.00	0.00	0.00	0.00
Yellow-breasted Greenfinch	0.00	1.00	0.00	0.00	0.00	0.00

Birds were grouped into specialist or generalist based on their sighting in a particular habitat or multiple habitats (Figure 5.2a). It was found that there are more habitat specialists (103) than generalists (63) in JJCR. There were 4 commensals. The abundance of generalist birds are more than habitat specialists (Figure 5.2b). Some of the most abundant generalist birds in JJCR are Baya Weaver, Jungle Babbler, Red-vented Bulbul, Rose-ringed Parakeet and Spotted Dove. House Crow, Rock Pigeon, House Sparrow and Common Myna are human commensals. Riverine habitat supported the maximum number of habitat specialists (Figure 5.2c).

Several birds in Jhilmil Jheel CR are habitat specialists or near habitat specialists, found more or less restricted to their habitats, making the conservation of each habitat vital to the long-term sustenance of the IBA. JJCR has many grassland birds such as Common Stonechat, White-tailed Stonechat, Red avadavat, Zitting Cisticola, Sarus Crane, Yellow-bellied Prinia, Bristled Grassbird and Striated Grassbird. Among these White-tailed Stonechat, Yellow-bellied Prinia, Striated Grassbird and Bristled Grassbird are considered as grassland bird specialist. Bristled Grassbird and Sarus Crane are vulnerable. It has been stated that JJCR can be a possible site for the introduction of Swamp Francolin in this place as the wet grasslands surrounded by sugarcane fields can provide a suitable site for it (Rahmani et al., 2016). Some notable waterbirds are River Lapwing, River Tern, Black-bellied Tern, Little Tern while some water dependent birds are Pied Kingfisher, Stork-billed Kingfisher, Great Thick-knee. River Lapwing and River Tern are near threatened. Black-bellied Tern is endangered. Some of the prominent scrub habitat specialists are Black Francolin and Grey Francolin. In plantations of Eucalyptus and Teak, few birds favouring open woodland habitats were more frequent such as Black-hooded Oriole and Black Bulbul. Prominent bird species of mixed deciduous forests are Red Junglefowl and Indian Grey Hornbill. Sarus Cranes is one of the notable species found in agricultural fields.

The general pattern of usage of different strata of tree canopy and other microhabitats by various bird species of JJCR was documented. The middle canopy formed the maximum percentage of foraging strata followed by aquatic, understory, terrestrial, lower canopy, upper canopy and aerial (Figure 5.3 a). The middle canopy also had the highest bird diversity (Table 5.3b). Middle canopy had the maximum number of bird species in agricultural field-human settlement, mixed deciduous forest, plantation and scrub forest while terrestrial birds were more speciose in grassland and aquatic birds in riverine habitat (Figure 5.4 a, b, c, d, e, f). Red-vented Bulbuls dominated the middle canopy, Spotted Doves dominated the lower canopy, Baya Weavers dominated the terrestrial, Jungle Babblers were the most abundant birds in the understorey, and Black-hooded Orioles dominated the upper canopy. Barn Swallow was the most abundant aerial bird whereas Ruddy Shelduck was the most abundant aquatic bird.





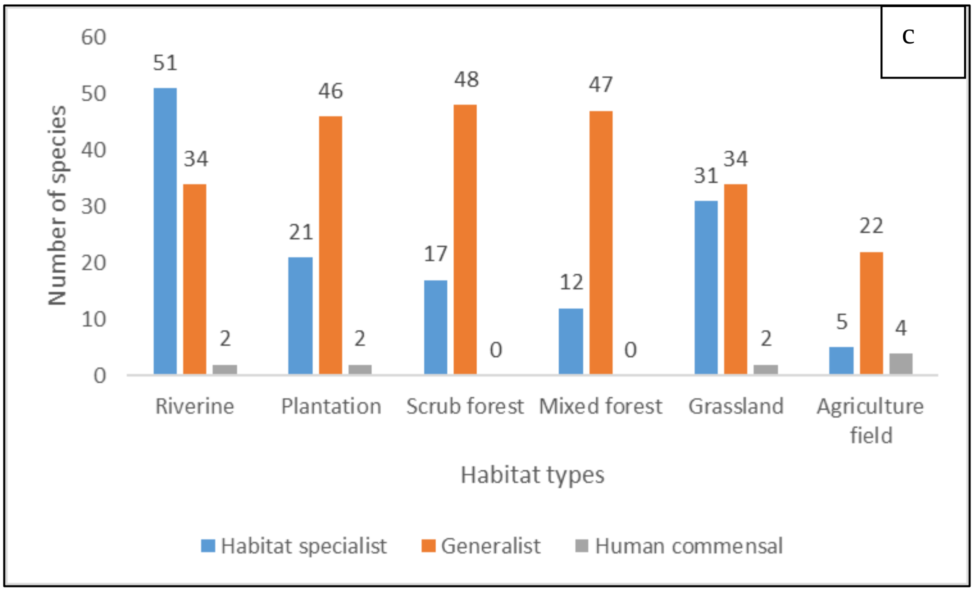


Figure 5.2. (a) Proportion (%) of Specialist-Generalist birds species in JJCR (b) Abundance of habitat specialist-generalist birds species in JJCR(c) Number of habitat specialist-generalist in every habitat

PERMANOVA result showed a significant difference in bird composition in different vertical strata in different seasons (p=0.0001). The bird composition significantly differed across vertical strata in different habitats in the summer (p=0.0001) and winter seasons (p=0.0001).

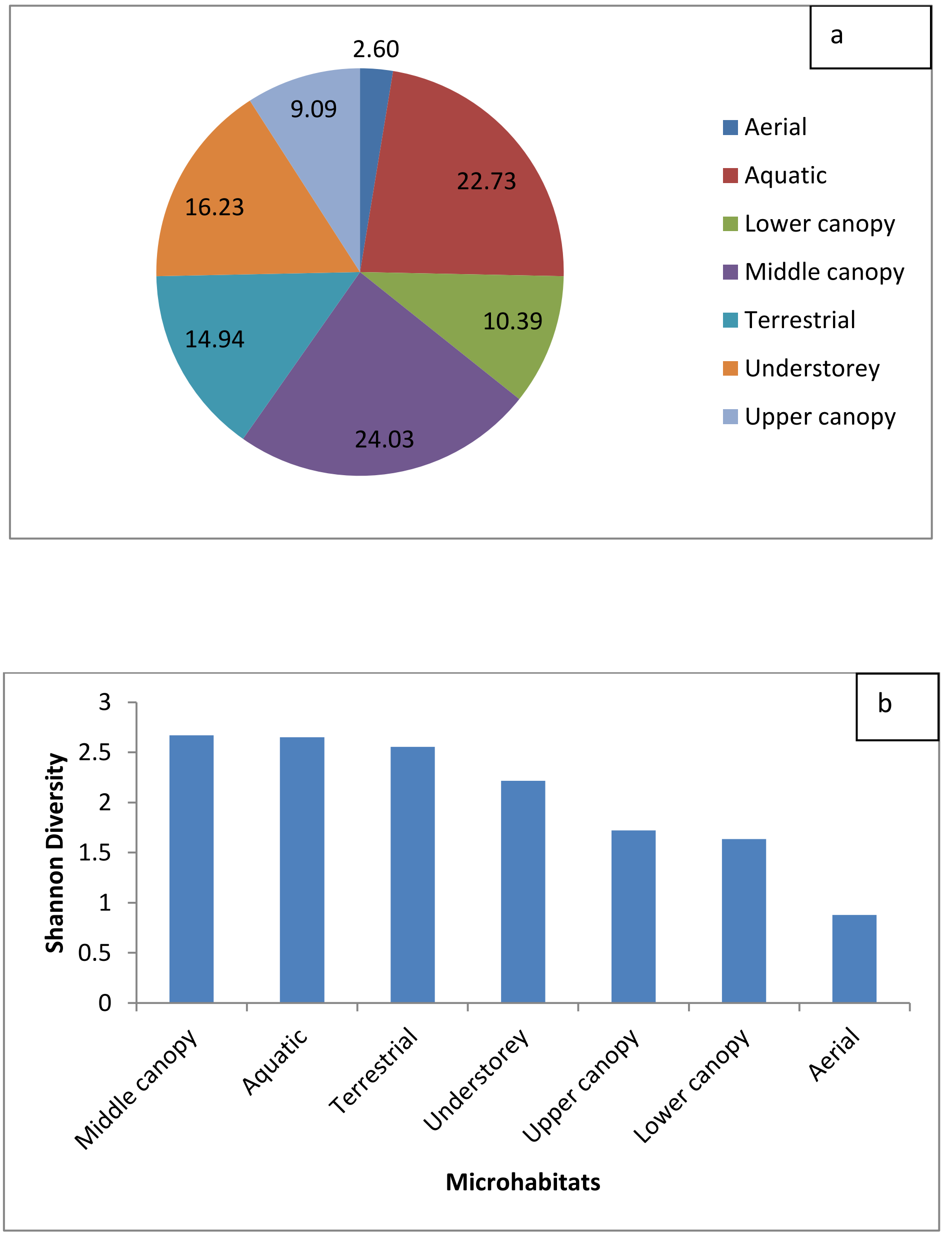
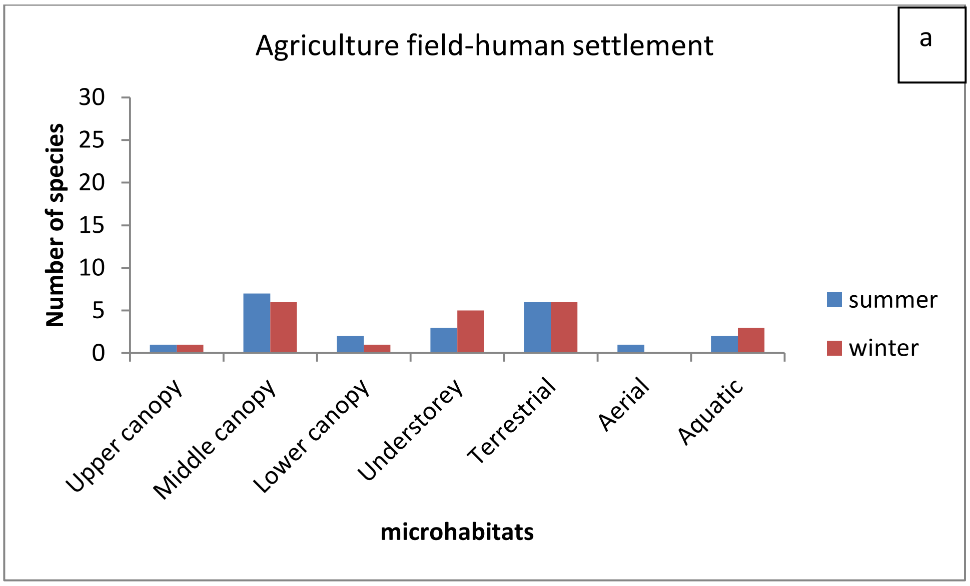
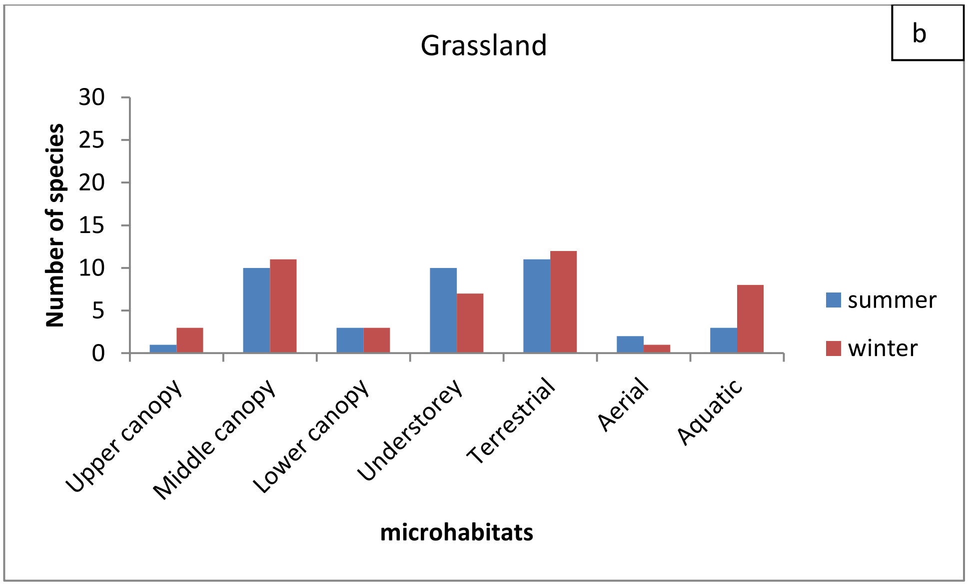
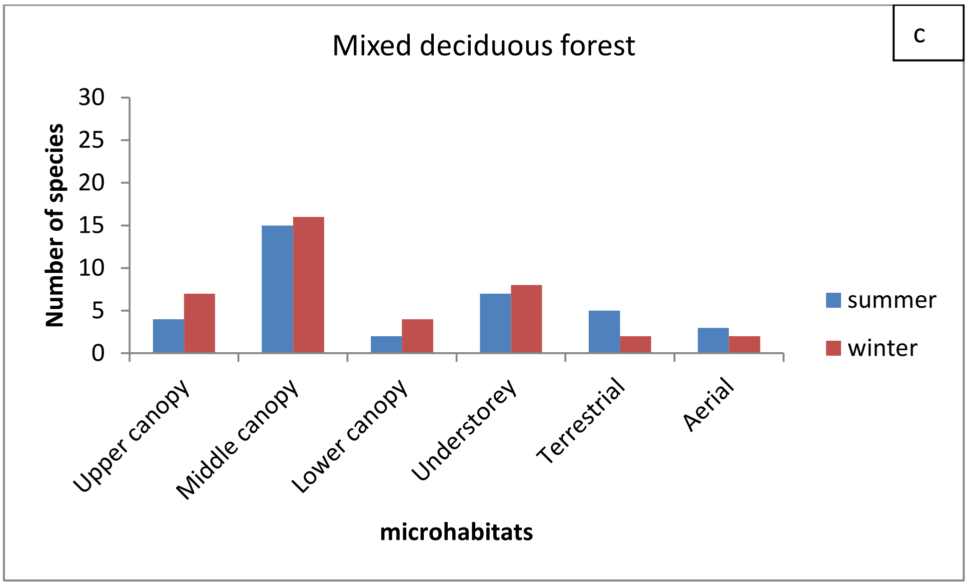


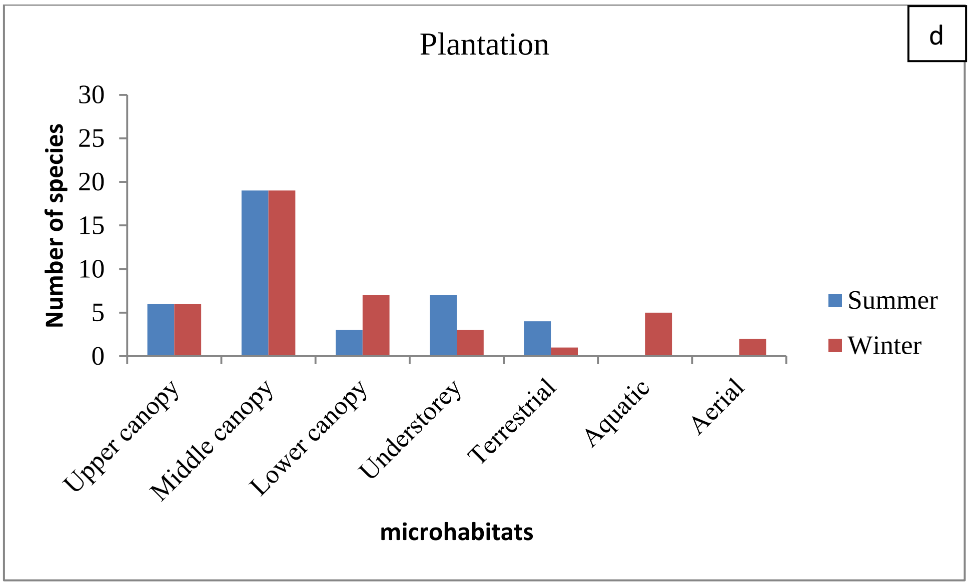
Figure 5.3. (a) Species encountered (%) in different microhabitats (b) Shannon diversity of birds in different microhabitats


Agriculture field-human settlement
a
Number of species
30
25
20
15
10
5
0
Upper canopy
Middle canopy
Lower canopy
Understorey
Terrestrial
Aerial
Aquatic
microhabitats
summer
winter

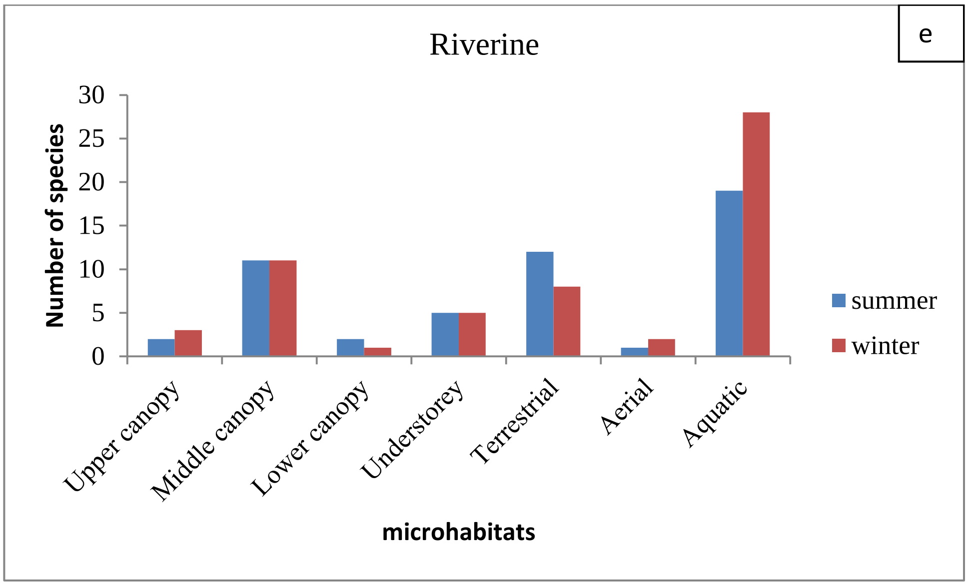

Grassland
b
Number of species
30
25
20
15
10
5
0
Upper canopy
Middle canopy
Lower canopy
Understorey
Terrestrial
Aerial
Aquatic
microhabitats
summer
winter



c
Mixed deciduous forest
Number of species
30
25
20
15
10
5
0
Upper canopy
Middle canopy
Lower canopy
Understorey
Terrestrial
Aerial
microhabitats
summer
winter



d
Plantation
Number of species
30
25
20
15
10
5
0
Upper canopy
Middle canopy
Lower canopy
Understorey
Terrestrial
Aquatic
Aerial
microhabitats
Summer
Winter



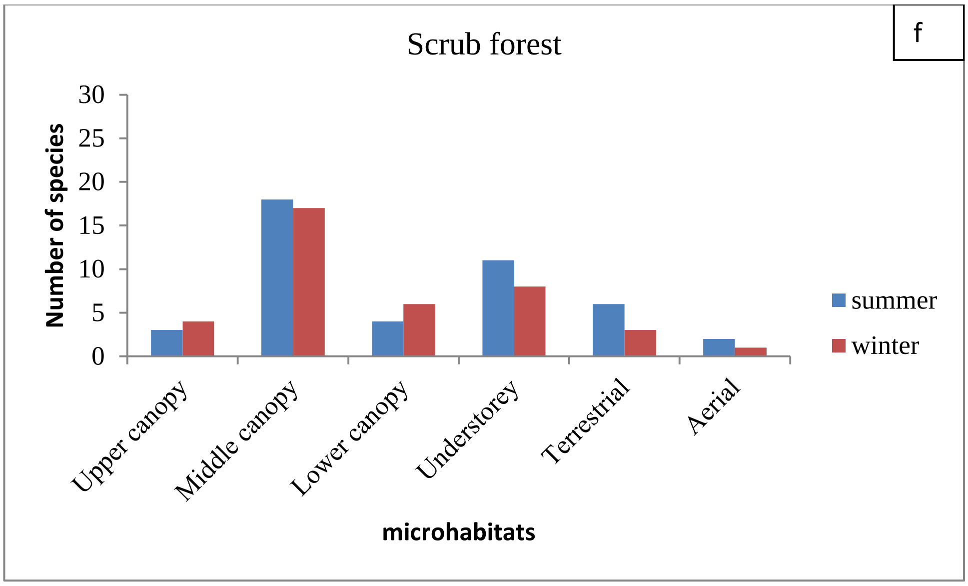


Figure 5.4. Vertical strata in every habitat (a) Agriculture fields-human settlements (b) Grassland (c) Mixed deciduous forest (d) Plantation (e) Riverine habitat (f) Scrub forest

Indicator values of all bird species were computed for every habitat type and those species with statistically significant values ($P < 0.001$) were considered as suitable indicators for a particular habitat. High indicator values reflect high species abundance and prevalence within a landcover type (Hayes, 2020). In summer season out of 110 species, 60 species were identified as indicator species. Grassland had 11 indicator species, mixed deciduous forest-12, Plantation-12, Riverine habitat-15, Agriculture field-human settlement had 3 indicator species and scrub forest had 7 indicator species (Table 5.3). In winter season out of 131 species, 64 species were identified as indicator species. Grassland had 10 indicator species, plantation-12, riverine-16, riverine-16, agriculture field-human settlement-3, mixed and scrub forest had 7 and 16 indicator species respectively (Table 5.4).

Habitat-wise detailed description has been given as follows:

Agriculture field and human settlement: Rock Pigeon and House Sparrow were significantly associated with agriculture and human settlement in both seasons. Rock Pigeon had the highest indicator value (57%) during summer whereas Cattle Egret had the highest indicator value (64.9%) during winter.

Grassland: Paddyfield Pipit, Common Stonechat, Red-wattled Lapwing, Pied Buschat, Yellow-bellied Prinia were strongly associated with grasslands in summer. Species such as Common Stonechat, Red-wattled Lapwing, Paddyfield Pipit and White-tailed Stonechat were strongly associated with grassland during winter season. Paddyfield Pipit had the highest indicator value (96.9%) in summer whereas Common Stonechat had the highest indicator value of 88.8% during winter.

Mixed deciduous forest: Baya Weaver, Red Junglefowl, Rose-ringed Parakeet, Black-chinned Babbler, Indian Peafowl, Blue-tailed Bee-eater, Chestnut-shouldered Petronia were strongly associated with mixed deciduous forest during summer while Red Junglefowl, Oriental White-eye and Indian Grey Hornbill were strongly associated during winter season. Baya Weaver had the highest Indicator value (91.4%) during summer and Red Junglefowl had the highest indicator value of 70% during winter.

Riverine habitat: River Lapwing, River Tern, Little Egret and Little Cormorant had strong association during summer and birds namely Little Cormorant, White Wagtail, Citrine Wagtail and Pied Kingfisher have strong association during winter season. River Lapwing had the highest indicator value 93.1% during summer season and Little Cormorant had the highest indicator value of 77.5% during winter.

Plantation: Black-hooded Oriole, Indian Paradise-Flycatcher, Oriental Magpie-Robin and Indian Pitta had strong association with plantation during summer while Black-hooded Oriole, Black Bulbul, Rose-ringed Parakeet, Taiga Flycatcher, Spangled Drongo had strong association during winter season. Black-hooded Oriole had strong association with the plantation with an indicator value of 92.8% and 81.9% during summer and winter respectively.

Scrub forest: Indian Robin, Purple Sunbird, Spotted Dove and Green Bee-eater were strongly associated with scrub forest during summer while Lesser Whitethroat, Indian Robin, Plain Prinia, Spotted Dove and Purple Sunbird were strongly associated during winter season. Indian Robin had the highest indicator value (75%) during summer season and Lesser whitethroat had highest indicator value of 83.5% during winter season.

Table 5.3. Indicator bird species in different habitats in summer season

Agriculture and settlement	A	B	Indicator value	p.value	Significance codes
Rock Pigeon	1	0.3333	0.577	0.0002	***
House Sparrow	1	0.2667	0.516	0.0006	***
Pond Heron	0.9091	0.2	0.426	0.0075	**
Grassland	A	B	Indicator value	p.value	
Paddyfield Pipit	0.9868	0.9524	0.969	0.0001	***
Common Stonechat	0.9237	0.619	0.756	0.0001	***
Red-wattled Lapwing	0.7163	0.7619	0.739	0.0001	***
Pied Bushchat	0.6593	0.6667	0.663	0.0001	***
Yellow-bellied Prinia	1	0.381	0.617	0.0001	***
Oriental Skylark	0.8972	0.3333	0.547	0.0001	***
Striated Grassbird	1	0.2381	0.488	0.0015	**
Zitting Cisticola	1	0.2381	0.488	0.0015	**
Striated Babbler	1	0.1429	0.378	0.0162	*
Yellow-wattled Lapwing	1	0.1429	0.378	0.0128	*
Grey Bushchat	0.8108	0.1429	0.34	0.0453	*
Mixed deciduous forest					
	A	B	Indicator value	p.value	Significance codes
Baya Weaver	0.8347	1	0.914	0.0001	***
Red Junglefowl	0.6767	0.9333	0.795	0.0001	***
Rose-ringed Parakeet	0.6235	0.9333	0.763	0.0001	***
Black-chinned Babbler	0.6486	0.8	0.72	0.0001	***
Indian Peafowl	0.5469	0.8	0.661	0.0001	***
Blue-tailed Bee-eater	0.8077	0.5333	0.656	0.0001	***
Chestnut-shouldered Petronia	0.6893	0.5333	0.606	0.0001	***
Red-vented Bulbul	0.3347	1	0.578	0.0003	***
Rufous Treepie	0.4802	0.4667	0.473	0.0051	**
Oriental White-eye	0.4158	0.4667	0.44	0.017	*
Grey-breasted Prinia	0.5499	0.3333	0.428	0.0081	**
Jungle Myna	1	0.1333	0.365	0.0447	*
Plantation					

	A	B	Indicator value	p.value	Significance codes
Black-hooded Oriole	0.8928	0.9643	0.928	0.0001	***
Indian Paradise-Flycatcher	0.8069	0.6786	0.74	0.0001	***
Oriental Magpie-Robin	0.4737	0.8571	0.637	0.0001	***
Indian Pitta	0.4856	0.8214	0.632	0.0001	***
Common Myna	0.6393	0.5357	0.585	0.0006	***
Jungle Babbler	0.4683	0.6071	0.533	0.002	**
Brown-headed Barbet	0.9205	0.2857	0.513	0.0018	**
Black Drongo	0.5058	0.5	0.503	0.002	**
Common Hawk-Cuckoo	0.641	0.3571	0.478	0.0032	**
Indian Grey Hornbill	0.5855	0.3571	0.457	0.0059	**
Jungle Owlet	1	0.1786	0.423	0.0068	**
Indian Cuckoo	0.5687	0.25	0.377	0.032	*
Riverine					
	A	B	Indicator value	p.value	Significance codes
River Lapwing	0.942	0.92	0.931	0.0001	***
River Tern	1	0.64	0.8	0.0001	***
Little Egret	1	0.6	0.775	0.0001	***
Little Cormorant	1	0.52	0.721	0.0001	***
House Crow	0.5904	0.6	0.595	0.0004	***
Spot-billed Duck	1	0.24	0.49	0.0007	***
Little-ringed Plover	1	0.2	0.447	0.0036	**
Ruddy Shelduck	1	0.2	0.447	0.0024	**
White-browed Wagtail	1	0.2	0.447	0.0048	**
Pied Kingfisher	1	0.16	0.4	0.0121	*
White-bellied Drongo	0.7706	0.2	0.393	0.0156	*
Large-billed Crow	0.622	0.24	0.386	0.0293	*
Grey Heron	1	0.12	0.346	0.0377	*
Gray Wagtail	1	0.12	0.346	0.0432	*
Small Pratincole	1	0.12	0.346	0.0408	*
Scrub forest					
	A	B	Indicator value	p.value	Significance codes
Indian Robin	0.96	0.58	0.75	0.0001	***
Purple Sunbird	0.5079	1.00	0.713	0.0001	***
Spotted Dove	0.4453	1.00	0.667	0.0001	***

Green Bee-eater	0.4531	0.9167	0.645	0.0001	***
Common Tailorbird	0.4693	0.6667	0.559	0.0003	***
Common Iora	0.4966	0.5833	0.538	0.0005	***
Laughing Dove	0.7241	0.25	0.425	0.0059	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table 5.4. Indicator bird species in different habitats in winter season

Agriculture and settlement					
	A	B	Indicator value	p.value	Significance codes
Cattle Egret	0.9023	0.4667	0.649	0.0001	***
House Sparrow	1	0.3333	0.577	0.0001	***
Rock Pigeon	1	0.2	0.447	0.0047	**
Grassland					
	A	B	Indicator value	p.value	Significance codes
Common Stonechat	0.9194	0.8571	0.888	0.0001	***
Red-wattled Lapwing	0.901	0.7619	0.829	0.0001	***
Paddyfield Pipit	0.736	0.9048	0.816	0.0001	***
White-tailed Stonechat	1	0.619	0.787	0.0001	***
Pied Bushchat	0.6696	0.4762	0.565	0.0002	***
Indian Roller	0.5043	0.381	0.438	0.0105	*
Indian Pied Starling	1	0.1905	0.436	0.0035	**
White-throated Kingfisher	0.5263	0.3333	0.419	0.0124	*
Yellow-bellied Prinia	1	0.1429	0.378	0.0142	*
Yellow-wattled Lapwing	1	0.1429	0.378	0.0198	*
Mixed deciduous forest					
	A	B	Indicator value	p.value	Significance codes
Red Junglefowl	0.7368	0.6667	0.701	0.0001	***
Oriental White-eye	0.5021	0.8667	0.66	0.0002	***
Indian Grey Hornbill	0.8438	0.4667	0.627	0.0001	***
Red-whiskered Bulbul	0.4462	0.6667	0.545	0.0009	***
Humes Warbler	0.2558	0.8667	0.471	0.0258	*
Plum-headed Parakeet	0.4866	0.3333	0.403	0.0252	*
Crimson Sunbird	0.507	0.2667	0.368	0.0308	*
Plantation					

	A	B	Indicator value	p.value	Significance codes
Black-hooded Oriole	0.7231	0.9286	0.819	0.0001	***
Black Bulbul	1	0.5357	0.732	0.0001	***
Rose-ringed Parakeet	0.6016	0.7143	0.656	0.0002	***
Taiga Flycatcher	1	0.4286	0.655	0.0001	***
Spangled Drongo	0.6497	0.6429	0.646	0.0001	***
Common Myna	0.7851	0.3214	0.502	0.0017	**
Grey-headed Canary Flycatcher	1	0.2143	0.463	0.0027	**
Jungle Owlet	0.8108	0.25	0.45	0.0043	**
White-throated Fantail	0.4334	0.4643	0.449	0.01	**
Large-billed Crow	0.5384	0.3571	0.438	0.0224	*
Jungle Babbler	0.4063	0.4643	0.434	0.0304	*
House Crow	0.5744	0.3214	0.43	0.0251	*
Riverine					
	A	B	Indicator value	p.value	Significance codes
Little Cormorant	1	0.6	0.775	0.0001	***
White Wagtail	0.9522	0.6	0.756	0.0001	***
Citrine Wagtail	0.7489	0.68	0.714	0.0001	***
Pied Kingfisher	0.9216	0.52	0.692	0.0001	***
Ruddy Shelduck	0.9795	0.32	0.56	0.0009	***
River Lapwing	0.592	0.52	0.555	0.0016	**
Gray Wagtail	0.466	0.48	0.473	0.0066	**
Eurasian Collared-Dove	1	0.2	0.447	0.0045	**
Temminck Stint	1	0.2	0.447	0.0047	**
White-browed Wagtail	1	0.2	0.447	0.0031	**
Brahminy Starling	1	0.16	0.4	0.0162	*
Goosander	1	0.16	0.4	0.0143	*
Little Egret	1	0.16	0.4	0.0149	*
Little-ringed Plover	1	0.16	0.4	0.0128	*
Red-crested Pochard	1	0.16	0.4	0.0139	*
River Tern	0.9023	0.16	0.38	0.021	*
Scrub forest					
	A	B	Indicator value	p.value	Significance codes
Lesser Whitethroat	0.6966	1	0.835	0.0001	***
Indian Robin	1	0.5833	0.764	0.0001	***
Plain Prinia	0.7343	0.75	0.742	0.0001	***

Spotted Dove	0.5063	0.8333	0.65	0.0001	***
Purple Sunbird	0.6187	0.6667	0.642	0.0001	***
Small Minivet	1	0.3333	0.577	0.0001	***
Ashy Prinia	0.7937	0.4167	0.575	0.0001	***
Red-vented Bulbul	0.5178	0.5833	0.55	0.0263	*
Greenish Warbler	0.463	0.5833	0.52	0.0021	**
Yellow-footed Green-Pigeon	1	0.25	0.5	0.0009	***
Indian Silverbill	0.8596	0.25	0.464	0.0022	**
Oriental Magpie-Robin	0.3736	0.5	0.432	0.0193	*
Indian Peafowl	0.5571	0.3333	0.431	0.0103	*
Red-breasted Flycatcher	0.5294	0.3333	0.42	0.0103	*
Lesser Goldenback	0.5568	0.25	0.373	0.0438	*
Greater Coucal	0.8333	0.1667	0.373	0.0186	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

5.5. Discussion

I have provided here a quantitative demonstration of habitat selection in the natural assemblage of bird species using resource selection function based on proportional use and availability. Using RSF I found 48 bird species had 100% selection for a particular habitat in summer and 71 bird species had 100% selection for particular habitat in winter. There is more RSF in winter because of the presence of many winter visitors. The riverine habitat had the highest RSF possibly because of the presence of many microhabitats and attracting many winter waterbirds. As, within the bird community, some are generalist and some are specialist to specific habitat, more number of habitat specialist bird species could be because of habitat heterogeneity (Surasinghe and Alwis, 2010), while generalist birds were more abundant as they can adapt to a variety of environmental conditions and utilize a variety of resources.

JJCR is rich in bird species and vertical stratification is possibly one of the key factors for promoting diversity and the underlying concept has also been stated in other studies on stratification by Bernard (2001), Molleman et al., (2006) and Oliveira and Scheffers (2019). Vertical stratification has been associated with major shifts in biotic communities, emphasizing the great variety of niches and high species co-existence possible in tropical forests at small scales (Brown, 1981; Mottl et al., 2020; Scheffers et al., 2017). It is also important to determine the most important strata that are used by the forest bird community (Peh et al., 2006). The middle canopy had the highest proportion of bird species in JJCR. This is also supported by other studies (Jayson and Mathew, 2003; Dinanti et al., 2018). Upper canopy had the lowest number of bird species as compared to other vertical strata which could be due to unfavourable conditions i.e. physical (rain, wind, heat) and biological factors (predators), and is energetically adverse for behaviours like feeding, breeding, or roosting (Turton and Siegenthaler, 2004).

There was seasonal variation in birds of different vertical strata possibly because of the arrival of many summer and winter visitors in their respective seasons.

The indicator bird species also represented birds belonging to various strata of the forests, i.e. upper canopy, middle canopy, lower canopy, understory, terrestrial and aquatic. The bird species namely Paddyfield Pipit, Red-wattled Lapwing Common Stonechat, White-tailed Stonechat and Yellow-bellied Prinia showed strong association with the grassland habitat as indicator species. Paddyfield Pipit, Red-wattled Lapwing (Manakadan, 2014), Common Stonechat, Yellow-bellied Prinia (Madge et al., 2020) commonly found in grasslands and White-tailed Stonechat is obligate grassland bird (Baral, 2001; Baral, 2004; Roberts, 1992). They can be monitored for understanding the effect of management in grasslands. Subtropical grasslands in Indian subcontinent are of international significance for biodiversity (Collar, 1996; Peet et al., 1999) and regarded as the most threatened habitat in Indian subcontinent and many grassland birds are also threatened (Baral et al., 1996; Grimmett et al., 1998). Lesser White throat, Indian Robin, Purple Sunbird were identified as indicator species of scrub forest in JJCR. Lesser White throat (Aymí et al., 2021), Indian Robin (Collar and Bonan, 2020), Purple Sunbird (Cheke and Mann, 2020) are usually found in scrub habitats and thus can be monitored easily. Black-hooded Oriole, Black Bulbul, Indian Paradise-Flycatcher were obtained as indicator species in plantations in JJCR. Black-hooded Oriole (Walther and Jones, 2020), Indian Paradise-Flycatcher (Moeliker et al., 2020) are found in plantations and can be used to monitor this habitat. House Sparrow and Rock Pigeon were reported as the indicator species of agriculture and human settlements in JJCR. House Sparrow and Rock pigeon are human commensal and thus can be easily seen in and nearby human settlements (Leveau and Leveau, 2016). The lack of forest birds in agricultural fields and human settlements could be attributed to pesticide usage, chemical fertilizers, incompatible agricultural practices, and semi-natural habitats. Rising levels of pesticides in agriculture fields have negative impacts on invertebrate population which in turn leads to decline of farmland bird population (Boatman et al., 2004; Hallman et al., 2014; Stanton et al., 2018). Unfriendly agricultural practices pose threats to many forest-dependent birds (Naidoo, 2004). Some of the factors responsible for degradation in agriculture fields are changing in cropping species and pattern, reduction in prey abundance, removal of semi natural habitats etc. (Sundar and Kittur, 2013; Redhead et al., 2018). Forest specialist birds are sensitive to monoculture agricultural lands and changes in vegetation characteristics can impact bird assemblages (Maas et al., 2009; Schulze and Riedl, 2008). The intensification of agriculture and its expansion is threat to biodiversity (Foley et al., 2005; Laurance et al., 2013). There has been long history of disturbance in mixed deciduous forests of Shiwalik region. Forests in these regions are under pressure from an influx of people, expanding human habitation, lopping, grazing (Gautam et al., 2016). Baya Weaver, Red Junglefowl and Indian Grey Hornbill can be used as indicator species for monitoring Mixed deciduous forest. Baya Weaver were seen to be involved in nesting in these forests. Moreover, the high indicator value of Red Junglefowl (Palei et al., 2016) and Indian Grey Hornbill (Balasubramanian et al., 2005) within deciduous forests is not surprising, given that they are typically found within this habitat. Among the indicator bird species from riverine habitat River Lapwing and River Tern are species of conservation concern. River Lapwing is a near threatened and River Tern is vulnerable.

Our results provide a starting point for selecting which species to monitor and also the current study states the importance of vertical stratification as the ability of species to respond to canopy characteristics may, therefore, be useful in predicting the effects of forest management on bird communities (Hinsley et al., 2009). Such studies are useful in the broader context of increasing anthropogenic pressure on tropical ecosystems and calls for action to prevent biodiversity loss (Barlow et al., 2018). Monitoring the spatial and temporal changes of biodiversity is one of the prerequisites for effective integration of biodiversity conservation in forest management planning. JJCR is rich in bird species, including habitat specialists and threatened bird species. All the habitats were explored for potential ecological indicators for determining a baseline for future monitoring of habitats using bird species. This study demonstrates a significant link between the bird species and the habitat. The indicator bird species including the threatened and habitat specialists have definite preferences for a particular habitat. All the habitats including plantations have their own relevance for birds. Understanding the link between indicator species and habitat is important for habitat management. Potential indicator species reflects the on–site ecological conditions. The analysis is based on data from six habitats representing different vegetation composition, so the determined indicator species can be used as bio-indicators for future monitoring of the management of every habitat. Management recommendations can be issued based on the status of indicator species.

CHAPTER 6

BIRD CO-OCCURRENCE IN DIFFERENT HABITATS

6.1. Introduction

Species assemblages are formed due to species interaction (Cadotte and Tucker, 2017). Species interaction helps in shaping avian communities and understanding interaction helps in land management (MacKenzie et al,. 2004, Halme et al. 2009). Co-occurrence models help in estimating co-occurrence patterns of multispecies at a site, it also helps in detecting changes in the occupancy of one species in response to the presence of another (Estevo et al., 2017). Species co-occurrence results from niche overlap, intra and interspecific competition (Grinde and Niemi, 2016), mutualism, predation (Chase et al., 2002) and facilitative interactions (Bruno et al., 2003).

Competition has been considered one of the major drivers of species co-occurrence (Wisz et al., 2013). Competition is higher between sympatric species (Estevo et al., 2017). Habitat partitioning also influences species co-occurrence. Habitat partitioning has been seen in various sympatric taxa such as birds (Laiolo, 2013), mammals (Jones et al., 2001) and reptiles (Buckley, 2005). Some species co-occur depending on time partitioning and habitat selection. Habitat heterogeneity increases bird diversity (Tews et al., 2004) whereas habitat homogeneity increases the density of a stronger competitor and decreases subordinate species occurrence (Steen et al., 2014). Estevo et al., (2017) stated that habitat characteristics could play major role in co-existence of species. Basile et al. (2021) showed that species can prefer different habitats according to the presence and abundance of co-occurring and associated species.

Currently, many statistical techniques have been developed to study whether species are found together less often (negative co-occurrence; segregation) or more often (positive co-occurrence; aggregation) than predicted by random chance (Dormann et al., 2018). Non-random patterns of species co-occurrence are the basis of community (Tulloch et al., 2018). Positive co-occurrence results from similar habitat requirements and mutual interaction between species. Negative co-occurrence results from dissimilar habitat requirements and antagonistic behaviour. MacKenzie et al. (2004), Halme et al. (2009) also mentioned that positive and negative interaction between species happens because of selecting or avoiding similar habitats. Various studies have reported random species pairwise co-occurrences (Pitta et al., 2012; Lyons et al., 2016; Kohli et al., 2018).

Bird co-occurrence network provides a framework to understand complexity of co-occurrence pattern and can improve bird conservation (Kim et al., 2017). Network theory is a new approach in many fields. Network analysis also helps to understand co-existence, stability of species and coevolutionary process (Bascompte and Jordano, 2007). Mutualistic network is considered as the architecture of biodiversity (Bascompte and Jordano, 2007). Co-occurrence network analysis can also predict the loss of number of species. Co-existence theory states that a species positively associated with a lost species, might also decline as they share the same habitat. A species might increase in the absence of other species if both have negative interaction with each other. Tylianakis and Morris (2017) stated that environmental factors might affect the structure of the network as it affects the frequency with which species interact. One can better understand local processes drive group-level properties by representing community as network of interactions (Bascompte, 2007; Farine and Whitehead, 2015; Tylianakis and Morris, 2017). Species interact with each other and this interaction forms community structure (Montaño-Centellas, 2020; CaraDonna et al., 2017). Network theory provides framework to study communities by considering species composition and interaction (Montaño-Centellas, 2020). Interspecific interactions link species within communities and generate community structure (CaraDonna et al. 2017).

Changes in the co-occurrence structure indicate changes in environmental conditions (Araújo et al., 2011). Reduced number of links or loss of co-occurrence has been found in sites affected with anthropogenic disturbance as compared to less disturbed sites (Kay et al., 2018; Tulloch et al., 2018). It is also used to predict the response of species to different management practices. Tylianakis et al. (2010) mentioned that loss of positive co-occurrences might decline the ecological functions of ecosystem. Species co-existence is sensitive to changes in environment and community composition (Tulloch et al., 2018). Basile et al. (2021) stated that species co-occurrence could affect the habitat use of species and the species association can mitigate the effect of management intensity on forest birds. Bird conservation at the local level should also be strongly recommended, as careful attention to bird habitat may improve the efficiency of conservation efforts (Kim et al., 2017).

Research questions addressed in this chapter are

(i) What is the co-occurrence pattern of birds in different seasons?

(ii) What is the network complexity of birds community in different habitats?

6.2. Methods

The bird sampling was carried out from March 2018 to March 2020 based on point count method following Bibby et al. (2000) to collect abundance data of birds in all available habitat types. We executed habitat-wise point count (Bibby et al. 2000) to collect abundance data of birds covering plantation (28), mixed forest (15), scrub forest (12), riverine (25) and grassland (21) and agriculture fields-human settlement (15). Each point count station was spatially separated from adjacent points by 200 m). Birds were counted from 5:30 am to 8:30 am during summer and from 8:00 am to 10:30 am during winter season. The bird counts survey lasted for 10 minutes on each point count station. All the direct sightings and indirect signs such as calls of the birds were recorded. Birds in flight were not taken into consideration. Each sampling point was visited ten times in summer (March-June) and winter (November-February). Survey was specifically conducted during low-moderate wind days and days with no rain to avoid these variable’s effect on species detection (O’ Connor and Hicks, 1980). Bird species were identified following Ali and Ripley (1987) and Grimmett et al. (2011).

6.3. Data analysis

The statistical analysis involved i) evaluating the co-occurrence pattern of birds in different seasons (ii) assessing the network complexity of birds community in different habitats.

Bird species co-occurrence was done using *cooccur* package (Griffith et al., 2016) in R (R Core Team, 2020). Birds association with other co-occurring birds were determined. Network analysis was done to assess the network complexity of birds community in different habitats using *igraph* package (Csardi et al., 2016) in R (R Core Team, 2020). Species network analysis was used to compare the complexity of the bird communities among the six habitat types.

6.4. Results

Species co-occurrence in different seasons

Generalist species had the highest number of positive associations. Specialist species had the maximum number of negative associations in both seasons.

In summer, birds having more than 30 sightings i.e. 32 species were used for the anal ysis. Of 496 species pair combinations, no pair was removed from the analysis becau se the expected co-occurrence was > 1 and 496 pairs were analysed. The co-occur an alysis revealed 278 non-random associations between species. Of these 153 were pos itive associations, 125 were negative. There were 218 random associations (Figure 6. 1a). Purple Sunbird, Jungle Babbler and Indian Pitta had the highest number of positi ve interaction. Those with highest number of negative associations were Red-wattled Lapwing, Paddyfield Pipit and River Lapwing.

Grassland specialists such as Paddyfield Pipit had positive associations with Pied Bushchat, Red- wattled Lapwing, Common Stonechat and Plain Prinia. Red-wattled Lapwing had positive association with River Lapwing, River Tern, Common Stonechat and Green Bee-eater. River Lapwing, a riverine specialist was positively associated with River Tern, Green Bee-eater, Red-wattled Lapwing and House Crow.

River Tern was positively associated with Green Bee-eater, River Lapwing, Red-wattled Lapwing and House Crow. Little Egret had positive association with Green Bee-eater. Common Stonechat had positive association with Red-wattled Lapwing, Pied Bushchat and Paddyfield Pipit.

In winter, birds with more than 30 sightings i.e 35 species were used for analysis (Fig ure. 6.1b). Of 595 species pair combinations, one pair (0.17 %) were removed from the analysis because the expected co-occurrence was < 1 and 594 pairs were analysed .The co-occur analysis revealed 275 non-random associations between species. Of these, 146 were positive associations, 129 were negative. There were 319 random associations. Oriental Magpie Robin had the highest number of positive association. Those with the highest number of negative associations were Paddyfield Pipit,Citrine Wagtail and Common Stonechat.

River Lapwing was positively associated with Little Cormorant, White-tailed Stonechat, White wagtail, Ruddy Shelduck and Indian Roller. Little Cormorant was positively associated with River Lapwing and White Wagtail. Paddyfield Pipit had positive association with Common Stonechat, River Lapwing, Pied Bushchat, Red wattled Lapwing, White-tailed Stonechat, Indian Roller. Common Stonechat had positive association with River Lapwing, Pied Bushchat, Red-wattled Lapwing, White-tailed Stonechat, Indian Roller. Citrine Wagtail had positive association with Gray Wagtail, River Lapwing, Little Cormorant, White Wagtail, Ruddy Shelduck and Indian Roller.

Network complexity in different habitats

The 6 types of habitats are different in terms of network complexity (Figure 6.2). Riverine and scrub forest had the highest bird community complexity followed by plantation, mixed forest and grassland. Agriculture had no significant association between bird species. Spotted Dove, Common Iora, Rufous Treepie, Red-whiskered Bulbul, Jungle Babbler, Oriental Magpie-Robin, Greenish Warbler, Red Junglefowl and Black-hooded Oriole had significant association in mixed deciduous forest. In scrub forest, species which showed significant association are Greenish Warbler, Oriental White- eye, Jungle Babbler, Chestnut-shouldered Petronia, Red-whiskered Bulbul, Humes Warbler, Red vented Bulbul, Plain Prinia, Spangled Drongo, Red Junglefowl, Black Drongo, Himalayan Bulbul, Rufous Treepie, Purple Sunbird. Common Tailorbird, Purple Sunbird, Green Bee-eater, River Tern, River Lapwing, Little Cormorant, Black Drongo, Red-vented Bulbul, Humes Warbler, Citrine Wagtail, Indian Roller, Ruddy Shelduck, House Crow and Rufous Treepie had significant association in riverine habitat. In grassland habitat, Ashy Prinia, Common Stonechat, River Lapwing, Red-wattled Lapwing, Pied Bushchat, Black Drongo, White-tailed Stonechat, had significant association. In plantation Purple sunbird, Greenish Warbler, Oriental White-eye, Jungle Babbler, Chestnut-shouldered Petronia, Red-whiskered Bulbul, Humes Warbler, Red-vented Bulbul, Plain Prinia, Spangled Drongo, Red Junglefowl, Spotted Dove, Himalayan Bulbul and Rufous Treepie had significant association.

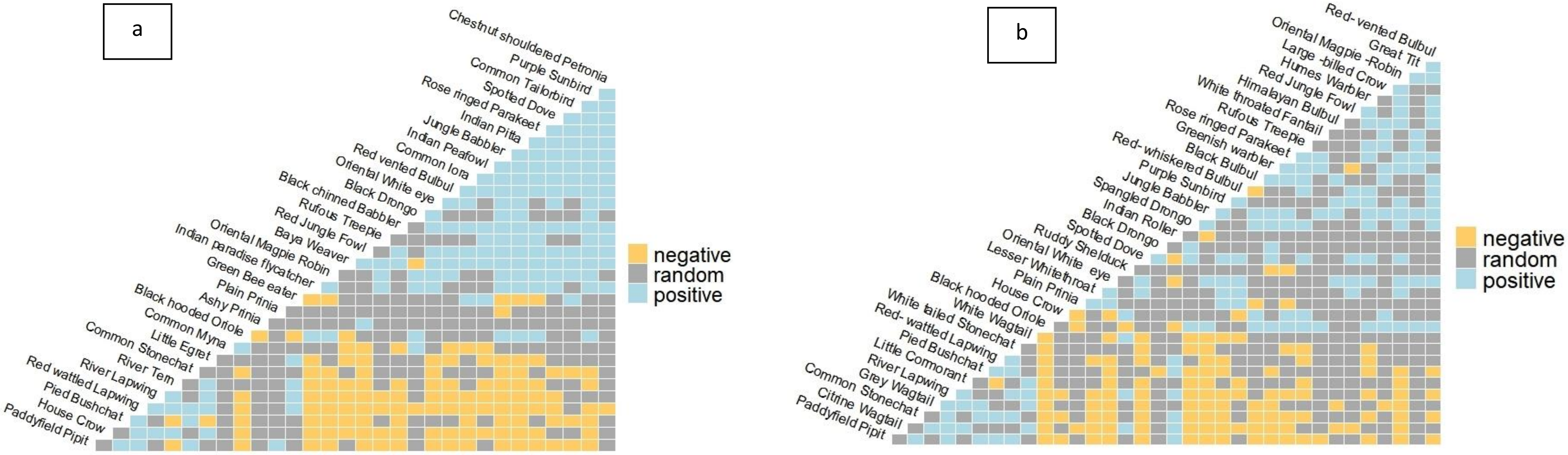
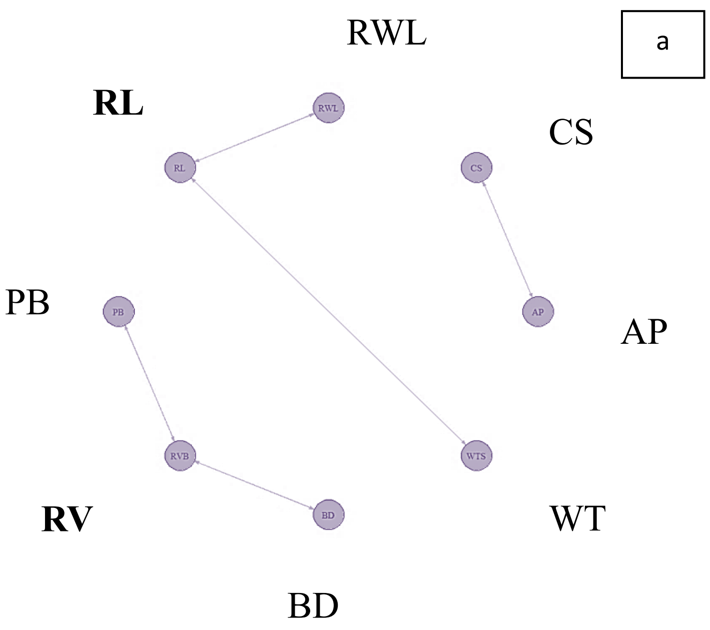
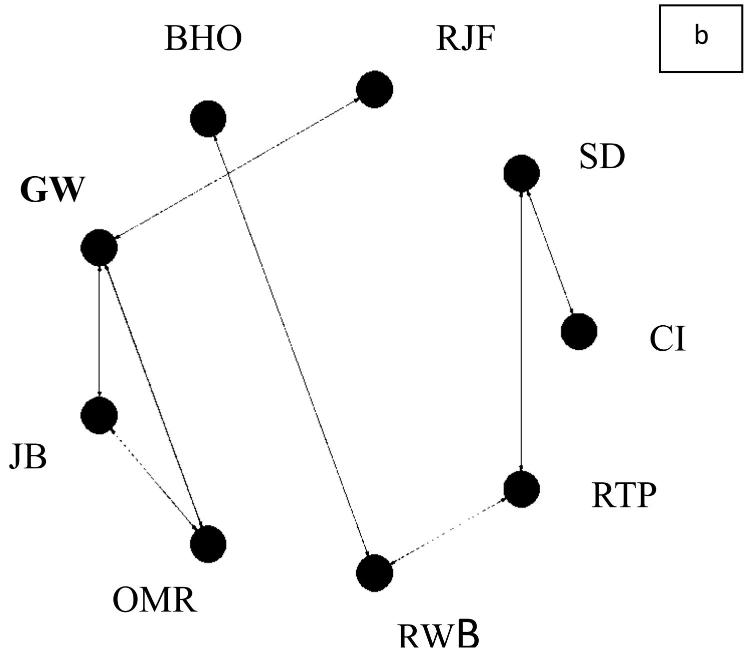


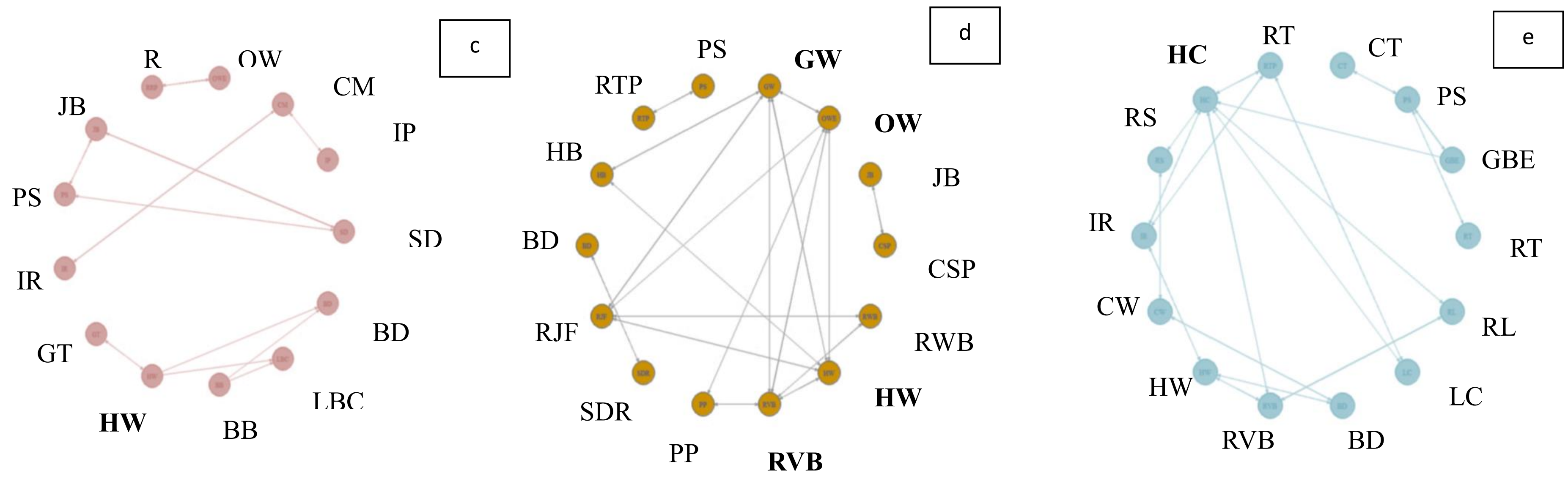
Figure 6.1. Species co-occurrence matrix in (a) summer season and (b) winter season



(a) Grassland



(b) Mixed Deciduous forest



(c) Plantation (d) Scrub forest (e) Riverine

Figure 6.2. Bird network complexity in (a) grassland (b) mixed forest (c) plantation (d) scrub forest and (e) riverine habitat. Bold letters shows birds with maximum number of significant associations.

*Nodes represent bird species and edges represent association between them. Ashy Prinia=AP, Common Stonechat=CS, Red-wattled Lapwing=RWL, River Lapwing=RL, Pied Bushchat=PB, Red-vented Bulbul=RVB, Black Drongo=BD, White-tailed Stonechat=WT, Spotted Dove=SD, Common Iora=CI, Rufous Treepie=RTP, Red-whiskered Bulbul=RWB, Jungle Babbler=JB, Oriental Magpie-Robin=OMR, Greenish Warbler=GW, Red Junglefowl=RJF and Black-hooded Oriole=BHO, Oriental White-eye=OW, Chestnut-shouldered Petronia=CSP, Humes Warbler=HW, Plain Prinia=PP, Spangled Drongo=SDR, Himalayan Bulbul=HB, Purple Sunbird=PS, Common Tailorbird=CT, Green Bee-eater=GBE, River Tern=RT, Large-billed Crow=LBC, River Lapwing=RL, Little Cormorant=LC, Citrine Wagtail=CW, Indian Roller=IR, Ruddy Shelduck=RS, House Crow=HC, BB=Black Bulbul, Great Tit=GT, Indian Pitta=IP

6.5. Discussion

Species co-occurrence pattern is a useful way to visualise community structure (Araújo et al., 2011; Barberán et al., 2012; Morueta-holme et al., 2016). It helps in explaining the distribution characteristics of many species (Basile et al., 2021). These co-occurrence patterns are usually explored using interaction networks within the species community (Barberán et al., 2012). Interaction networks are related to the stability and robustness of the system (Bascompte and Jordano, 2007; Tylianakis et al., 2010) and interaction pattern helps in identifying species with relevant roles. It is important as it helps in evaluating the effects of species that have disappeared due to habitat fragmentation and anthropogenic disturbances (Montoya-Arango, 2019). The present study focused on the co-occurrence pattern and the network complexity of bird communities in different habitats of JJCR.

The association could be due to mixed flock species, belonging to same feeding guild, preference for same habitat type or same habitat features. The ratio of more positive links than negative links are in consistent with studies of network from around the world (Veech, 2013). Purple Sunbird, Jungle Babbler and Indian Pitta had the highest number of positive association in summer and Oriental Magpie Robin had the highest number of positive association in winter due to their more number of co-occurrences as they are habitat generalists and thus are widely spread. Red-wattled Lapwing, Paddyfield Pipit, River Lapwing had highest number of negative associations in summer and Paddyfield Pipit, Citrine Wagtail and Common Stonechat had highest number of negative associations in winter probably due to their less number of co-occurrences as they are habitat specialist and thus restricted to their habitats. There is a significant positive association when species co-occur more and negative association when species co-occur less frequently than by chance (Royan et al., 2016).

In summer season, Paddyfield Pipit co-occurred with Pied Bushchat, Red-wattled Lapwing, Common Stonechat, Plain Prinia because they all belong to the same habitat (Tyler, 2020; Collar and Christie, 2020; Wiersma. and Kirwan, 2020; Collar, 2021; Madge, 2020). Moreover, they all belong to same feeding guild i.e. insectivores. Common Stonechat co-occurred with Red-wattled Lapwing, Pied Bushchat and Paddyfield Pipit. They all belong to grassland and they are insectivores. As Red-wattled Lapwing was present in both grasslands and riverine areas, so it co-occurred with birds present in both habitats namely River Lapwing, River Tern, Common Stonechat and Green Bee-eater. River Lapwing co-occurred with River Tern, Little Egret, Green Bee-eater, Red-wattled Lapwing and House Crow because all are present in riverine habitat (Wiersma and Kirwan, 2020; del Hoyo, 2020). River Tern, River Lapwing and Little Egret are riverine specialists. Little Egret co-occurred with Green Bee-eater could be because of presence in the same habitat.

In winter season, River Lapwing co-occurred with Little Cormorant, White-tailed Stonechat, White wagtail, Ruddy Shelduck and Indian Roller because all of them occurred in riverine habitat (Orta *et* al., 2020; Fry and Kirwan, 2020; Collar, 2020). Little Cormorant co-occurred with River Lapwing and White Wagtail because all of them are riverine birds. Similarly, Citrine Wagtail co-occurred with Gray Wagtail, River Lapwing, Little Cormorant, White Wagtail, Ruddy Shelduck, Indian Roller because all were found in riverine habitat. Likewise, Paddyfield Pipit co-occurred with Common Stonechat, River Lapwing, Pied Bushchat, Red-wattled Lapwing, White-tailed Stonechat and Indian Roller as they were found in grassland habitat. Common Stonechat co-occurred with River Lapwing, Pied Bushchat, Red-wattled Lapwing, White-tailed Stonechat and Indian Roller as they are found in grassland habitat.

Maximum bird species showed random co-occurrence. This is also in line with other studies of pairwise co-occurrences which have reported random co-occurrence pattern prevailing across different taxa (Pitta et al., 2012; Lyons et al., 2016; Kohli et al., 2018). The major mechanism behind species co-occurrence is stochasticity (Elo et al., 2021). The co-existence of different species reflects evolutionary processes and ecological adaptations at different spatial and temporal scales. Observed distribution patterns can be related to the spatial structure and the habitat requirements of individual species or to spatial aspects of population dynamics which need further insights.

The most bird network complexity was found in the riverine habitat which might be because of more number of bird species associations found in this habitat, whereas no bird network complexity was observed in agriculture field and settlement, as it had no significant bird association. This is likely due to anthropogenic intervention prevailing in this habitat. Our result is supported by various studies which state that anthropogenic changes disrupts colonisation, dispersal, direction, frequency and intensity of species associations (Lai et al., 2015; Tylianakis et al., 2008 ; Blois et al., 2013). The maximum number of associations were shown by Red-vented Bulbul and River Lapwing in grasslands, Greenish Warbler in mixed deciduous forests, Humes Warbler in plantation, Red-vented Bulbul, Humes Warbler, Greenish Warbler, Oriental White-eye in in scrub forest, House Crow in riverine habitat because all are generalist bird species and thus co-occur with many species across their range, while habitat specialists co-occur with relatively few species. This also concurs with the study by Fridley et al. (2007).

Co-occurrences are important for maintaining community structure and function (Naeem et al., 1994). Understanding species co-existence helps in designing recovery actions and helps in recovering species from various disturbances (Tulloch et al., 2018). Co-existence theory provides the framework to understand the effect of anthropogenic activity and its mitigation on community co-occurrence and structure (Hille Ris Lambers, 2012).

CHAPTER 7

FEEDING GUILD STRUCTURE OF BIRD ASSEMBLAGE

7.1. Introduction

In a community, certain animal and plant species live closely associated together using common pool resources or sharing benefits from the common resources and helping each other, thus promoting species' co-existence. Guilds are groups of species in a community that exploit the same set of resources in a similar manner and overlap significantly in their niche requirements but are not necessarily closely related taxonomically (Root, 1967; Simberloff and Dayan, 1991; Jaksić and Medel, 1990). Guilds have been viewed as 'natural ecological units' and forms building blocks of the community (Simberloff and Dayan, 1991; Hawkins and MacMahon, 1989). Guild categorization among birds emphasizes the functional component of community in an ecosystem (Panda et al., 2021). The classification of bird species into feeding guilds and habitat guilds is the best way to understand bird community structure (Thiollay, 1995; Clough et al., 2009; González-Salazar et al., 2014; Kornan and Kropil, 2014; Wiens, 1989; Paszkowski and Tonn, 2006). Feeding guild reflects the types of food availability in a habitat (Blake, 1983). The distribution of birds and community structure is determined by the availability of food and the way food is used in a particular habitat (Rosenberg, 1990; Albrecht and Gotelli, 2001; Palmer et al., 2003; Evans and Dugan, 1984; Gotelli and Colwell, 2011; Bonilla et al., 2012).

Besides food supply, bird feeding guild distribution is influenced by the vegetation structure, floristics, and predators (Pearman, 2002; O'Connell, 2000; Kissling et al., 2012; Katuwal et al., 2016). To best suit their nesting, perching, roosting and foraging, birds prefer to live in heterogeneous landscapes (Berg, 2002; Aggarwal et al., 2008; Veech et al., 2011) and thus the guild structure varies spatially (Holmes, et al., 1979; Holmes and Recher, 1986). Guild structure and niche characteristics are important indicators of quantitative niche partitioning of a community (Simberloff and Dayan, 1991). Species within a guild respond similarly to environmental change (Verner, 1984) and different bird guilds respond differently to such changes (Barragan et al., 2011; Phalan et al., 2011; Newbold et al., 2014). This information can be used to manage and monitor bird species in forest ecosystems for conservation and management purposes. Grouping species into a guild facilitates understanding and predicting ecological patterns in them (Root, 1967; Simberloff and Dayan, 1991) and depicts their resilience to the changing land use patterns (Chatterjee and Basu, 2017) and devise methods for mitigating the impact (Johnson, 1980). The significance of bird guild structure in regulating bird assemblages emphasizes habitat conservation and improvement measures to be incorporated into the policy framework (Sohil and Sharma, 2020).

Different organisms need different habitats as per their requirement and adaptation. Determining the factors responsible for different bird species in different habitats is one of the main things in community ecology (Lubchenco et al., 1991). Holmes and Robinson (1988) consider that the composition of guilds differs between sites and correlates with habitat features and with the methods used by animals to exploit the resources. Bird species richness was related mainly to the availability of vegetation strata, secondarily to climatic factors (Cueto and Casenav, 1999). Birds actively select their habitat based on landscape features, terrain, substrate, arrangement and structure of vegetation (Wiens, 1969). Habitat selection helps species to co-exist (Rosenzweig, 1981). Community patterns within and between habitats may differ according to the influencing variables, like within habitat diversity of birds could be attributed to the spatial heterogeneity of vegetation and bird adaptation to the vegetation structure and function (MacArthur and MacArthur, 1961). Vegetation structure is important at a coarse regional scale (across habitats) and floristics might determine bird species composition at a more local scale (within habitats) (Rottenberry, 1985). The vegetative structure is the primary proximate factor determining where and how a species uses resources (Nsor et al., 2018). Habitat structure determines the bird species diversity (Martin and Possingham, 2005; James and Wamer, 1982; MacArthur and MacArthur 1961; Willson 1974). Variation in habitat types accommodates different bird guilds and habitat specialists (Chhetri et al., 2005). Larger greenspaces with high structural diversity might be effective in maintaining high bird diversity (Khera et al., 2009).

Bird-habitat association has been represented through various methods such as ordination techniques and resource selection fuction index. Mutualistic network is related to the stability and robustness of the system (Bascompte and Jordano, 2007; Tylianakis et al., 2010). Network theory provides the framework to study communities by considering both species composition and species interaction (Montaño-Centellas, 2020).

Small PAs such as Jhilmil Jheel Conservation Reserve (JJCR) has a considerable good number of bird species. But it lies amid human-dominated landscape and is facing various anthropogenic disturbances such as fuelwood and fodder, grass collection and livestock grazing. Anthropogenic disturbances lead to habitat fragmentation and degradation (Dendup et al., 2021). Anthropogenic disturbances like grazing influence the regeneration of woody species and affect the vegetation composition of the forest (Colter, 2006). The change in vegetation structure and tree composition significantly impacts the native faunal populations, with specialized niche requirements (Bawa and Seidler, 1998).

The present study was undertaken to understand the habitat preferences and foraging dynamics of birds in Jhilmil Jheel Conservation Reserve. The study signifies the importance of small protected areas in conserving and harbouring the diversity and importance of habitat heterogeneity in influencing different feeding guilds and the role of avian guild structure in regulating bird assemblage. It also emphasizes the need to include feeding guilds in conservation planning.

The research questions addressed in this chapter are:

(i) What are the various feeding guilds in JJCR and are there any seasonal changes in feeding guild structure across various habitat types?

(ii) What is the association between different feeding guilds and different habitats and habitat features?

7.2. Methods

Bird sampling

Systematic surveys were conducted in 116 point count stations, separated by 200 meters from each other to avoid double counting of birds. All the point count stations were sampled through the point count method (Bibby et al., 2000) in the early morning 5:30 am to 8:30 am during summer(April-June) and from 8:00 am to 10:30 am during winter season (November-mid March). The sampling was done 10 times in each season from 2018-2020. Birds were recorded for their species, abundance, feeding guild and habitat type. Surveys were avoided during inclement weather. Birds were identified by referring to field guides Ali, 2002; Grimmett et al., 2011) whereas bird's call and songs were identified through xeno-canto (2020). Bird species were categorized into fine foraging guilds (Mohan, 2007; Kaushik et al., 2022) based on their food preferences: Insectivore, Granivore, Herbivores, Nectarivore, Frugivore, Frugiore-Insectivore (FI), Nectarivore-Insectivore (NI), Frugivore-Insectivore-Nectarivore (FIN), fruit seed nectar (FSN), feeding on fruit-seed-nectar and insects (FSNI), Omnivore and Piscivore.

Habitat quantification

For habitat quantification, two vegetation plots were laid in each point count station (n=232).

Information on trees were collected in quadrat of 10X10 m^2 followed by 5x5 m^2 plot nested inside the 10x10 m^2 plot for shrub information and 1x1 m^2 nested at the four corners for herb and grass information. We identified each tree and shrub to species level with the help of available field guides (Kanjilal and Gupta, 1979; Krishen, 2006). All woody vegetation of 20 cm girth at breast height (GBH) or more were considered trees. Tree characteristics such as tree species, abundance, GBH, height, density, basal area and canopy cover were assessed. Tree cover (Canopy cover), shrub cover and ground cover were estimated following the line intercept method (Canfield, 1941). Disturbance data such as presence of livestock, presence of trail and presence of logged trees were taken in presence/absence form.

7.3. Data analysis

For fulfilling the objective to assess the feeding guilds along the different habitat gradients and in different seasons the fine-level guild classification was done based on information collated from available literature (Mohan, 2007; Kaushik et al., 2022) and personal observation. I assessed the Shannon diversity of feeding guilds using PAST software (version 4.03). PERMANOVA test (Anderson 2001) was done to assess the difference in bird feeding guild composition in different habitats. For fulfilling the objective to explore the association between different feeding guilds and habitat and habitat features Network analysis was done using bipartite package in R (version R 3.6.3). It was then followed by Generalized linear model (GLM). The abundance data of different species in each feeding guild was used for the analysis. Generalized linear model (GLM) was done in R (version R 3.6.3), using the package MuMIN (Barton, 2018) to see the influence of vegetation structure and disturbance factors on the bird feeding guild. Prior to modelling we selected the explanatory variables deemed most likely to affect individual guilds. The physiognomic characteristics of the habitat collected during the vegetation sampling were used to understand the dependency of the bird guild on habitat heterogeneity. The vegetation features such as tree, shrub and ground cover characteristics and disturbance factors such as presence of livestock, trails and invasive species cover were used to assess the association of different feeding guilds with the habitat features. The data was standardized and AIC (Akaike Information criterion corrected for small sample size) was used to rank the most parsimonious model. Inferences were made using top models with the least AICc value.

7.4. Results

In total 13 foraging guilds were observed in JJCR. The number of bird species that belonged to different foraging guilds are given in Figure 7.1. The Insectivore guild had the highest number of bird species containing 91 species whereas Fruit–seed–nectar (FSN) guild had the lowest number of bird species i.e. one species. The most abundant bird species of carnivore guild are Crested Serpent-Eagle, Jungle Owlet and Shikra. Yellow-footed Green-Pigeon, Indian Grey Hornbill, Rose-ringed Parakeet and Red-vented Bulbul were the most abundant frugivorous bird belonging to FI, FSN and FSNI respectively. Maroon Oriole was the only bird belonging to FIN. The most abundant bird species of insectivore guild are Jungle Babbler, Barn Swallow and Red-wattled Lapwing. Aquatic birds Ruddy Shelduck and Little Cormorant were the most abundant birds belonging to herbivores and piscivores respectively. The most abundant bird species of granivore guild is Baya Weaver. Purple Sunbird represented the most abundant Nectarivore-Insectivore guild. Omnivore was abundantly represented by House Crow. Scavenger was represented by very few species with Himalayan Griffon being abundant among them. Insectivore feeding guild had the highest Shannon diversity index, followed by

Piscivore, Granivore, FSNI, Omnivore, Scavenger, FI, Herbivore, Carnivore, NI, FSN, Frugivore and FIN (Table 7.1). Insectivore was the most species-rich feeding guild in all the habitats (Figure 7.2 a, b, c, d, e, f). PERMANOVA test was done to see if there was a significant difference in the feeding guild composition in different seasons and habitats. The results showed a significant difference between different feeding guilds in summer season (p=0.0001) and in winter season (p=0.0001). This is possibly due to the availability of different food items in both seasons. Network analysis was done to see the association of feeding guilds with different habitats in both the summer and winter seasons. In the summer season plantation was mostly preferred, followed by mixed forest (deciduous), riverine habitat, grassland, scrub forest and agriculture field-human settlements (Figure7.3a). Herbivores, Piscivores and Omnivores were majorly dependent on riverine habitat. FSN had the most preference for mixed deciduous forest, FI and FSNI on plantation. Granivores were majorly dependent on mixed deciduous forest while Insectivores on plantation, grassland and riverine. NI had the most preference for scrub, mixed and plantation and omnivore on riverine. In winter season, riverine habitat was mostly preferred, followed by plantation, mixed forest, scrub forest, grassland and agriculture fields-human settlements (Figure7.3b). Piscivores and herbivores were majorly dependent on riverine habitat. Insectivores had the most preference for riverine, grassland and plantation, while omnivore on plantation. FSNI were majorly dependent on plantation, mixed and scrub forest and NI on mixed and scrub forest. Granivores were dependent on grassland and agriculture fields.

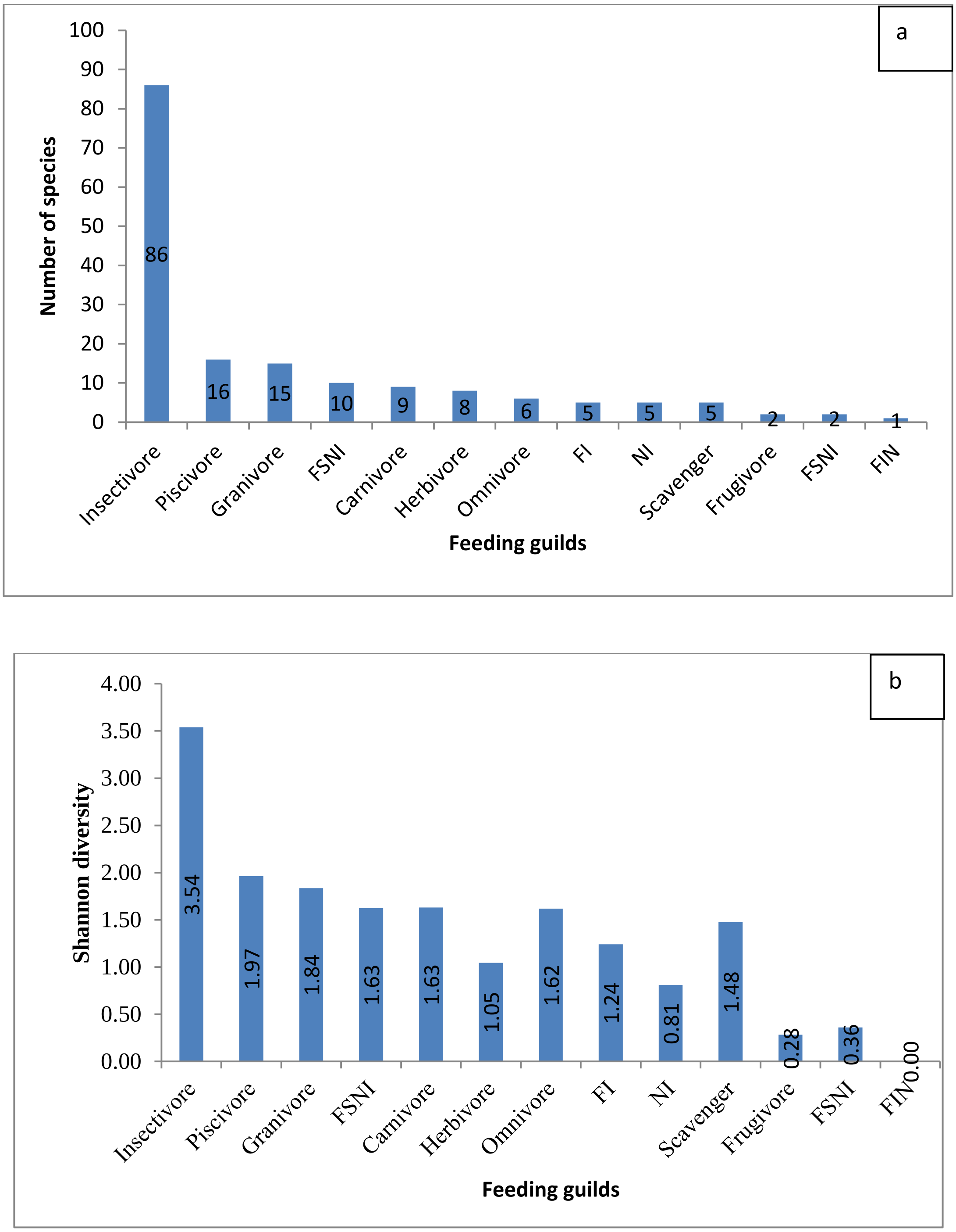
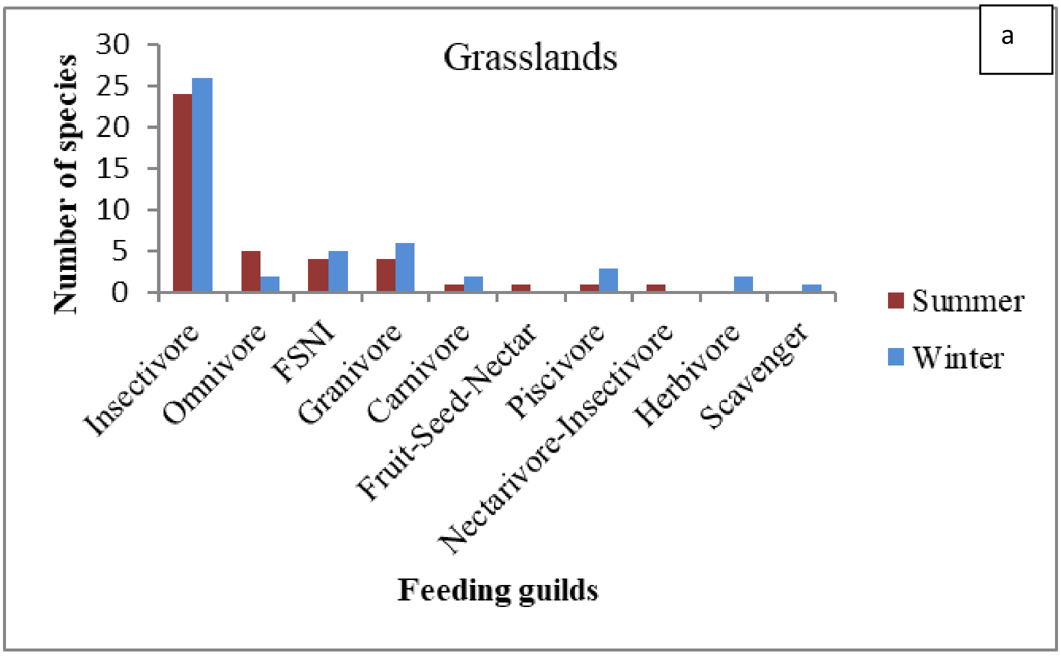
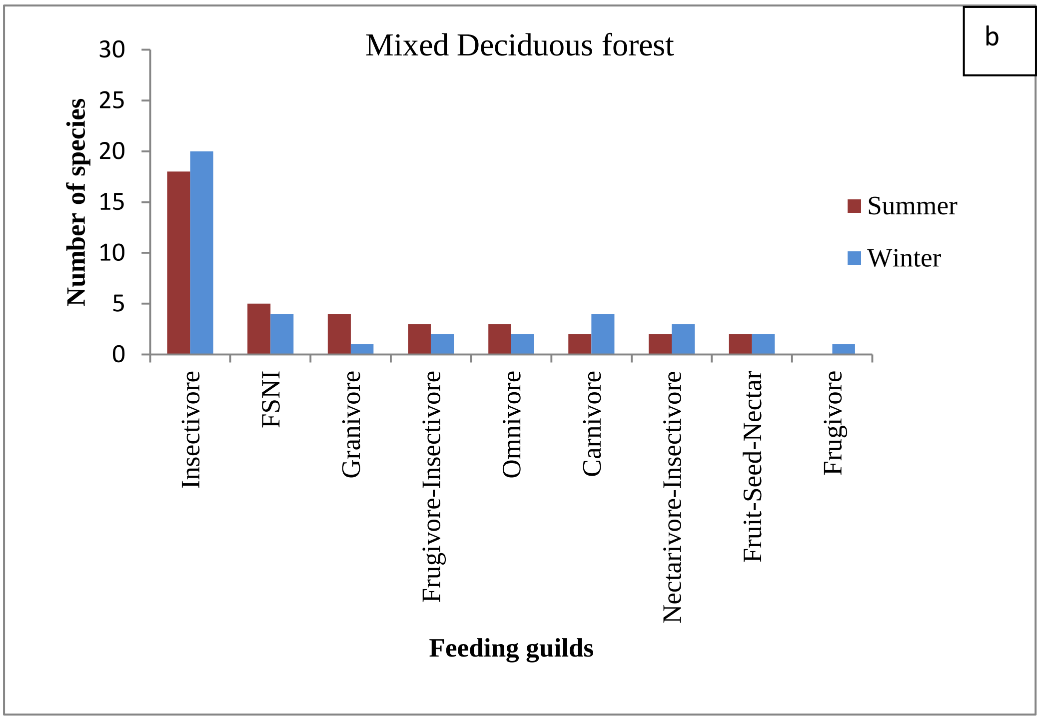
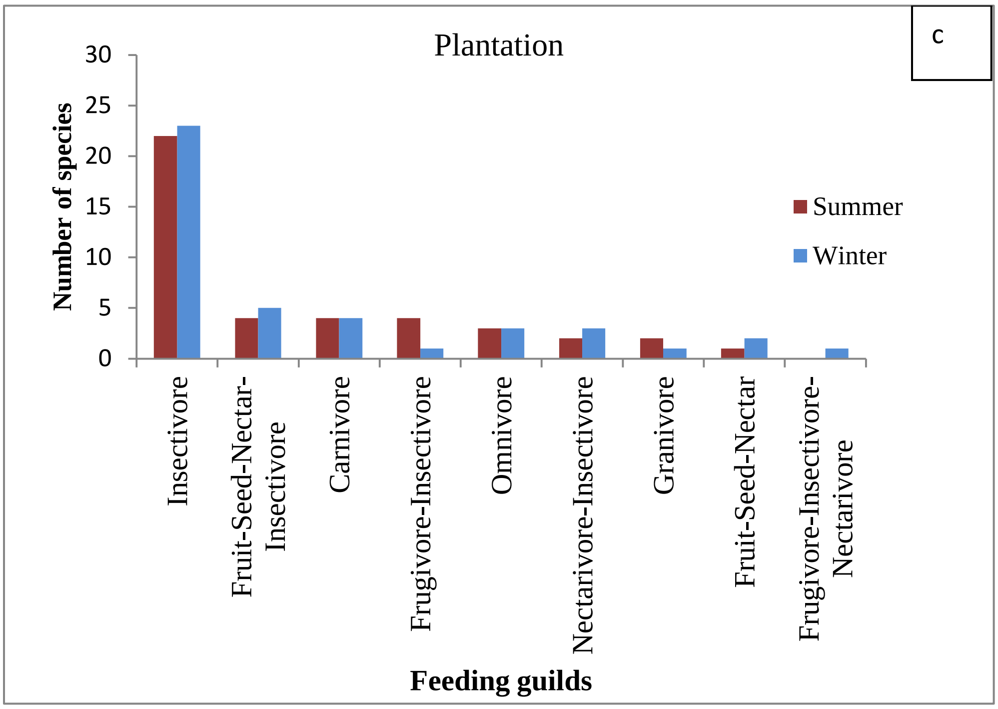
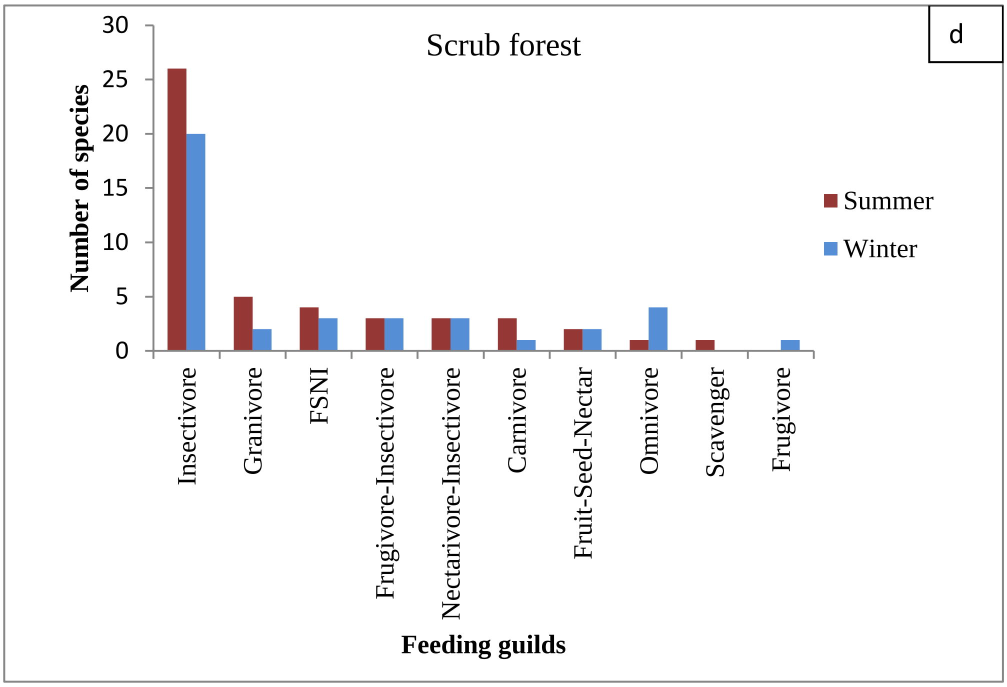


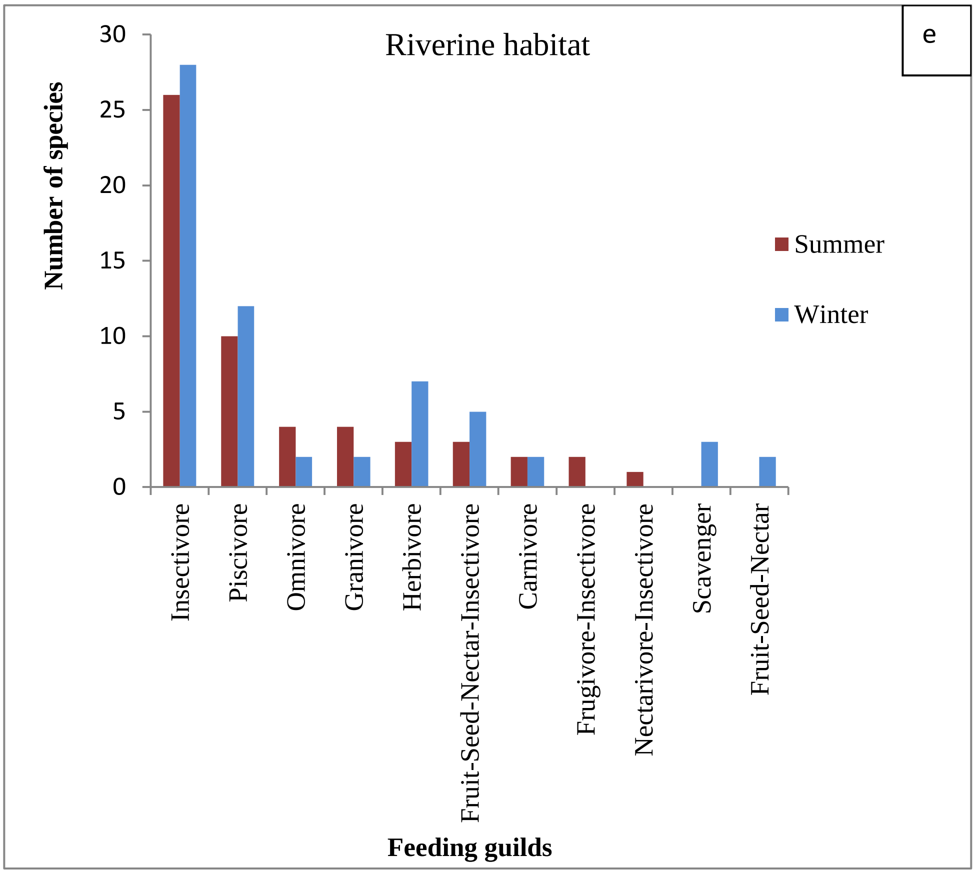
Figure 7.1.(a) Feeding guilds in different habitat (b) Shannon diversity index of different feeding guilds


a
Grasslands
Number of species
30
25
20
15
10
5
0
Insectivore
Omnivore
FSNI
Granivore
Carnivore
Fruit-Seed-Nectar
Piscivore
Nectarivore-Insectivore
Herbivore
Scavenger
Summer
Winter
Feeding guilds


b
Mixed Deciduous forest
Number of species
30
25
20
15
10
5
0
Insectivore
FSNI
Granivore
Frugivore-Insectivore
Omnivore
Carnivore
Nectarivore-Insectivore
Fruit-Seed-Nectar
Frugivore
Summer
Winter
Feeding guilds


c
Plantation
Number of species
30
25
20
15
10
5
0
Summer
Winter
Insectivore
Fruit-Seed-Nectar-Insectivore
Carnivore
Frugivore-Insectivore
Omnivore
Nectarivore-Insectivore
Granivore
Fruit-Seed-Nectar
Frugivore-Insectivore-Nectarivore
Feeding guilds


d
Scrub forest
Number of species
30
25
20
15
10
5
0
Summer
Winter
Insectivore
Granivore
FSNI
Frugivore-Insectivore
Nectarivore-Insectivore
Carnivore
Fruit-Seed-Nectar
Omnivore
Scavenger
Frugivore
Feeding guilds



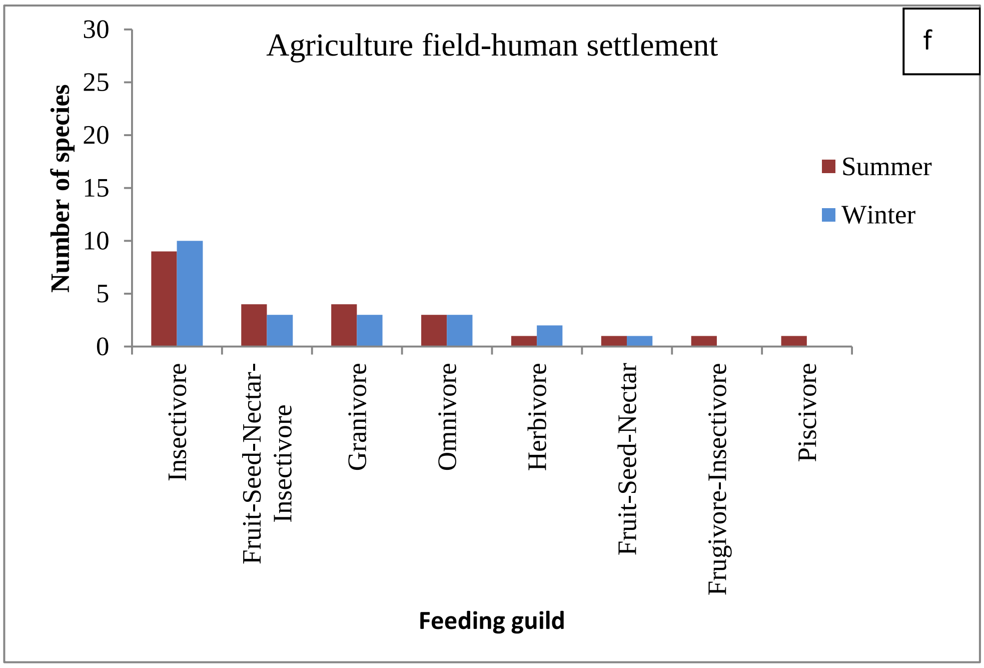


Figure 7.2. Feeding guilds in different habitats and season (a) grasslands (b) mixed deciduous forest, (c) plantation (d) scrub forest (e) riverine habitat (f) agriculture field-human settlement

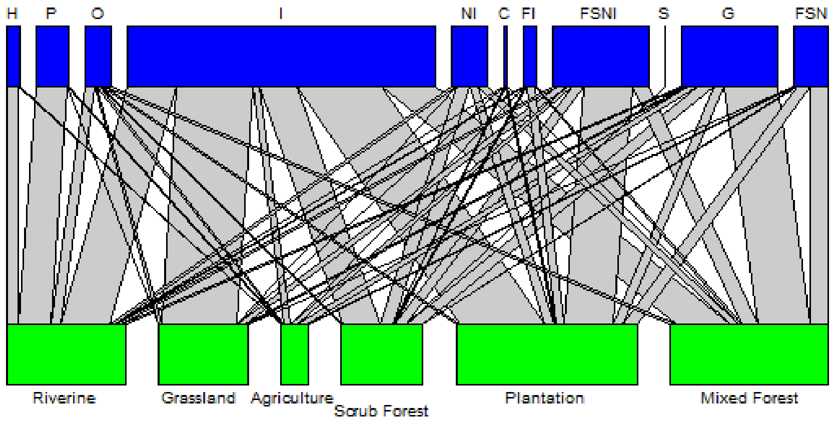
Nectarivore

Generalized linear model (Glm) was done to see the association between feeding guild and different habitat variables in summer and winter season. Details of model selection tables and best model selection for different feeding guilds have been presented in table 7.1 and table 7.2 respectively.

Carnivore

In summer season, Carnivore showed positive association with GBH (β= 0.148561) and canopy cover (β=0.07937), but it was not significant. In winter season, carnivore showed significant positive association with GBH (β =-0.31732 and significant negative association with shrub cover (β =-0.24586).

a



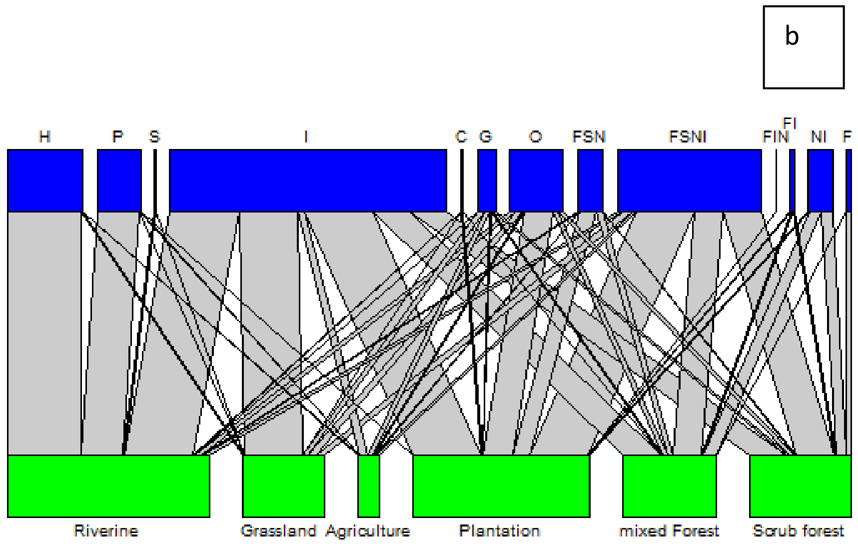


Figure 7.3. (a) Network analysis for the feeding guild-habitat association in summer season and (b) winter season

Insectivore

In summer season Insectivore had significant negative association with presence of trail (β =0.07031). In winter, it had significant positive association with bareground (β =0.33959) and significant positive association with herb cover % (β =0.09326).

Nectarivore-Insectivore

In summer season it showed significant positive association with shrub species richness (β =0.26367) and herb cover %. In winter, Nectarvore-Insectivore had significant positive association with invasive species cover (β =0.15131), shrub abundance (β =0.13646) and significant negative association with leaf litter (β = -0.18633) and presence of trail (β =0.15644).

FSNI

It had significant positive association with leaf litter (β =0.24729 and shrub cover (β= 0.16739). In winter season, FSNI had significant positive association GBH (β =0.16956), significant negative association with presence of livestock (β =-0.0675).

Granivore

It has significant positive association with herb (β =1.59965), GBH, % (β= 0.31145) grass cover(β=2.36245), shrub richness (β= 0.1633), leaf litter (β= 1.36951), bareground % (β= 2.32314), invasive species cover (β=0.17959) and significant negative association with presence of livestock (β=- 0.26275). In winter season, it had significant negative association with presence of trail (β =-0.05025) and tree height (β =-0.03420).

TSR-Tree richness, TA-Tree abundance, CC-Canopy cover, TH-Tree height, GBH-Girth at breast height, SR-Shrub richness, SA-Shrub abundance, SC-Shrub cover, IC-Invasive species cover, LL-Leaf litter, H-Herb cover, BG-Bareground cover, GC-Grass cover, PT-Presence of trail, PLT-Presence of logged trees, PL-Presence of livestock

Table 7.1. Models selection

Summer					**Winter**				
CARNIVORE	**logLik**	**AICc**	**delta**	**weight**	**CARNIVORE**	**logLik**	**AICc**	**delta**	**weight**
GBH +CC	29.509	-50.6	0	0.597	GBH+CC+SC	19.224	-27.8	0	0.522
GBH +CC+TH	29.577	-48.5	2.08	0.211	GBH+CC+SC+H	19.445	-26	1.82	0.21
GBH +CC+TH+LL	30.164	-47.4	3.17	0.123	GBH+CC+SC+H+SA	20.352	-25.5	2.32	0.164
GBH +CC+TH+LL+ TA	30.267	-45.3	5.27	0.043	GBH+CC+SC+H+SA+IC	20.361	-23.2	4.66	0.051
GBH +CC+TH+LL+ TA+GC	30.426	-43.3	7.31	0.015	GBH+CC	15.167	-21.9	5.9	0.027
GBH +CC+TH+LL+ TA+GC+TSR	30.907	-41.8	8.77	0.007	GBH+CC+SC+H+SA+IC+SR	20.363	-20.7	7.07	0.015
GBH +CC+TH+LL+ TA+GC+TSR+PT	30.922	-39.4	11.2	0.002	GBH+CC+SC+H+SA+IC+SR+BG	20.823	-19.2	8.62	0.007
GBH +CC+TH+LL+ TA+GC+TSR+PT+SC	31.254	-37.5	13.06	0.001	GBH+CC+SC+H+SA+IC+SR+BG+PLT	20.958	-16.9	10.87	0.002
					GBH+CC+SC+H+SA+IC+SR+BG+PLT+LL	21.465	-15.4	12.43	0.001
INSECTIVORE	**logLik**	**AICc**	**delta**	**weight**	**INSECTIVORE**	**logLik**	**AICc**	**delta**	**weight**
PT+PL	46.36	-84.3	0	0.63	BG+GBH+PL+H	61.741	-110.6	0	0.507
PT+PL+CC	46.401	-82.2	2.13	0.217	BG+GBH+PL+SR	61.114	-109.3	1.26	0.27
PT+PL+CC+GBH	46.618	-80.3	3.96	0.087	BG+GBH+PL+PLT	60.921	-108.9	1.64	0.223
PT+PL+CC+GBH+TH	46.696	-78.2	6.11	0.03					
PT+PL+CC+GBH+TH+GC+TA+SR+LL	50.96	-77	7.35	0.016					
PT+PL+CC+GBH+TH+GC	46.707	-75.8	8.45	0.009					
PT+PL+CC+GBH+TH+GC+TA+SR+LL+BG	51.043	-74.5	9.76	0.005					
PT+PL+CC+GBH+TH+GC+TA	46.707	-73.4	10.87	0.003					
PT+PL+CC+GBH+TH+GC+TA+SR	47.383	-72.3	11.98	0.002					
PT+PL+CC+GBH+TH+GC+TA+SR+LL+BG+IC	51.045	-71.9	12.4	0.001					

NECTARIVORE- INSECTIVORE	**logLik**	**AICc**	**delta**	**weight**	**NECTARIVORE- INSECTIVORE**	**logLik**	**AICc**	**delta**	**weight**
SR+SA+SC	33.407	-56.2	0	0.333	IC+SA+LL+PT	55.633	-98.4	0	0.318
SR+SA+SC+IC	34.341	-55.8	0.39	0.273	IC+SA+LL+PT+GBH	56.689	-98.2	0.2	0.288
SR+SA	32.003	-55.6	0.59	0.248	IC+SA+LL+PT+GBH+TH+BG+H+PLT+PL+TR	63.462	-96.7	1.63	0.141
SR+SA+SC+IC+GBH	34.488	-53.8	2.41	0.1	IC+SA+LL+PT+GBH+TH	56.951	-96.3	2.03	0.115
SR+SA+SC+IC+GBH+TA	34.49	-51.4	4.77	0.031	IC+SA+LL+PT+GBH+TH+BG+H+PLT+PL+TR+TA	63.64	-94.4	3.98	0.044
SR+SA+SC+IC+GBH+TA+CC	34.526	-49.1	7.11	0.01	IC+SA+LL+PT+GBH+TH+BG	57.092	-94.2	4.17	0.04
SR+SA+SC+IC+GBH+TA+CC+PLT	34.721	-47	9.18	0.003	IC+SA+LL+PT+GBH+TH+BG+H	58.091	-93.7	4.63	0.031
SR+SA+SC+IC+GBH+H+TA+CC+PLT+PL	36.959	-46.4	9.81	0.002	IC+SA+LL+PT+GBH+TH+BG+H+PLT	58.7	-92.4	5.94	0.016
					IC+SA+LL+PT+GBH+TH+BG+H+PLT+PL	59.11	-90.7	7.7	0.007
FSNI	**logLik**	**AICc**	**delta**	**weight**	**FSNI**	**logLik**	**AICc**	**delta**	**weight**
LL+TA+SC	40.78	-70.9	0	0.332	GBH+SR+SC+PL	64.193	-115.5	0	0.32
LL+TA+SR	40.376	-70.1	0.81	0.222	GBH+SR	61.777	-115.1	0.36	0.268
LL+TA+GC	39.599	-68.6	2.36	0.102	GBH+SR+SC	62.449	-114.3	1.23	0.173
LL+TA+GBH	39.205	-67.8	3.15	0.069	GBH+SR+SC+PL+CC	64.674	-114.1	1.35	0.163
LL+TA+TR	39.201	-67.8	3.16	0.068	GBH+SR+SC+PL+CC+TA	64.7	-111.8	3.66	0.051
LL+TA+SA	39.152	-67.7	3.26	0.065	GBH+SR+SC+PL+CC+TA+H	64.702	-109.4	6.07	0.015
LL+TA+PLT	38.659	-66.7	4.24	0.04	GBH+SR+SC+PL+CC+TA+H+TH	64.704	-107	8.53	0.005
LL+TA+CC	38.592	-66.6	4.38	0.037	GBH+SR+SC+PL+CC+TA+H+TH+IC	64.836	-104.7	10.79	0.001
LL+TA+BG	38.452	-66.3	4.66	0.032	GBH+SR+SC+PL+CC+TA+H+TH+IC+BG+GC+PLT	67.976	-103.1	12.43	0.001
LL+TA+PT	38.449	-66.3	4.66	0.032					
GRANIVORE	**logLik**	**AICc**	**delta**	**weight**	**GRANIVORE**	**logLik**	**AICc**	**delta**	**weight**

H+PL+GBH+GC+SR+LL+BG+IC	37.775	-53.1	0	0.454	PT+TH	87.754	-167.1	0	0.654
H+PL+GBH+GC+SR+LL+BG+IC+SA	38.324	-51.7	1.42	0.223	PT+TH+TA	87.759	-164.9	2.2	0.217
H+PL+GBH+GC+SR+LL+BG	35.438	-50.9	2.21	0.151	PT+TH+TA+GBH	87.771	-162.6	4.44	0.071
H+PL+GBH+GC+SR+LL+BG+IC+SA+PLT	39.2	-50.9	2.25	0.147	PT+TH+TA+GBH+LL	88.128	-161.1	6.04	0.032
H+PL+GBH+GC+SR+LL	32.354	-47.1	5.96	0.023	PT+TH+TA+GBH+LL+CC	88.609	-159.7	7.44	0.016
H+PL+GBH+GC+SR	28.793	-42.4	10.72	0.002	PT+TH+TA+GBH+LL+CC+TR	88.985	-158	9.1	0.007
					PT+TH+TA+GBH+LL+CC+TR+BG	88.985	-155.5	11.57	0.002
					PT+TH+TA+GBH+LL+CC+TR+BG+GC	89.048	-153.1	13.96	0.001

Table 7.2. Best model selection

Summer		**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**		**Winter**		**Estimate**	**Std.Error**	**tvalue**	**Pr(>|t|)**	
Carnivore	Intercept	0.00318	0.03079	0.103	0.918		Carnivore	Intercept	0.0225	0.0344	0.653	0.5156	
	GBH	0.14856	0.11204	1.326	0.188			GBH	0.31732	0.1234	2.57	0.0117	*
	CC	0.07937	0.08552	0.928	0.356			CC	0.04001	0.0955	0.419	0.67627	
								SC	-0.24586	0.0863	-2.848	0.00536	**

Insectivore		Estimate	Std.Error	t value	Pr(>|t|)		Insectivore		Estimate	Std.Error	t value	Pr(>|t|)	
	Intercept	0.46926	0.0698	6.723	1.19E-09	***		Intercept	0.18816	0.0562	3.347	0.00117	***
	PT	-0.07031	0.03781	-1.859	0.066	.		BG	0.33959	0.0730	4.649	1.06E-05	
	PL	-0.09509	0.06146	-1.547	0.125			GBH	0.04648	0.0821	0.566	0.57292	*
								PL	-0.08599	0.0379	-2.266	0.02569	.
								H	0.09326	0.0551	1.692	0.09384	

Nectarivore-Insectivore		Estimate	Std.Error	t value	Pr(>|t|)		Nectarivore-Insectivore		Estimate	Std.Error	t value	Pr(>|t|)	
	Intercept	0.06411	0.02322	2.761	0.00689	**		Intercept	0.21196	0.0442	4.791	6.05E-06	***
	SR	0.26367	0.13957	1.889	0.06185	.		IC	0.15131	0.0698	2.167	0.03274	*
	SA	0.22347	0.18468	1.21	0.2292			SA	0.13646	0.0819	1.665	0.09910	.
	SC	0.25483	0.15414	1.653	0.10152			LL	-0.18633	0.0482	-3.865	0.00020	***
								PT	-0.15644	0.0386	-4.049	0.00010	***

FSNI		Estimate	Std.Error	t value	Pr(>|t|)		FSNI		Estimate	Std.Error	tvalue	Pr(>|t|)	
	Intercept	0.08541	0.02455	3.479	0.00075	***		Intercept	0.07595	0.0411	1.844	0.06822	.
	LL	0.24729	0.06429	3.847	0.00021	***		GBH	0.16956	0.0621	2.729	0.00755	**
	TA	0.07601	0.11023	0.69	0.49213			SR	0.06122	0.0969	0.632	0.5292	
	SC	0.16739	0.07812	2.143	0.03464	*		SC	0.11569	0.0979	1.181	0.2406	
								PL	-0.0675	0.0367	-1.837	0.06929	.
Granivore		**Estimate**	**Std.Error**	**t value**	**Pr(>|t|)**		**Granivore**		**Estimate**	**Std.Error**	**t value**	**Pr(>|t|)**	
	Intercept	-2.04384	1.01352	-2.017	0.04665	*		Intercept	0.08533	0.0222	3.836	0.00022	***
	H	1.59965	0.71217	2.246	0.02708	*		PT	-0.05025	0.0265	-1.896	0.06084	.
	PL	-0.26275	0.07185	-3.657	0.00042	***		TH	-0.0342	0.0380	-0.899	0.37084	
	GBH	0.31145	0.11291	2.758	0.00700	**							
	GC	2.36245	1.01016	2.339	0.02151	*							
	SR	0.1633	0.0866	1.886	0.06248	.							
	LL	1.36951	0.68714	1.993	0.04921	*							
	BG	2.32314	1.01038	2.299	0.02375	*							
	IC	0.17959	0.08604	2.087	0.03962	*							

7.5. Discussion

The present study is an attempt to create a database on habitat-wise feeding guilds in JJCR. It shows that habitat heterogeneity profoundly affects bird feeding guilds and explains the structural and functional association of different feeding guilds with habitat. It also shows the effect of human disturbances on the feeding guilds. We analysed the habitat features determining the patterns of bird feeding guilds in JJCR.

In total, 13 feeding guilds were recorded namely Insectivore, Carnivore, Granivore, Herbivores, Nectarivore, Frugivore, Frugivore-Insectivore (FI), Nectarivore-Insectivore (NI), FIN (Frugivore-Insectivore-Nectarivore), FSN (feeding on Fruit Seed nectar), FSNI (feeding on Fruit-Seed-Nectar and Insects), Omnivore and Piscivore, which shows that JJCR supports diversity of feeding guilds. As JJCR has a cluster of various habitats namely plantations, mixed deciduous forests, scrub forests, riverine, grasslands and agriculture fields-human settlement, so the presence of heterogeneity of habitats caters to the needs of a variety of feeding guilds. This is in line with other studies which states that variation in vegetation structure influences the distribution of bird feeding guilds (Pearman, 2002; Menon et al., 2019). Insectivore guild constituted the most species-rich feeding guild. The dominance of insectivore guild over other feeding guilds is a common trend as evident in other studies (Sultana and Khan, 2000; Aggarwal et al., 2008; Acharya et al., 2010; Joshi and Bhatt, 2011; Khan and Chandan, 2015; Tanveer et al., 2019).

There was a clear seasonal variation in the preferred habitat structures, which was evident by most birds preferring riverine habitats in the winter, mostly due to the arrival of migratory bird species. Unlike winters, the summer season showed plantation to be the most preferred might be because of its larger area. The agriculture field was the least preferred possibly because of the least resources available in this habitat. Herbivores and Piscivores were either waterbirds or water-dependent birds, so were associated with riverine habitat (Prajapati and Prajapati, 2013; Panda et al., 2021). Piscivore has been considered as a potential important indicator of riverscape condition (Sullivan et al., 2007). Though insectivores were present in large proportion in every habitat but were mostly dependent on plantation, riverine and grassland which could be because of more number of insects found in these habitats. FSN feeding guild was mostly dependent on mixed deciduous forest and plantation possibly because of more fruits, seeds and nectar available from this habitat. FSNI was dependent on plantation in summer and plantation, mixed forest and scrub forest in winter could be because availability of fruit, nectar, seeds and insects in this habitats. NI had the most preference for mixed forest and scrub forest possibly because of more nectar bearing flowers and insects in these habitats. Granivore was mostly dependent on mixed forest in summer and agriculture and grasslands during winter which could be due to more availability of seeds in these habitats.

Different feeding guilds showed different preferences for habitat variables. Carnivores preferred trees with GBH and canopy cover. Carnivores preference for trees with GBH and canopy cover is also evident in other studies (Rao and Koli, 2017). Association with GBH shows preference for old-aged trees. Canopy cover provides shade and has cooling effect. Anthropogenic disturbances in terms of trail and livestock had a significant impact on the Insectivores indicated by their negative association. Such disturbances raise concerns as Insectivores play an important role in controlling insects and their loss can lead to pest outbreaks and damage to forests leading to economic loss (Nyffeler et al., 2018; Sekercioğlu et al., 2004). Similarly, Nectarivore-insectivore and Granivore showed negative association with presence of trail, while FSNI and Granivore showed negative association with presence of livestock. Insectivore, Nectarivore-Insectivore, FSNI and Granivore showed positive association with the understorey which has been found to be an important habitat in many studies (Raman et al., 1998; Martin and McIntyre, 2007; Shahabuddin and Kumar, 2007; Dahal et al., 2015) being an important refuge for several bird groups (Sekercioğlu et al., 2002). Some of the guilds such as Nectarivore-Insectivore, Granivore showed positive association with invasive species cover (mainly *Lantana* cover) which is in line with other studies which state about the preference for fruit and nectar of flowers of Lantana by bird species (Taneja et al., 2022). Lantana's fruits are preferred as they are fleshy and available throughout the year (Aravind et al., 2010; Grass et al., 2013).

Different guilds showed preferences for different habitats in our study. The entire guild needs to be accommodated in management planning. It is difficult to provide specific recommendations for bird conservation, and guild-specific results like those in this study can contribute to a better understanding and provide conservation implications for protecting the biodiversity of JJCR.

CHAPTER 8

SYNTHESIS AND CONCLUSION

Though Jhilmil Jheel Conservation Reserve (JJCR) is renowned for Swamp Deer, it is also a paradise of birds. So, this study has been aimed to contribute towards the knowledge of the seasonal patterns of habitat selection by birds of Jhilmil Jheel Conservation Reserve and is very important for the better understanding of the conservation needs. Although there are few preliminary checklists of bird species of JJCR, the present detailed quantitative analysis of bird diversity of JJCR has given a better understanding of the community structure of birds in a small-sized PA. Besides discussing the most important findings of this study, this chapter aims to give recommendations for habitat restoration in JJCR.

8.1. Synthesis

The present work is the first detailed study of the bird community in Jhilmil Jheel Conservation Reserve. The study depicted that habitat heterogeneity, vegetation structure and composition, seasonality and species co-occurrence bring difference in bird species assemblage. Small isolated protected areas with habitat heterogeneity can harbour good biodiversity of avifauna. The study stated about the status of the overall bird community structure and the spatial and temporal pattern of bird species in JJCR. JJCR has high species richness index and the highest avifaunal diversity was observed in the riverine habitat. I found high species turnover compared to low species nestedness within and among the different habitats. The distribution of birds is mostly observed to be in single habitat in both summer and winter season.

For effective management strategies it is important to understand how species use resources. The study highlights the role of habitat variables in determining bird composition in a small-sized PA in human-dominated landscape. The bird species assemblage differed significantly across the different habitats in summer and winter seasons. The bird species distribution also depended on different physiognomic characteristics of vegetation such as canopy cover, tree height, ground cover and presence of fruiting trees. Thus, the small protected areas having habitat heterogeneity can harbor good biodiversity of lifeforms.

The study has documented the resource selection function of birds in different habitats. It has also described the general pattern of habitat use in different vertical stratas of JJCR emphasizing the importance of microhabitats. It also stated the importance of indicator species for monitoring the status of different habitats. The indicator bird species including various habitat specialists have definite preference for a particular habitat. All the habitats including plantations have their own relevance for birds. Maintaining functionally diverse bird assemblages in any landscape is an important management goal.

The study also investigated the patterns of species co-occurrence in the summer and winter seasons and the network complexity of bird communities in different habitats. Generalist species showed more co-occurrence than habitat specialists. There was a significant positive association when species co-occur more and negative association when species co-occur less frequently than by chance.

JJCR also supports variety of feeding guilds as it provides a diverse array of food sources for different bird species to feed on. Functional diversity shows the ecological trait variation of organisms. Majority of the feeding guilds showed positive association with GBH stating preference for old growth forest stands and showed negative association with anthropogenic disturbances such as presence of livestock and the presence of trails. Vegetation complexity should be preserved and retention of old growth forest stands better conserve birds. The small protected areas having habitat heterogeneity can harbour good biodiversity of lifeforms irrespective of anthropogenic disturbances. The findings indicate that anthropogenic activities such as livestock grazing may cause biodiversity loss in the long run. Anthropogenic disturbances can be detrimental to birds, jeopardising their ecological functions and threatening ecosystem resilience.

Conservation of forest biodiversity is therefore an important issue at local, national and global levels. The following recommendations are prescribed based on our data and observations in the field and the previous management plans of the Jhilmil Jheel Conservation Reserve:

8.2. Habitat Management

While managing habitats for different bird species, plants of all growth stages should be maintained from bare ground through young and old growth to decaying wood.

1. Maintaining plantation

The previous management committee had advised to remove all monoculture plantations of eucalyptus for the development of grassland and habitat improvement in a phased manner. But some old plantations (mixed with other tree species of regeneration forest) should be left untouched, as these old and tall trees are often important nesting sites for raptors particularly White-rumped Vultures, which are critically endangered. Fruiting plants such as *Morus alba, Ficus palmata, Grewia obtiva, Grewia tenax* can be planted.

2. Mixed Deciduous forest

There should be a check on logging and lopping. There should be conservation and restoration of fruit-yielding trees. As mentioned in the previous management plan, fodder plants can be planted. The fodder plants preferred by wild animals are as follows: *Terminalia tomentosa, Emblica officinalis, Mangifera indica, Ficus bengalensis, Zizyphus mauritiana, Aegle marmelos, Anogeissus latifolia, Grewia latifolia, Ehertia laevis, Bridelia retusa, Lagerstroemia parviflora, Ficus gromerata* and *Terminalia chebula*.

3. Scrub habitat

The scrub forest was used as a dumping site for waste by the nearby settlement. Disposal of waste should be prohibited as the degradation of scrub can affect birds which are dependent on scrub forest.

4. Grassland

There should be a proper grassland management plan for the reserve, maintaining diversity of grassland habitats ranging from wet marshy to dry grasslands. Grassland habitats are occupied by a small number of uniquely adapted bird species and they select a particular suite of habitat features. So, a mosaic of grassland habitat types should be maintained as some birds prefer short sparse grasslands and some prefer tall dense grasslands.

There is weed and invasive species infestation in grasslands. Though, Lantana shrubs were removed from some areas but more has to be removed from the interior. *Parthenium* should be removed in the sapling stage only. Broadcast seeding can be done to promote the regeneration of native grass flora. There should be a nursery for growing indigenous grassland species. For this plan, seeds of local species of grasses like *Saccharum spontaneum* and *Cynodon dactlylon* may be preferred for sowing after the first shower of monsoon rains. Mowing and haying on the grassland areas should not be conducted during the breeding season. The efficacy of grassland management practices should be monitored and documented. Highest priority should be appropriate management and preservation of existing native grasslands to avoid habitat fragmentation and degradation. There should be active management of the grasslands to control woody encroachment. Habitat loss should be prevented from the succession of grassland to cropland and shrubland. Unregulated livestock grazing poses threat to JJCR. So livestock grazing should be controlled. But the reserve management is currently understaffed to regulate and monitor the illegal grazing of cattle inside the reserve. So, patrolling needs to be strengthened with increase in manpower and local villagers and Gujjar deras should be encouraged to take up stall-feeding. Ecodevelopment committees comprising local communities of the reserve can facilitate the implementation of these measures.

5. Riverine habitat management

This habitat is of critical conservation concern. This habitat helps in nutrient recycling, water purification and surface and groundwater recharge. They act as habitats for many bird species including waterbirds, water-dependent birds, terrestrial bird species and winter visitors. There should be conservation of river banks through checks on livestock grazing. Some of the native species which supports avifaunal abundance, such as *Syzygium cumini*, *Madhuca sp.*, *Terminalia arjuna* can be planted.

6. Agriculture fields

Properly managed agricultural lands will support a large number of biodiversity and can serve as safe corridors for wildlife dispersal between patches. Forest bird species richness can be increased in agriculture landscape by maintaining heterogeneity through scattered trees which act as stepping stone for movement through agricultural landscapes and perch sites for foraging behaviour.

Besides habitat management there are other areas where management is required:

7. Waste management

JJCR currently needs a proper solid waste management system as the garbage generated by human settlements and tourists is disposed of through some ad hoc measures like burning. Segregation of waste at source is essential. Organic waste should be converted to bio-manure and platic and metal items should be recycled. Hundreds of devotees cross the reserve on foot during Shivaratri festival and often camp here, leaving lots of garbage behind. Increased vigilance and awareness need to be put in place. Plastic bottles containing packaged drinking water should not be permitted inside the reserve, and tourists should be encouraged to fill water at designated RO/purification points set up inside the tourism complex.

Avitourism

Bird-watching can promote both conservation and local community livelihoods through ecotourism. Regular bird identification and population monitoring training courses for field staff and local community is rcommended as they need more formal training in this regard.

8.3. Direction for future research

Following are some of the key research priorities for Jhilmil Jheel Conservation Reserve to be taken up for the benefit of the management:

- Though JJCR is known for its terai grasslands, there has yet to be a study on grassland-specialist birds of the region. Ecology of grassland birds of JJCR should be investigated on priority basis. So, there is a need for research on grassland birds of JJCR and their seasonal movements. The knowledge should be enhanced on the winter distribution, ecology and habitat requirements of many grassland birds. Grassland habitat management for Swamp Deer should be developed, and this should maintain the habitat value of these tall wet grasslands to birds that are unique to this ecosystem.
- Further study should be carried out to better characterize the use of co-occurrence in habitat management.
- Future studies should identify how life history traits such as body mass and diet specialization interact with habitat features, landscape attributes and anthropogenic disturbances and how this ultimately affects the functional traits. Understanding the relative importance of different traits on species'

vulnerability to disturbance is essential for predicting future ecological impacts of habitat disturbance.

- A study on comparative ecology between the generalist and specialist communities can be done and resource partitioning between congenic species like Red-vented Bulbul, Red-whiskered Bulbul and Himalayan Bulbul can be done.
- Periodical soil and water monitoring need to be put in place at JJCR, as the wetlands are highly dynamic ecosystems. Effect of soil and water quality (with focus on their physico-chemical and biological characteristics) on bird communities can be explored.
- Role of plantations in harbouring the biodiversity of the conservation reserve and a roadmap for plantation management in response to biodiversity value can be developed.

8.4. General conclusions

At the end, it was possible to state that habitat heterogeneity whether in large or in small conservation areas can attribute to assemblage of diverse bird community. In the present study we found JJCR as a small isolated protected area with habitat heterogeneity harbours good avifauna diversity. JJCR serves as an important foraging and resting habitat for migratory and resident birds. The indicator species should be included in the management plan as it would help monitoring the habitat quality. The understanding of co-occurrence is of relevance, especially in small PAs such as JJCR which are often islands in a matrix of human–dominated landscape and are susceptible to human exploitation. Maintaining functionally diverse bird assemblages in any landscape is an important management goal and it would be valuable to include feeding guild in the conservation plans and monitoring programmes.

Even though the present study area is protected being a conservation reserve still some threat persists such as logging lopping, livestock grazing etc. which might affect bird community in the long run. For the long term management of this Conservation Reserve, proper management plan and regulation is needed. These small forest patches like JJCR, therefore, need to be better managed to maintain high biological diversity by meeting the habitat requirements of a variety of wildlife, including birds.

REFERENCES

Abdar, M. R. (2014). Seasonal diversity of birds and ecosystem services in agricultural area of Western Ghats, Maharashtra state, India. Journal of Environmental Science, Toxicology and Food Technology, 8(1), 100-105.

Acharya, B. K., Vijayan, L., and Chettri, B. (2010). The bird community of Shingba Rhododendron Wildlife Sanctuary, Sikkim, Eastern Himalaya, India. Tropical Ecology, 51(2), 149-159.

Acharya BK, Vijayan L. (2017). Vertical stratification of birds in different vegetation types along an elevation gradient in the Eastern Himalaya, India. Ornithol Soc Japan 16: 131-140.

Adams, R. H. (1941). Stratification, diurnal and seasonal migration of the animals in a deciduous forest. Ecological Monographs, 11(2), 189-227.

Aggarwal S, Sahi DN, Wani A (2008) Feeding guilds of avifauna of Nandni Wildlife Sanctuary, Jammu (Jammu and Kashmir). The Ecoscan 2:157–160

Ahmed T., Bargali H.S., Bisht D., Mehra G.S. and Khan A. (2019). Status of water birds in Haripura-Baur Reservoir, western Terai-Arc landscape, Uttarakhand, India. Journal of Threatened Taxa 11(9): 14158–14165.

Ahmed, T., Bargali, H. S., and Khan, A. (2019). Status and Distribution of Avifauna in Ramnagar Forest Division, Western Terai-Arc Landscape, Uttarakhand. Indian Forester, 145(10), 935-945.

Ahmed, T., and Khan, A. (2022). Avifaunal feeding guilds' response to landscape compositional heterogeneity and their drivers in forest mosaic, Uttarakhand, India. Journal of Tropical Ecology, 38(4), 183-193.

Albrecht, M., and Gotelli, N. J. (2001). Spatial and temporal niche partitioning in grassland ants. Oecologia, 126(1), 134-141.

Aleixo, A. (1999). Effects of selective logging on a bird community in the Brazilian Atlantic Forest. The Condor, 101(3), 537-548.

Alexandrino ER, Buechley ER, Karr JR, Ferraz KMPMB, Ferraz SFB, Couto HTZ, Sekercioglu CH (2017) Bird based Index of Biotic Integrity: Assessing the ecological condition of Atlantic Forest patches in human-modified landscape. Ecological Indicators 73: 662–675. https://doi.org/10.1016/j.ecolind.2016.10.023

Ali, S. (1979). Bird study in India: Its history and its importance. India International Centre Quarterly, 6(2), 127-139.

Ali S. (2002). The Book of Indian Birds. 13th Edition. Oxford University Press, New Delhi, 326pp

Bachan, A. K. H. (2003). Riparian vegetation along the middle and lower zones of the Chalakkudy River. Limnological Association of Kerala, Iringalakkuda Kerala, IN.

Allouche, O., Kalyuzhny, M., Moreno-Rueda, G., Pizarro, M., and Kadmon, R. (2012). Area–heterogeneity tradeoff and the diversity of ecological communities. Proceedings of the National Academy of Sciences, 109(43), 17495-17500.

Anderson, S. H., and H. H. Shugart, Jr. (1974). Avian community analysis of Walker Branch Water-shed. ORNL/TM-4700. Oak Ridge National Laboratory, Union Carbide Corporation Nuclear Division, Oak Ridge, Tenn

Anderson, M.J. (2001). A new method for non-parametric multivariate analysis of variance. Austral Ecol.. 26: 32-46. doi:10.1111/j.1442-9993.2001.01070.pp.x.

Antongiovanni, M., and Metzger, J. P. (2005). Influence of matrix habitats on the occurrence of insectivorous bird species in Amazonian forest fragments. Biological Conservation, 122, 441–451.

Araújo, M. B., Rozenfeld, A., Rahbek, C., and Marquet, P. A. (2011). Using species co-occurrence networks to assess the impacts of climate change. Ecography, 34(6), 897-908.

Aravind, N. A., Rao, D., Ganeshaiah, K. N., Uma Shaanker, R., and Poulsen, J. G. (2010). Impact of the invasive plant, Lantana camara, on bird assemblages at Male Mahadeshwara Reserve Forest, South India. Tropical Ecology, 51(2S), 325-338

Arnold, G.W. (1983). The influence of ditch and hedgerow structure, length of hedgerows and area of woodland and gardens on bird numbers on farmland. J. Appl. Ecol., 20, 731.750.

Arnold, G.W., (1988). The effects of habitat structure and floristics on the densities of bird species in Wandoo woodland. Australian Wildlife Research 15, 499–510.

Aymí, R. and G. Gargallo (2021). Lesser Whitethroat (Curruca curruca), version 1.1. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.leswhi4.01.1

Balodi K.N., Anwar M. and Budhani L. (2018). Diversity and Conservation status of Avifauna in Ramnagar Forest division, Corbett Landscape, Uttarakhand, India. Bird-o-soar #12. In: Zoo’s Print 33(2): 35:45.

Bashir, T., Behera, S. K., Khan, A., and Gautam, P. (2012). An inventory of mammals, birds and reptiles along a section of the river and banks of upper Ganges, India. Journal of Threatened Taxa, 2900-2910.

Baskaran, N., Kannan, G., Anbarasan, U., Thapa, A., & Sukumar, R. (2013). A landscape-level assessment of Asian elephant habitat, its population and elephant–human conflict in the Anamalai hill ranges of southern Western Ghats, India. Mammalian Biology, 78(6), 470-481.

Bibby C. J., Burgess N. D., Hill D. A., and Mustoe S. (2000). Bird census techniques. Elsevier, 85-104.

Balda, R. P. (1969) Foliage use by birds of the oak-juniper wood land and ponderosa pine forest in southeastern Arizona. Condor. 71: 399-412. https://doi.org/10.2307/1365738

Baldi A (2003) Using higher taxa as surrogates of species richness: a study based on 3700 Coleoptera, Diptera, and Acari species in Central-Hungarian reserves. Basic Appl Ecol 4:589–593

Baldwin, R. F., and Fouch, N. T. (2018). Understanding the biodiversity contributions of small protected areas presents many challenges. Land, 7(4), 123. DOI:10.3390/land7040123.

Balmford,A.,Green,R.E., and Scharlemann, J.P.W.(2005).Sparingland for nature:exploring the potential impact of changes in agricultural yield on theareaneededforcropproduction.Glob.Chang.Biol. 11,1594–1605.doi: 10.1111/j.1365-2486.2005.001035.x.

Barberan, A., Bates, S. T., Casamayor, E. O., and Fierer, N. (2012).Using network analysis to explore co-occurrence patterns in soil microbial communities. ISME Journal, 6, 343–351. https ://doi.org/10.1038/ismej .2011.119.

Bar-Massada, A., Radeloff, V.C., Stewart, S.I. (2014). Biotic and abiotic effects of human

settlements in the wildland–urban interface. Bioscience 64, 429–437. DOI:10.1093/biosci/biu039.

Barragan F, Moreno CE, Escobar F, Halffte G, Navarrete D (2011) Negative impacts of human land use on dung beetle functional diversity. PLoS One 6:e17976

Barton, K., 2018. MuMIn: Multi-Model Inference. R package version 1.40.4. https:// CRAN.R-project.org/package=MuMIn.

Basile, M., Asbeck, T., Cordeiro Pereira, J. M., Mikusiński, G., and Storch, I. (2021). Species co-occurrence and management intensity modulate habitat preferences of forest birds. BMC biology, 19(1), 1-15.

Bascompte, J. (2007). Networks in ecology. Basic and Applied Ecology, 8(6), 485-490.

Bascompte, J., and Jordano, P. (2007). Plant-animal mutualistic networks: the architecture of biodiversity. Annu. Rev. Ecol. Evol. Syst., 38, 567-593.

Bates, M. (1944). Observations on the distribution of diurnal mosquitoes in a tropical forest. Ecology, 25(2), 159-170.

Bawa, K. S., and Seidler, R. (1998). Natural forest management and conservation of biodiversity in tropical forests. Conservation biology, 12(1), 46-55.

Beaudrot,L.,Ahumada,J.A.,O'Brien,T.,Alvarez-Loayza,P.,Boekee,K.,Campos Arceiz,A.,etal.(2016).Standardizedassessmentofbiodiversitytrendsintropicalforestprotectedareas:theendisnotinsight.PLoSBiol.14:e1002357.doi:10.1371/journal.pbio.1002357.

Beccaloni, G. W., and Gaston, K. J. (1995). Predicting the species richness of neotropical forest butterflies: Ithomiinae (Lepidoptera: Nymphalidae) as indicators. Biological conservation, 71(1), 77-86.

Berg, Å. (2002). Breeding birds in short-rotation coppices on farmland in central Sweden—the importance of Salix height and adjacent habitats. Agriculture, Ecosystems and Environment, 90(3), 265-276.

Bhagwat, S. A., Kushalappa, C. G., Williams, P. H., and Brown, N. D. (2005). The role of informal protected areas in maintaining biodiversity in the Western Ghats of India. Ecology and Society, 10(1). DOI:10.5751/ES-01285-100108.

Blair, R. B. (1996). Land use and avian species diversity along an urban gradient. Ecological applications, 6(2), 506-519. https://doi.org/10.2307/2269387.

Blair, R. B., and Launer, A. E. (1997). Butterfly diversity and human land use: Species assemblages along an urban grandient. Biological conservation, 80(1), 113-125. https://doi.org/10.1016/S0006-3207(96)00056-0.

Blake, J. G., and Karr, J. R. (1984). Species composition of bird communities and the conservation benefit of large versus small forests. Biological Conservation, 30(2), 173-187. DOI:10.1016/0006-3207(84)90065-X.

Bibby C. J., Burgess N. D., Hill D. A., and Mustoe S. (2000). Bird census techniques. Elsevier, 85-104

Blake, R. W. (1983). Mechanics of gliding in birds with special reference to the influence of the ground effect. Journal of biomechanics, 16(8), 649-654.

Blaum N, Mosner E, Schwager M, Jeltsch F (2011) How functional is functional? Ecological groupings in terrestrial animal ecology: towards an animal functional type approach. Biodivers Conserv 20:2333–2345. https://doi.org/10.1007/s10531-011-9995-1

Block, W. M., and Brennan, L. A. (1993). The habitat concept in ornithology. In Current ornithology (pp. 35-91). Springer, Boston, MA.

Blois, J. L., Zarnetske, P. L., Fitzpatrick, M. C., and Finnegan, S. (2013). Climate change and the past, present, and future of biotic interactions. Science, 341(6145), 499-504.

Brambilla, M., Rizzolli, F., Franzoi, A., Caldonazzi, M., Zanghellini, S., and Pedrini, P. (2020). A network of small protected areas favoured generalist but not specialized wetland birds in a 30-year period. Biological Conservation, 248, 108699. DOI:10.1016/j.biocon.2020.108699.

Brereton, T., van Swaay, C. H. R. I. S., and van Strien, A. R. C. O. (2009). Developing a butterfly indicator to assess changes in Europe's biodiversity. Avocetta, 33, 19-27.

Böhning-Gaese, K., and Oberrath, R. (1999). Phylogenetic effects on morphological, life-history, behavioural and ecological traits of birds. Evolutionary Ecology Research, 1(3), 347-364.

Boyce, M. S., and McDonald, L. L. (1999). Relating populations to habitats using resource selection functions. Trends in ecology and evolution, 14(7), 268-272.

Bruno JF, Stachowicz JJ, Bertness MD. (2003) Inclusion of facilitation into ecological theory. Trends Ecol Evol.;18(3):119–25. https://doi.org/10.1016/S0169-5347(02)00045-9.

Buckley L, Roughgarden J. (2005) Lizard habitat partitioning on islands: the interaction of local and landscape scales. J Biogeogr. Dec 1; 32(12): p. 2113±21.

Butler, S. J., Freckleton, R. P., Renwick, A. R., and Norris, K. (2012). An objective, niche-based approach to indicator species selection. Methods in Ecology and Evolution, 3(2), 317-326.

Bachan, K.H.A., 2003 [viewed 25 August 2013]. Riparian vegetation along the middle and lower zones of the Chalakkudy River, Kerala, India. Project Report 26/2000 [online]. Available from: https:// web.archive.org/web/20090319060415/http://krpcds.org/ report/amita.pdf.

Badyaev, A. V., D. D. Gibson, B. Kessel, P. Pyle, and M. A. Patten (2020). White Wagtail (Motacilla alba), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.whiwag.01

Balasubramanian, P., V.S. Vijayan, S.N. Prasad, and R. Venkitachalam. (2005). Status and distribution of the hornbills in the Eastern Ghats, Project Report, Salim Ali Centre for Ornithology and Natural History, Coimbatore, India. 32 pp

Baldiviezo, C. D. V., Passos, M. F. D. O., and Azevedo, C. S. D. (2021). Bird-plant interaction networks in native forests and eucalyptus plantations within a protected area. Papéis Avulsos de Zoologia, 61.

Baral, H. S. (1996). Grassland birds of Nepal. Bird conservation Nepal Newsletter, 485(481), 4.

Baral, H. S. (2001). Community structure and habitat association of lowland grassland birds in Nepal. University of Amsterdam, The Netherlands. Ph. D thesis Published

Baral, N., N. Timilsina and B. Tamang (2003). Status ofBengal Florican Houbaropsis bengalensis in Nepal.Forktail 19: 51-55.

Baral, H. S., and Inskipp, C. (2009). The birds of Sukla Phanta wildlife reserve, Nepal. Our Nature, 7(1), 56-81.

Baral, H. S. (2004) Status, distribution, ecology and behaviour of White-tailed Stonechat Saxicola leucura in Nepal with reference to Indian subcontinent. FOR ORNITHOLOGISTS.

Barlow, J., Gardner, T. A., Araujo, I. S., Ávila-Pires, T. C., Bonaldo, A. B., Costa, J. E., ... and Peres, C. A. (2007). Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. Proceedings of the National Academy of Sciences, 104(47), 18555-18560.

Barlow, J., França, F., Gardner, T. A., Hicks, C. C., Lennox, G. D., Berenguer, E., and Graham, N. A. (2018). The future of hyperdiverse tropical ecosystems. Nature, 559(7715), 517-526.

Bayle, G.K. (2019). Eological and social impacts of eucalyptus tree plantation on the environment. Journal of Biodiversity Conservation and Bioresource Management, 5: 93-104.

Blackburn, T. M., and Gaston, K. J. (2002). Scale in macroecology. Global Ecology and Biogeography, 11(3), 185-189.

Beck, J. (2006). Are rank--abundance distributions a useful tool of assemblage discrimination in tropical moths? Dong wu xue bao. [Acta Zoologica Sinica], 52(6), 1148-1154.

Beedy, E. C. (1981). Bird communities and forest structure in the Sierra Nevada of California. The Condor, 83(2), 97-105.

Bellamy, P. E., Hinsley, S. A., and Newton, I. (1996). Factors influencing bird species numbers in small woods in south-east England. Journal of Applied Ecology, 249-262.

Bell, H. L. (1982). A bird community of lowland rainforest in New Guinea. 4. Birds of secondary vegetation. Emu, 82(4), 217-224.

Bengtson, S. A., and Ulfstrand, S. (1971). Food resources and breeding frequency of the harlequin duck Histrionicus histrionicus in Iceland. Oikos, 235-239.

Benton TG, Vickery JA, Wilson JD (2003) Farmland biodiversity: Is habitat heterogeneity the key? Trends in Ecology and Evolution 18(4): 182–188. https://doi.org/10.1016/S0169- 5347(03)00011-9

Bennett AF, Radford JQ, Haslem A (2006) Properties of land mosaics: Implications for nature conservation in agricultural environments. Biological Conservation 133(2): 250–264. https://doi.org/10.1016/j.biocon.2006.06.008

Berg, Å. (1997). Diversity and abundance of birds in relation to forest fragmentation, habitat quality and heterogeneity. Bird study, 44(3), 355-366.

Berg, Å.and Pärt, T. (1994). Abundance of breeding farmland birds on arable and set-aside fields at forest edges. Ecography, 17, 147.152.

Bernard, E. (2001). Vertical stratification of bat communities in primary forests of Central Amazon, Brazil. Journal of Tropical Ecology, 115–126. BirdLife International (2015) Species factsheet: Chaetornis striata.http://www.birdlife.org on 08/05/2015.

Bersier, L.F., Meyer, D.R., 1994. Bird assemblages in mosaic forests: the relative importance of vegetation structure and floristic composition along the successional gradient. Acta Oecologica 15, 561–576.

Blake, J. G. (2007). Neotropical forest bird communities: a comparison of species richness and composition at local and regional scales. The Condor, 109(2), 237-255.

Blake, J. G., and Karr, J. R. (1984). Species composition of bird communities and the conservation benefit of large versus small forests. Biological Conservation, 30(2), 173-187.

Boatman, N. D., Brickle, N. W., Hart, J. D., Milsom, T. P., Morris, A. J., Murray, A. W., ... and Robertson, P. A. (2004). Evidence for the indirect effects of pesticides on farmland birds. Ibis, 146, 131-143.

Basavarajappa, S. (2006). Avifauna of agro-ecosystems of Maidan area of Karnataka. Zoos' Print Journal, 21(4), 2217-2219.

Bonebrake, T. C., Ponisio, L. C., Boggs, C. L., and Ehrlich, P. R. (2010). More than just indicators: a review of tropical butterfly ecology and conservation. Biological conservation, 143(8), 1831-1841.

Borgelt, J., Dorber, M., Høiberg, M. A., & Verones, F. (2022). More than half of data deficient species predicted to be threatened by extinction. Communications biology, 5(1), 1-9.

Borsboom, A.; Wang, J.; Lees, N.; Mathieson, M. and Hogan, L. (2002). Measurement and integration of fauna biodiversity values in Queensland agroforestry system. Canberra, Joint Venture Agroforestry Program. Rural Industries Research and Development Corporation, 2: 44.

Boutin, S., Haughland, D. L., Schieck, J., Herbers, J., and Bayne, E. (2009). A new approach to forest biodiversity monitoring in Canada. Forest Ecology and Management, 258, S168-S175.

Brawn, J. D., Robinson, S. K., and Thompson III, F. R. (2001). The role of disturbance in the ecology and conservation of birds. Annual review of Ecology and Systematics, 251-276.

Brown, J. H. (1981). Two decades of homage to Santa Rosalia: Toward a general theory of diversity. American Zoologist, 21(4), 877–888. https://doi.org/10.1093/icb/21.4.877

Bryce SA, Hughes RM, Kaufmann PR. (2002). Development of a bird integrity index: using bird assemblages as indicators of riparian condition. Environ Manage 30:294–310.

Cáceres, M. D., & Legendre, P. (2009). Associations between species and groups of sites: indices and statistical inference. *Ecology*, *90*(12), 3566-3574.

Cam, E., Nichols, J. D., Sauer, J. R., Hines, J. E., and Flather, C. H. (2000). Relative species richness and community completeness: birds and urbanization in the Mid-Atlantic States. Ecological Applications, 10(4),1196-1210. DOI:10.1890/1051-0761(2000)010[1196:RSRACC]2.0.CO;2

Canfield, R. H. (1941). Application of the line interception method in sampling range vegetation. Journal of forestry, 39(4), 388-394.

Canterbury, G. E., Martin, T. E., Petit, D. R., Petit, L. J., and Bradford, D. F. (2000). Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conservation Biology, 14(2), 544-558.

Capon, S., James, C., and Reid, M. (Eds.). (2016). Vegetation of Australian riverine landscapes: biology, ecology and management. Csiro publishing.

CaraDonna, P. J., Petry, W. K., Brennan, R. M., Cunningham, J. L., Bronstein, J. L., Waser, N. M., & Sanders, N. J. (2017). Interaction rewiring and the rapid turnover of plant–pollinator networks. Ecology letters, 20(3), 385-394.

Chapman, K. A., and Reich, P. B. (2007). Land use and habitat gradients determine bird community diversity and abundance in suburban, rural and reserve landscapes of Minnesota, USA. Biological Conservation, 135(4), 527-541. https://doi.org/10.1016/j.biocon.2006.10.050

Chatterjee S, Basu P (2017) Food preferences determine habitat selection at multiple scales: implication for bird conservation in tropical forests. Anim Conserv 21:332–342. https://doi.org/10.1111/acv.12397

Chettri, N., Sharma, E., and Deb, D. C. (2001). Bird community structure along a trekking corridor of Sikkim Himalaya: a conservation perspective. Biological Conservation, 102(1), 1-16.

Chettri, N., Deb, D. C., Sharma, E., and Jackson, R. (2005). The relationship between bird communities and habitat. Mountain Research and Development, 25(3), 235-243.

Clough, Y., Putra, D. D., Pitopang, R., and Tscharntke, T. (2009). Local and landscape factors determine functional bird diversity in Indonesian cacao agroforestry. Biological Conservation, 142(5), 1032-1041.

Cody, M. L. (1981). Habitat selection in birds: the roles of vegetation structure, competitors, and productivity. BioScience, 31(2), 107-113.

Cody. M. L. ed. (1985). Habitat selection in birds. Academic Press, New York.

Cohen, J. E. (1978). Food webs and niche space. Princeton University Press, Princeton, New Jersey, USA

Cohen, J. E., F. Briand, and C. M. Newman. (1990). Community food webs: data and theory. Springer-Verlag, Berlin, Germany.

Collar, N. (2021). Siberian Stonechat (Saxicola maurus), version 1.1. In Birds of the World (Editor not available). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.sibsto1.01.1

Collar, N. and D. A. Christie (2020). Pied Bushchat (Saxicola caprata), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.piebus1.01

Collins, S.L. (1981). A comparison of nest-site and perch-site vegetation structure for seven species of warblers. Wilson Bull. 93, 542-547.

Cole, B. J. (1981). Colonizing abilities, island size, and the number of species on archipelagoes. The American Naturalist, 117(5), 629-638.

Cooke, S. C., Balmford, A., Johnston, A., Newson, S. E., and Donald, P. F. (2020). Variation in abundances of common bird species associated with roads. Journal of Applied Ecology, 57(7), 1271-1282.https://doi.org/10.1111/1365-2664.13614

Cox, D. T., and Gaston, K. J. (2015). Likeability of garden birds: Importance of species knowledge and richness in connecting people to nature. PloS one, 10(11), e0141505.

Cramer, M. J., and Willig, M. R. (2002). Habitat heterogeneity, habitat associations, and rodent species diversity in a sand–shinnery-oak landscape. Journal of mammalogy, 83(3), 743-753.

Crooks, K. R., Suarez, A. V., and Bolger, D. T. (2004). Avian assemblages along a gradient of urbanization in a highly fragmented landscape. Biological conservation, 115(3), 451-462.

Crowe, T. M., and Crowe, A. A. (1982). Patterns of distribution, diversity and endemism in Afrotropical birds. Journal of Zoology, 198(4), 417-442.

Cueto, V. R., and de Casenave, J. L. (1999). Determinants of bird species richness: role of climate and vegetation structure at a regional scale. Journal of Biogeography, 26(3), 487-492.

Cadotte MW, Tucker CM. Should environmental filtering be abandoned? Trends Ecol Evol. (2017);32(6):429–37. https://doi.org/10.1016/j.tree.2017.03.004.

Chase JM, Abrams PA, Grover JP, Diehl S, Chesson P, Holt RD. (2002). The interaction between predation and competition: a review and synthesis. Ecol Lett.;5(2):302–15. https://doi.org/10.1046/j.1461-0248.2002.00315.x.

Cody ML (2001) Bird diversity components in Australian Eucalyptus and north temperate Quercus woodlands. Auk 118: 443–456.

Cohen JE. 1978. Food Webs and Niche Space. Princeton, NJ: Princeton Univ. Press

Cohen JE, Briand F, Newman CM. 1990. Community Food Webs: Data and Theory. Berlin: Springer-Verlag

Connor, E. F., and Simberloff, D. (1983). Interspecific competition and species co-occurrence patterns on islands: null models and the evaluation of evidence. Oikos, 455-465.

Compton, B. W., Rhymer, J. M., and McCollough, M. (2002). Habitat selection by wood turtles (Clemmys insculpta): an application of paired logistic regression. Ecology, 83(3), 833-843.

Carignan, V., and Villard, M. A. (2002). Selecting indicator species to monitor ecological integrity: a review. Environmental monitoring and assessment, 78(1), 45-61.

Carvalho F, Fabián ME and Menegheti JO (2013) Vertical structure of an assemblage of bats (Mammalia: Chiroptera) in a fragment of Atlantic Forest in Southern Brazil. Zoologia 30: 491–498.

Cassola, F., and Pearson, D. L. (2000). Global patterns of tiger beetle species richness (Coleoptera: Cicindelidae): their use in conservation planning. Biological Conservation, 95(2), 197-208.

Caccamise, D. F., Reed, L. M., DeLay, L. S., Bennett, K. A., and Dosch, J. J. (1996). The avian communities of a suburban grassland refugium: population studies at an airport in Northeastern United States. Acta Ornithologica, 1(31), 3-13.

Capon, S.J., James, C. and Reid, M., eds. 2016. Vegetation of Australian riverine landscapes: biology, ecology and management. Australia: CSIRO Publishing Co., 407 p.

Carnus, J. M., Parrotta, J., Brockerhoff, E., Arbez, M., Jactel, H., Kremer, A., and Walters, B. (2006). Planted forests and biodiversity. Journal of forestry, 104(2), 65-77.

Champion, H. G., and Seth, S. K. (1968). A revised survey of the forest types of India. Manager of publications.

Chase, J. M., and Leibold, M. A. (2009). Ecological niches: linking classical and contemporary approaches. University of Chicago Press.

Cheke, R. and C. Mann (2020). Purple Sunbird (Cinnyris asiaticus), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.pursun4.01

Chettri, N., Sharma, E., and Deb, D. C. (2001). Bird community structure along a trekking corridor of Sikkim Himalaya: a conservation perspective. Biological Conservation, 102(1), 1-16.

Chettri, N., Deb, D. C., Sharma, E., and Jackson, R. (2005). The relationship between bird communities and habitat. Mountain Research and Development, 25(3), 235-243.

Cincotta, R. P., Wisnewski, J., and Engelman, R. (2000). Human population in the biodiversity hotspots. Nature, 404(6781), 990-992.

Clement, P. (2020). Hume's Warbler (Phylloscopus humei), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.humwar1.01

Clout, M., and Gaze, P. D. (1984). Effects of plantation forestry on birds in New Zealand. Journal of applied ecology, 795-815.

Collar, N. and A. Bonan (2020). Indian Robin (Copsychus fulicatus), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.indrob1.01

Cody, M. L. (1968). On the methods of resource division in grassland bird communities. Am. Nat.102:107-147

Colquhoun, M. K., and Morley, A. (1943). Vertical zonation in woodland bird communities. The Journal of Animal Ecology, 75-81.

Croonquist MJ, Brooks RP (1993) Effects of habitat disturbance on bird communities in riparian corridors. J Soil Water Conserv 48:65–70.

Csardi, G., and Nepusz, T. (2006). The igraph software package for complex network research. InterJournal, complex systems, 1695(5), 1-9.

C. L. Seymour and R. E. Simmons, (2008). “Can severely fragmented patches of riparian vegetation still be important for arid-land bird diversity?” Journal of Arid Environments, vol. 72, no. 12, pp. 2275–2281.View at: Publisher Site | Google Scholar.

Dagan, U., and Izhaki, I. (2019). Understory vegetation in planted pine forests governs bird community composition and diversity in the eastern Mediterranean region. Forest Ecosystems, 6(1), 1-16.

Dahal, B.R., Mcalpine, C.A., Maron, M., (2015). Impacts of extractive forest uses on bird assemblages vary with landscape context in lowland nepal. Biol. Conservat. 186, Daily G , Ehrlich P, Sanchez-Azofeifa A. (2001) Countryside Biogeography Use of human-dominated habitats by the avifauna of southern Costa Rica, Ecological Application 11 (1) 1-13

Daniels R.J.(1989), A Conservation Strategy for the Birds of the Uttara Kannada District, Phd. Thesis, Centre for Ecological Sciences, Bengaluru.

Dasgupta, S., Bhattacharya, T., Bhamburkar, P., and Kaul, R. (2022). Role of Anthropogenic drivers in altering the forest community structure in a prime tiger habitat in central India. Canadian Journal of Forest Research, 52(3), 406-415.

Das, J. P., Nath, N. K., Singha, H., and Sahu, H. K. (2007). Winter birds of Kakoijana (Proposed) Wildlife Sanctuary, Assam, India. J. Bombay Nat. Hist. Soc, 80, 141-143.

Das S. K., Dashahare A., Marathe S., Kundu N., and Kesharwani R. (2011). Status of raptors with special reference to vultures in and around Rajaji National Park, India. World Journal of Zoology, 6(4), 350-356.

Dauglas D. C. Ratti, J. T., Black, R. A. and Alldredge R. A. (1992) Avian habitat associations in riparian zones of Idaho's Centennial mountains. Wilson Bull. 104:485-500

De Graaf R. M., Tilghman N. G., and Anderson S. H. (1985). Foraging guilds of North American birds. Environmental Management, 9(6), 493-536.

Decocq, G., Andrieu, E., Brunet, J., Chabrerie, O., De Frenne, P., De Smedt, P., ... & Wulf, M. (2016). Ecosystem services from small forest patches in agricultural landscapes. Current Forestry Reports, 2(1), 30-44.

Deikumah, J. P., McAlpine, C. A., and Maron, M. (2014). Mining matrix effectson West African rainforest birds. Biological Conservation, 169, 334–343.

del Hoyo, J., A. Martínez-Vilalta, A. Motis, N. Collar, G. M. Kirwan, and D. A. Christie (2020). Little Egret (Egretta garzetta), version 1.0. In Birds of the World (S. M. Billerman, B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.litegr.01

Dendup, P., Wangdi, L., Jamtsho, Y., Kuenzang, P., Gyeltshen, D., Tashi, T., and Tshering, B. (2021). Bird diversity and conservation threats in Jigme Dorji National Park, Bhutan. Global Ecology and Conservation, 30, e01771.

Devi, A., Hussain, S. A., Sharma, M., Gopi, G. V., and Badola, R. (2022). Seasonal pattern of food habits of large herbivores in riverine alluvial grasslands of Brahmaputra floodplains, Assam. Scientific reports, 12(1), 1-15.

Devictor, V., and Jiguet, F. (2007). Community richness and stability in agricultural landscapes: The importance of surrounding habitats. Agriculture, Ecosystems and Environment, 120, 179–184.

Dhindsa, M. S., and Saini, H. K. (1994). Agricultural ornithology: an Indian perspective. Journal of biosciences, 19(4), 391-402.

Dilger, W. C. (1956). Adaptive modifications and ecological isolating mechanisms in the thrush genera Catharus and Hylocichla. Wilson Bull. 68:171-199.

Dinanti, R. V., Winarni, N. L., and Supriatna, J. (2018). Vertical stratification of bird community in Cikepuh wildlife reserve, West Java, Indonesia. Biodiversitas Journal of Biological Diversity, 19(1), 134-139.

Dirzo, R., and Raven, P. H. (2003). Global state of biodiversity and loss. Annual review of Environment and Resources, 28(1), 137-167.

Drapeau, P., Leduc, A., Giroux, J. F., Savard, J. P. L., Bergeron, Y., and Vickery, W. L. (2000). Landscape-scale disturbances and changes in bird communities of boreal mixed-wood forests. Ecological Monographs, 70(3), 423-444.

Dendup, P., Wangdi, L., Jamtsho, Y., Kuenzang, P., Gyeltshen, D., Tashi, T., ...andTshering, B. (2021). Bird diversity and conservation threats in Jigme Dorji National Park, Bhutan. Global Ecology and Conservation, 30, e01771.

de Bonilla, E. P. D., León-Cortés, J. L., and Rangel-Salazar, J. L. (2012). Diversity of bird feeding guilds in relation to habitat heterogeneity and land-use cover in a human-modified landscape in southern Mexico. Journal of Tropical Ecology, 28(4), 369-376.

De Villiers, M. S. (2009). Birds and environmental change: building an early warning system in South Africa.

Dey, S., Dey, S., Choudhary, S. K., and Kelkar, N. (2014). An annotated bird checklist of the Vikramshila Gangetic Dolphin Sanctuary, Bhagalpur, Bihar, India, with an assessment of threats to bird conservation. Forktail (November 30): 34â, 40.

Diamond, J. M. (1975). Assembly of species communities. In M. L.CodyandJ. M. Diamond (Eds.), Ecology and evolution of communities (pp. 342–444). Cambridge, MA: Belknap Press.

Diamond, J. M. (1976). Island biogeography and conservation: strategy and limitations. Science, 193(4257), 1027-1029.

Donázar, J. A., Cortés-Avizanda, A., Fargallo, J. A., Margalida, A., Moleón, M., Morales-Reyes, Z., and Serrano, D. (2016). Roles of raptors in a changing world: from flagships to providers of key ecosystem services. Ardeola, 63(1), 181-234.

Dormann, C. F., Bobrowski, M., Dehling, D. M., Harris, D. J., Hartig, F., Lischke, H., and Kraan, C. (2018). Biotic interactions in species distribution modelling: 10 questions to guide interpretation and avoid false conclusions. Global ecology and biogeography, 27(9), 1004-1016.

Dubey, S. K., Chakraborty, D. C., Sandipan, G., Mahashweta, M., Ranita, B.,andNeogy, A. B. (2015). Avian diversity in the Jaldapara National Park, West Bengal, India with a notes on their habitat association and feeding guild. Indian Forester, 141(10), 1092-1101.

Duelli, P., and Obrist, M. K. (1998). In search of the best correlates for local organismal biodiversity in cultivated areas. Biodiversity and Conservation, 7(3), 297-309.

Dufrêne, M., & Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological monographs*, *67*(3), 345-366.

Dunlavy, J. C. (1935). Studies on the phyto-vertical distribution of birds. The Auk, 425-431.

Ehrlich, P., Dobkin, D. S., and Wheye, D. (1988). Birder's handbook. Simon and Schuster.

Elias JE (1997) Avian species richness and abundance levels indifferent habitats along the Band River Corridor, northern Wisconsin. Passenger Pigeon 59:21–44.

Elo, M., Ketola, T., and Komonen, A. (2021). Species co-occurrence networks of ground beetles in managed grasslands. Community Ecology, 22(1), 29-40.

Elsen, P. R., Kalyanaraman, R., Ramesh, K., and Wilcove, D. S. (2017). The importance of agricultural lands for Himalayan birds in winter. Conservation biology, 31(2), 416-426.

Emlen, J. T., Dejong, M. J., Jaeger, M. J., Moermond, T. C., Rusterholz, K. A., and White, R. P. (1986). Density trends and range boundary constraints of forest birds along a latitudinal gradient. The Auk, 103(4), 791-803.

Erard, C. (1989). Bird community structure in two rainforests: Africa (Gabon) and South America (French Guiana)-A comparison. In Vertebrates in complex tropical systems (pp. 89-122). Springer, New York, NY.

Erdelen, M. (1984). Bird communities and vegetation structure: I. Correlations and comparisons of simple and diversity indices. Oecologia, 61(2), 277-284.

Estevo, C. A., Nagy-Reis, M. B., and Nichols, J. D. (2017). When habitat matters: Habitat preferences can modulate co-occurrence patterns of similar sympatric species. PLoS One, 12(7), e0179489.

Evans, K. L., Newson, S. E., and Gaston, K. J. (2009). Habitat influences on urban avian assemblages. Ibis, 151(1), 19-39.

Evans, P. R., & Dugan, P. J. (1984). Coastal birds: numbers in relation to food resources, p. 8–28. PR Evans, JD Goss-Custard, et WG Hale, Coastal waders and wildfowl in winter. Ecology, 33, 301-309.

Evans, P.R., Goss-Custard, J.D.andHale, W.G. (eds), Coastal Waders and Wildfowl in Winter: 8-28. London: Cambridge University Press.

Fahrig L, Baudry J, Brotons L, Burel FG, Crist TO, Fuller RJ, Sirami C, Siriwardena GM, Martin JL (2011) Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. Ecology Letters 14(2): 101–112. https://doi.org/10.1111/j.1461- 0248.2010.01559.x

Fahrig, L., Girard, J., Duro, D., Pasher, J., Smith, A., Javorek, S., Tischendorf, L. (2015). Farmlands with smaller crop fields have higher within-field biodiversity. Agriculture, Ecosystems and Environment, 200, 219–234.

FAO. (2010). Global Forest Resources Assessment 2010 Main Report. FAO

Fanfarillo, E., Latini, M., and Abbate, G. (2020). Patterns of co-occurrence of rare and threatened species in winter arable plant communities of Italy. Diversity, 12(5), 195.

Farine, D. R., and Whitehead, H. (2015). Constructing, conducting and interpreting animal social network analysis. Journal of animal ecology, 84(5), 1144-1163.

Fernandez-Juricic, E., (2004). Spatial and temporal analysis of the distribution of forest specialists in an urban-fragmented landscape (Madrid, Spain): implications for the local and regional bird conservation. Landscape and Urban Planning, vol. 69, no. 1, pp. 17-32. http://dx.doi.org/10.1016/j.landurbplan.2003.09.001.

Ferris, R., and Humphrey, J. W. (1999). A review of potential biodiversity indicators for application in British forests. Forestry, 72(4), 313-328.

Ficken, M. S., and Ficken, R. W. (1967). Age-specific differences in the breeding behavior and ecology of the American Redstart. The Wilson Bulletin, 188-199.

Fischer,J.,Brosi,B.,Daily,G.C.,Ehrlich,P.R.,Goldman,R.,Goldsten,J.(2008).Should agricultural policies encourage land sparing or wildlife-friendly farming? Front.Ecol. Environ. 6,380–385.doi:10.1890/070019

Fishpool, L. and J. A. Tobias (2020). Black Bulbul (Hypsipetes leucocephalus), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.blabul1.01

Fischer J, Lindenmayer DB. (2002). The conservation value of paddock trees for birds in a variegated landscape in southern New South Wales. 2. Paddock trees as stepping stones. Biodiversity and Conservation 11(5): 833–849. https://doi.org/10.1023/A:1015318328007

Fitzsimons, J. A., and Michael, D. R. (2017). Rocky outcrops: a hard road in the conservation of critical habitats. Biological Conservation, 211, 36-44.

Fjeldså, J., Bowie, R. C., and Rahbek, C. (2012). The role of mountain ranges in the diversification of birds. Annual Review of Ecology, Evolution, and Systematics, 43, 249-265.

Fournier, B., Mouly, A., and Gillet, F. (2016). Multiple assembly rules drive the co-occurrence of orthopteran and plant species in grasslands: Combining network, functional and phylogenetic approaches. Frontiers in Plant Science, 7, 1224.

Foley, J.A., Defries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Ferris, R., and Humphrey, J. W. (1999). A review of potential biodiversity indicators for application in British forests. Forestry, 72(4), 313-328.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N. and Snyder, P.K. (2005) Global consequences of land use. Science, 309, 570–574.

Franzreb, K. E., and Ohmart, R. D. (1978). The effects of timber harvesting on breeding birds in a mixed-coniferous forest. The Condor, 80(4), 431-441.

Fridley, J.D.; Vandermast, D.B.; Kuppinger, D.M.; Manthey, M.; Peet, R.K. (2007) Co-occurrence based assessment of habitat generalists and specialists: A new approach for the measurement of niche width. J. Ecol., 95,707–722.

Fry, H. and G. M. Kirwan (2020). Indian Roller (Coracias benghalensis), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.indrol2.01

Garcia, D., Zamora, R., and Amico, G. C. (2010). Birds as suppliers of seed dispersal in temperate ecosystems: conservation guidelines from real-world landscapes. Conservation biology, 24(4), 1070-1079.

Gaston, K. J., Cox, D. T., Canavelli, S. B., García, D., Hughes, B., Maas, B., ... and Inger, R. (2018). Population abundance and ecosystem service provision: the case of birds. BioScience, 68(4), 264-272.

Gautam, M. K., Manhas, R. K., and Tripathi, A. K. (2016). Patterns of diversity and regeneration in unmanaged moist deciduous forests in response to disturbance in Shiwalik Himalayas, India. Journal of Asia-Pacific Biodiversity, 9(2), 144-151.

Ghosh, K. (2022). Distribution of Avian Diversity in Different Habitats from Gangetic Plains of West Bengal, India.

Ghosh, P., Chakraborty, A., & Sengupta, S. (2021). Winter avifaunal assemblage in a periurban agricultural landscape of Gangetic West Bengal, India. Ecology, Environment and Conservation, 27(1), 323-331.

Gillespie TW and Walter H (2001) Distribution of bird species richness at a regional scale in tropical dry forest of Central America. J Biogeogr 28: 651–662.

Gooch, P. (2009). Victims of conservation or rights as forest dwellers: Van Gujjar pastoralists between contesting codes of law. Conservation and Society, 7 (4), 239.

Griffith, D. M., Veech, J. A., and Marsh, C. J. (2016). Cooccur: probabilistic species co-occurrence analysis in R. Journal of Statistical Software, 69, 1-17.

Grinde AR, Niemi GJ. A synthesis of species interactions, metacommunities, and the conservation of avian diversity in hemiboreal and boreal forests. J Avian Biol. (2016);47(5):706–18. https://doi.org/10.1111/jav.01036.

Gaston, K. J., and Biodiversity, A. (1996). A biology of numbers and difference. London, UK.

Grimmett R., Inskipp C. and Inskipp T. (1998). Birds of the Indian Subcontinent. Oxford University Press, Delhi, 889pp.

Gardner, T. A., Barlow, J., Chazdon, R., Ewers, R. M., Harvey, C. A., Peres, C. A., and Sodhi, N. S. (2009). Prospects for tropical forest biodiversity in a human-modified world. Ecology letters, 12(6), 561-582.

Geis, A.D., (1974). Effects of urbanization and type of urban development on bird populations. In: Noyes, J.H., Progulske, D.R. (Eds.), Wildlife in an Urbanizing Environment. University of Massachusetts Press, Amherst, MA, pp. 97–105

Gentilli, J. (1992). Numerical clines and escarpments in the geographical occurrence of avian species; and a search for relevant environmental factors. Emu, 92(3), 129-140.

Glennon, M. J., and Porter, W. F. (2005). Effects of land use management on biotic integrity: an investigation of bird communities. Biological conservation, 126(4), 499-511.

Gregory RD, Noble D, Field R, Marchant J, Raven M, Gibbons DW (2003) Using birds as indicators of biodiversity. Ornis Hungarica 12–13:11–24.

Gould, S. F. and Mackey, B. G. (2015) Site vegetation characteristics are more important than landscape context in determining bird assemblages in revegetation. Restor Ecol, , 23: 670-680. Doi:10.1111/rec.12222

Grimmett R, Inskipp C, Inskipp T (2011) Birds of the Indian subcontinent, 2nd edn. Oxford University PressandChristopher Helm, London

Gentilli, J. (1992). Numerical clines and escarpments in the geographical occurrence of avian species; and a search for relevant environmental factors. Emu, 92(3), 129-140.

Girma, Z., Mamo, Y., Mengesha, G., Verma, A., and Asfaw, T. (2017). Seasonal abundance and habitat use of bird species in and around Wondo Genet Forest, south-central Ethiopia. Ecology and Evolution, 7(10), 3397-3405.

González-Salazar, C., Martínez-Meyer, E., and López-Santiago, G. (2014). A hierarchical classification of trophic guilds for North American birds and mammals. Revista Mexicana de Biodiversidad, 85(3), 931-941.

Grass I, Berens DG, Farwig N (2013) Guild-specific shifts in visitation rates of frugivores with habitat loss and plant invasion. Oikos 123:575–582.

Grimmett R, Inskipp C, Inskipp T (2011) Birds of the Indian subcontinent, 2nd edn. Oxford University PressandChristopher Helm, London

Grinnell, J. (1917). The niche-relationships of the California Thrasher. The Auk, 34(4), 427-433.

Gandhi, T. (1986). A comparative study of birds in monoculture plantations and natural scrub near Madras. MSc Thesis, University of Mumbai.

Gandhi, T. (2006). Birds in scrub jungles and monocultures in Tamil Nadu. Blackbuck 21: 1–11.

Germaine, S. S., Rosenstock, S. S., Schweinsburg, R. E., and Richardson, W. S. (1998). Relationships among breeding birds, habitat, and residential development in greater Tucson, Arizona. Ecological applications, 8(3), 680-691.

Glover, F. A. (1969). Birds in grassland ecosystems.

Ghosh-Harihar, M., An, R., Athreya, R., Borthakur, U., Chanchani, P., Chetry, D., ... & Price, T. D. (2019). Protected areas and biodiversity conservation in India. Biological Conservation, 237, 114-124.

Ghosh, P., Chakraborty, A., and Sengupta, S. (2021). Winter avifaunal assemblage in a periurban agricultural landscape of Gangetic West Bengal, India. Ecology, Environment and Conservation, 27(1), 323-331.

Green, R.E., Cornell, S.J., Scharlemann, J.P.W., (2005). Farming and the Fate of Wild Nature. Science (80-.). 307, 550–555.

Gentilli, J. (1992). Numerical clines and escarpments in the geographical occurrence of avian species; and a search for relevant environmental factors. Emu, 92(3), 129-140.

Gochfeld, M., J. Burger, E. F. J. Garcia, and P. F. D. Boesman (2020). River Tern (Sterna aurantia), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.rivter1.01

Gorenzel, W. P., and Salmon, T. P. (1994). Swallows.

Gotelli, N. J., and R. K. Colwell. (2011). Estimating species richness. In A. E. Magurran, and B. J. McGill (Eds.). Biological diversity: Frontiers in measurement and assessment, pp. 39– 54. Oxford University Press, Oxford, UK.

Grzędzicka, E., and Reif, J. (2020). Impacts of an invasive plant on bird communities differ along a habitat gradient. Global Ecology and Conservation, 23, e01150.

Gurung, K. K. (1983). Heart of the jungle: the wildlife of Chitwan, Nepal. A. Deutsch.

Gutzwiller KJ, Clements KL, Marcum HA, Wilkins CA and Anderson SH (1998) Vertical distributions of breeding-season birds: is human intrusion influential Wilson Bull 110: 497–503.

Haddow, A. J., Williams, M. C., Woodall, J. P., Simpson, D. I., and Goma, L. K. (1964). Twelve isolations of Zika virus from Aedes (Stegomyia) africanus (Theobald) taken in and above a Uganda forest. Bulletin of the World Health Organization, 31(1), 57.

Halme, P., Mönkkönen, M., Kotiaho, J. S., YLISIRNIÖ, A. L., and Markkanen, A. (2009). Quantifying the indicator power of an indicator species. Conservation Biology, 23(4), 1008-1016

Hallmann, C. A., Foppen, R. P., Van Turnhout, C. A., De Kroon, H., & Jongejans, E. (2014). Declines in insectivorous birds are associated with high neonicotinoid concentrations. Nature, 511(7509), 341-343.

Hamm, M., and Drossel, B. (2017). Habitat heterogeneity hypothesis and edge effects in model metacommunities. Journal of theoretical biology, 426, 40-48.

IUCN (2022). The IUCN Red List of Threatened Species.<http://www.iucnredlist.org/> Downloaded on 29 January 2022.

Morris AJ, Murray AWA, Murray KA, Robertson PA. 2004 Evidence for the indirect effects of pesticides on farmland birds. Ibis 146, 131–143. (doi:10.1111/j.1474-919X.2004. 00347.x).

Harvey, C. A., Komar, O., Chazdon, R., Ferguson, B. G., Finegan, B., Griffith, D. M. Soto-Pinto, L. (2008). Integrating agricultural landscapes with biodiversity conservation in the Mesoamerican hotspot. Conservation Biology, 22, 8–15.

Haney, J. C., and Lydic, J. (1999). Avifauna and Vegetation Structure in an Old-Growth Oak-Pine Forest on the Cumberland Plateau, Tennessee(USA). Natural Areas Journal, 19(3), 199-210.

Hanioka, M., Yamaura, Y., Senzaki, M., Yamanaka, S., Kawamura, K., and Nakamura, F. (2018). Assessing the landscape-dependent restoration potential of abandoned farmland using a hierarchical model of bird communities. Agriculture, Ecosystems and Environment, 265, 217-225

Hansson, L. (2000). Indicators of biodiversity: recent approaches and some general suggestions. EU FAIR.

Harrison, J. L. (1962). The distribution of feeding habits among animals in a tropical rain forest. The Journal of Animal Ecology, 53-63.

Hart, L. A., Rogers, A., and van Rensburg, B. J. (2020). Common Myna (Acridotheres tristis Linnaeus, 1766). Invasive birds: global trends and impacts, 25-32.

Hartley, P. H. T. (1953). An ecological study of the feeding habits of the English titmice. The Journal of Animal Ecology, 261-288.

Harvey, C. A., Komar, O., Chazdon, R., Ferguson, B. G., Finegan, B., Griffith, D. M., ... and Wishnie, M. (2008). Integrating agricultural landscapes with biodiversity conservation in the Mesoamerican hotspot. Conservation biology, 22(1), 8-15.

Hawkins, C. P., and MacMahon, J. A. (1989). Guilds: the multiple meanings of a concept. Annual review of entomology, 34(1), 423-451.

Hayes, W. M., Fisher, J. C., Pierre, M. A., Bicknell, J. E., and Davies, Z. G. (2020). Bird communities across varying landcover types in a Neotropical city. Biotropica, 52(1), 151-164.

Hilden, O. 1965. Habitat selection in birds. Ann. Zool. Fenn. 2:53-75.

Hille Ris Lambers, J., Adler, P. B., Harpole, W. S., Levine, J. M. and Mayfield, M. M. (2012). Rethinking Community Assembly through the Lens of Coexistence Theory. Ann Review Ecol Evol Systematics 43, 227-248, doi: doi:10.1146/annurev-ecolsys-110411-160411

Hilty, J., and Merenlender, A. (2000). Faunal indicator taxa selection for monitoring ecosystem health. Biological conservation, 92(2), 185-197.

Hinsley, S., Hill, R., Fuller, R., Bellamy, P., and Rothery, P. (2009). Bird species distributions across woodland canopy structure gradients. Community Ecology, 10(1), 99-110.

Holloway, J. D. (1985). Moths as indicator organisms for categorizing rain-forest and monitoring charges and regeneration processes. In Tropical rain-forest: the Leeds Symposium. Leeds Philosophical and Literary Society.

Holmes, R. T., Bonney Jr, R. E., and Pacala, S. W. (1979). Guild structure of the Hubbard Brook bird community: a multivariate approach. Ecology, 60(3), 512-520.

Holmes, R. T., and Recher, H. F. (1986). Search tactics of insectivorous birds foraging in an Australian eucalypt forest. The Auk, 103(3), 515-530.

Holmes, R. T., and Robinson, S. K. (1988). Spatial patterns, foraging tactics, and diets of ground-foraging birds in a northern hardwoods forest. The Wilson Bulletin, 377-394.

Hossain, A., and Aditya, G. (2016, June). Avian diversity in agricultural landscape: records from Burdwan, West Bengal, India. In Proceedings of the Zoological Society (Vol. 69, No. 1, pp. 38-51). Springer India.

Howe, R. W. (1984). Local dynamics of bird assemblages in small forest habitat islands in Australia and North America. Ecology, 65(5), 1585-1601.

H. Pöysä, J. Elmberg, K. Sjöberg, and P. Nummi, "Habitat selection, rules in breeding mallards (Anas platyrhynchos): A test of two competing hypotheses," Oecologia, vol. 114, no. 2, pp. 283–287, 1998.

Hunter, M. L., and Hunter Jr, M. L. (Eds.). (1999). Maintaining biodiversity in forest ecosystems. Cambridge university press. https://doi.org/10.1046/j.1365-2664.1999.00459-3.x

Hurst, Z.M., McCleery, R.A., Collier, B.A., Fletcher Jr., R.J., Silvy, N.J., Taylor, P.J., Monadjem, A., (2013). Dynamic edge effects in small mammal communities across a conservation-agricultural interface in Swaziland. PloS One 8, 1–9.

Hutchinson, G. E. (1957). Concluding remarks. population studies: animal ecology and demography. In Cold Spring Harbor Symposia on Quantative Biology (Vol. 22, pp. 415-427).

Hutto, R. L. (1985). Habitat selection by nonbreeding, migratory land. Habitat selection in birds, 455.

Imbeau, L., Mönkkönen, M., and Desrochers, A. (2001). Long-term effects of forestry on birds of the eastern Canadian boreal forests: a comparison with Fennoscandia. Conservation Biology, 15(4), 1151-1162.

Inman RL, Prince HH, Hayes DB (2002) Avian communities in forested riparian wetlands of southern Michigan, USA. Wetlands 22:647–660.

Inskipp, C. and T. Inskipp (1983). Report on a Survey of Bengal Floricans (Houbaropsis bengalensis) in Nepal and India, 1982. Cambridge, UK: International Council for Bird Preservation (Study Report 2).

Izsák, J., and Pavoine, S. (2012). Links between the species abundance distribution and the shape of the corresponding rank abundance curve. Ecological Indicators, 14(1), 1-6.

James, F. C. (1971). Ordinations of habitat relationships among breeding birds. Wilson Bull. 83:215-236.

Javed, S. and Rahmani, A. R. (1998). Conservation of the avifauna of Dudwa National Park, India. Forktail, 55-64.

Veraart, J. A., De Groot, R. S., Perelló, G., Riddiford, N. J., & Roijackers, R. (2004). Selection of (bio) indicators to assess effects of freshwater use in wetlands: a case study of s' Albufera de Mallorca, Spain. Regional Environmental Change, 4(2), 107-117.

J. D. Brawn, S. K. Robinson, and F. R. Thompson III, "The role of disturbance in the ecology and conservation of birds," Annual Review of Ecology and Systematics, vol. 32, pp. 251–276, 2001.View at: Publisher Site | Google Scholar.

J. Davis, E. Rocky, T. (2000). Diet differentiation and habitat selection of birds in forested and clear-cut areas Biology Department, Frostburg State University, Final Paper, 11.

Jain, M., and Balakrishnan, R. (2011). Microhabitat selection in an assemblage of crickets (Orthoptera: Ensifera) of a tropical evergreen forest in Southern India. Insect Conservation and Diversity, 4(2), 152-158.

Jaksić, F. M., and Medel, R. G. (1990). Objective recognition of guilds: testing for statistically significant species clusters. Oecologia, 82(1), 87-92.

James, F. C., and Wamer, N. O. (1982). Relationships between temperate forest bird communities and vegetation structure. Ecology, 63(1), 159-171.

James, F. C., and Rathbun, S. (1981). Rarefaction, relative abundance, and diversity of avian communities. The Auk, 98(4), 785-800.

Jankowski, J. E., Merkord, C. L., Rios, W. F., Cabrera, K. G., Revilla, N. S., and Silman, M. R. (2013). The relationship of tropical bird communities to tree species composition and vegetation structure along an Andean elevational gradient. Journal of Biogeography, 40(5), 950-962.

Jarvinen, O and R. A. Vaisanen (1979) Changes in Bird Population as Criteria of Environmental Changes. Holarctic Ecol. 2:75-80

Jayapal, R. (1997). A Study On Bird Communities-Habitat Structure Relationships In Pench National Park, MPM Sc (Doctoral dissertation, Thesis. Saurashtra University, Rajkot).

Jayapal, R., Qureshi, Q., and Chellam, R. (2009). Importance of forest structure versus floristics to composition of avian assemblages in tropical deciduous forests of Central Highlands, India. Forest Ecology and Management, 257(11), 2287-2295.

Jayson, E. A., and Mathew, D. N. (2003). Vertical stratification and its relation to foliage in tropical forest birds in Western Ghats (India). Acta ornithologica, 38(2), 111-116.

Jeganathan, P., A.R. Rahmaniand R.E. Green (2005). Construction of Telugu-Ganga Canal in and around two protected areas in Cuddapah District, Andhra Pradesh, India. Immediate threat to the world population of the Critically Endangered Jerdon's Courser Rhinoptilus bitorquatus. Survey Report. Bombay Natural History Society, Mumbai, India, 10pp.

Jeganathan, P., A.R. Rahmani, R.E. Green, K. Norris, I.N. Vogiatzakis, C. Bowden and D. Pain (2008). Quantification of threats and suggested ameliorative measures for the conservation of the Critically Endangered Jerdon's Courser Rhinoptilus bitorquatus and its habitat. Journal of the Bombay Natural History Society 105(1): 73–83.

Jobin, B., Des Granges, J. L., and Boutin, C. (1996). Population trends in selected species of farmland birds in relation to recent developments in agriculture in the St. Lawrence Valley. Agriculture, Ecosystems and Environment, 57(2-3), 103-116.

Joern, A. (1982). Vegetation structure and microhabitat selection in grasshoppers (Orthoptera, Acrididae). The Southwestern Naturalist, 197-209.

John, J. R., and Kabigumila, J. D. (2007). Impact of Eucalyptus plantations on the avian breeding community in the East Usambaras, Tanzania. Ostrich-Journal of African Ornithology, 78(2), 265-269.

John, J. R., and Kabigumila, J. D. (2011). The use of bird species richness and abundance indices to assess the conservation value of exotic Eucalyptus plantations. Ostrich, 82(1), 27-37.

Johnsingh, A.J.T., M.H. Martin, J. Balasingh and V. Chelladu (1987). Vegetation and avifauna in a thorn scrub habitat in south India.Tropical Ecology 28: 22–34.

Johnsingh, A. J. T., K. Ramesh, Q. Qureshi, A. David, S. P. Goyal, G. S. Rawat, K. Rajapandian, and S. Prasad. (2004). Conservation status of tiger and associated species in the Terai Arc Landscape, India. Research Report RR04/001. Wildlife Institute of India, Dehradun, India

Johnson, D. H. (1980). The comparison of usage and availability measurements for evaluating resource preference. Ecology, 61(1), 65-71.

Joshi, K. K., and Rautela, P. (2014). Avian diversity and species composition along elevation at Doon valley forest of Dehradun district (Garhwal Himalaya) in Uttarakhand state, India. Asian Journal of Conservation Biology, 3(1), 48-59.

Jones M, Mandelik Y, Dayan T. (2001) Coexistence of temporally partitioned spiny mice: roles of habitat structure and foraging behavior. Ecology. Aug 1; 82(8): p. 2164±76.

Joshi K. and Bhatt D. (2011). Birds of three different forest habitats in Nainital district (Western Himalaya), Uttarakhand, India. Indian Birds, 7(2), 33-37.

Joshi R., and Dixit A. (2012). Wildlife mortality on national highway 72 and 74 across the rajaji national park and the haridwar conservation area, north india. International Journal of Conservation Science, 3(2).

Kallimanis, A. S., Bergmeier, E., Panitsa, M., Georghiou, K., Delipetrou, P.,and Dimopoulos, P. (2010). Biogeographical determinants for total and endemic species richness in a continental archipelago. Biodiversity and Conservation, 19(5), 1225-1235.

Kanjilal, U., and Gupta, B. L. (1979). Forest flora of Dehradun. Bishen Singh Mahendra Pal Singh, Dehradun.

Kanowski, J.; Catterall, C.and Wardelljohnson, G. (2005). Consequences of broadscale timber plantations for biodiversity in cleared rainforest landscapes of tropical and subtropical Australia. Forest Ecology and Management, 208(1-3): 359-372.

Karanth, K. K., Sankararaman, V., Dalvi, S., Srivathsa, A., Parameshwaran, R., Sharma, S., and Chhatre, A. (2016). Producing diversity: Agroforests sustain avian richness and abundance in India's Western Ghats. Frontiers in Ecology and Evolution, 4, 111.

Karr, J. R. (1968). Habitat and avian diversity on strip-mined land in east-central Illinois. The Condor, 70(4), 348-357.

Karr, J. R., and Freemark, K. E. (1983). Habitat selection and environmental gradients: dynamics in the" stable" tropics. Ecology, 64(6), 1481-1494.

Karr J. R. and R. R. Roth. (1971). Vegetation Structure and Avian Diversity in Several New World Areas. The American Naturalist, Vol. 105, No. 945, pp. 423-435.

Karr, J. R. (1971). Structure of avian communities in selected Panama and Illinois habitats. Ecol. Monogr. 41:207-233.

Karr, J. R., Robinson, S. K., Blake, J. G., and Bierregaard Jr, R. O. (1990). Birds of four Neotropical forests. Four neotropical rainforests, 237-269.

Kati, V., Dimopoulos, P., Papaioannou, H., and Poirazidis, K. (2009). Ecological management of a Mediterranean mountainous reserve (Pindos National Park, Greece) using the bird community as an indicator. Journal for Nature Conservation, 17(1), 47-59.

Katuwal, H. B., Basnet, K., Khanal, B., Devkota, S., Rai, S. K., Gajurel, J. P., and Nobis, M. P. (2016). Seasonal changes in bird species and feeding guilds along elevational gradients of the Central Himalayas, Nepal. PLoS One, 11(7), e0158362.

Kaushik M., Mohan D. and Singh P. (2012). Response of migrant and resident bird communities to anthropogenic disturbances in Shiwalik landscape, Uttarakhand, India. J. Bombay Nat. Hist. Soc, 109, 111-122.

Kaushik, M., Tiwari, S., and Manisha, K. (2022). Habitat patch size and tree species richness shape the bird community in urban green spaces of rapidly urbanizing Himalayan foothill region of India. Urban Ecosystems, 25(2), 423-436.

Kay, G. M., Tulloch, A., Barton, P. S., et al. (2018). Species co-occurrence networks show reptile community reorganization under agricultural transformation. Ecography, 41, 113–125. https ://doi.org/10.1111/ecog.03079

Kellner, K. F. (2018). Local-scale habitat components driving bird abundance in eastern deciduous forests. The American Midland Naturalist, 180(1), 52-65.

Kendeigh, S. C. (1947). Bird population studies in the coniferous forest biome during a spruce budworm outbreak (No. 1). Department of Lands and Forests.

Kennedy, C. M., Marra, P. P., Fagan, W. F., and Neel, M. C. (2010). Landscape matrix and species traits mediate responses of Neotropical resident birds to forest fragmentation in Jamaica. Ecological Monographs, 80,651–669.

Khan, M. S., Aftab, A., Syed, Z., Nawab, A., Ilyas, O., and Khan, A. (2013). Composition and conservation status of avian species at Hastinapur Wildlife Sanctuary, Uttar Pradesh, India. Journal of Threatened Taxa, 5(12), 4714-4721.

Khan T. A. and Chandan (2015). A pilot survey of the avifauna of Rangdum Valley, Kargil, Ladakh (Indian Trans-Himalaya). Journal of Threatened Taxa 7(6): 7274–7281.

Khera, N., Mehta, V., and Sabata, B. C. (2009). Interrelationship of birds and habitat features in urban greenspaces in Delhi, India. Urban Forestry and urban greening, 8(3), 187-196.

Kim, Y. M., Hong, S., Lee, Y. S., Oh, K. C., Kim, G. Y., and Joo, G. J. (2017). Co-occurrence patterns of bird species in the world. Korean Journal of Ecology and Environment, 50(4), 478-482.

Kirkpatrick, J. B., and Gilfedder, L. (1995). Maintaining integrity compared with maintaining rare and threatened taxa in remnant bushland in subhumid Tasmania. Biological Conservation, 74(1), 1-8.

Kissling, W. D., Sekercioglu, C. H., and Jetz, W. (2012). Bird dietary guild richness across latitudes, environments and biogeographic regions. Global Ecology and Biogeography, 21(3), 328-340.

Kohli, B. A., Terry, R. C., and Rowe, R. J. (2018). A trait-based framework for discerning drivers of species co-occurrence across heterogeneous landscapes. Ecography, 41, 1921–1933. https ://doi.org/10.1111/ecog.03747

Koli, V. K. (2014). Diversity and status of avifauna in Todgarh-Raoli Wildlife Sanctuary, Rajasthan, India. Journal of Asia-Pacific Biodiversity, 7(4), 401-407.

Koran, M., and Kropil, R. (2014). What are ecological guilds? Dilemma of guild concepts. Russian Journal of Ecology, 45(5), 445.

Kremen, C. (1992). Assessing the indicator properties of species assemblages for natural areas monitoring. Ecological applications, 2(2), 203-217.

Krishen, P. (2006). Trees of Delhi: A field Guide. Penguin Books India.

Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, C.I., Ramankutty, N., Snyder, P.K., 2005. Global consequences of land use. Science 309, 570–575.

Kumar, D. (1986). Place of Eucalyptus in Indian agroforestry systems. Eucalyptus in India, Past Present and Future (eds. JK Sharma, CTS Nair, K. Kedhanarth and S. Kondus), Kerala Forest Research Institute, India, 257-260.

Kumar, P., and Sahu, S. (2020). Composition, diversity and foraging guilds of avifauna in agricultural landscapes in Panipat, Haryana, India. Journal of Threatened Taxa, 12(1), 15140-15153.

Kumar, N., and Nautiyal, S. (2013). An inventory of medicinal wealth of Jhilmil Jheel Conservation Reserve. International Journal of Herbal Medicine, 1(2), 1-8.

Krebs, J. R., Wilson, J. D., Bradbury, R. B., and Siriwardena, G. M. (1999). The second silent spring? Nature, 400(6745), 611-612.

Kremen, C. (1992). Assessing the indicator properties of species assemblages for natural areas monitoring. Ecological applications, 2(2), 203-217.

Kwok, H. K., and Corlett, R. T. (2000). The bird communities of a natural secondary forest and a Lophostemon confertus plantation in Hong Kong, South China. Forest Ecology and Management, 130(1-3), 227-234.

Lai, H. R., Mayfield, M. M., Gay-des-combes, J. M., Spiegelberger, T., and Dwyer, J. M. (2015). Distinct invasion strategies operating within a natural annual plant system. Ecology Letters, 18(4), 336-346.

Laiolo P. From inter-specific behavioural interactions to species distribution patterns along gradients of habitat heterogeneity. Oecologia. (2013) Jan 1; 171(1): p. 207±15. https://doi.org/10.1007/s00442-012-2392-y PMID: 22806401

Lack, P. C. (1987). The structure and seasonal dynamics of the bird community in Tsavo East National Park, Kenya. Ostrich, 58(1), 9-23.

Lambeck RJ (1997) Focal species: a multi-species umbrella for nature conservation. Conserv Biol 11: 849–856

Larsen, F. W., Bladt, J., Balmford, A., and Rahbek, C. (2012). Birds as biodiversity surrogates: will supplementing birds with other taxa improve effectiveness? Journal of Applied Ecology, 49(2), 349-356.

Laurance, W.F., Sayer, J., Cassman, K.G., (2013). Agricultural expansion and its impacts on tropical nature. Trends Ecol. Evol. 1–10.

Lawton, J. H., Bignell, D. E., Bolton, B., Bloemers, G. F., Eggleton, P., Hammond, P. M., andWatt, A. D. (1998). Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. Nature, 391(6662), 72-76.

Lee, S. D., and Kang, H. K. (2019). Seasonal fluctuations and changing characteristics of a temperate zone wetland bird community. Journal of Ecology and Environment, 43(1), 1-13.

Lewinsohn, T. M., Inácio Prado, P., Jordano, P., Bascompte, J., and M. Olesen, J. (2006). Structure in plant–animal interaction assemblages. Oikos, 113(1), 174-184.

Lim, H. C., Sodhi, N. S., Brook, B. W., and Soh, M. C. (2003). Undesirable aliens: factors determining the distribution of three invasive bird species in Singapore. Journal of Tropical Ecology, 19(6), 685-695.

Lin, B. B., and Fuller, R. A. (2013). Sharing or sparing? How should we grow the world's cities? Journal of applied ecology, 50(5), 1161-1168.

Lindenmayer, D. (2019). Small patches make critical contributions to biodiversity conservation. Proceedings of the National Academy of Sciences, 116(3), 717-719. https://doi.org/10.1073/pnas.1820169116

Lindenmayer, D. B., Margules, C. R., and Botkin, D. B. (2000). Indicators of biodiversity for ecologically sustainable forest management. Conservation biology, 14(4), 941-950.

Liu, X., Toxopeus, A. G., Skidmore, A. K., Shao, X., Dang, G., Wang, T., and Prins, H. H. (2005). Giant panda habitat selection in foping nature reserve, China. The Journal of wildlife management, 69(4), 1623-1632.

Leveau, L. M., and Leveau, C. M. (2016). Does urbanization affect the seasonal dynamics of bird communities in urban parks? Urban ecosystems, 19(2), 631-647.

Loegering JP, Anthony RG (1999) Distribution, abundance, and habitat associations of riparian-obligate and –associated birds in the Oregon Coast Range. Northwest Nat 73:168–185.

Lomov, B., Keith, D. A., Britton, D. R., and Hochuli, D. F. (2006). Are butterflies and moths useful indicators for restoration monitoring? A pilot study in Sydney's Cumberland Plain Woodland. Ecological Management and Restoration, 7(3), 204-210.

Lubchenco, J., et al. (1991). The sustainable biosphere initiative: an ecological research agenda. Ecology72: 371−412.

Lyons, S. K., Amatangelo, K. L., Behrensmeyer, A. K., et al. (2016). Holocene shifts in the assembly of plant and animal communities implicate human impacts. Nature, 529, 80–83. https ://doi.org/10.1038/natur e1644 7.

Maas, B., Putra, D. D., Waltert, M., Clough, Y., Tscharntke, T., and Schulze, C.H. (2009). Six years of habitat modification in a tropical rainforest margin of Indonesia do not affect bird diversity but endemic forest species. Biological Conservation, 142, 2665–2671.

MacArthur, R. H., and MacArthur, J. W. (1961). On bird species diversity. Ecology, 42(3), 594-598.

MacArthur, R. H., and Wilson, E. O. (1967). The theory of island biogeography, vol. 1 Princeton.

MacArthur, R. H., and MacArthur, J. W. (1961). On bird species diversity. Ecology, 42(3), 594-598.

MacArthur, R., and Levins, R. (1964). Competition, habitat selection, and character displacement in a patchy environment. Proceedings of the National Academy of Sciences of the United States of America, 51(6), 1207.

Machado LOM, Rosa GAB (2005) Avian frugivory in Cytharexyllum myrianthum Cham (Verbenaceae) in pastures near Campinas, Sao Paulo. Ararajuba 13(1): 113–115.

MacKenzie, D. I., L. B. Larissa, and J. D. Nichols. (2004). Investigating species co-occurrence patterns when species are detected imperfectly. Journal of Animal Ecology 73:546-555. http://dx.doi.org/10.1111/j.0021-8790.2004.00828.x

Mac Nally, R.C., 1990. The roles of floristics and physiognomy in avian community composition. Australian Journal of Ecology 15, 321–327.

Madge, S. (2020). Plain Prinia (Prinia inornata), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.plapri1.01

Madge, S., J. del Hoyo, G. M. Kirwan, and N. Collar (2020). Yellow-bellied Prinia (Prinia flaviventris), version 1.0. In Birds of the World (S. M. Billerman, B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.yebpri1.01

Malard F, Tockner K, Ward JV (2000) Physicochemical heterogeneity in a glacial riverscape. Landsc Ecol 15:679–695.

Maleque, M. A., Ishii, H. T., and Maeto, K. (2006). The use of arthropods as indicators of ecosystem integrity in forest management. Journal of Forestry, 104(3), 113-117.

Malcolm, A. (2007). Habitat Management for Conservation: A Handbook of Techniques. Oxford University Press, Oxford, 411pp.

Malhi, C. S. (2006). Status of avifauna in agricultural habitat and other associated sub-habitats of Punjab. Environment and Ecology, 24(1), 131-143.

Mallorca, Spain," Regional Environmental Change, vol. 4, no. 2-3, pp. 107–117, 2004.View at: Publisher Site | Google Scholar.

Manakadan, R. (2014). The Grassland Birds of Rollapadu Wildlife Sanctuary, Andhra Pradesh, India, with Special Reference to the Impact of Grazing-Free Enclosures. Â Journal of the Bombay Natural History Society, 111(2), 81â.

Manikandan. P. and Kunhikannan, C (2016). Avian flower visitors of Helicteres isora L. a deciduous forest species in Thathengalam forest of Kerala in Western Ghats. International Journal of Advanced Research in Biological Sciences,3 (10). DOI: 10.22192/ijarbs.2016.03.10.023

Malizia, L. R. (2001). Seasonal fluctuations of birds, fruits, and flowers in a subtropical forest of Argentina. The Condor, 103(1), 45-61.

Margalef, R. (1958). Information theory in Ecology-Gen. Sys. 3: 36-71. Transl. R. Acad. Ciene. Artes. Barc, 32, 373-449.

Martin, T. E. (1993). Nest predation and nest sites. BioScience, 43(8), 523-532.

Martin, T. E. (1995). Avian life history evolution in relation to nest sites, nest predation, and food. Ecological monographs, 65(1), 101-127.

Martin, T. E., and Li, P. (1992). Life history traits of open-vs. cavity-nesting birds. Ecology, 73(2), 579-592.

McCune, B., Grace, J. B., and Urban, D. L. (2002). Analysis of ecological communities (Vol. 28). Gleneden Beach, OR: MjM software design.

McGill, B. J., Etienne, R. S., Gray, J. S., Alonso, D., Anderson, M. J., Benecha, H. K., and White, E. P. (2007). Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. Ecology letters, 10(10), 995-1015.

Martin, T. G., & McIntyre, S. (2007). Impacts of livestock grazing and tree clearing on birds of woodland and riparian habitats. Conservation Biology, 21(2), 504-514.

Martin, T. G., and Possingham, H. P. (2005). Predicting the impact of livestock grazing on birds using foraging height data. Journal of Applied Ecology, 42(2), 400-408.

Matuoka, M. A., Benchimol, M., de Almeida-Rocha, J. M., and Morante-Filho, J. C. (2020). Effects of anthropogenic disturbances on bird functional diversity: A global meta-analysis. Ecological Indicators, 116, 106471.

Manly, B. F. L., McDonald, L., Thomas, D. L., McDonald, T. L., and Erickson, W. P. (2007). Resource selection by animals: statistical design and analysis for field studies. Springer Science and Business Media.

Marsden, S.; Whiffin, M. and Galetti, M. (2001). Bird diversity and abundance in forest fragments and Eucalyptus plantations around an Atlantic Forest reserve, Brazil. Biodiversity and Conservation, 10(5): 737-751.

Mathur, P. K., Kumar, H., Lehmkuhl, J. F., Tripathi, A., Sawarkar, V. B., and De, R. (2011). Mammal indicator species for protected areas and managed forests in a landscape conservation area of northern India. Biodiversity and Conservation, 20(1), 1-17.

Mali, S., Srinivasulu, C., and Rahmani, A. R. (2017). Avifaunal diversity in the scrub forest of Sri Lankamalleswara Wildlife Sanctuary, Andhra Pradesh, India. Journal of Threatened Taxa, 9(9), 10679-10691.

Malizia, L. R. (2001). Seasonal fluctuations of birds, fruits, and flowers in a subtropical forest of Argentina. The Condor, 103(1), 45-61.

Mamba, M., Fasel, N.J., Mahlaba, T.A.M., Austin, J.D., McCleery, R.A., Monadjem, A., 2019. Influence of sugarcane plantations on the population dynamics and community structure of small mammals in a savanna-agricultural landscape. Glob. Ecol. Conserv.20, 1–12.

Margalef, R. (1958). Information theory in Ecology-Gen. Sys. 3: 36-71. Transl. R. Acad. Ciene. Artes. Barc, 32, 373-449.

Martin, T. E. (1993). Nest predation and nest sites. BioScience, 43(8), 523-532.

Martin, T. E. (1995). Avian life history evolution in relation to nest sites, nest predation, and food. Ecological monographs, 65(1), 101-127.

Martin, T. E. and Li, P. (1992). Life history traits of open-vs. cavity-nesting birds. Ecology, 73(2), 579-592.

Marzluff, J. M., Bowman, R., and Donnelly, R. (2001). A historical perspective on urban bird research: trends, terms, and approaches. In Avian ecology and conservation in an urbanizing world (pp. 1-17). Springer, Boston, MA.

Matson, P. A., Parton, W. J., Power, A. G., and Swift, M. J. (1997). Agricultural intensification and ecosystem properties. Science, 277(5325), 504-509.

May RM (1973) Stability and complexity in model ecosystems, 2nd edn. Princeton University Press, Princeton.

McCune B, Grace JB. Analysis of Ecological Communities. Gleneden Beach, Oregon: MJM Software; 2002.

McGill, B. J., Etienne, R. S., Gray, J. S., Alonso, D., Anderson, M. J., Benecha, H. K., andWhite, E. P. (2007). Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. Ecology letters, 10(10), 995-1015.

Medvin, M. B., and Beecher, M. D. (1986). Parent-offspring recognition in the barn swallow (Hirundo rustica). Animal Behaviour, 34(6), 1627-1639.

Mehta P. (1998), The effects of forestry Practices on bird species diversity in Satpuda hill ranges, Phd. Thesis, Wildlife Institute of India, Dehradun.

Mekonen, S. (2017). Birds as biodiversity and environmental indicator. Indicator, 7(21).

Mellink, E. (1991). Bird communities associated with three traditional agroecosystems in the San Luis Potosi Plateau, Mexico. Agriculture, ecosystems and environment, 36(1-2), 37-50.

Mengesha, G., and Bekele, A. (2008). Diversity and relative abundance of birds of Alatish National Park, North Gondar, Ethiopia. International Journal of Ecology and Environmental Sciences, 34(2), 215-222.

Mengesha, G., Mamo, Y., and Bekele, A. (2011). A comparison of terrestrial bird community structure in the undisturbed and disturbed areas of the Abijata Shalla lakes national park, Ethiopia. International Journal of Biodiversity and conservation, 3(9), 389-404.

Menon T., Sridhar H., and Shahabuddin G. (2019). Effects of extractive use on forest birds in Western Himalayas: Role of local and landscape factors. Forest Ecology and Management, 448, 457-465.

Miller, B., Reading, R., Strittholt, J., Carroll, C., Noss, R., Soulé, M., Sánchez, O., Terborgh, J., Brightsmith, D., Cheeseman, T., Foreman, D., (1998). Using Focal Species in the Design of Nature Reserve Networks. Wild Earth.

Mills, G.S., J.B. Dunning Jr., and J.M. Bates. (1991). The relationship between breeding bird density and vegetation volume. Wilson Bulletin, 103:468-479.

Mishra, H., Kumar, V., and Kumar, A. (2016). Foraging guild status, diversity and population structure of waders of the River Ganges in district Rae Bareli, Uttar Pradesh, India. Journal of Entomology and Zoology Studies, 4(6), 415e419.

Mohan, D., A.P. Singh, S. Sondhi, R. Kumar, P. Singh & S.B. Datta (2016). A Checklist of the Birds of Asan Conservation Reserve. Uttarakhand Forest Department.

Moeliker, K., D. A. Christie, and G. M. Kirwan (2020). Indian Paradise-Flycatcher (Terpsiphone paradisi), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.aspfly1.01

Molleman, F., Kop, A., Brakefield, P. M., De vries, P. J., and Zwaan, B. J. (2006). Vertical and temporal patterns of biodiversity of fruit-feeding butterflies in a tropical forest in Uganda. Biodiversity and Conservation, 15(1), 107–121.

Mohan D. (1997). Birds of New Forest, Dehra Dun, India. Forktail, 21-30.

Mohan, D., Singh A.P., Sondhi S., Kumar R., Singh P. and Datta S.B. (2016). A Checklist of the Birds of Asan Conservation Reserve. Uttarakhand Forest Department.

Mohan D., Sondhi S., Lodha T.A., Kumar R. and Datta S.B. (2018). A preliminary Checklist of Birds of Jhilmil Jheel Conservation Reserve. Uttarakhand Forest Department.

Mohan, D., and Sondhi, S. (2015). An updated checklist of the birds of Uttarakhand. Uttarakhand Forest Department, Dehradun.

Mohan D (2007) Habitat selection of birds in New forest, Dehradun. Forest Research Institute, Dehradun

Monkkonen, M. (1994). Diversity patterns in Palaearctic and Nearctic forest bird assemblages. Journal of Biogeography, 183-195.

Montaño-Centellas, F. A. (2020). Interaction networks of avian mixed-species flocks along elevation in the tropical Andes. Ecography, 43(6), 930-942.

Montgomery, R. A., Redilla, K. M., Ortiz-Calo, W., Smith, T., Keller, B., and Millspaugh, J. J. (2018). Evaluating the individuality of animal-habitat relationships. Ecology and Evolution, 8(22), 10893-10901.

Montoya-Arango, S., Acevedo-Quintero, J. F., and Parra, J. L. (2019). Abundance and size of birds determine the position of the species in plant-frugivore interaction networks in fragmented forests. Community Ecology, 20(1), 75-82.

Morris, D. W. (2003). Toward an ecological synthesis: a case for habitat selection. Oecologia, 136(1), 1-13.

Morrison, M. C., Marcot, B. G. and Mannan, R. W. (1992). Wildlife habitat relationships: concepts and applications. University of Wisconsin Press, Madison.

Morrison III, W. R., Waller, J. T., Brayshaw, A. C., Hyman, D. A., Johnson, M. R., and Fraser, A. M. (2012). Evaluating multiple arthropod taxa as indicators of invertebrate diversity in old fields. The Great Lakes Entomologist, 45(1 and 2), 7.

Morse, D. H. (1967). Competitive relationships between Parula Warblers and other species during the breeding season. The Auk, 84(4), 490-502.

Mottl, O., Yombai, J., Fayle, T. M., Novotný, V., and Klimeš, P. (2020). Experiments with artificial nests provide evidence for ant community stratification and nest site limitation in a tropical forest. Biotropica, 52(2), 277–287.https://doi.org/10.1111/btp.12684

Moynihan, M. H. (1962). The organization and probable evolution of some mixed species flocks of neotropical birds.

Mukhopadhyay, S., and Mazumdar, S. (2019). Habitat-wise composition and foraging guilds of avian community in a suburban landscape of lower Gangetic plains, West Bengal, India. Biologia, 74(8), 1001-1010.

Manly, B. E., Thomas, L., McDonald, D., and Erickson, T. J. et al. (2002). Resource selection by animals: statistical design and analysis for field studies.

May RM. 1973. Stability and Complexity in Model Ecosystems. Princeton, NJ: Princeton Univ. Press McLoughlin, P. D., Cluff, H. D., and Messier, F. (2002). Denning ecology of barren-ground grizzly bears in the central Arctic. Journal of Mammalogy, 83(1), 188-198.

Miranda, B., and Pasinelli, G. (2001). Habitat requirements of the Lesser Spotted Woodpecker (Dendrocopos minor) in forests of north eastern Switzerland.

Mohd-Azlan, J., Noske, R. A., and Lawes, M. J. (2015). The role of habitat heterogeneity in structuring mangrove bird assemblages. Diversity, 7(2), 118-136.

Morueta-holme, N., Blonder, B., Sandel, B., et al. (2016). A network approach for inferring species associations from co-occurrence data. Ecography, 39, 1139–1150. https ://doi.org/10.1111/ecog.01892.

Montoya-Arango, S., Acevedo-Quintero, J. F., and Parra, J. L. (2019). Abundance and size of birds determine the position of the species in plant-frugivore interaction networks in fragmented forests. Community Ecology, 20(1), 75-82.

Montaño-Centellas, F. A. (2020). Interaction networks of avian mixed-species flocks along elevation in the tropical Andes. Ecography, 43(6), 930-942.

Morales M. B., Traba J., Carriles E., Delgado M. P., García de la Morena E. L. (2008). Sexual differences in microhabitat selection of breeding little bustards Tetrax tetrax: Ecological segregation based on vegetation structure. Acta Oecol. 34: 345–353.

Müller, J., Stadler, J., and Brandl, R. (2010). Composition versus physiognomy of vegetation as predictors of bird assemblages: The role of lidar. Remote Sensing of Environment, 114(3), 490-495.

Naeem, S., Thompson, L. J., Lawler, S. P., Lawton, J. H.and Woodfin, R. M. (1994). Declining biodiversity can alter the performance of ecosystems. Nature 368, 734-737.

Naka LN (2003) Structure and organization of canopy bird assemblages in Central Amazonia. Auk 121:88–102

Nakashizuka, T. (2004). The role of biodiversity in Asian forests. Journal of forest research, 9(4), 293-298.

Naidoo, R. (2004). Species richness and community composition of songbirds in a tropical forest-agricultural landscape. Animal Conservation, 7, 93–105.

Naka LN (2004) Structure and organization of canopy bird assemblages in Central Amazonia. Auk 121: 88–102.

Nandy, S., Kushwaha, S. P. S., and Gaur, P. (2012). Identification of Swamp deer (Cervus duvauceli duvauceli Cuvier) potential habitat in Jhilmil Jheel Conservation Reserve, Uttarakhand, India using multi-criteria analysis. Environmental Management, 49(4), 902-914.DOI:10.1007/s00267-012-9826-5

Naniwadekar, R, Chaplod, S, Datta, A, Rathore, A, Sridhar, H. (2019) Large frugivore matter: Insights from network and seed dispersal effectiveness approaches. J Anim Ecol. 2019; 88: 1250-1262. https://doi.org/10.1111/1365-2656.13005

Napier, J. R. (1966). Stratification and primate ecology. J. Anim. Ecol. 35:411-412.

Narayana, B. L., Rao, V. V., and Venkateswara Reddy, V. (2019, December). Composition of Birds in Agricultural Landscapes of Peddagattu and Sherpally Area: a proposed uranium mining sites in Nalgonda, Telangana, India. In Proceedings of the Zoological Society (Vol. 72, No. 4, pp. 380-400). Springer India.

Natesh, M., Atla, G., Nigam, P., Jhala, Y. V., Zachariah, A., Borthakur, U., & Ramakrishnan, U. (2017). Conservation priorities for endangered Indian tigers through a genomic lens. Scientific reports, 7(1), 1-11.

Neate-Clegg, M. H., Morshuis, E. C., and Banks-Leite, C. (2016). Edge effects in the avifaunal community of riparian rain-forest tracts in Tropical North Queensland. Journal of Tropical Ecology, 32(4), 280-289.

Neupane, J., Khanal, L., Gyawali, B., and Chalise, M. K. (2020). Elevational pattern and seasonality of avian diversity in Kaligandaki River Basin, central Himalaya. Journal of Threatened Taxa, 12(14), 16927-16943.

Newbold, T., Scharlemann, J. P., Butchart, S. H., Şekercioğlu, Ç. H., Joppa, L., Alkemade, R., and Purves, D. W. (2014). Functional traits, land-use change and the structure of present and future bird communities in tropical forests. Global ecology and biogeography, 23(10), 1073-1084.

Newmark, W. D. (1995). Extinction of mammal populations in western North American national parks. Conservation biology, 9(3), 512-526.

Newton, I. (2008). The ecology of bird migration. Academic Press, London, UK.

Nielsen, S. E., Boyce, M. S., Stenhouse, G. B., and Munro, R. H. (2003). Development and testing of phenologically driven grizzly bear habitat models. Ecoscience, 10(1), 1-10.

Nielsen, S. E., Johnson, C. J., Heard, D. C., and Boyce, M. S. (2005). Can models of presence-absence be used to scale abundance? Two case studies considering extremes in life history. Ecography, 28(2), 197-208.

Niemi, G. J., Hanowski, J. M., Lima, A. R., Nicholls, T., and Weiland, N. (1997). A critical analysis on the use of indicator species in management. The Journal of Wildlife Management, 1240-1252.

Norris, K. (2008). Agriculture and biodiversity conservation: Opportunity knocks. Conservation Letters, 1, 2–11.

Nsor, C. A., Acquah, E., Mensah, G., Kusi-Kyei, V., and Boadi, S. (2018). Avian Community Structure as a Function of Season, Habitat Type, and Disturbance, in Mole National Park, Northern Region (Ghana). International Journal of Ecology, 2018.

Nyffeler, M., Şekercioğlu, Ç.H., Whelan, C.J., (2018). Insectivorous birds consume an estimated 400–500 million tons of prey annually. Naturwissenschaften 105. https://doi.org/10.1007/s00114-018-1571-z.

Oberrath, R., and Böhning-Gaese, K. (1999). Floral color change and the attraction of insect pollinators in lungwort (Pulmonaria collina). Oecologia, 121(3), 383-391.

O'Connell, T. J., Jackson, L. E., and Brooks, R. P. (2000). Bird guilds as indicators of ecological condition in the central Appalachians. Ecological Applications, 10(6), 1706-1721.

O'Connor, R. J., and Hicks, R. K. (1980). The influence of weather conditions on the detection of birds during Common Birds Census fieldwork. Bird Study, 27(3), 137-151.

Ogle, C. C. (1987). The incidence and conservation of animal and plant species in remnants of native vegetation within New Zealand. Nature conservation: The role of remnants of native vegetation. Surrey Beatty and Sons Pty Limited, 79-87.

Ohsawa, M. (2010). Beetle families as indicators of Coleopteran diversity in forests: a study using Malaise traps in the central mountainous region of Japan. Journal of insect conservation, 14(5), 479-484.

Okes NC, Hockey PAR and Cumming GS (2008) Habitat use and life history as predictors of bird responses to habitat change. Conserv Biol 22: 151–162.

Oliveira, B. F., and Scheffers, B. R. (2019). Vertical stratification influences global patterns of biodiversity. Ecography, 42(2), 249. https://doi.org/10.1111/ecog.03636.

Orta, J., F. Jutglar, E. F. J. Garcia, G. M. Kirwan, and P. F. D. Boesman (2020). Little Cormorant (Microcarbo niger), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.litcor1.01

Ozanne, C. M., Anhuf, D., Boulter, S. L., Keller, M., Kitching, R. L., Körner, C., and Yoshimura, M. (2003). Biodiversity meets the atmosphere: a global view of forest canopies. Science, 301(5630), 183-186.

Özkan, K., Svenning, J. C., and Jeppesen, E. (2013). Environmental species sorting dominates forest-bird community assembly across scales. Journal of Animal Ecology, 82(1), 266-274.

Palei, H. S., Sahu, H. K., and Nayak, A. K. (2016). Estimating the density of Red Junglefowl Gallus gallus (Galliformes: Phasianidae) in the tropical forest of Similipal Tiger Reserve, eastern India. Journal of Threatened Taxa, 8(2), 8495-8598.

Palmer, M. W. (1994). Variation in species richness: towards a unification of hypotheses. Folia Geobotanica et Phytotaxonomica, 29(4), 511-530.

Pandey S., Joshua J., Rai N. D., Mohan D., Rawat G. S., Sankar K., and Johnsingh A. J. T. (1994). Birds of Rajaji National Park, India. Forktail, 10, 105-114.

Palmer TM, Stanton ML, Young TP (2003) Competition and coexistence: exploring mechanisms that restrict and maintain diversity within mutualist guilds. Am Nat 162: S63–S79

Panda, B. P., Prusty, B. A. K., Panda, B., Pradhan, A., and Parida, S. P. (2021). Habitat heterogeneity influences avian feeding guild composition in urban landscapes: evidence from Bhubaneswar, India. Ecological Processes, 10(1), 1-10.

Pannek, A.; Manthey, M.; Diekmann, M. (2016) Comparing resource-based and co-occurrence-based methods for estimating species niche breadth. J. Veg. Sci., 27, 596–605.

Pardini, R., de Souza, S. M., Braga-Neto, R., and Metzger, J. P. (2005). The role of forest structure, fragment size and corridors in maintaining small mammal abundance and diversity in an Atlantic forest landscape. Biological conservation, 124(2), 253-266.

Paszkowski, C. A., and Tonn, W. M. (2006). Foraging guilds of aquatic birds on productive boreal lakes: environmental relations and concordance patterns. Hydrobiologia, 567(1), 19-30.

Patil, V. (1995). Local communities and Eucalyptus: an experience in India. RAPA Publication (FAO).

Patthey, P., Signorell, N., Rotelli, L., and Arlettaz, R. (2012). Vegetation structural and compositional heterogeneity as a key feature in Alpine black grouse microhabitat selection: conservation management implications. European journal of wildlife research, 58(1), 59-70.

Pearman, P. B. (2002). The scale of community structure: habitat variation and avian guilds in tropical forest understory. Ecological monographs, 72(1), 19-39.

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

Peh, K. S. H., Sodhi, N. S., De Jong, J., Sekercioglu, C. H., Yap, C. A. M., and Lim, S. L. H. (2006). Conservation value of degraded habitats for forest birds in southern Peninsular Malaysia. Diversity and Distributions, 12(5), 572-581.

Pérez-Crespo, M. J., Fonseca, J., Pineda-López, R., Palacios, E., and Lara, C. (2013). Foraging guild structure and niche characteristics of waterbirds in an epicontinental lake in Mexico. Zoological Studies, 52(1), 1-17.

Perfecto, I., and Vandermeer, J. (2002). Quality of agroecological matrix in a tropical montane landscape: Ants in coffee plantations in southern Mexico. Conservation Biology, 16, 174–182.

Perfecto, I., and Vandermeer, J. (2008). Biodiversity conservation in tropical agroecosystems. Annals of the New York Academy of Sciences, 1134, 173–200.

Petersen, B.S. (1996). The Distribution of Birds in Danish Farmland. Pesticide Research No. 17. Ministry of Environment and Energy, Copenhagen.

Petersson RP, Ball JP, Renhorn K, Esseen P, Sjoberg K (1995) Invertebrate communities in boreal forest canopies as influenced by forestry and lichens with implications for passerine birds. Biol Conserv 74:57–63.

Petit, L. J., and Petit, D. R. (1996). Factors governing habitat selection by prothonotary warblers: field tests of the Fretwell-Lucas models. Ecological Monographs, 66(3), 367-387.Pimm SL. 1982. Food Webs. London: Chapman.

Petit LJ, Petit DR, Christian DG, Powell HD (1999) Bird communities of natural and modified habitats in Panama. Ecography 22(3): 292–304. https://doi. org/10.1111/j.1600-0587. 1999.tb00505. x.

Petit LJ, Petit DR (2003) Evaluating the importance of human-modified lands for neotropical bird conservation. Conservation Biology 17(3): 687–694. https://doi.org/10.1046/ j.1523-1739.2003.00124. x.

Phalan B, Onial M, Balmford A, Green RE (2011) Reconciling food production and biodiversity conservation: Land sharing and land sparing compared. Science 333(6047): 1289–1291. https://doi.org/10.1126/science.1208742 .

Phalan B, Green RE, Dicks LV, Dotta G, Feniuk C, Lamb A, Strassburg BBN, Williams DR, Ermgassen EKHJzu, Balmford A (2016) How can higher-yield farming help to spare nature? Science 351(6272): 450–451. https://doi.org/10.1126/science.aad0055.

Pimm, S. L. (1982). Food webs. In Food webs (pp. 1-11). Springer, Dordrecht.

Pitelka, F. A. (1941). Distribution of birds in relation to major biotic communities. American Midland Naturalist, 113-137.

Pitta, E., Giokas, S., and Sfenthourakis, S. (2012). Significant pairwise co-occurrence patterns are not the rule in the majority of biotic communities. Diversity, 4, 179–193. https ://doi.org/10.3390/d4020 179

Pizo MA (2007) Frugivory by birds in degraded areas of Brazil. In: Dennis AJ, Schupp EW, Green RJ, Westcott DW (Eds) Seed dispersal: theory and its application in changing word. CABI Publishing, Wallingford.

Pizo MA, Santos BTP (2011) Frugivory, post-feeding flights of frugivorous birds and the movement of seeds in a Brazilian fragmented landscape. Biotropica 43(3): 335–342. https://doi.org/10.1111/j.1744-7429.2010.00695.x.

Pomara, L. Y., Ruokolainen, K., Tuomisto, H., and Young, K. R. (2012). Avian Composition Co-varies with Floristic Composition and Soil Nutrient Concentration in Amazonian Upland Forests. Biotropica, 44(4), 545-553.

Popotnik GJ, Giuliano WM (2000) Grazing and riparian birds. J Wildlife Manage 64:972–982.

Poudyal, L.P., P.B. Singh and S. Maharjan 2008a. Status and distribution of Bengal Florican.

Poudyal, L.P., P.B. Singh and S. Maharajan 2008b. The decline of Bengal Florican Hourbaropsis bengalensis in Nepal. Danphe 17(1): 4-6.http://www.birdlifenepal.org/newsletter/danfe_mar_08.pdf .

Poulsen, B.O., 2002. Avian richness and abundance in temperate Danish forests: tree variables important to birds and their conservation. Biodiversity and Conservation11, 1551–1566.

Prajapati SH, Prajapati RP (2013) Classified guilds in avian community with respect to food and feeding behaviour. Indian J Sci Res Technol 1:1–7

Prevedello JA, Almeida-Gomes M, Lindenmayer DB (2018) The importance of scattered trees for biodiversity conservation: A global meta-analysis. Journal of Applied Ecology 55: 205–214. https://doi.org/10.1111/1365-2664.12943.

Price, T. D., Hooper, D. M., Buchanan, C. D., Johansson, U. S., Tietze, D. T., Alström, P., and Mohan, D. (2014). Niche filling slows the diversification of Himalayan songbirds. Nature, 509(7499), 222-225.

Proença, V. M., Pereira, H. M., Guilherme, J., and Vicente, L. (2010). Plant and bird diversity in natural forests and in native and exotic plantations in NW Portugal. Acta Oecologica, 36(2), 219-226.

Pulliam, H. R., and Danielson, B. J. (1991). Sources, sinks, and habitat selection: a landscape perspective on population dynamics. The American Naturalist, 137, S50-S66.

Raman, T. R. (2006). Effects of habitat structure and adjacent habitats on birds in tropical rainforest fragments and shaded plantations in the Western Ghats, India. In Forest Diversity and Management (pp. 517-547). Springer, Dordrecht.

Rahmani A.R., Islam M.Z. and Kasambe R.M. (2016) Important Bird and Biodiversity Areas in India: Priority Sites for Conservation (Revised and updated). Bombay Natural History Society, Indian Bird Conservation Network, Royal Society for the Protection of Birds and BirdLife International (U.K.). Pp. 1992 + xii, 1826-1828.

Rajpar, M. N., and Zakaria, M. (2011). Bird species abundance and their correlationship with microclimate and habitat variables at Natural Wetland Reserve, Peninsular Malaysia. International Journal of Zoology, 2011.

Ranius, T. (2002). Osmoderma eremita as an indicator of species richness of beetles in tree hollows. Biodiversity and Conservation, 11(5), 931-941.

Rao, S., and Koli, V. K. (2017). Edge effect of busy high traffic roads on the nest site selection of birds inside the city area: guild response. Transportation Research Part D: Transport and Environment, 51, 94-101.

Recher, H. F. (1969). Bird species diversity and habitat diversity in Australia and North America. The American Naturalist, 103(929), 75-80.

Recher, H. F., Holmes, R. T., Schulz, M., Shields, J., and Kavanagh, R. (1985). Foraging patterns of breeding birds in eucalypt forest and woodland of southeastern Australia. Australian Journal of Ecology, 10(4), 399-419.

Recher JR, H. F., and Davis, W. E. (1998). The foraging profile of a wandoo woodland avifauna in early spring. Australian Journal of Ecology, 23(6), 514-527.

Redhead, J. W., Hinsley, S. A., Beckmann, B. C., Broughton, R. K. and Pywell, R. F. (2018). Agriculture, Ecosystems and Environment Effects of agri-environmental habitat provision on winter and breeding season abundance of farmland birds. Agriculture, Ecosystems and Environment. 251: 114–123.

Remsen Jr, J. V., and Parker III, T. A. (1983). Contribution of river-created habitats to bird species richness in Amazonia. Biotropica, 223-231.

Reynolds, C., Fletcher Jr., R.J., Carneiro, C.M., Jennings, N., Ke, A., LaScaleia, M.C., Lukhele, M.B., Mamba, M.L., Sibiya, M.D., Austin, J.D., Magagula, C.N., Mahlaba, T.,Monadjem, A., Wisely, S.M., McCleery, R.A., (2018). Inconsistent effects of landscape heterogeneity and land-use on animal diversity in an agricultural mosaic: a multiscale and multi-taxon investigation. Landsc. Ecol. 33, 241–255.

Roberts, T. J. (1992). The birds of Pakistan. Vol. II. Oxford University Press, Karachi.

Robin, V. V., Gupta, P., Thatte, P., & Ramakrishnan, U. (2015). Islands within islands: Two montane palaeo-endemic birds impacted by recent anthropogenic fragmentation. Molecular Ecology, 24(14), 3572-3584.

Robin, V. V., Vishnudas, C. K., Gupta, P., and Ramakrishnan, U. (2015). Deep and wide valleys drive nested phylogeographic patterns across a montane bird community. Proceedings of the Royal Society B: Biological Sciences, 282(1810), 20150861.

Romanov, A. A., Koblik, E. A., Melikhova, E. V., Arkhipov, V. Y., Golubev, S. V., Volchenkova, M. V., and Astakhova, M. A. (2016). Richness in bird species of the Eastern Himalayas in early spring. Contemporary problems of ecology, 9(5), 529-534.

Romdal, T. S., and Rahbek, C. (2009). Elevational zonation of afrotropical forest bird communities along a homogeneous forest gradient. Journal of Biogeography, 36(2), 327-336.

Rice, J. (1983) Habitat selection attributes of an avian community; A discriminant analysis investigation. Ecol. Monogr. 53:263-290.

Richardson, D. M., and Rejmánek, M. (2011). Trees and shrubs as invasive alien species–a global review. Diversity and distributions, 17(5), 788-809.

Robbins, P., Chaatre, A., and Karanth,K.(2015).Political ecology of commodity agroforests and tropical biodiversity. Conserv.Lett. 8,77–85.doi:10.1111/conl.12169.

Roberge, J. M., and Angelstam, P. (2006). Indicator species among resident forest birds–a cross-regional evaluation in northern Europe. Biological Conservation, 130(1), 134-147.

Robertson, J.G.M. and Berg, Å. (1992). Status and population changes of farmland birds in southern Sweden. Ornis Svecica, 2, 119.130.

Robertson, J. M. (1931). Birds and eucalyptus trees. The Condor, 33(4), 137-139. Native Eucalyptus plantation in Australia provide good habitat and nesting site for birds (Keast , 1990).

Robinson, W. D., Brawn, J. D., and Robinson, S. K. (2000). Forest bird community structure in central Panama: influence of spatial scale and biogeography. Ecological Monographs, 70(2), 209-235.

Rocamora, G., J. del Hoyo, N. Collar, D. Yeatman-Berthelot, D. A. Christie, and G. M. Kirwan (2020). Hair-crested Drongo (Dicrurus hottentottus), version 1.0. In Birds of the World (S. M. Billerman, B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.hacdro1.01.

Rocha, R., Virtanen, T., and Cabeza, M. (2015). Bird assemblages in a Malagasy forest-agricultural frontier: effects of habitat structure and forest cover. Tropical Conservation Science, 8(3), 681-710.

Rodgers, W. A., and Panwar, H. S. (1988). Planning a wildlife protected area network in India.

Rodrigues, J. L., Pellizari, V. H., Mueller, R., Baek, K., Jesus, E. d. C., Paula, F. S., Feigl, B. (2013). Conversion of the Amazon rainforest to agriculture results in biotic homogenization of soil bacterial communities. Proceedings of the National Academy of Sciences, 110, 988–993.

Root, R. B. (1967). The niche exploitation pattern of the blue-gray gnatcatcher. Ecological monographs, 37(4), 317-350.

Rosenberg, G. H. (1990). Habitat specialization and foraging behavior by birds of Amazonian river islands in northeastern Peru. The Condor, 92(2), 427-443.

Rosenzweig, M. L. (1981). A theory of habitat selection. Ecology, 62(2), 327-335.

Rosenzweig, M. L. (1995). Species diversity in space and time. Cambridge university press.

Rotenburg J (2007) Ecological role of a tree (Gmelina arborea) plantation inguatemala: an assessment of an alternative land use for tropical avian conservation, The Auk 94 (2) 201-210.

Rotenberry, J.T., (1985). The role of habitat in avian community composition: physiognomy or floristics? Oecologia 67 (2), 213–217. https://doi.org/10.1007/BF00384286.

Rotenbery, J. T. Why measure bird habitat? The use of multivariate statistics in studies of wildlife habitat (ed) D. Capen, (1981). 29-32. USDA Forest service General Technical Report RM-87. USDA Forest service, Fort Collins.

Rotenberry, J. T., and Wiens, J. A. (1980). Habitat structure, patchiness, and avian communities in North American steppe vegetation: a multivariate analysis. Ecology, 61(5), 1228-1250.

Røv, N. (1975). Breeding bird community structure and species diversity along an ecological gradient in deciduous forest in western Norway. Ornis Scandinavica, 1-14.

Richardson, D. M., and Rejmánek, M. (2011). Trees and shrubs as invasive alien species–a global review. Diversity and distributions, 17(5), 788-809.

Ruiz-Guerra, B., Renton, K., and Dirzo, R. (2012). Consequences of fragmentation of tropical moist forest for birds and their role in predation of herbivorous insects. Biotropica, 44, 228–236.

Robin VV and Davidar P (2002) The vertical stratification of birds in mixed species flocks at Parambikulam, south India: a comparison between two habitats. J Bom Nat Hist Soc 99: 389–399.

Robinson WD, Brawn JD, Robinson SK. Forest bird community structure in central Panama: influence of spatial scale and biogeography. Ecol Monogr. 2000; 70: 209±235. doi: 10.1890/0012-9615(2000) 070[0209: FBCSIC]2.0.CO;2

Roth R (1976) Spatial heterogeneity and bird species diversity. Ecology 57: 773–782.

Royan, A., Reynolds, S. J., Hannah, D. M., Prudhomme, C., Noble, D. G., and Sadler, J. P. (2016). Shared environmental responses drive co-occurrence patterns in river bird communities. Ecography, 39(8), 733-742.

Sabo, S. R., and Holmes, R. T. (1983). Foraging niches and the structure of forest bird communities in contrasting montane habitats. The Condor, 85(2), 121-138.

Salvador, A. and J. A. Amat (2022). Ruddy Shelduck (Tadorna ferruginea), version 3.0. In Birds of the World (S. M. Billerman, M. A. Bridwell, and B. K. Keeney, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.rudshe.03

Santharam, V. (1989). Species richness and avifaunal composition of scrub jungles in and around Madras City. MSc Dissertation Pondicherry University.

Santos, T., Tellería, J. L., Díaz, M., and Carbonell, R. (2006). Evaluating the benefits of CAP reforms: can afforestations restore bird diversity in Mediterranean Spain? Basic and Applied Ecology, 7(6), 483-495.

Saura, S., Estreguil, C., Mouton, C., and Rodríguez-Freire, M. (2011). Network analysis to assess landscape connectivity trends: application to European forests (1990–2000). Ecological Indicators, 11(2), 407-416.

Sekercioğlu, C.H., Ehrlich, P.R., Daily, G.C., Aygen, D., Goehring, D.M., Sandi, R.F., 2002.Disappearance of insectivorous birds from tropical forest fragments. Proc. Nat. Acad.
Sci. USA 99 (1), 263–267. https://doi.org/10.1073/pnas.012616199.

Sekercioğlu, C.H., Daily, G.C., Ehrlich, P.R., (2004). Ecosystem consequences of bird declines. Proc. Natl. Acad. Sci. 101 (52), 18042–18047. https://doi.org/10.1073/pnas.0408049101

Scalercio, S., Infusino, M., and Woiwod, I. P. (2009). Optimising the sampling window for moth indicator communities. Journal of Insect Conservation, 13(6), 583-591.

Scheffers, B. R., Edwards, D. P., Diesmos, A., Williams, S. E., and Evans, T. A. (2014). Microhabitats reduce animal's exposure to climate extremes. Global change biology, 20(2), 495-503.

Scheffers, B. R., Shoo, L., Phillips, B., Macdonald, S. L., Anderson, A., VanDerWal, J., Storlie, C., Gourret, A., and Williams, S. E. (2017). Vertical (arboreality) and horizontal (dispersal) movement increase the resilience of vertebrates to climatic instability. Global Ecology and Biogeography, 26(7), 787–798. https://doi.org/10.1111/geb.12585

Schroth, G., da Fonseca, G. A., Vasconcelos, H. L., Harvey, C. A., Gascon, C., and Izac, A. M. N. (Eds.). (2004). Agroforestry and biodiversity conservation in tropical landscapes. Island Press.

Schroth, G. (2004). Agroforestry and biodiversity conservation in tropical landscapes. Washington, DC: Island Press.

Schulze, C. H., and Riedl, I. (2008). Bird assemblages of forested and human-modified countryside habitats in the Pacific lowlands of southern Costa Rica. Natural and Cultural History of the Golfo Dulce Region, Costa Rica. Stapfia, 88, 395–408.

Scoble, M.J. (1995). The Lepidoptera. (The Natural History Museum and Oxford University Press: Oxford)

Schmiegelow, F. K., and Mönkkönen, M. (2002). Habitat loss and fragmentation in dynamic landscapes: avian perspectives from the boreal forest. Ecological applications, 12(2), 375-389.

Sekercioglu, C. H. (2002). Effects of forestry practices on vegetation structure and bird community of Kibale National Park, Uganda. Biological Conservation, 107(2), 229-240.

Sekercioglu CH (2012) Bird functional diversity in tropical forests, agroforests and open agricultural areas. Journal of Ornithology 153(Supplement): 153–161. https://doi.org/10.1007/s10336-012-0869-4.

Seto, K. C., Fleishman, E., Fay, J. P., and Betrus, C. J. (2004). Linking spatial patterns of bird and butterfly species richness with Landsat TM derived NDVI. International Journal of Remote Sensing, 25(20), 4309-4324.

Shahabuddin G., Kumar R., and Verma A. (2006). Annotated checklist of the birds of Sariska Tiger Reserve, Rajasthan, India. Indian birds, 2(3), 71-76.

Shwartz, A., Turbé, A., Julliard, R., Simon, L., and Prévot, A. C. (2014). Outstanding challenges for urban conservation research and action. Global environmental change, 28, 39-49.

Simamora, T. I., Purbowo, S. D., and Laumonier, Y. (2021). Looking for indicator bird species in the context of forest fragmentation and isolation in West Kalimantan, Indonesia. Global Ecology and Conservation, 27, e01610.

Simberloff D (2004) Community ecology: is it time to move on? Am Nat 163: 787–799.

Singh A. P. (2000). Birds of lower Garhwal Himalayas: Dehra Dun valley and neighbouring hills. Forktail, 101-124.

Sinha S.P., Sinha B. and Qureshi Q. (2011). Management and Conservation of Jhilmil Jheel Conservation Reserve. LAP Lambert Academic Publishing, 15-18.

Sinha, A., Chatterjee, N., Ormerod, S. J., Adhikari, B. S., and Krishnamurthy, R. (2019). River birds as potential indicators of local-and catchment-scale influences on Himalayan river ecosystems. Ecosystems and People, 15(1), 90-101.

Simberloff, R. B. (1967). The niche exploitation pattern of the blue-gray gnatcatcher. Ecological monographs, 37(4), 317-350.

Simberloff, D. (2004). Community Ecology: Is It Time to Move On? (An American Society of Naturalists Presidential Address). The American Naturalist, 163(6), 787-799.

Siriwardena, G. M., Baillie, S. R., Buckland, S. T., Fewster, R. M., Marchant, J. H., and Wilson, J. D. (1998). Trends in the abundance of farmland birds: a quantitative comparison of smoothed Common Birds Census indices. Journal of Applied Ecology, 35(1), 24-43.

Singh, A., Shi, H., Foresman, T., and Fosnight, E. A. (2001). Status of the world's remaining closed forests: an assessment using satellite data and policy options. Ambio: a journal of the human environment, 30(1), 67-69.

Sinha, A., Hariharan, H., Adhikari, B. S., and Krishnamurthy, R. (2019). Bird diversity along riverine areas in the Bhagirathi Valley, Uttarakhand, India. Biodiversity data journal, 7.

Shahabuddin, G., and Kumar, R. (2006). Influence of anthropogenic disturbance on bird communities in a tropical dry forest: role of vegetation structure. Animal conservation, 9(4), 404-413.

Shankar Raman, T.R., Rawat, G.S., Johnsingh, A.J.T., (1998). Recovery of tropical rainforest
avifauna in relation to vegetation succession following shifting cultivation in Mizoram, north-east India. J. Appl. Ecol. 35, 214–231. https://doi.org/10.1046/j.1365-2664.1998.00297.x.

Simamora, T. I., Purbowo, S. D., and Laumonier, Y. (2021). Looking for indicator bird species in the context of forest fragmentation and isolation in West Kalimantan, Indonesia. Global Ecology and Conservation, 27, e01610.

Simberloff, D., Ehrand Dayan, T. (1991). The guild concept and the structure of ecological communities. Annual review of ecology and systematics, 22(1), 115-143.

Simberloff, D. (1998). Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? Biological conservation, 83(3), 247-257.

Singh A. P. (2000). Birds of lower Garhwal Himalayas: Dehra Dun valley and neighbouring hills. Forktail, 101-124.

Singh, P. B., and Buckingham, D. L. (2015). Population status and habitat ecology of Bristled Grassbird Chaetornis striata in Chitwan National Park, central Nepal. Forktail, 31, 87-91.

Sinha S.P., Sinha B. and Qureshi Q. (2011). Management and Conservation of Jhilmil Jheel Conservation Reserve. LAP Lambert Academic Publishing, 15-18.

Söderström, B. O., and Pärt, T. (2000). Influence of landscape scale on farmland birds breeding in semi-natural pastures. Conservation Biology, 14(2), 522-533.

Sodhi, N.S., (1992). Comparison between urban and rural bird communities in Prairie Saskatchewan urbanization and short term population trends. Canadian Field-Naturalist 106, 210–215

Sohil, A., and Sharma, N. (2020). Assessing the bird guild patterns in heterogeneous land use types around Jammu, Jammu and Kashmir, India. Ecological Processes, 9(1), 1-15.

Steen DA, McClure CJ, C BJ, Craig Rudolph D, Pierce JB, Lee JR, et al. (2014) Snake co-occurrence patterns are best explained by habitat and hypothesized effects of interspecific interactions. J Anim Ecol. Jan; 83(1): p. 286±95. https://doi.org/10.1111/1365-2656.12121 PMID: 23998642

Stiles, F. G. (1978). Ecological and evolutionary implications of bird pollination. American Zoologist, 18(4), 715-727.

Sultana, M., Corlatti, L., and Storch, I. (2021). The interaction of imperviousness and habitat heterogeneity drives bird richness patterns in south Asian cities. Urban Ecosystems, 24(2), 335-344.

Sultana A. and Khan J. A. (2000). Birds of oak forests in the Kumaon Himalaya, Uttar Pradesh, India. Forktail, 131-146.

Sultana, M., Corlatti, L., and Storch, I. (2021). The interaction of imperviousness and habitat heterogeneity drives bird richness patterns in south Asian cities. Urban Ecosystems, 24(2), 335-344.

Shahabuddin, G., and Kumar, R. (2007). Effects of extractive disturbance on bird assemblages, vegetation structure and floristics in tropical scrub forest, Sariska Tiger Reserve, India. Forest Ecology and Management, 246(2-3), 175-185.

Shirley, S. (2004). The influence of habitat diversity and structure on bird use of riparian buffer strips in coastal forests of British Columbia, Canada. Canadian Journal of Forest Research, 34:1499-1510.

Slud, P. (1960). The birds of Finca" La Selva," Costa Rica: a tropical wet forest locality. American Museum of Natural History.Sick H (1997) Ornitologia Brasileira. Nova Fronteira, Rio de Janeiro, 862 pp.

Smith, Y.C.E., Smith, D.A.E., Seymour, C.L., The_bault, E., van Veen, F.F.J., (2015). Response of avian diversity to habitat modification can be predicted from life-history traits and ecological attributes. Landsc. Ecol. 30, 1225–1239.

Sundar, K. S. G. and Kittur, S. (2013). Can wetlands maintained for human use also help conserve biodiversity/? Landscape-scale patterns of bird use of wetlands in an agricultural landscape in north India. Biological Conservation. 168: 49-56.

Sohi, G. K., and Kler, T. K. (2017). Adaptations in avian nesting behavior in relation to indigenous trees and housing structures in Punjab. Journal of Entomology and Zoology Studies, 5, 1045-1051.

Sridhar, H., & Sankar, K. (2008). Effects of habitat degradation on mixed-species bird flocks in Indian rain forests. Journal of Tropical Ecology, 24(2), 135-147.

Stanton RL, Morrissey CA, Clark RG. 2018. Analysis of trends and agricultural drivers of farmland bird declines in North America: a review. Agr. Ecosyst. Environ. 254, 244–254. (doi: 10.1016/j.agee.2017.11.028).

Stauffer, F., and Best, L. B. (1980). Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. The Journal of Wildlife Management, 1-15.

Stephens, P. A., Mason, L. R., Green, R. E., Gregory, R. D., Sauer, J. R., Alison, J., and Willis, S. G. (2016). Consistent response of bird populations to climate change on two continents. Science, 352(6281), 84-87.

Stanton, R. L., Morrissey, C. A., and Clark, R. G. (2018). Analysis of trends and agricultural drivers of farmland bird declines in North America: A review. Agriculture, Ecosystems and Environment, 254, 244-254.

Steinmetz J, Kohler SL, Soluk DA (2003) Birds are overlooked top predators in aquatic food webs. Ecology 84:1324–1328. Sullivan SMP, Watzin MC, Hession WC (2006) Differences in the reproductive ecology of belted kingfishers (Ceryle alcyon) across streams with varying geomorphology and habitat quality. Waterbirds 29:258–270.

Styring, A. R., M. Zakaria. 2004. Foraging ecology of woodpeckers in and lowland Malaysian rain forests. J. Trop. Ecol. 20: 487–494.

Surasinghe, T. D., and De Alwis, C. (2010). Birds of Sabaragamuwa University campus, Buttala, Sri Lanka. Journal of Threatened Taxa, 876-888.

Sullivan SMP, Watzin MC, Hession WC (2006) Differences in the reproductive ecology of belted kingfishers (Ceryle alcyon) across streams with varying geomorphology and habitat quality. Waterbirds 29:258–270.

Sullivan, S. M. P., Watzin, M. C., and Keeton, W. S. (2007). A riverscape perspective on habitat associations among riverine bird assemblages in the Lake Champlain Basin, USA. Landscape Ecology, 22(8), 1169-1186.

Sundar, K. G., and Kittur, S. (2013). Can wetlands maintained for human use also help conserve biodiversity? Landscape-scale patterns of bird use of wetlands in an agricultural landscape in north India. Biological conservation, 168, 49-56.

Taneja, Y. V., Page, N. V., Kumar, R. S., and Naniwadekar, R. (2022). Effects of canopy cover on fruiting intensity and fruit removal of a tropical invasive weed. Forest Ecology and Management, 523, 120502.

Tanveer, A., Bargali, H. S., and Afifullah, K. (2019). Status and distribution of avifauna in Ramnagar Forest Division, Western Terai-Arc Landscape, Uttarakhand. Indian Forester, 145(10), 935-945.

Team, R. C. (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www. R-project. org/.

Telleria, J. L., Santos, T., Sanchez, A., and Galarza, A. (1992). Habitat structure predicts bird diversity distribution in Iberian forests better than climate. Bird Study, 39(1), 63-68.

Terborgh, J. (1976). Island biogeography and conservation: strategy and limitations. Science, 193(4257), 1029-1030.

Terborgh, J. O. H. N. (1985). Habitat selection in Amazonian birds. Habitat selection in birds, 311, 338.

Terborgh, J. (1977). Bird species diversity on an Andean elevational gradient. Ecology, 58(5), 1007-1019.

Terborgh J, Robinson S.K. Parker T. A., Munn C. A. and Pierpont N. (1990) Structure and organization of an Amazonian forest bird community. Ecol. Monogr. 60:213-238

Tewari, R., and Rawat, G. S. (2013). Assessment of Swamp deer habitat in and around Jhilmil Jheel Conservation Reserve, Haridwar, Uttarakhand, India. International Journal of Conservation Science, 4(2).

Tews, J., Brose, U., Grimm, V., Tielbörger, K., Wichmann, M. C., Schwager, M., and Jeltsch, F. (2004). Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. Journal of biogeography, 31(1), 79-92.

T. E. Martin, "Nest predation and nest sites," Bioscience, vol. 43, no. 8, pp. 523–532, 1993.

Thakur, M.L., Mattu V.K., Lal, H., Sharma, V.N., Raj, H.and Thakur, V. 2010. Avifauna of Arki Hills, Solan.

Thinh V.T. (2006) Bird species richness and diversity in relation to vegetation in Bavi National Park, Vietnam, Ornithol. Sci., 5(1): 121-125 (2006).

Thiollay, J. M. (1995). The role of traditional agroforests in the conservation of rain forest bird diversity in Sumatra. Conservation biology, 9(2), 335-353.

Thompson, I.D., Guariguata, M.R., Okabe, K., Bahamondez, C., Nasi, R., Heymell, V., Sabogal, C., (2013). An operational framework for defining and monitoring forest degradation. Ecol. Soc. 18. https://doi.org/10.5751/es-05443-180220

Tilman, D., and Pacala, S. (1993). The maintenance of species richness in plant communities. Scanning Electron Microsc Meet at, 13-25.

Titchenell, M. A., Williams, R. A., and Gehrt, S. D. (2011). Bat response to shelterwood harvests and forest structure in oak-hickory forests. Forest Ecology and Management, 262(6), 980-988.

Tiwari R, (2009), "A Study on the Habitat Use and Food Habits of Swamp Deer (Cervus duvauceli duvauceli) In Jhilmil Jheel Conversation Reserve, Haridwar Forest Division, Uttarakhand", thesis PhD, Saurashtra University,142-143.

Torre-Cuadros, L., De Los Ángeles, M., Herrando-Pérez, S., and Young, K. R. (2007). Diversity and structural patterns for tropical montane and premontane forests of central Peru, with an assessment of the use of higher-taxon surrogacy. Biodiversity and Conservation, 16(10), 2965-2988.

Trivedi P. (2006), Ecology and Conservation of Avifauna of Some Forested Areas in Gujarat, India, Unpublished Phd. Thesis, Saurashtra University.

T. R. Shankar Raman, G. S. Rawat, and A. J. T. Johnsingh, "Recovery of tropical rainforest avifauna in relation to vegetation succession following shifting cultivation in Mizoram, north-east India," Journal of Applied Ecology, vol. 35, no. 2, pp. 214–231, 1998.

T. R. Shankar Raman, "Effect of slash-and-burn shifting cultivation on rainforest birds in Mizoram, Northeast India," Conservation Biology, vol. 15, no. 3, pp. 685–698, 2001.

Tulloch, A. I. T., Chades, I., and Lindenmayer, D. B. (2018). Species co-occurrence analysis predicts management outcomes for multiple threats. Nature Ecology and Evolution, 2, 465–474.

Tu, H. M., Fan, M. W., and Ko, J. C. J. (2020). Different habitat types affect bird richness and evenness. Scientific reports, 10(1), 1-10.

Turnbull, J. W. (1999). Eucalypt plantations. New Forests, 17(1), 37-52.

Turton SM and Siegenthaler DT (2004) Immediate impacts of a severe tropical cyclone on the micro-climate of a tropical rain forest canopy in Northeast Australia. J Trop Ecol 20: 583–586.

Tyler, S. (2020). Gray Wagtail (Motacilla cinerea), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.grywag.01

Tyler, S. (2020). Paddyfield Pipit (Anthus rufulus), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA.

Tyler, S. and G. M. Kirwan (2020). Citrine Wagtail (Motacilla citreola), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.citwag.01.

Tylianakis, J. M., and Morris, R. J. (2017). Ecological networks across environmental gradients. Annual Review of Ecology, Evolution, and Systematics, 48, 25-48.

Tylianakis, J. M., Didham, R. K., Bascompte, J., and Wardle, D. A. (2008). Global change and species interactions in terrestrial ecosystems. Ecology letters, 11(12), 1351-1363.

Tylianakis, J. M., Laliberte, E., Nielsen, A., and Bascompte, J. (2010). Conservation of species interaction networks. Biological Conservation, 143, 2270–2279. https ://doi.org/10.1016/j.biocon.2009.12.004

Uezu A, Beyer DD, Metzger JP (2008) Can agroforest woodlots work as stepping stones for birds in the Atlantic forest region? Biodiversity and Conservation 17(8): 1907–1922. https://doi.org/10.1007/s10531-008-9329-0.

Upamanyu, H., and Uniyal, V. P. (2008). Diversity and composition of spider assemblages in five vegetation types of the Terai Conservation Area.

Uys, C., Hamer, M. and Slotow, R. (2010). Step process for selecting and testing surrogates and indicators of Afrotemperate forest invertebrate diversity. PLoS One, 5(2), e9100.

Valduga, M.; Zenni, R. and Vitule, J. (2016). Ecological impacts of non-native tree species plantations are broad and heterogeneous: A review of Brazilian research. Anais da Academia Brasileira de Ciências, 88(3): 1675-1688

Veech, J. A., Small, M. F.and Baccus, J. T. (2011). The effect of habitat on the range expansion of a native and an introduced bird species. Journal of Biogeography, 38(1), 69-77.

Verdade LM, Penteado M, Gheler-Costa C, Dotta G, Rosalino LM, Pivello VR, Piña CI, Lyra-Jorge MC (2014) The conservation value of agricultural landscapes. In: Verdade LM, Lyra-Jorge MC, Piña CI (Eds) Applied Ecology and Human Dimensions in Biological Conservation. Springer, London, 228 pp. https://doi.org/10.1007/978-3-642-54751-5.

Verner, J. (1984). The guild concept applied to management of bird populations. Environmental Management, 8(1), 1-13.

Verschuyl, J. P., Hansen, A. J., McWethy, D. B., Sallabanks, R.and Hutto, R. L. (2008). Is the effect of forest structure on bird diversity modified by forest productivity? Ecological Applications, 18(5), 1155-1170.

Vieira EM and Monteiro-Filho ELA (2003) Vertical stratification of small mammals in the Atlantic rainforest of south-eastern Brazil. J Trop Ecol 19: 501–507.

Vitousek, P. M. (1994). Beyond global warming: ecology and global change. Ecology, 75(7), 1861-1876.

Vitorino BD, Rodrigues MB, da Frota AVB, de Avelar DM, Rodrigues WL, Castrillon SKI, Nunes JRS (2018) Birds of rural landscape in the Midwest region of the state of Minas Gerais, Brazil. Neotropical Biology and Conservation 13(1): 62–73. https://doi.org/10.4013/nbc.2018.131.08.

Vivian-Smith, G. (1997). Microtopographic heterogeneity and floristic diversity in experimental wetland communities. Journal of Ecology, 71-82.

Vogel HF, McCarron VEA, Zocche JJ (2018) Use of artificial perches by birds in ecological restoration areas of the Cerrado and Atlantic Forest biomes in Brazil. Neotropical Biology and Conservation 13(1): 24–36. https://doi.org/10.4013/nbc.2018.131.04.

Walsberg, G. E. (1981). Nest-site selection and the radiative environment of the Warbling Vireo. The Condor, 83(1), 86-88.

Waltert, M., Bobo, K. S., Sainge, N. M., Fermon, H., and Mühlenberg, M. (2005). From forest to farmland: habitat effects on Afrotropical forest bird diversity. Ecological Applications, 15(4), 1351-1366.

Walther, B. and P. Jones (2020). Black-hooded Oriole (Oriolus xanthornus), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.blhori1.01

Walther, B. A. 2002. Vertical stratification and use of vegetation and light habitats of Neotropical forest birds. J. Ornithol. 143: 64–81.

Ward, J.V., Tockner, K., Arscott, D.B. and Claret, C., (2002). Riverine landscape diversity. Freshwater Biology, vol. 47, no. 4, pp. 517-539. http://dx.doi.org/10.1046/j.1365-2427.2002.00893.x.

Wasnik, S., Telkhade, P. M., Tijare, R. V., and Charde, P. N. (2014). Ecology of little Green Bee-eater (Merops Orientalis) from Nagpur area (India). Ecology, 2347, 517X.

Watson, J. E., Whittaker, R. J., and Freudenberger, D. (2005). Bird community responses to habitat fragmentation: how consistent are they across landscapes? Journal of Biogeography, 32(8), 1353-1370.

Webb, C. O., Ackerly, D. D., McPeek, M. A., and Donoghue, M. J. (2002). Phylogenies and community ecology. Annual review of ecology and systematics, 33(1), 475-505.

Weins, J.A., Rotenberry, J. T. and Van Horne, B. (1987) Habitat occupancy patterns of North American Shrubsteppe birds: the effect of spatial scale. Oikos, 48, 132-147.

Weins, J. A., The Ecology of Bird community. (1992). Vol.2. Cambridge University Press. Cambridge.

Whitcomb, R. F., Lynch, J. F., Opler, P. A., & Robbins, C. S. (1976). Island biogeography and conservation: strategy and limitations. Science, 193(4257), 1030-102.

Whitehurst AS, Swatantran A, Blair JB, Hofton MA, Dubayah R. 2013.Characterization of canopy layering in forested ecosystems using FullWaveform Lidar. Rem Sens 5: 2014-2036.

Wiersma, P. and G. M. Kirwan (2020). River Lapwing (Vanellus duvaucelii), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.rivlap1.01

Wiersma, P. and G. M. Kirwan (2020). Red-wattled Lapwing (Vanellus indicus), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.rewlap1.01

Wielstra, B., Boorsma, T., Pieterse, S. M., andde Iongh, H. H. (2011). The use of avian feeding guilds to detect small-scale forest disturbance: a case study in East Kalimantan, Borneo. Forktail, 27(27), 55-62.

Wiens, J. A., and Rotenberry, J. T. (1981). Habitat associations and community structure of birds in shrubsteppe environments. Ecological monographs, 51(1), 21-42.

Wiens, J. A. (1969). An approach to the study of ecological relationships among grassland birds. Ornithological monographs, (8), 1-93.

Wiens, J. A. (1974). Habitat heterogeneity and avian community structure in North American grasslands.

Wiens, J. A. (1989). Spatial scaling in ecology. Functional ecology, 3(4), 385-397.

Wiens, J.A. (1989) The Ecology of Bird Communities, Vol. 2. Processes and Variations. Cambridge University Press, Cambridge.

WII (2005). Vegetation and ungulate habitat characteristics.in: The relationships among large herbivores,habitats and peoples in rajaji-corbett national park : A study in uttaranchal,northern india. Technical report, Wildlife Institute of India (WII), Dehradun

Wikramanayake, E., McKnight, M. E. G. H. A. N., Dinerstein, E., Joshi, A., Gurung, B., and Smith, D. (2004). Designing a conservation landscape for tigers in human-dominated environments. Conservation Biology, 18(3), 839-844.

Wilson, E. O, and MacArthur, R. H. (1967). The theory of island biogeography (Vol. 1). Princeton, NJ: Princeton University Press.

Willson, M. F. (1974). Avian community organization and habitat structure. Ecology, 55(5), 1017-1029.

Wintle BA, et al. (2019) Global synthesis of conservation studies reveals the importance of small habitat patches for biodiversity. Proc Natl Acad Sci USA116:909–914. doi: 10.1073/pnas.1813051115

Wiens, J. A. (1973). Pattern and process in grassland bird communities. Ecological monographs, 43(2), 237-270.

Wisz M, Pottier J, Kissling W, Pellissier L, Lenoir J, Damgaard C, et al. (2013). The role of biotic interactions inshaping distributions and realised assemblages of species: implications for species distribution modelling.

Wiens JA. The Ecology of Bird Communities: Volume 1 Foundations and Patterns. New York: Cambridge University Press; doi: 10.1017/CBO9780511608568 PMID: 178121741989.

Wiens JA. The Ecology of Bird Communities: Volume 2 Processes and Variations. New York: Cambridge University Press; 1989. doi: 10.1017/CBO9780511608568

Wiens, J.A., Rotenberry, J.T., (1981). Habitat associations and community structure of birds in shrubsteppe environments. Ecological Monographs 51, 21–41.

Wiens, J.A., Rotenberry, J.T., Van Horne, B., (1987). Habitat occupancy patterns of North American shrubsteppe birds: the effects of spatial scale. Oikos 48, 132–147.

Wiersma, P. and G. M. Kirwan (2020). Red-wattled Lapwing (Vanellus indicus), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.rewlap1.01

Wood EM, Johnson MD, Jackson RD, Pidgeon AM and Garrison BA (2013) Avian community use and occupancy of California oak savanna. Condor 115: 712–724.

xeno-canto (2020). Sharing bird sounds from around the world. Available at: https://www.xeno-canto.org/. Accessed 10 May 2020

Yam, R. S., Huang, K. P., Hsieh, H. L., Lin, H. J., and Huang, S. C. (2015). An ecosystem-service approach to evaluate the role of non-native species in urbanized wetlands. International Journal of Environmental Research and Public Health, 12(4), 3926-3943. doi: 10.3390/ijerph120403926

Yom-Tov, Y., Imber, A., and Otterman, J. (1977). The microclimate of winter roosts of the starling Sturnus vulgaris. Ibis 119, 366-368.

Zozaya EL, Brotons L and Vallecillo S (2011) Bird community responses to vegetation heterogeneity following non-direct regeneration of Mediterranean forests after fire. Ardea 99: 73–84.

ZSI, 2014. Fauna of Jhilmil Jheel Conservation Reserve (Uttarakhand), Conservation Area Series, 50

APPENDICES

Appendix 1. List of birds observed in Jhilmil Jheel Conservation Reserve

Family	Bird species	Scientific name	IUCN Status	Feeding guild	Vertical strata	Habitats present
Anatidae	Lesser Whistling-duck	*Dendrocygna javanica*	LC	H	A	R
	Bar-headed Goose	*Anser indicus*	LC	H	A	R
	Ruddy Shelduck	*Tadorna ferruginea*	LC	H	A	R, G, A
	Indian Spot-billed Duck	*Anas poecilorhyncha*	LC	H	A	R
	Northern Pintail	*Anas acuta*	LC	H	A	R
	Gadwall	*Mareca strepera*	LC	H	A	R
	Red-crested Pochard	*Netta rufina*	LC	H	A	R
	Goosander	*Mergus merganser*	LC	P	A	R
Ardeidae	Indian Pond Heron	*Ardeola grayii*	LC	P	A	P, R, G, A
	Grey Heron	*Ardea cinerea*	LC	P	A	R
	Cattle Egret	*Bulbulcus ibis*	LC	I	T	P, R, G, A

	Great Egret	*Ardea alba*	LC	P	A	R
	Intermediate Egret	*Ardea intermedia*	LC	P	A	R
	Little Egret	*Egretta garzetta*	LC	P	A	R
Accipitridae	Black Kite	*Milvus migrans*	LC	C	-	R
	Osprey	*Pandion haliaetus*	LC	P	-	R
	Oriental Honey-buzzard	*Pernis ptilorhynchus*	LC	C	-	M
	Egyptian Vulture	*Neophron percnopterus*	EN	S	-	R
	White rumped Vulture	*Gyps bengalensis*	CR	S	-	G
	Slender-billed Vulture	*Gyps tenuirostris*	CR	S	-	R
	Himalayan Vulture	*Gyps himalayensis*	NT	S	-	S, R
	Cinereous Vulture	*Aegypius monachus*	LC	S	-	R
	Crested Serpent-Eagle	*Spilornis cheela*	LC	C	-	P, M, R, G
	Changeable Hawk-Eagle	*Nisaetus cirrhatus*	LC	C	-	P
	Shikra	*Accipiter badius*	LC	C	-	P, M
	Eurasian Sparrowhawk	*Accipiter nisus*	LC	C	-	M
	White-eyed Buzzard	*Butastur teesa*	LC	C	-	S

	Short-toed Snake-Eagle	*Circaetus gallicus*	LC	C	-	G
Acrocephalidae	Blyth's Reed Warbler	*Acrocephalus dumetorum*	LC	I	US	R
Alcedinidae	Stork-billed Kingfisher	*Pelargopsis capensis*	LC	P	A	R
	White-throated Kingfisher	*Halcyon smyrnensis*	LC	I	MC	P, R, G
	Common Kingfisher	*Alcedo atthis*	LC	P	A	R, G
	Pied Kingfisher	*Ceryle rudis*	LC	P	A	R
Aegithinidae	Common Iora	*Aegithina tiphia*	LC	I	MC	P, M, S
Alaudidae	Ashy-crowned Sparrow Lark	*Eremopterix griseus*	LC	G	T	R
	Oriental Skylark	*Alauda gulgula*	LC	I	T	R, G
	Crested Lark	*Galerida cristata*	LC	I	T	R
Apodidae	House Swift	*Apus nipalensis*	LC	I	Ae	A
	White-rumped Needletail	*Zoonavena sylvatica*	LC	I	Ae	M
Burhinidae	Great Thick-knee	*Esacus recurvirostris*	NT	C	T	R
Bucerotidae	Oriental Pied-Hornbill	*Anthracoceros albirostris*	LC	F	UC	M
	Indian Grey Hornbill	*Ocyceros birostris*	LC	FI	MC	P, M, S, R
Certhiidae	Bar-tailed Treecreeper	*Certhia himalayana*	LC	I	UC, MC	M

Ciconiidae	Woolly-necked Stork	*Ciconia episcopus*	VU	I	A	P
Charadriidae	River Lapwing	*Vanellus duvaucelii*	NT	I	A	R, G
	Yellow-wattled Lapwing	*Vanellus malabaricus*	LC	I	T	G
	Red-wattled Lapwing	*Vanellus indicus*	LC	I	A	P, R, G, A
	Little-ringed Plover	*Charadrius dubius*	LC	I	A	R
Chloropseidae	Golden-fronted Leafbird	*Chloropsis aurifrons*	LC	I	UC	M
Columbidae	Rock Pigeon	*Columba livia*	LC	G	T	A
	Yellow-footed Green-Pigeon	*Treron phoenicopterus*	LC	F	UC	S
	Eurasian Collared- Dove	*Streptopelia decaocto*	LC	G	MC	M, S, R
	Spotted Dove	*Spilopelia chinensis*	LC	G	LC	P, M, S, R, G, A
	Laughing Dove	*Spilopelia senegalensis*	LC	G	MC	S, G
Cuculidae	Common Hawk-Cuckoo	*Hierococcyx varius*	LC	I	MC	P, M
	Indian Cuckoo	*Cuculus micropterus*	LC	I	UC	P, M, S, A
	Common Cuckoo	*Cuculus canorus*	LC	I	UC	P
	Grey-bellied Cuckoo	*Cacomantis passerinus*	LC	I	LC	R, G
	Square-tailed Drongo-Cuckoo	*Surniculus lugubris*	LC	I	MC	P

	Pied Cuckoo	*Clamator jacobinus*	LC	I	LC	S
	Asian Koel	*Eudynamys scolopaceus*	LC	FI	MC	P, M, S, R, A
	Sirkeer Malkoha	*Taccocua leschenaultii*	LC	I	US	R
	Greater Coucal	*Centropus sinensis*	LC	O	US	S, A
Coraciidae	Indian Roller	*Coracias benghalensis*	LC	I	MC	P, M, S, R, G
Corvidae	Rufous Treepie	*Dendrocitta vagabunda*	LC	O	MC	P, M, S, A
	Large-billed Crow	*Corvus macrorhynchos*	LC	O	UC	P, M, S, R, G
	House Crow	*Corvus splendens*	LC	O	MC	P, R, G, A
Cisticolidae	Grey-breasted Prinia	*Prinia hodgsonii*	LC	I	US	P, M, S
	Yellow-bellied Prinia	*Prinia flaviventris*	LC	I	US	G
	Ashy Prinia	*Prinia socialis*	LC	I	US	M, S, G, R, A
	Plain Prinia	*Prinia inornata*	LC	I	US	M, S, G, A
	Zitting Cisticola	*Cisticola juncidis*	LC	I	US	G
	Common Tailorbird	*Orthotomus sutorius*	LC	I	US	P, M, S, R, A
Locustellidae	Striated Grassbird	*Cincloramphus palustris*	LC	I	US	G
	Bristled Grassbird	*Schoenicola striatus*	VU	I	US	G

Campephagidae	Small Minivet	*Pericrocotus cinnamomeus*	LC	I	MC	P, M, S
Caprimulgidae	Large-tailed Nightjar	*Caprimulgus macrurus*	LC	I	T	M
Dicruridae	Spangled Drongo	*Dicrurus hottentottus*	LC	I	MC	P, M, S, G
	Black Drongo	*Dicrurus macrocercus*	LC	I	MC	P, M, S, R, G
	Ashy Drongo	*Dicrurus leucophaeus*	LC	I	UC	G
	Bronzed Drongo	*Dicrurus aeneus*	LC	I	MC	G
	White-bellied Drongo	*Dicrurus caerulescens*	LC	I	MC	P, R
Dicaeidae	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	LC	NI	MC	S
	Thick-billed Flowerpecker	*Dicaeum agile*	LC	NI	MC	P
Estrildidae	Indian Silverbill	*Euodice malabarica*	LC	G	US	S, G
	Red Avadavat	*Amandava amandava*	LC	G	US	G
Falconidae	Eurasian Kestrel	*Falco tinnunculus*	LC	C	-	R
	Peregrine Falcon	*Falco peregrinus*	LC	C	-	R
Fringilidae	Yellow-breasted Greenfinch	*Chloris spinoides*	LC	G	LC	G
Gruidae	Sarus Crane	*Antigone antigone*	VU	H	T	R, G, A
Glareolidae	Small Pratincole	*Glareola lactea*	LC	I	A	R

Hemiprocnidae	Crested Treeswift	*Hemiprocne coronata*	LC	I	UC	M
Hirudinidae	Plain Martin	*Riparia chinensis*	LC	I	Ae	M, S, G
	Barn Swallow	*Hirundo rustica*	LC	I	Ae	P, R, G
Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	LC	H	A	G
Laridae	Pallas's Gull	*Ichthyaetus ichthyaetus*	LC	P	A	R
	Little Tern	*Sternula albifrons*	LC	P	A	R
	Black-bellied Tern	*Sterna acuticauda*	EN	P	A	R
	River Tern	*Sterna aurantia*	NT	P	A	R, G
Laniidae	Long-tailed Shrike	*Lanius schach*	LC	I	LC	S, G
	Bay-backed Shrike	*Lanius vittatus*	LC	I	LC	S
Motacillidae	Paddyfield Pipit	*Anthus rufulus*	LC	I	T	G
	Gray Wagtail	*Motacilla cinerea*	LC	I	T	R, A
	Citrine Wagtail	*Motacilla citreola*	LC	I	T	R, G
	White-browed Wagtail	*Motacilla maderaspatensis*	LC	I	A	R
	White Wagtail	*Motacilla alba*	LC	I	A	P, R
Muscicapidae	Oriental Magpie Robin	*Copsychus saularis*	LC	I	US	P, M, S, R, G

	Indian Robin	*Copsychus fulicatus*	LC	I	T	S, R
	Common Stonechat	*Saxicola maurus*	LC	I	T	R, G
	White-tailed Stonechat	*Saxicola leucurus*	LC	I	US	G
	Pied Bushchat	*Saxicola caprata*	LC	I	US	S, R, G, A
	Grey Bushchat	*Saxicola ferreus*	LC	I	LC	S, G, A
	Brown Rock Chat	*Oenanthe fusca*	LC	I	T	G, A
	Tickell’s Blue Flycatcher	*Cyornis tickelliae*	LC	I	LC	P
	Verditer Flycatcher	*Eumyias thalassinus*	LC	I	LC	S
	Red-breasted Flycatcher	*Ficedula parva*	LC	I	LC	M, S
	Taiga Flycatcher	*Ficedula albicilla*	LC	I	LC	P
	Asian Brown Flycatcher	*Muscicapa dauurica*	LC	I	MC	P, M
	Small Niltava	*Niltava macgrigoriae*	LC	I	US	M
	Chestnut-bellied Rock-Thrush	*Monticola rufiventris*	LC	I	T	P
	Rufous-gorgeted Flycatcher	*Ficedula strophiata*	LC	I	US	M
Monarchidae	Indian Paradise-Flycatcher	*Terpsiphone paradisi*	LC	I	LC	P, M
	Black-naped Monarch	*Hypothymis azurea*	LC	I	LC	P

Meropidae	Asian Green Bee-eater	*Merops orientalis*	LC	I	Ae	P, M, S, R, G, A
	Blue-tailed Bee-eater	*Merops philippinus*	LC	I	Ae	M, S
Nectariniidae	Purple Sunbird	*Cinnyris asiaticus*	LC	NI	MC	P, M, S, R, G
	Crimson Sunbird	*Aethopyga siparaja*	LC	NI	MC	M, S
Oriolidae	Maroon Oriole	*Oriolus traillii*	LC	FIN	UC	P
	Black-hooded Oriole	*Oriolus xanthornus*	LC	FSNI	UC	P, M, R
Phasianidae	Grey Francolin	*Francolinus pondicerianus*	LC	G	T	R, G
	Red Junglefowl	*Gallus gallus*	LC	G	T	P, M, S
	Indian Peafowl	*Pavo cristatus*	LC	O	T	P, M, S, G
	Black Francolin	*Francolinus francolinus*	LC	G	T	R,G
Pandionidae	Osprey	*Pandion haliaetus*	LC	P	-	R
Phalacrocoracidae	Little Cormorant	*Microcarbo niger*	LC	P	A	R
	Great Cormorant	*Phalacrocorax carbo*	LC	P	A	R
Psittaculidae	Rose-ringed Parakeet	*Psittacula krameri*	LC	FSN	MC	P, M, S, R, G, A
	Plum-headed Parakeet	*Psittacula cyanocephala*	LC	FSN	MC	P, M, S, R

Picidae	Lesser Goldenbacked Woodpecker	*Dinopium benghalense*	LC	I	MC	P, S
	Streak- throated Woodpecker	*Picus xanthopygaeus*	LC	I	MC	M
Pittidae	Indian Pitta	*Pitta brachyura*	LC	I	US	P, M, S
Paridae	Great Tit	*Parus major*	LC	I	MC	P, M, S
Pycnonotidae	Himalayan Bulbul	*Pycnonotus leucogenys*	LC	FSNI	MC	P, M, S, G
	Red –whiskered Bulbul	*Pycnonotus jocosus*	LC	FSNI	MC	P, M, S, G, A
	Red-vented Bulbul	*Pycnonotus cafer*	LC	FSNI	MC	P, M, S, R, G, A
	Black Bulbul	*Hypsipetes leucocephalus*	LC	FSNI	UC	P
Passeridae	House Sparrow	*Passer domesticus*	LC	G	T	A
	Baya Weaver	*Ploceus philippinus*	LC	G	T	M, S, G, A
	Black-breasted Weaver	*Ploceus benghalensis*	LC	G	T	G
	Chestnut -shouldered Petronia	*Gymnoris xanthocollis*	LC	G	T	P, M, S, R
Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	LC	I	A	R
Rallidae	Common Moorhen	*Gallinula chloropus*	LC	O	A	reedbeds
	Brown Crake	*Zapornia akool*	LC	O	A	reedbeds

	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	C	A	reedbeds
Ramphastidae	Great Barbet	*Psilopogon virens*	LC	FI	MC	S
	Brown-headed Barbet	*Psilopogon zeylanicus*	LC	FI	UC	P, M, S
	Coppersmith Barbet	*Psilopogon haemacephalus*	LC	FI	UC	P, M, S
Rhipiduridae	White-throated Fantail	*Rhipidura albicollis*	LC	I	LC	P, S, R, G
Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	LC	I	A	R
	Common Greenshank	*Tringa nebularia*	LC	I	A	R
	Little Stint	*Calidris minuta*	LC	I	A	R
	Temminck's Stint	*Calidris temminckii*	LC	I	A	R
Stenostiridae	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis*	LC	I	UC, MC	M
Strigidae	Jungle Owlet	*Glaucidium radiatum*	LC	C	LC	P, M
	Spotted Owlet	*Athene brama*	LC	C	MC, LC	M
	Mottled Wood-Owl	*Strix ocellata*	LC	C	UC	M
Sylviidae	Hume's Warbler	*Phylloscopus humei*	LC	I	UC	P, M, S, R, A
	Lemon-rumped Warbler	*Phylloscopus chloronotus*	LC	I	LC	P
	Greenish Warbler	*Phylloscopus trochiloides*	LC	I	MC	P, M, S, R, G

	Grey- hooded Warbler	*Phylloscopus xanthoschistos*	LC	I	MC	M
	Lesser Whitethroat	*Curruca curruca*	LC	I	US	M, S
Sittidae	Chestnut- bellied Nuthatch	*Sitta cinnamoventris*	LC	I	MC	S
	Velvet-fronted Nuthatch	*Sitta frontalis*	LC	I	MC	P
Sturnidae	Indian Pied Starling	*Gracupica contra*	LC	FSNI	T	G, A
	Brahminy Starling	*Sturnia pagodarum*	LC	FSNI	T	M, S, R
	Common Myna	*Acridotheres tristis*	LC	FSNI	MC	P, S, R, G, A
	Jungle Myna	*Acridotheres fuscus*	LC	FSNI	MC	M
	Bank Myna	*Acridotheres ginginianus*	LC	FSNI	T	R
Threskiornithidae	Red-naped Ibis	*Pseudibis papillosa*	LC	O	A	P, R, G
Timaliidae	Rusty-cheeked Scimitar Babbler	*Erythrogenys erythrogenys*	LC	I	US	P
	Tawny-bellied Babbler	*Dumetia hyperythra*	LC	I	US	S
	Black- chinned Babbler	*Cyanoderma pyrrhops*	LC	I	US	P, M, S
	Striated Babbler	*Argya earlei*	LC	I	US	G
	Jungle Babbler	*Argya striata*	LC	I	US	P, M, S, A

Turdidae	Tickell's Thrush	*Turdus unicolor*	LC	I	T	G
Turnicidae	Barred Buttonquail	*Turnix suscitator*	LC	G	T	S
Upupidae	Common Hoopoe	*Upupa epops*	LC	I	T	G
Vangidae	Common Woodshrike	*Tephrodornis pondicerianus*	LC	I	MC	P
	Bar-winged Flycatcher-Shrike	*Hemipus picatus*	LC	I	MP	M
Zosteropidae	Indian White-eye	*Zosterops palpebrosus*	LC	NI	MC	P, M, S

IUCN Status: LC- Least concern, NT- Near threatened, VU- Vulnerable, EN- Endangered, CR- Critically Endangered

Feeding guild: G-Granivore, I-Insectivore, H-Herbivore, C-Carnivore, P-Piscivore, S-Scavenger, F-Frugivore, FI-Frugivore-Insectivore, FSNI-Fruit-Seed-Nectar-Insects, FIN-Frugivore-Insectivore-Nectarivore, FSN-Fruit-Seed-Nectar, NI-Nectarivore-Insectivore,

Vertical strata: U-Upper canopy-UC, MC-Middle canopy, LC-Lower canopy, US-Understorey, T-Terrestrial, A-Aquatic, Ae- aerial

Habitats: P-Plantation, M-Mixed deciduous forest, S-Scrub forest, R-Riverine, G-Grassland, A-Agriculture fields-human settlement

Appendix 2. Publication and conference certificates

Indian Forester, **148**(10) : 1049-1054, 2022
DOI: 10.36808/if/2022/v148i10/163182

ISSN: 0019-4816
eISSN: 2321-094X

Avian Community
Structure of Jhilmil Jheel Conservation Reserve, Haridwar, Uttarakhand

A survey of avifauna was carried out in Jhilmil Jheel Conservation Reserve (JJCR) of Haridwar Forest Division, Uttarakhand during 2018-2020. Point count method was used to count birds in six habitats viz., plantation, mixed forest, riverine habitat, scrub forest, grasslands and agriculture field. In total, 170 species of birds representing 16 orders and 64 families were recorded. The dominant order was Passeriformes, while the dominant foraging guild was insectivore birds. Most of the bird species were resident. The overall bird species diversity was 4.126. JJCR harbours 10 species of globally threatened avifauna including 3 Critically Endangered, 3 Endangered, and 4 Vulnerable species; in addition, the reserve also has 8 species of Near Threatened birds. The present documentation of avian community structure would help in developing conservation plan of this IBA.

Key words: Bird community, Diversity, Richness, Abundance, IBA, Jhilmil Jheel, Guild

Jhilmil Jheel Conservation Reserve Haridwar, Uttarakhand supports high diversity of avifauna.

ANKITA DAS,
RAMESH KRISHNAMURTHY AND
RAJAH JAYAPAL[1]
Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248001, India
E-mail: ankitadas22.ad@gmail.com

Received June, 2021
Accepted April, 2022

Introduction

Important Bird and Biodiversity Areas (IBAs) are a network of sites, which are exceptionally rich in birds and other taxa and hold significant populations of rare, endemic, and threatened species. These are places of International significance for the conservation of birds and other biodiversity. This identifies and conserves a network of sites critical for the long term survival of bird species that are threatened (Rahmani *et al.*, 2016). There are 554 IBAs in India and the state of Uttarakhand has 15 IBA sites, including the Jhilmil Jheel Conservation Reserve (JJCR) of Haridwar Forest Division. This IBA is a wetland in the terai landscape and represents one of the most productive and threatened ecosystems (Sinha *et al.*, 2011). Jhilmil Jheel was designated as a conservation reserve for its remnant patches of riverine grasslands and for the protection of the westernmost population of the globally vulnerable Swamp Deer (*Rucervus duvaucelii*). These riverine habitats are also rich in grassland avifauna. The present study focusses on the avian community structure and status of avifauna in JJCR. There are some avifaunal studies from this and the adjoining landscapes. Pandey *et al*. (1994) has worked on birds of Rajaji National Park. Das *et al*. (2011) has studied on the vultures of Rajaji National Park. Response of migrant and resident bird communities to anthropogenic disturbances in Shiwalik landscape, Uttarakhand was assessed by Kaushik *et al*. (2012). Mohan (1997) has worked on the birds of New Forest campus, Dehradun. Birds of Asan wetland were compiled by Mohan *et al*. (2016). Study on the diversity, status and distribution of avifauna in Ramnagar, Uttarakhand was done by Balodi *et al*. (2018) and Ahmed *et al*. (2019). The current study is the first systematic account of the birds of JJCR with particular focus on community structure of the IBA's avifauna and their conservation status.

[1] Sálim Ali Centre for Ornithology and Natural History, Anaikatty (Post), Coimbatore 641108, Tamil Nadu, India

Methods

Study area

Jhilmil Jheel Conservation Reserve (N 29°32' to 29°50' and E 78° to 78°15') (Fig. 1) lies in Rasiyabaad Forest Reserve, Haridwar Forest Division, Uttarakhand. It is located between the Haridwar – Najibabad Highway (NH74). It lies in the buffer area of Rajaji National Park. It has an area of 3782.50 ha of Reserve Forest. The altitude of the area varies from 200 to 250 meters above MSL. It is surrounded by Chiriyapur Forest Range on the east and southern side, Shyampur range on northern side and Lakshar range on the western side. Jhilmil Jheel which is the core of Rasiyabaad forest range is a saucer shaped wetland situated on the left bank of river Ganga. JJCR is located at the junction of the Bhabar and Terai formations. Thus it forms a very unique species rich ecosystem. JJCR has various kinds of habitats such as grasslands, moist deciduous forests (mixed forest), scrub forest, riverine habitat and plantation. It has sub-tropical climate. The temperature goes as high as 44°C in summer and as low as 2°C during winter. The average annual rainfall is around 1300 mm. It has 347 species of plants (Tiwari, 2009), 24 species of mammals, 20 reptile species, 7 species of amphibians, 35 fish species and 67 species of butterflies.

Methodology

Field work was carried out between March 2018 to March 2020. Bird sampling was done in six major habitats, found in the IBA: plantation, mixed forest, riverine habitat, scrub forest, grasslands and agriculture fields in summer and winter season. Bird sampling was done through point count method (Bibby *et al.*, 2000). Ten replications of sampling were done per season. Each point count station was 200 metres away from each other. Birds were observed for 10 minutes in each point count station. All the birds seen or heard during this time were recorded. Birds were surveyed from 5:30 am to 8:30 am during summer and from 8:00 am to 10:30 am during winter. Surveys during days of inclement weather were avoided.

Data analysis

Bird species diversity was computed using Shannon-Weiner index as follows:

$$(H) = -\sum_{k=1}^{S} (Pi * \ln Pi)$$

H = Species diversity

Pi = Proportion of abundance of species i

S = Total number of species in the habitat

The abundance of each bird species was categorised as follows: Very abundant (>51 sightings), abundant (26-50 sightings), common (6-25 sightings), rare (1-5 sightings) (Sultana *et al.*, 2000).

The similarity of different habitats with respect to their bird composition was calculated using Sorensen index as follows:

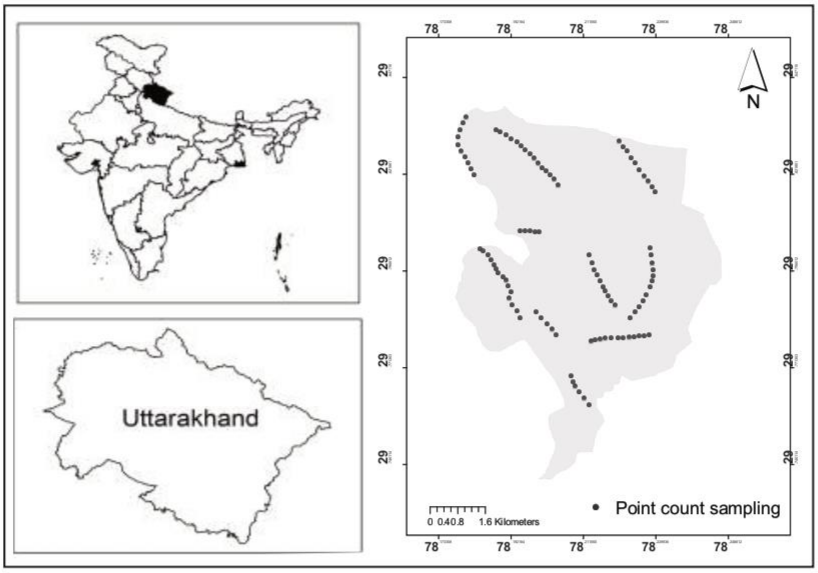


Fig. 1: Location of Jhilmil Conservation Reserve, Haridwar, Uttarakhand

= 2C/A+B, where,

A= Total number of species in habitat A

B = Total number of species in habitat B

C = Total number of species common to the habitats A and B

All the computations were done using PAST v.3

Results and Discussion

170 species were recorded in the point count sampling, representing 64 families (Fig. 2) and 16 orders. The dominant order was Passeriformes (92 species), followed by Charadriiformes (13 species) and Accipitriformes (12 species). The dominant family was Muscicapidae (15 species), followed by Accipitridae (12 species) and Cuculidae (9 species). The overall bird species diversity was 4.126. The diversity is high as JJCR is supported by cluster of various types of habitats. It has also been seen that different kind of habitat support large number of avifauna (Balodi *et al*., 2018).

Of the total bird species observed, 71 species were rare (41.76%), 42 species were common (24.70%), 18 species were abundant (10.58%) and 39 species were very abundant (22.94%) (Fig. 3). Red vented Bulbul (*Pycnonotus cafer)* was the most abundant bird species.

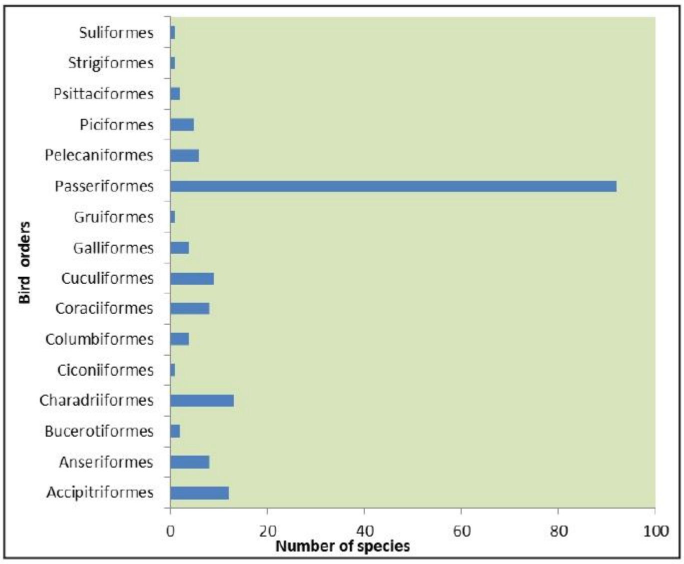


Fig. 2: Avian community composition of Jhilmil Jheel Conservation Reserve, Uttarakhand

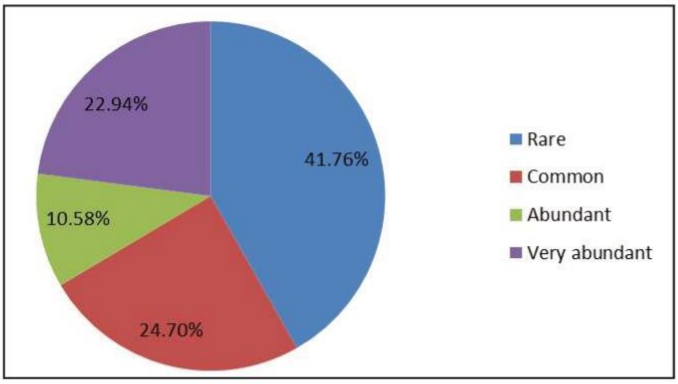


Fig. 3: Status of avifauna in Jhilmil Jheel Conservation Reserve, Uttarakhand

Red vented Bulbuls are generalist species and thus able to survive in a wide variety of conditions.

To determine the residential status, the avian species were categorised into residents, winter visitors, summer visitors and monsoon visitor. Majority of species are residents followed, by winter visitors, summer visitors and monsoon visitors. There were 112 resident species, 46 winter visitors, 11 summer visitors and 1 monsoon visitor (Fig. 4). This is supported by study done by Ahmed *et al.* (2019).

Birds were categorised into different feeding guilds (De Graaf *et al.*, 1985). They were categorised into insectivore, frugivore, grainivore, nectarivore, piscivore, carnivore, omnivore, herbivore and scavenger. The most dominant foraging guild was insectivore (Fig. 5).

Highest number of bird species (82 species) were recorded in riverine habitat. This might be due to as it is riparian habitat supporting both terrestrial and waterbirds. Least number of bird species was found in agriculture and human settlement area (29 species). Result of Sorensen similarity index showed that highest similarity (68%) of bird composition was between scrub forest and mixed forest whereas least similarity (25%) was between agriculture field and riverine habitat (Table 1).

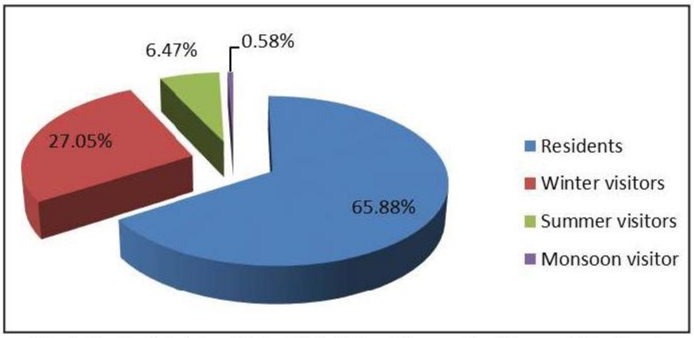


Fig. 4: Residential status of birds of Jhilmil Jheel Conservation Reserve, Uttarakhand

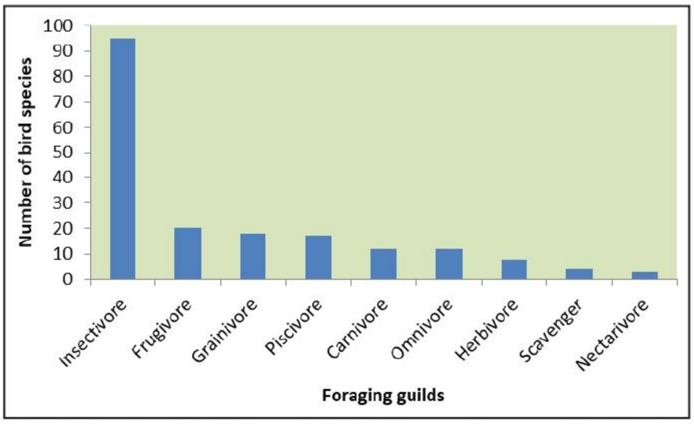


Fig. 5: Foraging guilds of avifauna of Jhilmi Jheel conversation reserve, Uttarakhand

Table 1: Sorensen similarity index value between different habitats

	Eucalyptus	Mixed	Scrub forest	Riverine	Grassland	Agriculture
Eucalyptus	0					
Mixed	0.655738	0				
Scrub forest	0.507692	0.683333	0			
Riverine	0.364865	0.304348	0.287671	0		
Grassland	0.267606	0.327586	0.354839	0.450704	0	
Agriculture	0.273684	0.258824	0.27957	0.252252	0.269663	0

Table 2: Threatened bird species of JJCR

Threatened category (IUCN status)	Bird species
Critically Endangered	Slender-billed Vulture, White-rumped Vulture, Red-headed Vulture
Endangered	Black bellied Tern, Egyptian Vulture, Steppe Eagle
Vulnerable	Sarus Crane, Woolly-necked Stork, Greater Spotted Eagle, Bristled Grassbird
Near Threatened	Black- necked Stork, Northern Lapwing, River Lapwing, River Tern, Great Hornbill, Alexandrine Parakeet, Cinereous Vulture, Himalayan Vulture

JJCR qualifies the IBA criteria of threatened species (Rahmani *et al.*, 2016). It has 3 critically endangered species, 3 endangered species, 4 vulnerable species and 8 near threatened species (Table 2).

Conclusion

JJCR is facing lot of threats which might affect the bird diversity in the long run. The gujjar settlements and villages in and around depend on the forests for fuelwood and fodder, grass collection, dry leaf collection, honey, fishing. Extraction of fuelwood and grazing causes changes in the landscape (Chhetri *et al.*, 2005; Singh *et al.*, 2000; Kaushik *et al*., 2012; Shahabuddin, Kumar and Verma, 2006; Menon, Sridhar and Shahabuddin, 2019). Moreover there is National Highway 74 which leads to wildlife road kills. A total of 352 individuals belonging to 39 species were found dead on NH 72, 74 and Haridwar-Chilla-Rishikesh motor road between June 2009-May 2011. Avian species were most affected leading to 38% of all mortalities. The vehicular traffic pressure on NH 74 was recorded to be an average of 9,900 vehicles per day (Joshi and Dixit, 2012). For long term management of this conservation reserve, proper management plan and regulation is needed.

झिलमिल झील संरक्षण रिजर्व, हरिद्वार (उत्तराखण्ड) में पक्षियों की सामुदायिक संरचना

अंकिता दास, रमेश कृष्णमूर्ति और राजा जयपाल

सारांश

झिलमिल झील कंजर्वेशन रिजर्व, हरिद्वार वन प्रभाग, उत्तराखण्ड में पक्षियों की सामुदायिक संरचना को समझने के लिए 2018-2020 के दौरान पक्षियों को प्वाइंट काउंट विधि का प्रयोग करते हुए गहन अवलोकन के साथ सर्वेक्षण किया गया था। इस शोध में छह आवासों जैसे की, वृक्षारोपण, मिश्रित वन, नदी, झाड़ीदार वन, घास के मैदान और कृषि क्षेत्र में पक्षियों की गिनती की गई। पक्षियों की 16 गण और 64 परिवारों से संबंधित कुल 170 प्रजातियों को दर्ज किया गया। पासरिफोर्मेस गण के अंतर्गत अधिकतम पक्षियों की प्रजातियों को दर्ज किया गया था। इस शोध में पक्षियों के भोजन सम्बन्धी अवलोकन को भी दर्ज किया गया है जिसमे कीटभक्षी पक्षी प्रमुख थे। पक्षियों की प्रजाति विविधता 4.126 पाई गई । झिलमिल झील संरक्षण रिजर्व विश्व स्तर पर संकटग्रस्त पक्षियों की 10 प्रजातियों को आश्रय देता है, जिनमें 3 गंभीर रूप से लुप्तप्राय, 3 लुप्तप्राय, और 4 संवेदनशील प्रजातियां शामिल हैं, इसके अलावा, रिजर्व में 8 निकट संकटग्रस्त पक्षी प्रजातियां हैं। पक्षियों की सामुदायिक संरचना का वर्तमान दस्तावेज़ीकरण, आई.बी.ए की संरक्षण योजना विकसित करने में मदद करेगी।

References

Ahmed T., Bargali H.S., Bisht D., Mehra G.S. and Khan A. (2019). Status of water birds in Haripura-Baur Reservoir, western Terai-Arc landscape, Uttarakhand, India. *Journal of Threatened Taxa,* **11**(9): 14158–14165.

Ali S. (2002). *The Book of Indian Birds. 13th Edition.* Oxford University Press, New Delhi, 326pp.

Balodi K.N., Anwar M. and Budhani L. (2018). Diversity and Conservation status of Avifauna in Ramnagar Forest division, Corbett Landscape, Uttarakhand, India. Bird-o-soar #12. In: *Zoo's Print,* **33**(2): 35:45.

Bibby C.J., Burgess N.D., Hill D.A. and Mustoe S. (2000). *Bird census techniques*. Elsevier, 85-104.

Chettri N., Deb D.C., Sharma E., and Jackson R. (2005). The relationship between bird communities and habitat. *Mountain Research and Development*, **25**(3), 235-243.

Das S.K., Dashahare A., Marathe S., Kundu N. and Kesharwani R. (2011). Status of raptors with special reference to vultures in and around Rajaji National Park, India. *World Journal of Zoology*, **6**(4), 350-356.

De Graaf R.M., Tilghman N.G., and Anderson S.H. (1985). Foraging guilds of North American birds. *Environmental Management*, **9**(6), 493-536.

Grimmett R., Inskipp C. and Inskipp T. (1998). *Birds of the Indian Subcontinent*. Oxford University Press, Delhi, 889pp.

Joshi K. and Bhatt D. (2011). Birds of three different forest habitats in Nainital district (Western Himalaya), Uttarakhand, India. *Indian Birds*, **7**(2), 33-37.

Joshi R. and Dixit A. (2012). Wildlife mortality on national highway 72 and 74 across the rajaji national park and the haridwar conservation area, north india. *International Journal of Conservation Science*, **3**(2).

Kaushik M., Mohan D. and Singh P. (2012). Response of migrant and resident bird communities to anthropogenic disturbances in Shiwalik landscape, Uttarakhand, India. *J. Bombay Nat. Hist. Soc*, **109**, 111-122.

Menon T., Sridhar H. and Shahabuddin G. (2019). Effects of extractive use on forest birds in Western Himalayas: Role of local and landscape factors. *Forest Ecology and Management*, **448**, 457-465.

Mohan D. (1997). Birds of New Forest, Dehra Dun, India. *Forktail*, **21**-30.

Mohan D., Singh A.P., Sondhi S., Kumar R., Singh P. and Datta S.B. (2016). A Checklist of the Birds of Asan Conservation Reserve. Uttarakhand Forest Department, 1-21.

Pandey S., Joshua J., Rai N.D., Mohan D., Rawat G.S., Sankar K. and Johnsingh A.J.T. (1994). Birds of Rajaji National Park, India. *Forktail*, **10**, 105-114.

Rahmani A.R., Islam M.Z. and Kasambe R.M. (2016) Important Bird and Biodiversity Areas in India: Priority Sites for Conservation (Revised and updated). *Bombay Natural History Society*, Indian Bird Conservation Network, Royal Society for the Protection of Birds and BirdLife International (U.K.). Pp. 1992 + xii, 1826-1828.

Shahabuddin G., Kumar R. and Verma A. (2006). Annotated checklist of the birds of Sariska Tiger Reserve, Rajasthan, India. *Indian birds*, **2**(3), 71-76.

Singh A.P. (2000). Birds of lower Garhwal Himalayas: Dehra Dun valley and neighbouring hills. *Forktail*, **101**-124.

Sinha S.P., Sinha B. and Qureshi Q. (2011). Management and Conservation of Jhilmil Jheel Conservation Reserve. LAP Lambert Academic Publishing, 15-18.

Sultana A. and Khan J.A. (2000). Birds of oak forests in the Kumaon Himalaya, Uttar Pradesh, India. *Forktail*, **131**-146.

Khan T.A. and Chandan (2015). A pilot survey of the avifauna of Rangdum Valley, Kargil, Ladakh (Indian Trans-Himalaya). *Journal of Threatened Taxa,* **7**(6): 7274–7281.

Tiwari R. (2009). "A Study on the Habitat Use and Food Habits of Swamp Deer (Cervus duvauceli duvauceli) In Jhilmil Jheel Conversation Reserve, Haridwar Forest Division, Uttarakhand", thesis PhD, Saurashtra University, 142-143.

Acknowledgement

The present study was a part of the project 'Developing conservation plans for select IBAs of India' funded by Ministry of Environment Forest and Climate Change. Authors are thankful to SACON (Salim Ali Centre for Ornithology and Natural History) and WII (Wildlife Institute of India) for providing various facilities to work in the field. They also express their gratitude to Uttarakhand Forest Department for giving permission to work in Jhilmil Conservation Reserve, Haridwar.

WORLD ENVIRONMENT DAY | Save Globe GRC India | नीरी NEERI | AMITY | G D GOENKA UNIVERSITY | AAJ

NATIONAL ONLINE CONFERENCE

(e-Conference | Digital-Lectures | e-Activities | e-Competitions)

Environment, Human Health and Sustainable Development Goals
and
WORLD ENVIRONMENT DAY 2020 CELEBRATION

5-6 June 2020

UN environment

Organized by
Environment and Social Development Association (ESDA), Delhi
Co-Organized by
Grass Roots Research and Creation India (P) Ltd., Noida

In association with
Dr. Bhim Rao Ambedkar College, University of Delhi, Delhi | CSIR-NEERI, DELHI
Amity University, Gurugram | G.D. Goenka University, Gurugram
IEI, Dr. R. M. L. Avadh University, Ayodhya, U.P. | Alumni Association of JNU

Certificate of Participation

This is to certify that

Ankita Das

Wildlife Institute of India, Dehradun

has participated in the NATIONAL ONLINE CONFERENCE as Delegate and presented a Paper (Oral) entitled **Status of Avifauna in Jhilmil Jheel Conservation Reserve, Haridwar (Uttarakhand)** during technical session.

Prof. P. B. Sharma	Dr. S. K. Goyal	Dr. G. K. Arora	Prof. R. K. Thakur	Dr. Jitendra K. Nagar
VC, Amity University Haryana	Head CSIR-NEERI-Delhi Zonal	Principal Dr. Bhim Rao Ambedkar College, DU	Dean GD Goenka Uni. Gurugram	Organising Secretary General Secretary, ESDA, Delhi

International Conference
On
BIODIVERSITY:
Exploration, Exploitation And Conservation For Sustainable Development
(ICB-01)
(On Blended Mode)

Ref : Cert/ICB01/PDUAMB/2022

Certificate of Participation

This is to certify that

ANKITA DAS

of

Wildlife Institute of India

has participated and presented a research paper (oral) entitled

Birds as indicator species for habitat management plan in Jhilmil Jheel Conservation Reserve (JJCR), Uttarakhand

in the International Conference on Biodiversity: Exploration, Exploitation and Conservation for Sustainable Development (ICB-01), organized by the Department of Botany, Pandit Deendayal Upadhyaya Adarsha Mahavidyalaya -Behali, Assam, India in association with ECO-CLUB (MoEFC, Govt. of India and ASTEC, Assam) on 5th January, 2022.

DR. DEBOJIT BARUAH	DR. SHAFIQUL ISLAM BHUYAN	DR. MOFIDUL ISLAM	MS. HEENA AGARWAL
Principal and Chairperson, ICB-01	Organizing Secretary, ICB-01	Joint Organizing Secretary, ICB-01	Joint Organizing Secretary, ICB-01

United Nations Decade on Biodiversity

CERTIFICATE

A Webinar on Biodiversity, Wildlife & Traditional Knowledge

8th -9th May 2020

This is to certify that Dr./Mr./Ms. ***Ankita Das*** *of* ***Wildlife Institute of India, Dehradun*** *has participated/ attended a Webinar on Biodiversity, Wildlife and Traditional Knowledge from 8th to 9th May 2020 organized by ENVIS-RP, Institute of Wildlife Sciences, ONGC Centre for Advanced Studies, University of Lucknow, Lucknow, Uttar Pradesh.*

He /She has presented a research paper (Oral) /session entitled ***"Bird-habitat Associations in Jhilmil Jheel Conservation Reserve: Towards Developing a Conservation Plan for the IBA"***

Amita Kanaujia
Organizing Secretary

Alok Kumar Rai
Vice Chancellor and Chief Patron