Progress Report
Role of urban green spaces for conservation of bird biodiversity in the rapidly urbanizing capital of Himalayan state of Uttarakhand, India

Submitted to
Forest Research Institute

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AWHO Colony - Army Welfare Housing Organization Colony

CBI Colony - Centre Bureau of Investigation Colony

FRI Colony - Forest Research Institute Colony

GBH - Girth at breast height

MDDA - Mussoorie Dehradun Development Authority

MKP College /MKP - Mahadevi Kanya Pathshala College

MM - Mindrolling Monastery (institute)

NIVH - National Institute for the Visually Handicapped

UGS - Urban green space

UPES - University of Petroleum & Energy Studies

WII - Wildlife Institute of India

WII Colony - Wildlife Institute of India Colony

ZSI - Zoological Survey of India

SUMMARY

Currently, 55 % of people live in urban cities and this proportion is predicted to increase to 68 % by 2025. Therefore, urban green spaces (hereafter UGS) should not only be designed as a means of recreation but also as a means for biodiversity conservation. This study identifies features of UGS at macro and micro-scale that supports sizeable bird species richness urban green spaces in Dehradun, Uttarakhand. We choose birds as a model taxon to study the conservation implications of UGS owing to intricate relationships with the habitat structure and composition of their surroundings.

Using google earth engine we identified 28 UGS in Dehradun, Uttarakhand (30.3165° N, 78.0322° E) across a range of spatial coverage (i.e.,0.3-224.5 hectare) and management regimes (I.e., public, private and government). Upon reconnaissance survey we shortlisted 19 UGS sites spreading across Dehradun city.

We digitized each UGS (size, perimeter, area and green cover) and its surrounding matrix (i.e., green cover, agricultural lands, built up, roads, barren lands, open area) and estimated the area of these features using ArcGIS platform. We laid systematic points with an interpoint distance of 200 meters within each UGS to collect data on vegetation and bird community.

We laid concentric plots of 10 m and 5 m radius to enumerate trees and shrubs, respectively. All woody vegetation with 20 cm girth at breast height (GBH) or above was considered as tree. In each 20 m radius plot, we recorded number, species identity, GBH, canopy spread in two perpendicular diameters and height (bole and crown height) of each tree. For each shrub we recorded species identity, number of individuals, height and canopy spread in two perpendicular diameters.

We collected bird data at each sampling points using variable radius point transect method. Each point was visited 3 times during the entire study period covering the non-breeding season (July – December 2018).

At macro-scale area of UGS, within UGS green cover, built up area and green cover of the

surrounding matrix influenced the bird species richness. Model containing size of the UGS had the maximum weight and had linear relationship with bird species richness (Breeding: R^2=0.71, p<0.005, Non-Breeding: R^2 = 0.62, p< 0.005). Percentage of agricultural area in the surrounding matrix led to linear increase in bird species richness (Breeding: R^2 = 0.29, p< 0.05, Non-Breeding: 0.36, p<0.05).

At micro-scale, vegetation richness and average tree GBH influenced the bird species richness. Increasing in tree (Breeding: R^2 = 0.51, p< 0.05; Non-Breeding: R^2 = 0.34, p< 0.05) and shrub richness (Breeding: R^2 = 0.25, p< 0.05; Non-Breeding: R^2 = 0.18, p< 0.05). During non-breeding season, increase in tree GBH across UGS resulted in decrease in bird species richness (R^2 = 0.22, p< 0.05).

Our result emphasizes the role of large parks as well as habitat enrichment by planting variety of local native tree and shrub species for improving the conservation potential of the urban green spaces.

INTRODUCTION

In 1992, United Nations Convention on Biological Diversity highlighted the significance of biodiversity. With increasing urbanization and huge amount of habitat loss, urban areas may aid in conservation of biodiversity. 68 % of people will be living in cities by the year 2025. (UN.DESA, 2018). As per the 2018 Revision of the World Urbanization Prospects, United Nations, India, Nigeria and China will account for 35% of the growth of the world's urban population between 2018 and 2050. 34% of Indians now live in urban areas and India may have as many as 416 million urban dwellers by 2050.

This increase in urbanization will reduce in the number of natural green spaces and will eliminate corridors. Urbanization leads to change in land use and land cover due (Müller et al., 2013). which in turn leads to habitat fragmentation. This suggests that green parks and plantations in urban areas can help the conservation of flora and fauna.

An Urban green space (hereafter UGS) is defined as an urban area covered by vegetation of any kind irrespective of size and function. The UGS can support blue spaces like ponds, lakes or streams. The green area must be accessible to users for it to be considered as a UGS(Aronson et al., 2017). This includes areas like institutions, city parks, gardens, colony parks and residential colonies. UGS not only conserve biodiversity but large UGS also provide cooling effects during the summer months. UGS also provide a space for recreational activities, social interactions, exercise and aesthetic pleasure. The World Health Organization recommends that people living in urban areas must have access to public green spaces within 300 meters of their homes (Euro.who.int, 2018).

Although urban areas cover less than 3 percent of the Earth's surface, the location and spatial pattern of urban areas have significant impacts on biodiversity (Müller et al., 2013). Urban ecology has not received much attention from conservation ecologists. This has led to the adoption of poor urban planning strategies with city plans which have less or no conservation implications.

Keeping the above factors in mind, the capital of Uttarakhand Dehradun was selected as the study area to understand the role of UGS in conserving bird diversity. Dehradun is a significant wintering and breeding area for Himalayan avifauna. Due to significant increase in urbanization and population in Dehradun, the central government has proposed it as a smart city. Birds were chosen as the model taxa due to their close association with their environment which is a result of the different roles (pollinators, seed dispersers, etc). Birds are excellent indicators of ecosystem health due to their diverse roles (pollinators, seed dispersers, nutrient cycling) and intricate relationship with their habitat (Eglington et al. 2012). Therefore, we selected birds to examine the characteristics of the UGS that improves overall biodiversity. Long-term association of the project team with the city and concerns for its winged sentinels motivated to find practical and scientific solutions for minimizing the impacts of urbanization on Himalayan bird diversity.

LITERATURE REVIEW

Though urban landscapes cover less than 3 percent of the Earth's surface, the increase in urban sprawl has led to government and research organizations to emphasize different features of urban green ecology. Worldwide researchers are working on urban areas to find out the best possible management practices of these overpopulated areas so that they can support biodiversity in urban areas. United Kingdom government has framed a policy to construct wildlife- friendly gardens by increasing the extent and range of public participation in urban areas of Sheffield, United Kingdom (Fuller and Irvine, 2010). Another study conducted in Munich, Germany shows that the majority of Urban green spaces in cities are small, privately owned gardens and yards, epitomized by community gardens, these small patches should be managed at the neighborhood scale and can be connected to nearest natural areas so that these areas could better support wildlife populations (Aronson et al., 2017).

According to the European Union Biodiversity Strategy to 2020 suggested green infrastructure should be promoted by the European Commission as it is a key instrument for ecosystem conservation for e.g. Green roofs, green alleys, and green schoolyards (Fábos et al., 2019). There is a need to manage the city parks and to build a connection between these parks with the roadside plantations and belts in and around these urban landscapes.

Some aspects that have been covered are- urban cooling (Osmond and Sharifi, 2017), mitigation of heat island intensity (Gunawardena et al., 2017), morphological characteristics of the present cities and urban areas in context to evolution (Yang et al., 2013), water scarcity due to growing urbanization (Hoekstra et al., 2018) effects of urbanization on human overall health (Phillips, 1993),etc. These UGS are critical habitat for urban biodiversity but unfortunately less attention has been given to their management and planning (Budruk *et al.*, 2009).

A recent study conducted in Bangalore found that the density of green parks impacts bird diversity more than the size of the parks in an area (Swamy et al., 2019). Another study conducted in Bangalore found that non-native plants in urban plants had reduced their capacity to support bird diversity in the UGS (Nagendra and Gopal, 2011). A study conducted in Delhi found that

Lutyens' Delhi supported more bird diversity than Dwarka owning to more diversity of tree species in the former. (Bhalla and Bhattacharya, 2015). In 2003, researchers in Yarkon Park, Tel Aviv, Israel found that the management of a UGS also impacts the species that the area can support. The study concluded that the most intensively managed areas have the least number of alien bird species, urban exploiters, were urban adapters and migrants. It also found that urban exploiters can be found in areas with all levels of management and that bird species richness increased with the number of woody plant species in an area (https://www.sciencedirect.com/science/article/pii/S0169204607001843).

But so far, the field of urban ecology in biodiversity conservation lies nascent in the Indian scenario. Although small green areas are enough in number and dominate the city scape, despite this they are often neglected and ignored by the conservationists, as they do not fulfill the large green spaces criteria. Hence, greater attention is to be paid to the management of urban green spaces, selection of trees species possessing favourable environmental and ecological parameters offering greater sustenance to biodiversity, particularly to avifauna. As UGS are different in size and are highly scattered and disconnected, and proper connectivity of these green spaces in urban areas through roadside plantations should be maintained. So that these areas could support the biodiversity and maximizes the environmental and ecosystem services (O'Sullivan *et al.*, 2017).

Though these studies provide some information about how urban green spaces should be managed in order to support the maximum number of bird species, more studies, emphasizing the UGS in developing countries need to be undertaken in order to understand the conservation implication of UGS. The continuous expansion of urban spaces has made it very important for us to understand the ecological functions performed by the green spaces that they hold (Lepczyk et al., 2017). But the management of urban green spaces presents several challenges. Limited funding, lack of research, lack of awareness, make the conservation of green spaces very difficult (Aronson et al. 2017).

OBJECTIVES

Therefore, the study "Role of urban green spaces for conservation of bird biodiversity in the rapidly urbanizing capital of Himalayan state of Uttarakhand, India" has undertaken with the following objectives:

1. Assessing the role of green space size, surrounding matrix and connectivity for conservation of bird diversity in rapidly urbanizing city of Dehradun, India.
2. Identification of features of urban green spaces important for maintaining diversity and density of birds in rapidly urbanizing capital of Himalayan state of Uttarakhand, India.

STUDY AREA

Dehradun (29 °58' N, 31°2'N, 77° 34' E, 78° 18'E) is located at the foothills of Himalaya between two important rivers, Yamuna and Ganga. It is spread across an area of 3088 km2 with moderate elevation variation (410m-700m). Although weather remains pleasant in Dehradun throughout the year due to its interesting geographic location, but the temperature could be as low as 0-1°C and sometimes the maximum temperature in summers could be as high as 40°C. However, from past few years maximum temperature during summer is increasing, in 2019 maximum temperature of 46°C was recorded for the first time in the month of May. Average annual rainfall of Dehradun is 2073.3 mm, largely during the monsoon season (July-August).

Dehradun was designated as capital of Uttarakhand state in the year 2000. Changed political status resulted in push towards infrastructural and developmental activities attracting migrants from hill villages of Uttarakhand and neighboring states for employment opportunities. Dehradun is also a major hub for education in the country. Therefore, several students visit it to complete their academic courses in various fields. The population of the city has increased from 4,47,808 (year 2001) to 16,96,694 (year 2018). This increased human population is obvious to take a toll on green cover of the city. According to a study conducted by Indian Institute of Remote Sensing in 2013 urban cover of Dehradun has nearly doubled during 1998-2008 (Chauhan et al., 2003). However, unplanned development, increased pressure on natural resources and has resulted in deterioration of air quality, health and sanitation (http://udd.uk.gov.in/files/CDP_DDUN.PDF).

It also created pressure on natural resources including water and green space. Major UGS within Dehradun are in form of gardens, orchards, tea gardens, tree belt along nallahs and reserved forests. In recent years, all these habitats have experienced shrinkage due to increasing built-up for residential, commercial and industrial purposes (http:// udd.uk.gov.in/files/CDP_DDUN.PDF).

Urban ecosystems are novel ecosystems and represent a subset of the landscape species diversity (Hobbs and Huenneke, 1992; Sattler et al., 2011). Considering this, Dehradun has high conservation value for the native Himalayan plant and bird diversity. High bird diversity within two research institutions (Wildlife Institute of India and Forest Research Institute; https://ebird.org/region/IN-UL-DD/hotspots?yr=all&m=) with ample green cover and minimal disturbance indicate the value of UGS for biodiversity. These areas not only house high bird diversity but acts as source habitats for the nearest green spaces.

According to “Revised Survey of Forest Types of India (1968)” Dehradun comes under Western Himalayas (biogeographic zone of India) and supports monocultural forests (Majumdar et al., 2012). The vegetation is divided into Sub-types Moist Shiwalik Sal forest, Moist Bhabhar Doon sal forests, and Dry Shiwalik Sal forests. The natural forests of Sal were removed during the British era. Most of the forested regions have poor regeneration capacity due to the dense canopy of the existing trees. The landscape supports a variety of climate and hence habitat types with many hotspots for e.g. with Forest Research Institute, Wildlife Institute of India and Shikhar falls, Maldevta temple. All forest types are undergoing a reduction in size due to urbanization. This is a prominent threat to native biodiversity.

The floral diversity in Doon Valley mainly comprises of approximate tree (591 sp.) shrubs (35 sp.), palms (15 sp.) and bamboos (21 sp.) with, 35 shrubs, 12 climbers, 15 palms and 21 bamboos (Negi, 2006). Around 190 species of trees, shrubs and palms were recorded from the urban green spaces of Dehradun. The most common tree species of the study area includes e species: *Shorea robusta, Bombax ceiba, Ceiba speciosa, Lagerstroemia speciosa, Cassia sp*. Etc. shrub *species: Murraya koenigii*, *Lantana camara, Hamelia patens*, *Tagetes sp.* etc.

The faunal diversity of urban green spaces of Dehradun comprises Birds, butterflies, bees, and other insects, feral dogs, cats, monkeys, and other mammals. Though this study area particularly deals with urban green spaces, yet varies sites had the dense green cover area for e.g. Wildlife Institute of India, FRI colony. Therefore, forest species like leopard (*Panthera pardus*), Civet cat (*Paradoxurus hermaphrodites*), Jackals (*Canis aureus*), wild boar (*Sus scrofa*) are also present. Dehradun harbors 42% (552 of 1308) of the avifaunal diversity of India and 84% (552 of 656) of Uttarakhand (www.indianbirds.in). Among them some are migratory birds, and some are residential.

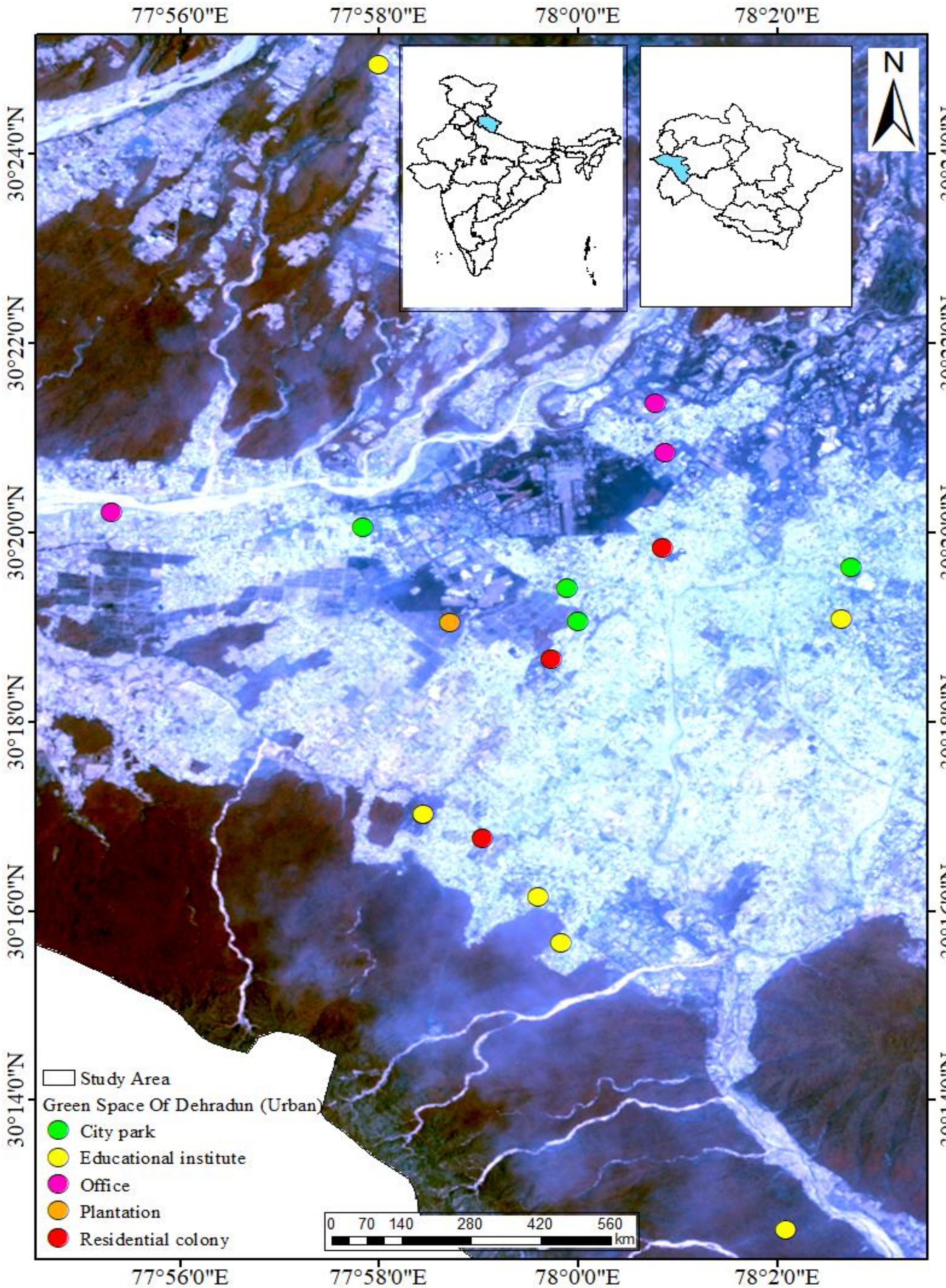


Figure 1: Map of study area showing location of intensive study sites.

MATERIALS AND METHODS

Selection of Urban Green Spaces

Location, size and type (park, institutions, residential colony and plantation) using satellite imagery of Google Earth software. We then visited the sites for ground truthing and gained permission for conduction vegetation and bird surveys in the selected areas.
19 UGS were selected after shortlisting 28 sites using google earth. Due to difficulty in gaining permission for sampling, one site was dropped from the study during the breeding season.

Digitization of matrix and green space

The matrix composition of the UGS were assessed by alienating a buffer of 250m through the boundary of each UGS. This was done using ArcGIS software. The elements of each matrix were categorized as agricultural field, open area (scrubland), green cover, barren area, water, built up and roads using polygon tool of Google Earth software. The overall length of roads in a matrix were assessed path tool of Google Earth software. Each urban green space of digitized using the same landuse categories.

Estimation of vegetation structure and composition

Trees and shrubs were sampled in a circle of 20m and 5m respectively at the centroids of the squares of grid measuring 200 x 200 m (drawn using ArcGIS).

Trees- Girth at breast height (G.B.H.) was recorded using a measuring tape, tree height and bole height (measured at the prominent branching site) were recorded using an Altimeter and canopy of the trees was estimated by measuring the diameter of the canopy in perpendicular directions.

Shrubs- Height of each shrub in the 5m plot was measured using a measuring tape and canopy of shrubs was estimated by measuring the diameter of the canopy in perpendicular directions.

Estimation of bird community characteristics

Data on birds was collected using the variable radius point transect method (Bibby et al., 1992). Point transects for recording bird species were centered on the same plots which were used for collecting data on vegetation. Point transects were used over line-transect sampling as the study aimed at understanding the habitat preferences of bird community over a large landscape in structurally complex vegetation types, tall and rugged terrain (Reynolds and Trost, 1980). This method presented an advantage as point transects can reveal information about the relationship between birds and habitat if habitat parameters are quantified around the points.

All point transects conducted in one season were conducted by the same observer to avoid observer bias. Field guides and guidance from experts were used in order to identify birds whenever needed. Bird sampling in each UGS was conducted 4 times during each season. Each species heard or seen was recorded during the early hours of the day. Number of individuals and distance from the observer were recorded for 7 minutes after waiting for 3 minutes at the point. A laser rangefinder was used to record the distance of birds from the observer. The points were visited after a gap of at least seven days in order to record the maximum species variation within each season. The order of visiting each sampling point within a site was reversed on each morning in order to reduce bias created by flushing of birds.

165 (55 points x 3 times) variable radius point transects were conducted during the non-breeding season and a total of 156 (52 points x 3 times) variable radius point transects were conducted during the non-breeding season.

DATA ANALYSIS

Bird diversity and richness

Species richness and diversity of birds at each site was estimated using sampling points as spatial replicates. The date of sampling was used as a temporal replicate in order to gain chao and Jack values in sites that had only one-point sampling.

Package vegan (Oksanen et al., 2013) was used for calculating species richness, species diversity, for tree species and shrub species and bird species site wise. Analysis was carried out in R studio.

Bird density

DISTANCE 5 was used to estimate the density of birds (Thomas et al., 2010). This program allows for stratification according to sampling design, global estimates (of the entire data set) of density and for 'post stratification' for known subsets of data.

We developed linear models using a priori information on the response of the bird community characteristics to the landscape and local scale variables in R studio (Gandrud, 2016).

RESULTS

Selection of UGS sites in Dehradun

Due to the paucity of the city parks, a total of 19 sites across five categories namely, offices, educational institutions, residential complexes, city park and plantation were selected. The area of these sites varied from 0.29 hectare (Netaji Park) to 224.5 hectare (Tea estate, an old plantation).

Figure 2: Area (in hectares) of sampling sites within each UGS category.

Compositional characteristics of UGS.

After digitizing the buffer of all the UGS it was found that the sites vary significantly in terms of matrix composition. The matrix composition of the sites depends on the location of the area. The length of roads was also quantified for all the green space. UPES had the maximum green cover in the buffer area whereas most of the city parks (Netaji Park, Vasant Vihar, Gandhi Park and MDDA had) maximum built-up landuse in the buffer area. Upon investigating the correlation, we found that built-up (%) had negative correlation with agricultural areas as well as percentage of water. However, barren areas had a positive relationship with the percentage of water in the buffer.

Figure 2: Matrix composition of the buffer areas around each UGS (m^2)

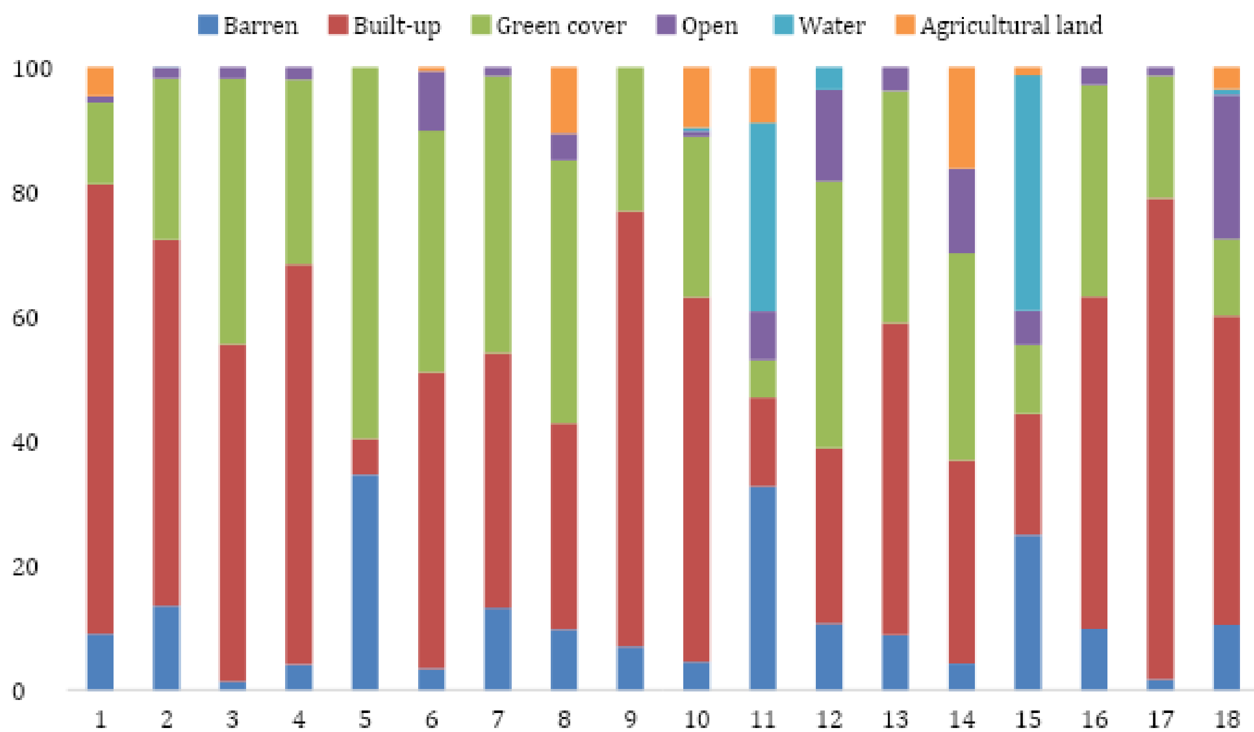


Table 1: Correlation matrix between land uses around UGS in Dehradun.

	Barren (%)	*Built-up (%)*	*Green cover (%)*	*Open area (%)*	*Water (%)*
Barren (%)	1				
Built-up (%)	-0.78**	1			
Green cover (%)	-0.05	-0.28*	1		
Open area (%)	-0.03	-0.29*	-0.20	1	
Water (%)	0.63**	-0.53**	-0.53**	0.11	1
Agricultural area (%)	-0.01	-0.25	-0.20	0.28*	0.11

Vegetation structure and composition

A total of 519 tree and 219 shrub individuals were sampled throughout the UGS. Structural attribute of a habitat play an important role in affecting bird diversity. Variates were significantly different from each other at all the sites. Highest GBH was found at Netaji Park followed by FRI colony. Maximum tree height was found at WII and followed by Tea estate (Table 2). The tree canopy cover was highest in WII and shrub canopy cover was highest in ZSI despite having smaller area (Table 2).

Table 2: Vegetation (tree and shrub) structural features across UGS.

UGS site	**Tree GBH (cm) ±SE**	**Range of tree GBH (cm)**	**Tree Height (m) ±SE**	**Range of Tree Height (m)**	**Tree crown cover (m^2)**	**Shrub crown cover (m^2)**
AWHO Colony	44.4 (6.1)	33-56	6.8 (0.99)	5 – 9	25.6	5.50
CBI Colony	79.07 (41.4)	35-153	10.43 (5.1)	5 – 19	25.3	1.07
FRI Colony	168.8 (±NA)	36-290	8.67 (4.3)	0.5 - 31.5	131.0	0.82
Gandhi park	116.5 (67)	30-371	10.5 (4.3)	4 – 24	79.3	1.31
Graphic Era	83.04 (22.8)	33-260	10.47 (2)	5 – 22	48.3	1.33
MDDA park	135.9 (10.8)	115-150	8.71 (2)	6 – 12	21.9	1.28
MM	102.2 (66.7)	35-480	9.5 (2.8)	4 – 24	44.3	1.97
MKP	109.9 (34.9)	56-234	15.07 (3.5)	7 – 25	46.0	2.52
Netaji Park	250(±NA)	250-250	20 (±NA)	20 – 20	283.4	2.12
NIVH	82.43(21)	2.2-260	11.43 (2.8)	0.2 – 28	104.3	3.23
Tea Estate	101.17(33.4)	33-270	14.17 (2.3)	5 – 24	93.3	7.61
Tourism Office	86.00(38.2)	35-127	7.83 (5.3)	4.5 - 18.5	15.0	1.51

UPES	57.43(12.2)	32.5-135	7.68 (1.3)	5 – 16	33.4	2.85
Vasant Vihar Park	75.67 (27.4)	30-120	10.67 (3.5)	7 – 14	31.4	2.13
Vigyan Dham	33.50 (11.2)	32-35	7 (2.3)	7 – 7	18.1	2.85
WII	60.80(13.9)	31-250	14.99(2.3)	2- 35	27.4	1.49
WII Colony	66.14(13.6)	33-122	9.36 (6.5)	2 – 76	30.25	0.92
ZSI	88.95(25.8)	35-212	11.72 (3)	2.2 - 22.5	43.8	8.55

Tree species richness (Jack1) was found maximum for the Wildlife Institute of India followed by Graphic era. However, tree species diversity was highest for Gandhi Park followed by CBI residential colony (Table 3). Shrub richness was highest for the WII colony followed by Graphic era (Table 3). However, the diversity was highest for FRI colony followed by tourism office.

Table 3: Vegetation (tree and shrub) compositional features across UGS.

Type	Sites	Tree species richness (Jack1)	Tree diversity	Shrub species richness (Jack1)	Shrub diversity
City Park	MDDA	2±NA	0.7	1±NA	±NA
	Gandhi park	24±8.4	1.9	9±3.4	0.8
	Netaji park	1±NA	NA	3±NA	1.1
	Vasant vihar park	2±NA	0.7	3±NA	1
Institute	UPES	13.3±3.2	0.9	16.8±5.4	0.7
	Graphic era	29±7.4	1.3	20.3±5.2	0.9
	MM	13.3±3.9	0.8	8.3±2.2	0.4
	NIVH	24.4±5.2	0.8	10.4±2.2	0.2
	MKP collage	9±3.4	0.8	27±11.9	1.4
	WII	29.2±6.4	1.1	11.2±1.6	0.8
Office	Vigyan dham	4.3±1.5	0.2	18.3±5.2	1.2
	Tourism office	1±NA	NA	6±NA	1.7
	ZSI	26.7±8.2	1.4	10±2.8	0.5
Plantation	Tea estate	11.2±2.3	0.3	6.5±1.4	0.2
Residential	AWHO colony	5.5±1.3	0.8	9±2.7	0.9
	CBI colony	6±NA	1.7	4±NA	1.3
	FRI colony	11.5±3.3	1.1	18±4.8	1.9

	WII colony	19.5±5	0.7	40.5±12.6	1.4

Bird species richness and composition

A total of 141 (4399 detections) bird species were recorded throughout the study period within the UGS. Bird species recorded during the breeding season was higher than the non-breeding season. Of 141 species seen during the entire study period, 102 were recorded during the non-breeding season whereas 123 were recorded during the breeding season. Maximum richness during breeding season was recorded from wildlife institute of India followed by Tea estate. However, during non-breeding season maximum bird species richness was recorded from NIVH followed by wildlife institute of India's residential complex (Figure 4). Bird species richness was highest for the institutes whereas lowest for the city parks across breeding and non-breeding seasons (Figure 5).

Figure 3: **Bird species richness across breeding (summer) and non-breeding season (winter) of each UGS.**

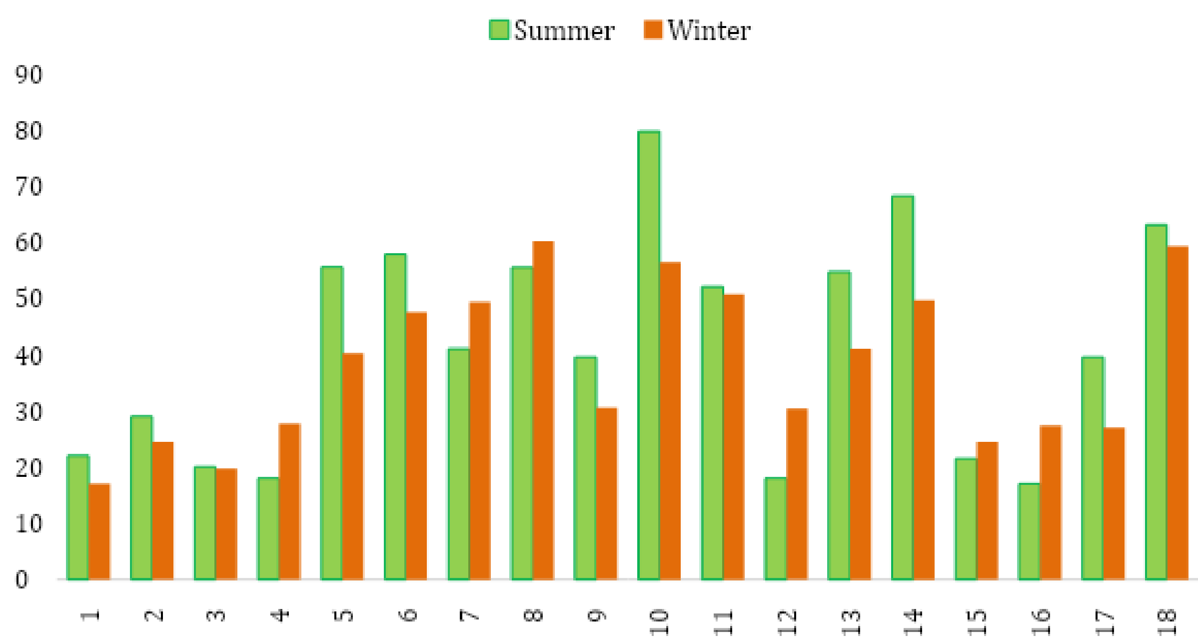


Figure 4: Bird species richness across UGS types for breeding and non-breeding season.

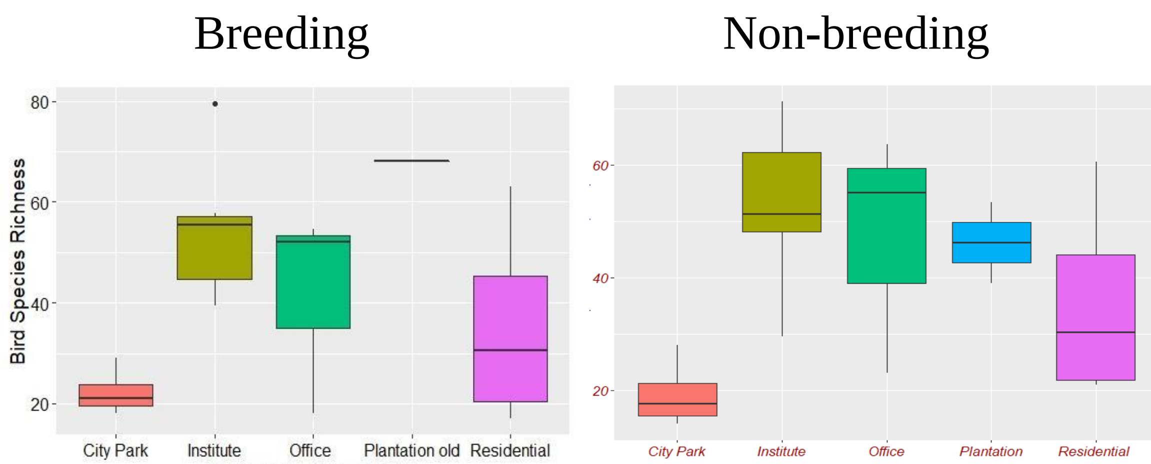
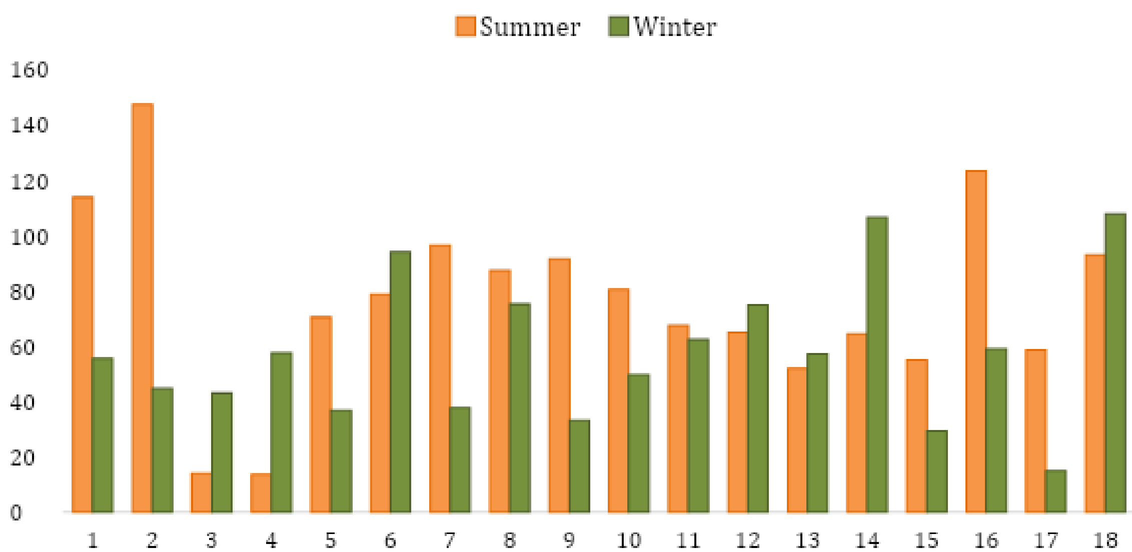


Figure 5: Bird species density across breeding (summer) and non-breeding season (winter) of each UGS.



Factors affecting the bird community characteristics

Significance of landscape level variables

We wanted to examine the effects of the local and landscape level features to understand the variation in bird species richness across UGS.As the size of the largest UGS was really high compared to the rest of the sites , we log transformed the area for all the sites to bring it on one scale. We built different univariate models to test the effect of size, matrix composition of the buffer on the bird species richness. Out of all the landscape level variables (park size, percentage of open area, percentage of water, percentage of agricultural area, percentage of built-up, percentage of green cover) only park area and percentage of agricultural area in the buffer had substantial effect on the bird species richness and density. It was found that the bird species richness increased with increasing park area for both breeding and non-breeding season (Figure 4). The finding from the current study supports rising evidence for size effect, that means large parks can support a greater diversity of ecological niches (Cantú-Salazar and Gaston, 2010; Dale, 2018). However, the effect was much stronger for the breeding season (Figure 7 breeding: R^2 =0.71, $p<0.005$) than the non-breeding season (Figure 7 non- breeding: R^2 =0.62, $p<0.005$). Out of all the land use types tested for effect on the bird richness in UGS, amount of agricultural area emerged as important land use explaining 29 % and 36 % of the variation (Figure 8).

We also examined the same set of hypotheses that were tested for the richness, to explain the variation in bird density across UGS. Interestingly, none of the variables explained variation in bird density during breeding season. On the contrary, during non-breeding season bird density within UGS increased significantly with increasing open area (Figure 9: R^2 =0.65, $p<0.005$) and agricultural areas (Figure 9: R^2 =0.36, $p=0.01$) in the buffer.

Figure 6: Effect of park area on the bird species richness during breeding and non-breeding season.

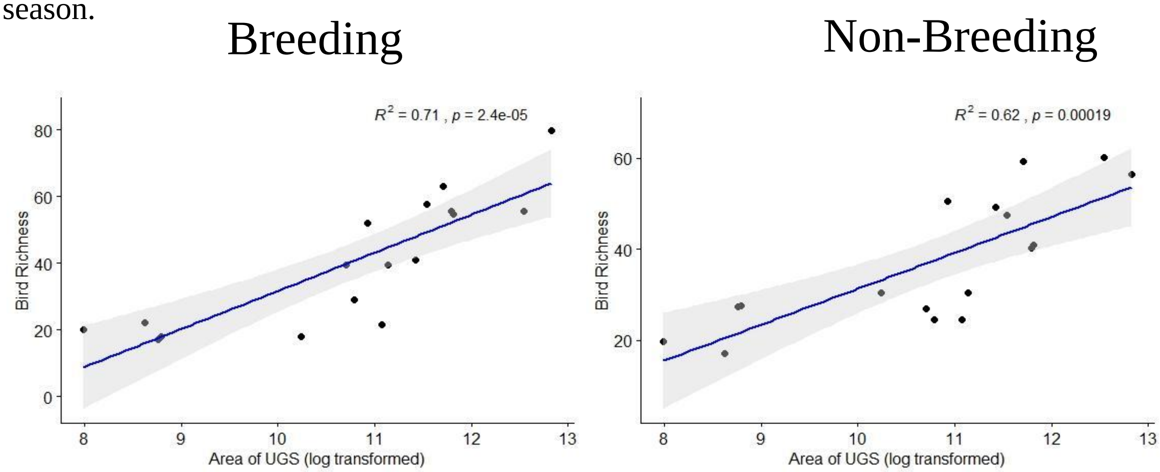


Figure 7: Effect of agricultural area in the buffer on the bird species richness during breeding and non-breeding season.

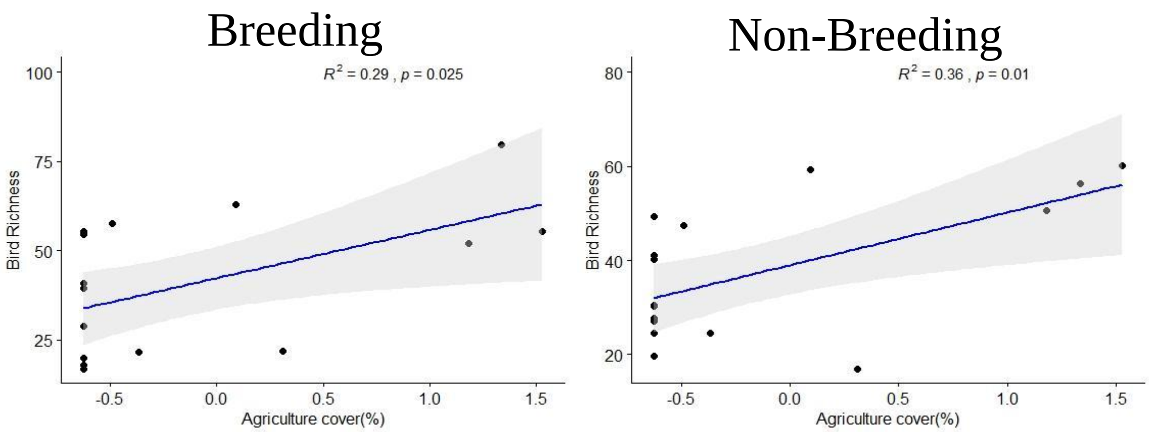


Figure 8: Effect of open area and agricultural area in the buffer on bird species richness during non-breeding season.

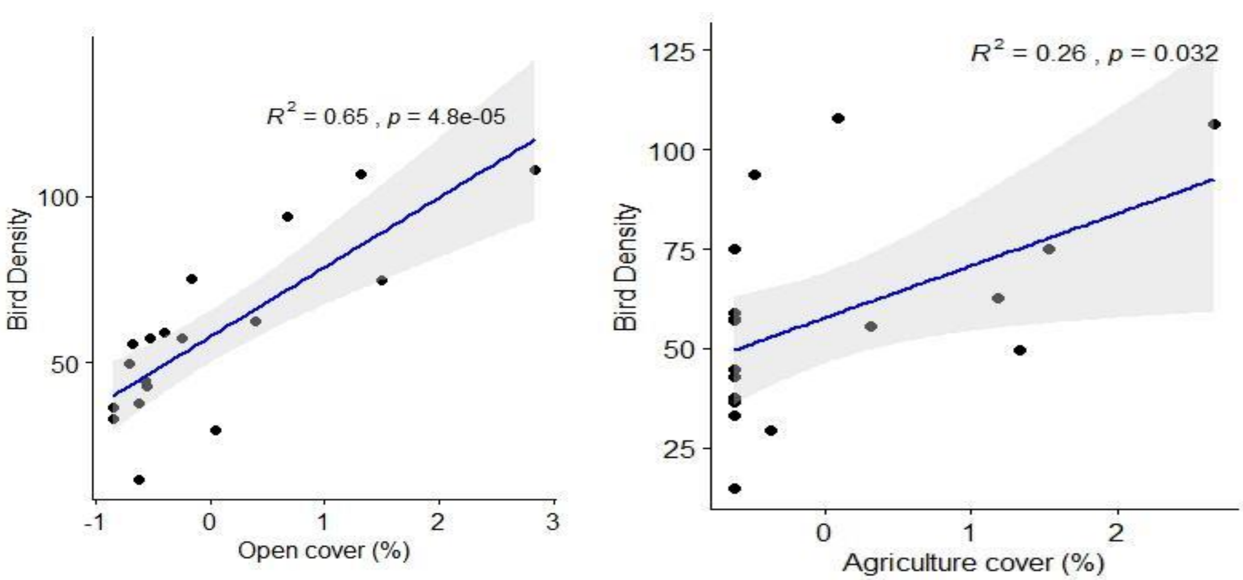
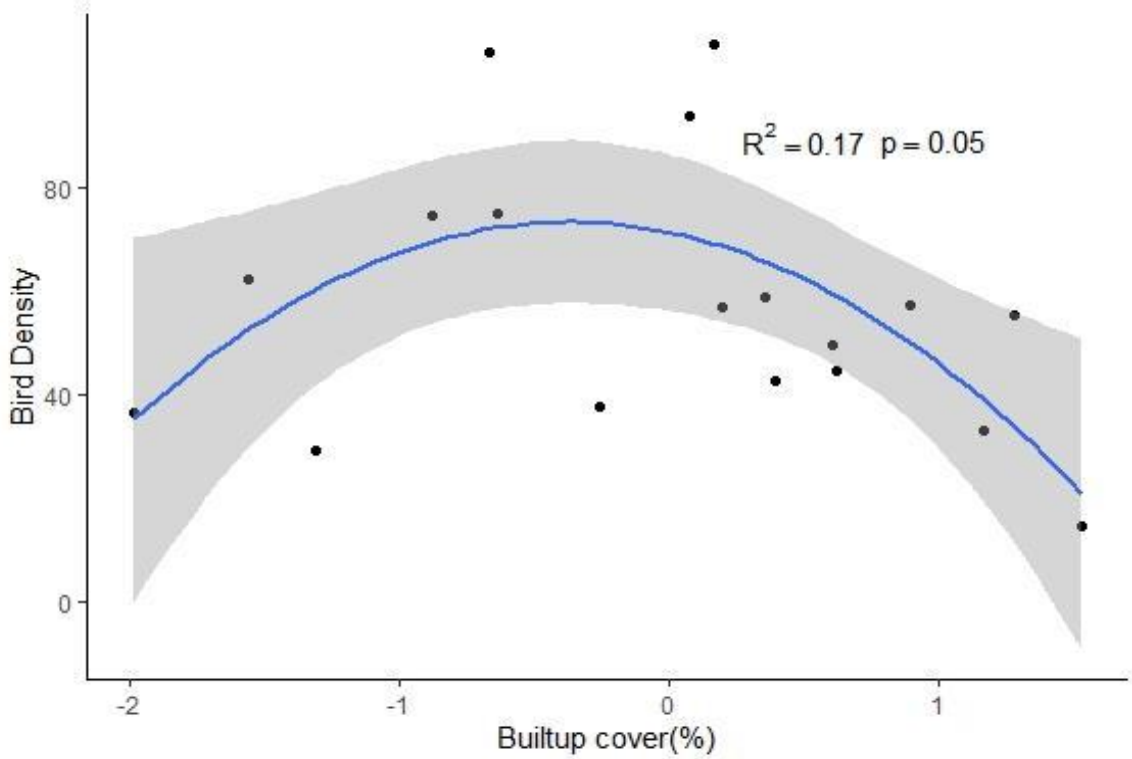


Figure 9: Effect built-up area in the buffer on bird species richness during non-breeding season.



Significance of local level variables

At local level, we investigated the effect of vegetation structural and compositional features on bird species richness and density. Our results indicate the importance of vegetation composition rather than its structure being more important for the birds in urban areas as out of all the local level variables our best model included tree species richness as the covariate explaining sizeable amount of variation in bird species richness during both breeding and non-breeding season (Figure 11:Breeding season: R^2 =0.51, p<0.005; non- breeding: R^2 =0.33, p=0.05). Following tree richness model, the next best model had shrub species richness as the explanatory variable (Figure 12: Breeding season: R^2 =0.25, p<0.05; non- breeding: R^2 =0.18, p=0.05). As summer season is important for bird species due to breeding activities, we build further models to investigate the role of various landscape level variables in affecting their population trends. Of all the variables, certain birds showed marked non-linear increase with increasing agricultural area (Figure 13) in the buffer whereas certain birds declined linearly with increasing built-up area (Figure 14).

Figure 10: Effect of tree species richness in the buffer on the bird species richness during breeding and non-breeding season.

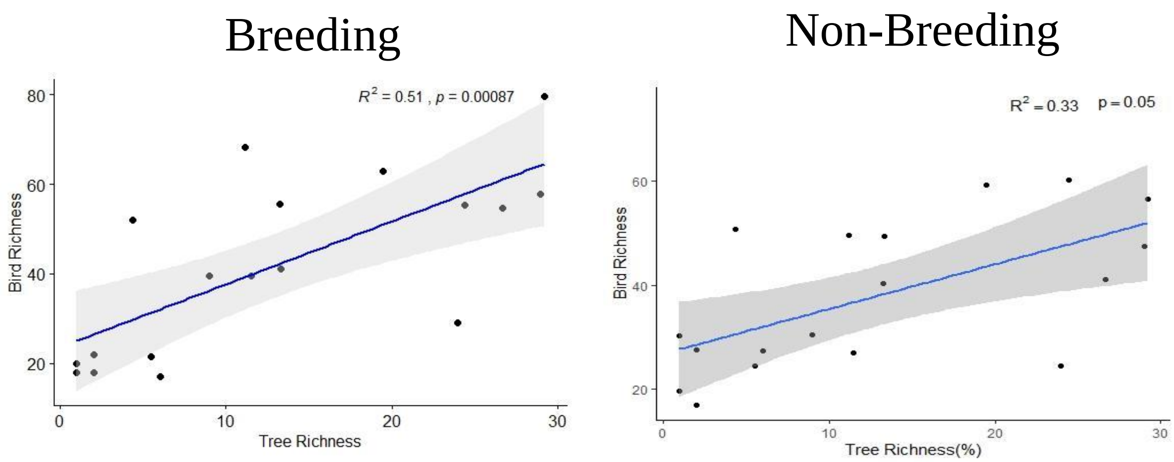


Figure 11: Effect of shrub species richness in the buffer on the bird species richness during breeding and non-breeding season.

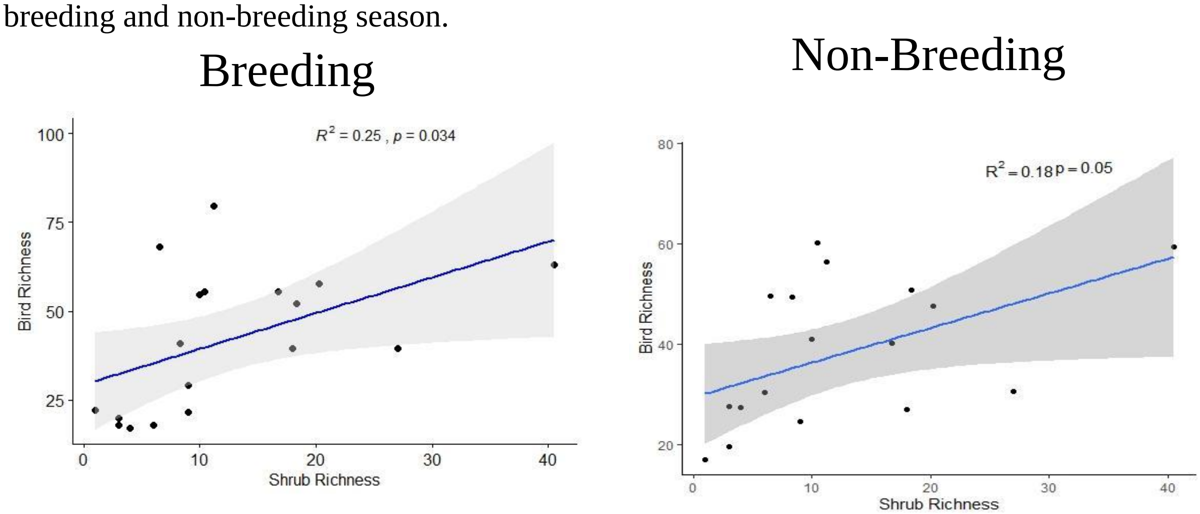


Figure 12: Species specific responses with increasing agricultural land use in the buffer.

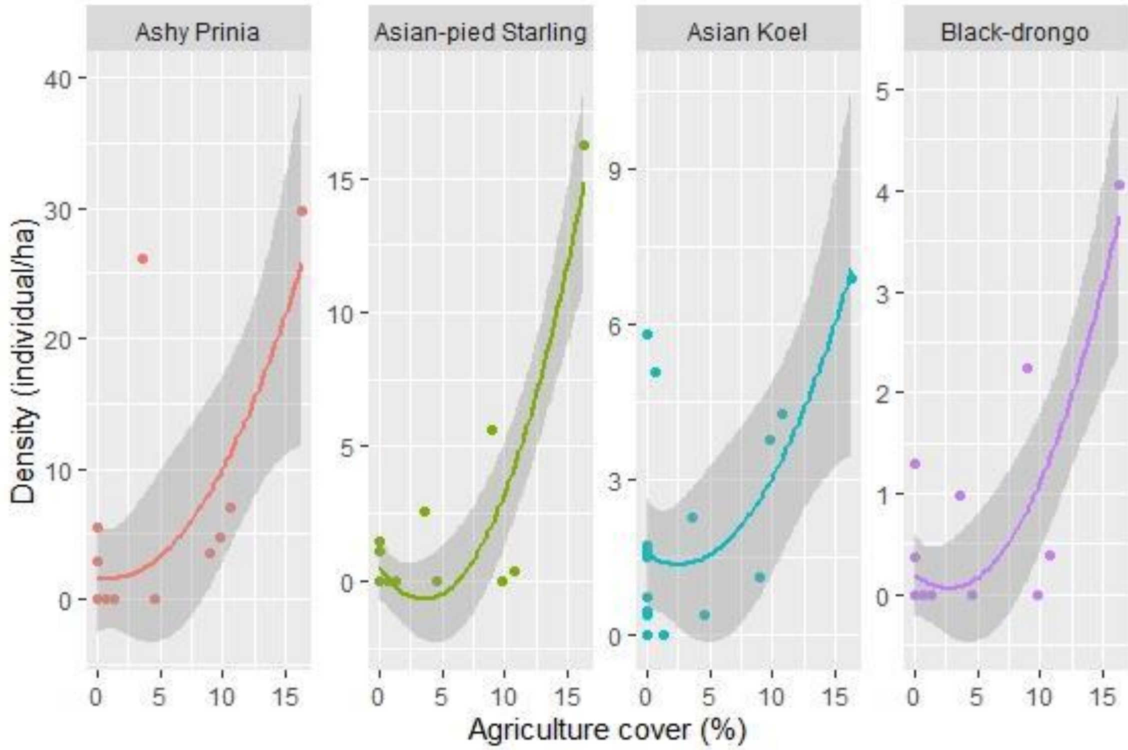
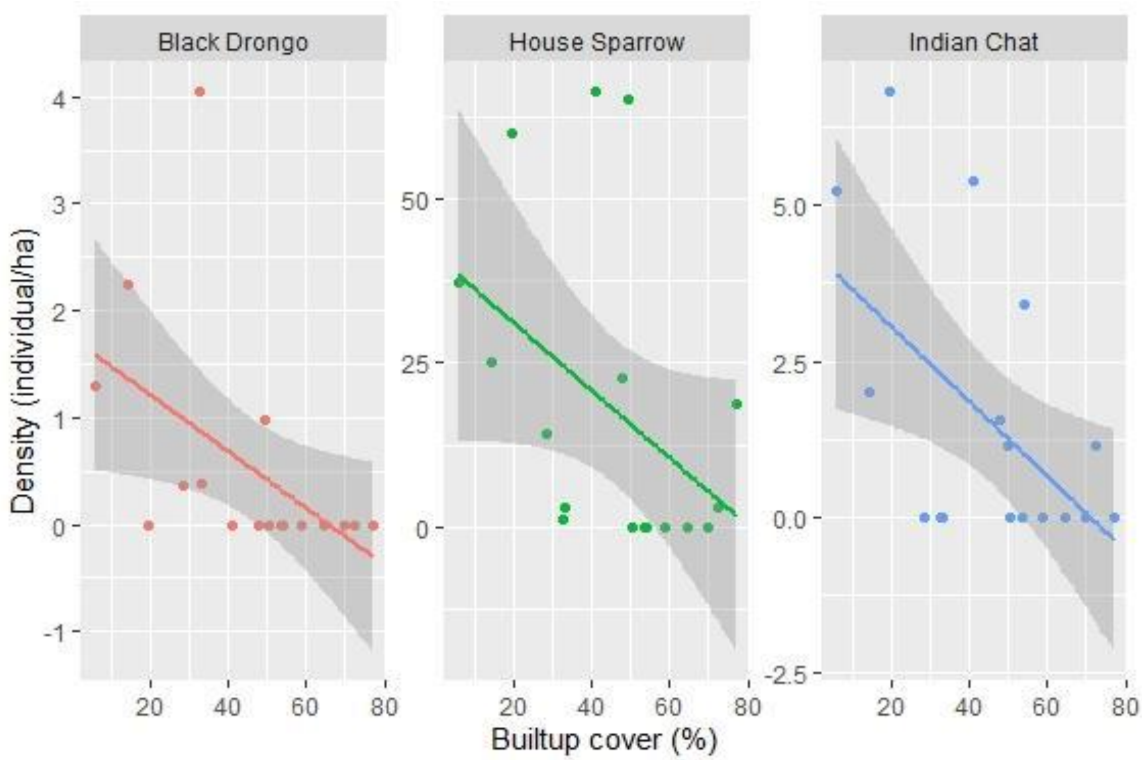


Figure 13: Species specific responses with increasing built-up land use in the buffer.



CONCLUSION

Our findings are relevant for urban planners as well as for managers of variety of UGS. Our result signifies the importance of both macro and micro-scale parameters in improving the biodiversity value of the UGS.

From the current study, it can be concluded that biodiversity potential of the urban areas can be improved correct planning and design of urban green spaces. While planning the layout of parks, size of the UGS as well as surrounding matrix should be kept in mind. Area is known to have impacted bird species diversity in urban green patches. Our study supports the positive relation between area of green patch and species richness that it holds. This also supports the island bibliography theory where the number of species found in a patch increases with area. The increase stops once the resources become limited or other factors begin to play a more crucial role in determining the number of species in the green patch. (Arrhenius 1921, Basham et al.2010, Faeth & Kane 1978; Pacheco & Vasconcelos 2007;). Species richness is also known to be positivity influenced by the sum of built up area in the matrix. This relationship is also validated by our study (Dickman 1987).

However, in case space constraints, improving the vegetation composition by planting local native tree and shrub species of wide variety can help in providing food and nesting resources to the bird species. For this adequate attention needs to be paid to tree phenology studies, which synchronize natural circadian rhythms whilst offering ecosystem services. Trees species possessing favorable environmental and ecological parameters offering greater sustenance to biodiversity, and particularly avifauna should the preferred greening material. Urbanization brings in its wake development, the physical embodiment of which is built up. From our findings, we concluded that the area under built up shows polynomial relationship with bird species density during non-breeding season. This could be because of the mixing of urban and green habitat as well as increased edge effect favoring certain bird species, which further supported by our species-specific analysis. Black Drongo, an insectivorous bird which feeds on insects and can be generally seen perching on telephone wires and poles near agricultural areas. Similarly, other insect feeding bird species, such as Ashy Prinia, increased within UGS with increasing agricultural areas in the surroundings. Perch trees near agricultural areas might provide useful resources to omnivores birds to feed and nest. In our study such omnivore

There is definite possibility of adaptors or generalist bird species, utilizing these concrete habitats as ready reservoirs of food either as bird feed or garbage material. In depth study on a species level, demands to be performed in order to unveil the intricate patterns of survival for synanthropic bird species.

Finally, our study also indicates the potential of biodiversity conservation through unconventional areas such as educational institutes, offices and residential colonies. Such areas generally do not experience too much disturbance and the bird species have safe breeding and foraging habitats. Also provides insights on the landscape matrix that could help enhance biodiversity support service within the surrounding neighborhood.

In this context, it is important that all aspects of urban green spaces should be studied along with their impact and determination must be done on how the breeding bird community is utilizing the habitat and how these species react towards the gradient of urbanization. This would help urban city planners to create artificial favorable niches for these winged creatures. Findings of this study could inform the managers to choose an optimum park size and degree of connectedness to maintain bird diversity in Dehradun valley, an important wintering and breeding area for Himalayan avifauna. Our results would be useful for authorities involved in “smart-city” proposal to finetune the proposed restoration activities in city parks. However, UGS within schools, research institutions and government colonies are managed by the administrative authorities as well as the residents. Therefore, we would provide our research insights that can be implemented by managers at different spatial scales (institutional and household).

One of the major contributions of our work would be to connect local people with their surrounding UGS and bird diversity. We envision that after the establishment of the base line data for the bird community in selected UGS, long-term monitoring could be carried by the students, teachers, birdwatchers and local households.

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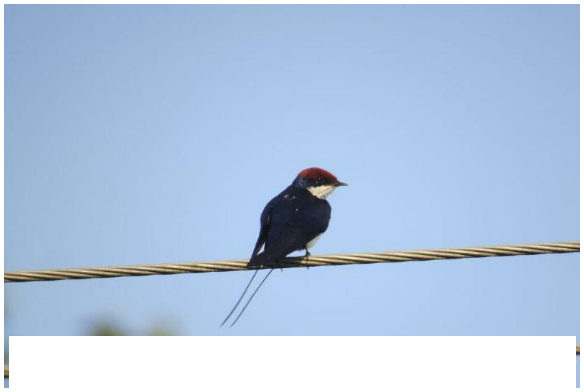
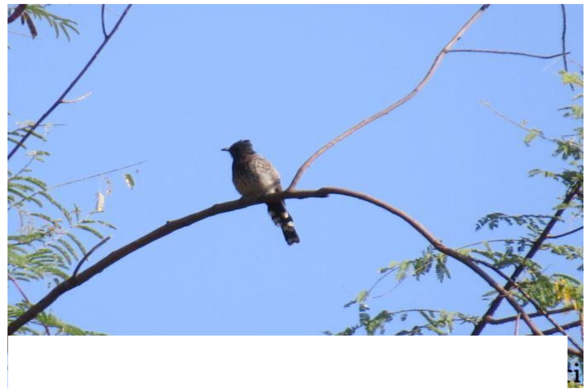
Annexure-I- Common bird species recorded in UGS.



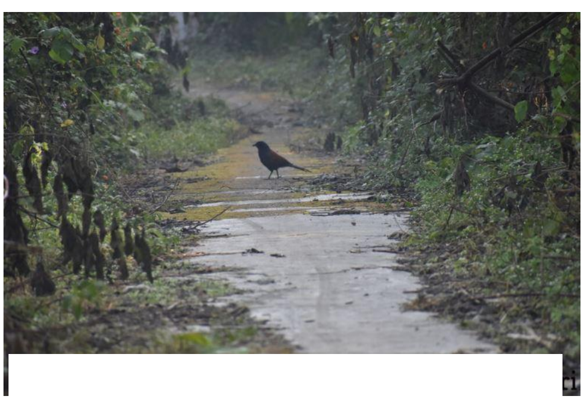
Wire-tailed swallow*(Hirundo smithii)*



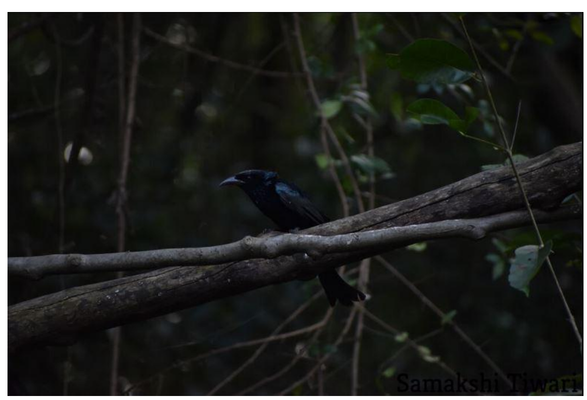
Red-vented bulbul *(Pycnonotus cafer)*

Grey bush chat *(Saxicola ferreus)*

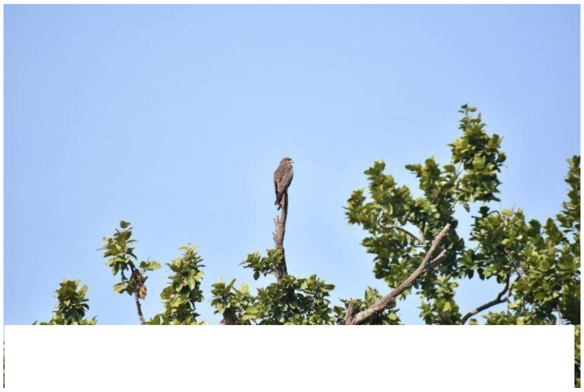
Scaly-breasted munia *(Lonchura punctulata)*



Greater coucal (*Centropus sinensis*)

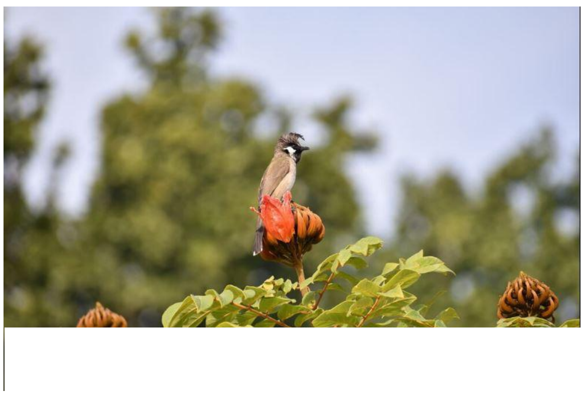


Hair-crested drongo (*Dicrurus bracteatus*)



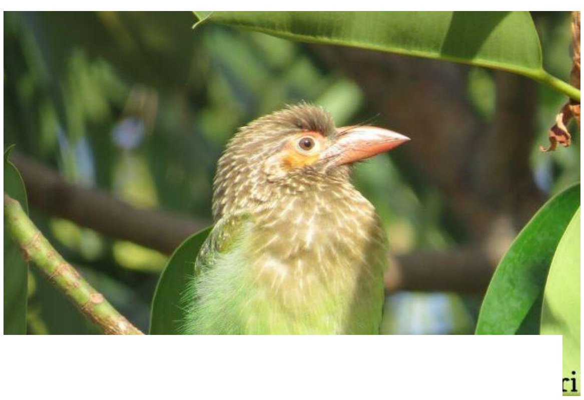
Black kite *(Milvus migrans)*

Rose-ringed parakeet *(Psittacula krameri)*



Himalayan bulbul *(Pycnonotus leucogenys)*

White-throated kingfisher(*Halcyon smyrnensis)*



Brown-headed barbet *(Psilopogon zeylanicus)*

White-capped water redstart *(Phoenicurus leucocephalus)*

Annexure-II- Checklist of bird species seen during the entire study period across breeding, non-breeding and all throughout the year.

The seasonality is represented by the alphabets S(summer), W(winter), B(both).

Common Name	Scientific Name	Seasonal Status
Alexandrine parakeet	*Psittacula eupatria*	B
Asain pied starling	*Gracupica contra*	B
Ashy drongo	*Dicrurus leucophaeus*	B
Ashy prinia	*Prinia socialis*	B
Asian koel	*Eudynamys scolopaceus*	B
Asian paradise flycatcher	*Terpsiphone paradisi*	B
Bar-tailed treecreeper	*Certhia himalayana*	W
Bar-winged flycatcher shrike	*Hemipus picatus*	B
Baya weaver	*Ploceus philippinus*	B
Black bulbul	*Hypsipetes lecocephalus*	B
Black chinned babbler	*Cyanoderma pyrrhops*	S
Black drongo	*Dicrurus macrocercus*	B
Black hooded oriole	*Oriolus xanthornus*	B
Black kite	*Milvus migrans*	B
Black redstart	*Phoenicurus ochruros*	S
Black rumped flameback woodpecker	*Dinopium benghalense*	W
Blue bearded bee eater	*Nyctyornis athertoni*	B
Blue-tailed bee eater	*Merops philippinus*	W
Bluethroat	*Cyanecula svecica*	W
Blue-whistling thrush	*Myophonus caeruleus*	B
Blyth's Pipit	*Anthus godlewskii*	B
Blyth's reed warbler	*Acrocephalus Dumetorum*	S
Brahminy starling	*Sturnia pagodarum*	B
Brown headed barbet	*Megalaima zeylanica*	B
Cattle egret	*Bubulcus ibis*	B
Chestnut-bellied rock thrush	*Monticola rufiventris*	B
Chestnut-headed bee-eater	*Merops leschenaulti*	W
Chestnut-tailed starling	*Sturnia malabarica*	S
Cinereous tit	*Parus major cinereus*	B
Common babbler	*Turdoides caudatus*	B
Common Chiffchaff	*Phylloscopus collybita*	S
Common Cuckoo	*Cuculus canorus*	S

Common hoopoe	*Upupa epops*	B
Common myna	*Acridotheres tristis*	B
Common rosefinch	*Carpodacus erythrinus*	S
Common stonechat	*Saxicola torquata*	W
Common tailorbird	*Orthotomus sutorius*	B
Common-hawk cuckoo	*Hierococcyx varius*	S
Coppersmith barbet	*Megalaima haemacephala*	B
Crested-serpent eagle	*Spilornis cheela*	S
Crimson sunbird	*Aethopyga siparaja*	B
Dark-sided flycatcher	*Muscicapa sibirica*	W
Dusky crag martin	*Hirundo concolor*	B
Emerald dove	*Chalcophas indica*	B
Eurasian collared dove	*Streptopelia decaocto*	S
Fire breasted flowerpecker	*Dicaeum ignipectus*	B
Fork-tailed drongo cuckoo	*Surniculus dicruroides*	S
Golden oriole	*Oriolus oriolus*	B
Greater coucal	*Centropus sinensis*	B
Green bee-eater	*Merops orientalis*	B
Green sandpiper	*Tringa ochropus*	W
Greenish Warbler	*Phylloscopus trochiloides*	B
Grey breasted prinia	*Prinia hodgsonii*	B
Grey bushchat	*Saxicola ferrea*	B
Grey hooded warbler	*Phylloscopus xanthoschistos*	B
Grey treepie	*Dendrocitta formosae*	B
Grey wagtail	*Motacilla cinerea*	B
Grey-capped pygmy woodpecker	*Picoides canicapillus*	W
Grey-headed canary flycatcher	*Culicicapa ceylonesis*	B
Grey-headed Woodpecker	*Picus canus*	B
Himalayan bulbul	*Pycnonotus leucogenys*	B
Himalayan goldenback	*Dinopium shorii*	S
himalayan griffon	*Gyps himalayensis*	S
House crow	*Corvus splendens*	B
House sparrow	*Passer domesticus*	B
Hume's warbler	*Phylloscopus humei*	B
Indian chat	*Oenanthe fusca*	B
Indian cuckoo	*Cuculus micropterus*	S
Indian grey hornbill	*Ocyceros birostris*	B
Indian Pond heron	*Ardeola grayii*	B
Indian robin	*Saxicoloides fulicata*	B
Indian roller	*Coracias benghalensis*	S

Jungle babbler	*Turdoides striatus*	B
Jungle Myna	*Acridotheres fuscus*	S
Jungle owlet	*Glaucidium radiatum*	W
Large billed crow	*Corvus macrorhynchos*	B
Large cuckooshrike	*Coracina macei*	W
Large grey babbler	*Argya malcolmi*	B
Laughing dove	*Spilopelia senegalensis*	B
Lemon-rumped Warbler	*Phylloscopus chloronotus*	W
Lesser-yellownape Woodpecker	*Picus chlorolophus*	W
Lineated Barbet	*Megalaima lineata*	B
Little Cormorant	*Microcarbo niger*	S
little swift	*Apus affinis*	S
Long tailed shrike	*Lanius schach.*	B
Orange-headed Thrush	*Geokichla citrina*	S
Oriental turtle dove	*Streptopelia orientalis*	B
Oriental white eye	*Zosterops palpebrosus*	B
Oriental-magpie Robin	*Copsychus saularis*	B
Oriental-pied Hornbill	*Anthacoceros albirostris*	B
Paddy field pipit	*Anthus rufulus*	B
Pale-billed flowerpecker	*Dicaeum erythrorhynchos*	B
Pied bushchat	*Saxicola caprata*	W
Pied Kingfisher	*Ceryle rudis*	S
Plain Prinia	*Prinia inornata*	S
Plum headed parakeet	*Psittacula cyanocephala*	B
Puff-throated babbler	*Pellorneum ruficeps*	B
Purple Sunbird	*Cinnyris asiaticus*	S
Red breasted flycatcher	*Ficedula parva*	B
Red jungle fowl	*Gallus gallus*	B
Red rumped swallow	*Cecropis daurica*	B
Red vented bulbul	*Pycnonotus cafer*	B
Red wattled lapwing	*Vanellus indicus*	B
Red whiskered bulbul	*Pycnonotus jocosus*	B
Red-billed blue Magpie	*Urocissa erythroryncha*	S
Rock pigeon	*Columba livia*	B
Rose-ringed parakeet	*Psittacula krameri*	B
Rosy minivet	*Pericrocotus roseus*	W
Rufous bellied niltava	*Niltava sundara*	W
Rufous treepie	*Dendrocitta vagabunda*	B
Rusty-cheeked scimitar babbler	*Pomatorhinus erythrogenys*	B
Scaly breasted munia	*Lonchura punctulata*	B
Scarlet Minivet	*Pericrocotus speciosus*	S

Shikra	*Accipiter badius*	B
Slaty blue flycatcher	*Ficedula tricolor*	W
Slaty-headed Parakeet	*Psittacula himalayana*	S
Small minivet	*Pericrocotus cinnamomeus*	B
Spangled drongo	*Dicrurus bracteatus*	B
Spotted dove	*Streptopelia chinensis*	B
Spotted owlet	*Athene brama*	B
Stoliczka's bushchat	*Saxicola macrorhynchus*	W
Stork-billed Kingfisher	*Pelargopsis capensis*	S
Streak throated swallow	*Petrochelidon fluvicola*	W
Striated babbler	*Argya earlei*	S
Taiga flycatcher	*Ficedula albicilla*	S
Thick billed flowerpecker	*Dicaeum agile*	S
Velvet fronted nuthatch	*Sitta frontalis*	B
Verditer flycatcher	*Eumyias thalassina*	W
whiskered yuhina	*Yuhina flavicollis*	S
Whistler's warbler	*Seicercus whistleri*	S
White breasted waterhen	*Amaurornis phoenicurus*	B
White browed wagtail	*Motacilla maderaspatensis*	B
White capped water redstart	*Chaimarrornis leucocephalus*	W
White throated fantail	*Riphidura albicollis*	B
White throated kingfisher	*Halcyon smyrnensis*	B
White wagtail	*Motacilla alba*	B
wire tailed swallow	*Hirundo smithii*	B
Yellow breasted green finch	*Carduelis spinoides*	B
Yellow eyed babbler	*Chrysomma sinense*	W
Yellow wagtail	*Motacilla flava*	W
Yellow wattled lapwing	*Vanellus malabaricus*	S

OUTREACH ACTIVITY

While working on the project we have organized nature walks so as to sensitize the young minds towards the need of conserving the winged species and how they can be beneficial to the human beings in creating a healthy environment which fits in the design of urban development.

The following visits were made with the purpose of creating awareness about the project:

Primary Kendriya Vidhyalaya FRI (Dehradun)

Visited: 17th March 2019

A bird walk was arranged in campus of FRI Dehradun for a group of 40 students of Primary Kendriya Vidhalaya FRI. Features to identify different bird species were explained to the students.

Government Primary School (Aamwala, Dehradun)

Visited: 20th March 2019

A group of 40 students of up to 8th standard of Aamwala government primary school were taken for nature walk on International Day of Forests, various activities were organized like bird walk, butterfly walk, trees walk.

Government Girls Intercollege (Kaulagarh, Dehradun)

Visited: 07th May 2019

An introductory session about the benefits of urban green spaces, was held with classes 8th, 9th, 10th, 11th and 12th of Government Girls Intercollege Kaulagarh, Dehradun. Questions such as, What are Urban green spaces? What is their role in biodiversity conservation? What all are the benefits of having urban green spaces for the human health? Were explained to the students for the better understanding of the project and to inculcate the curiosity amongst the young minds.

Annexure-III- Images of outreach carried out as a part of the project.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