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continued on the back inside cover

Cover: Oil painting of Humpback Whale *Megaptera novaeangliae*. © R. Mahesh.



## Avian richness and habitat selection patterns in Jhilmil Jheel Conservation Reserve, Uttarakhand, India

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**Abstract:** A survey of avifauna was carried out in Jhilmil Jheel Conservation Reserve (JJCR) of Haridwar Forest Division, Uttarakhand, during 2018–2020. The point count method was used to count birds in six habitats, viz.: plantation, mixed deciduous forest, riverine habitat, scrub forest, grasslands, and agricultural field. Ten replications each were done in the summer and winter seasons. The sampling effort across the six habitats, namely, plantation, mixed deciduous forest, scrub forest, riverine, grassland, and agricultural field, was 280, 150, 120, 250, 210, and 150 man minutes, respectively, resulting in a total effort of 1,160 man-minutes. There were 110 bird species in summer season and 131 bird species in winter season and a richness index of 17.73. Muscicapidae family had the highest relative diversity, followed by Accipitridae and Cuculidae. Rank abundance curve showed dominance of a few birds during winter season. Using the resource selection function (RSF), we examined seasonal habitat preferences of avian communities in the JJCR landscape. A total of 48 bird species in summer and 71 bird species in winter exhibited 100% habitat selection for specific habitat types. Riverine habitats showed the highest ecological significance, with 20 and 30 species exhibiting complete selection during summer and winter, respectively. Among the 170 recorded species, habitat specialists (103) outnumbered generalists (63), though the latter were more abundant. The remaining four species are human commensals. Riverine habitats supported the maximum number of specialists due to their distinct riparian vegetation and transitional features. Grassland specialists such as the White-tailed Stonechat, Yellow-bellied Prinia, Striated Grassbird, and Bristled Grassbird (Vulnerable) highlight the conservation importance of grasslands. PERMANOVA confirmed significant seasonal and vertical variations in species composition ( $p = 0.0001$ ), while indicator species analysis identified 60 and 64 key indicator species for summer and winter, respectively. The strong habitat specialization observed in riverine and grassland ecosystems underscores the need for prioritized management within this Important Bird and Biodiversity Area (IBA).

**Keywords:** Bird diversity, habitat heterogeneity, habitats, indicator species, microhabitats, rank abundance curve, relative abundance, resource selection function, terai grasslands, wetland.

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**Author contribution:** AD was responsible for conceptualizing and designing the study, conducting field data collection, organizing and analyzing the data, and drafting the manuscript. SD assisted with data analysis and contributed to the writing and refinement of the manuscript. RK provided overall supervision, strategic guidance, and critical review of the manuscript.

**Data Availability Statement:** The detailed data and the code is available with the first author and will be shared with the legitimate request made to the same.

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## INTRODUCTION

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 & Raven 2003). To monitor changes in forest biodiversity, indicators, which are surrogate measures of other components of forest biodiversity, are increasingly used (Boutin et al. 2009). They have also been described as ecological indicators of community or habitat types or indicators of environmental changes.

Birds are one of the best-studied taxonomic groups (Roberge & Angelstam 2006), and they are considered good indicators of biodiversity since they are present in almost all types of environments and sensitive to changes. The management of many bird species can be eased by considering only a group of indicator species, as monitoring the status of all species is difficult (Báldi 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 faster changes in a habitat than generalists, and resident species can also be used for year-round monitoring (Hilty & Merenlender 2000). They indicate the biological condition of the environment, thus considered as ecological disturbance indicator species (EDIS) as they have a strong association with their habitat.

The bird species assemblage of any particular location remains dynamic (Sinha et al. 2019). Species composition and abundance vary across the seasons and habitats (Lee & Kang 2019; Byju et al. 2025a). Spatial and temporal fluctuations in species richness and abundance are characteristic of most bird communities (Robinson et al. 2000; Malizia 2001; Byju et al. 2025b). Therefore, understanding the spatio-temporal variations in bird species richness, diversity, and abundance from small habitat patches is equally important (Archana et al. 2024). Multiple factors influence the bird community composition spatially: habitat structure, vegetation strata, proximity of the surrounding patches, and temporally: season and other anthropogenic disturbances (Byju et al. 2025c; Naveen et al. 2025). The seasonal variation in temperature and rainfall, spatial and temporal microhabitat conditions affect the availability of food for birds (Aggarwal et al. 2023), the breeding success and survival of bird species (Kim et al. 2022; Byju et al. 2025d). Processes acting in breeding and wintering grounds determine the patterns and

habitat occupancy and seasonal abundance in migratory bird species (García-Macía et al. 2025).

Birds select specific micro-habitats that may vary seasonally (Berlusconi 2025), and such habitat selection enables species coexistence (Bai et al. 2021). Resource Selection Functions (RSFs) help understand these patterns by comparing “used” versus “available” habitats (Jain & Balakrishnan 2011). RSFs estimate the probability of habitat use (Manly et al. 2002) and are widely applied to assess species distribution, abundance, and diversity (Boyce & McDonald 1999; Nielsen et al. 2003, 2005). Identifying selected resources provides insights into species' survival requirements (Manly et al. 2002).

The objective of the study was to assess the general pattern of bird assemblage and the resource selection function of birds in different habitats and identify the indicator bird species of different habitats in the summer and winter seasons. The research questions addressed in this study 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 the summer and winter seasons?

By assessing the general patterns of bird assemblage in different habitats, the study will contribute to our understanding of how avian communities are distributed across various habitats within the study area. This information is crucial for habitat conservation and management strategies.

## Study area

Jhilmil Jheel Conservation Reserve (JJCR) is a saucer-shaped wetland located in the Rasiyabaad forest range in Haridwar, Uttarakhand (Image 1). It lies between 29.53°–29.83° N and 78.00°–78.25° E with an elevation ranging 200–250 m. It is spread over 37 km<sup>2</sup>. It is comprised of various habitats such as grasslands, moist deciduous forests (mixed forest), scrub forest, riverine habitat, plantation, and agriculture field. The texture of the soil varies from sand to clay. It is rich in floral and faunal diversity. JJCR has 24 species of mammals, 20 reptile species, seven species of amphibians, 35 fish species, and 67 species of butterflies (Sinha et al. 2011).

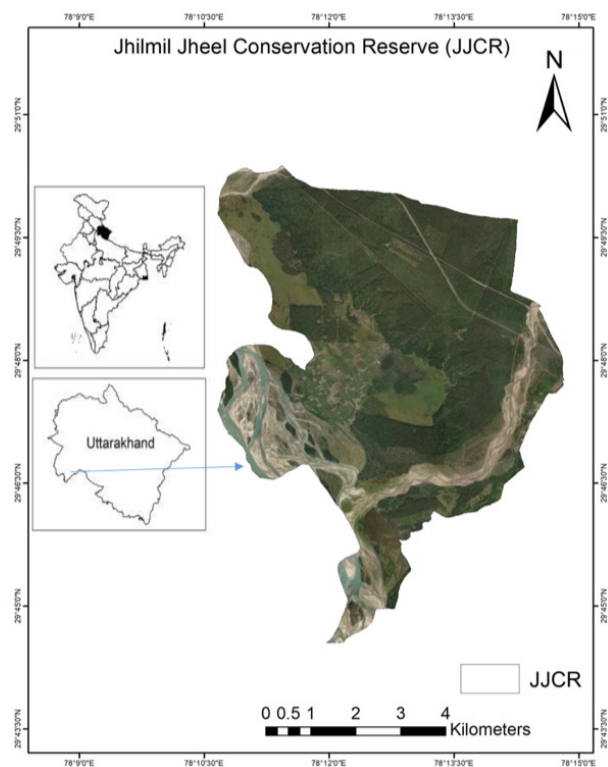


Image 1. Jhilmil Jheel Conservation Reserve, Haridwar, Uttarakhand.

## METHODS

### Bird sampling

From March 2018 to March 2020, bird sampling was conducted in different habitats of JJCR during both summer (mid-March–June) and winter (November–mid-February) (Bird list in Appendix Table 1). To count the birds in each habitat, the point count method (Bibby et al. 2000) was employed. Point count stations with a fixed width of 50-m radius were placed along existing forest trails in the six habitats: plantation (28), mixed forest (15), scrub forest (12), riverine (25), grassland (21), and agricultural fields (15) (Appendix Table 2). In total, 116 point count stations were utilized for the bird surveys, with a distance of 200 m between each station. Each point count station was visited 20 times, 10 times in summer and 10 times in winter (Appendix Table 3). The sampling effort across the six habitats, namely plantation, mixed deciduous forest, scrub forest, and riverine was 280, 150, 120, 250, 210, and 150 man minutes, resulting in a total effort of 1,160 man-minutes (Appendix Table 3). The surveys took place at 0530–0830 h during the summer and at 0800–1030 h during the winter. The observer recorded all birds seen or heard within a 10-minute period at each point count station, excluding birds in flight. Surveys were not conducted

during unfavourable weather conditions. Individual birds were identified using standard field guides (Grimmett et al. 2011).

## DATA ANALYSIS

### Richness index and diversity

The data analysis was based on the sum of 20 repeated observations. The survey data was used to calculate the various diversity indices. The richness index was computed as Margalef's richness index (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 in both seasons was computed using Shannon-Weiner index (Shannon & Weaver 1963) as follows:

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

H = Species diversity

P<sub>i</sub> = Proportion of abundance of species i

S = Total number of species in the habitat

### Rank abundance

Once abundance data for each species had been collected, it was organized by listing each species and its corresponding count. Then, the species were ranked in descending order of abundance, from the most common to the rarest. On the graph, the rank of each species was represented on the x-axis, with the most abundant species being assigned rank 1, the next rank 2, and so forth. The abundance of each species was represented on the y-axis and was expressed as the raw number of individuals or as relative abundance, which is the proportion of each species' individuals to the total. To construct the curve, data points were plotted on the graph, with the rank of each species on the x-axis and its abundance on the y-axis. Finally, the plotted points are connected with a line to create the rank abundance curve.

### Resource Selection Function

RSF was calculated following Jain & 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:

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

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

Based on RSF, birds were classified into habitat specialists if bird species were specifically preferring one or two habitats, habitat generalists if they were present in more than two habitats and human commensal, i.e., the birds which live in close proximity to human habitation (Pal et al. 2019).

Based on our field observations, birds were classified into different microhabitats, based on their perching and feeding height into vertical strata such as upper canopy, middle canopy, lower canopy, understorey, and ground-dwelling birds. Bird species which were either waterbirds or water-dependent were categorized as 'aquatic', while those which are adapted to air were categorized as 'aerial'. The diversity of different vertical strata was calculated through Shannon-Wiener diversity. PERMANOVA test (Anderson 2001) was performed to assess the difference in bird community assemblage in different strata in different seasons and habitats.

Indicator species analysis was done in R software using the package *Indval*, which measures the importance of habitat for a particular bird species. The indicator value index is the product of two components, called 'A' and 'B' (Dufrêne & Legendre 1997; Cáceres & Legendre 2009). Component 'A' is a 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 an indicator of the site group. Component 'B' is a 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 an indicator of the target site group. This method combines the faithfulness of occurrence of the species in a habitat with its 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 between 0 and 1, where 1 means 100% indicator of a particular habitat.

## RESULTS

### Richness index and diversity

A total of 170 bird species were encountered during the survey period, which constitutes 23.94% of the total number of species (710) reported from the state of Uttarakhand (Mohan & Sondhi 2024). The available data reports a total of 387 bird species for the region around JJCR.

In total, 110 and 131 bird species were recorded in the study area during the summer and winter seasons, respectively. The overall Margalef richness index was observed to be 17.7371, which shows that JJCR has high species richness. Rarefaction curves by habitat and season are mentioned in the Appendix Figures 1a,b. Family Muscipidae had the highest bird diversity, followed by Accipitridae and Cuculidae. The diversity of bird species was found to be 3.8 and 3.9 in the summer and winter seasons, respectively (Appendix Table 4).

### Rank abundance curves (RAD)

Rank abundance curves are useful tools to characterize and understand the structure of ecological communities. The shape and distribution of the curve provide valuable insights into the dynamics, health, and stability of the ecosystem, as well as the forces driving species abundance and diversity. They yield significant insights into two fundamental components of biodiversity: species richness, which denotes the total number of species, and species evenness, which reflects the relative abundance of those species. There are various RAD curves: 1) A log normal distribution indicates a balanced community where most species have moderate abundance, while a smaller number are either very abundant or very rare. This is typical of diverse ecosystems. 2) A geometric series is characterized by a few highly abundant species and many rare species. This pattern is often found in environments with strong competition or disturbance. 3) The broken stick model illustrates a hypothetical scenario where resources are perfectly distributed among all species, resulting in an even abundance. However, this idealized pattern is seldom found in real-world ecosystems.

There is less dominance and moderate evenness of individuals within each species in the bird community assemblage in the summer season within the study area (Figure 1a). Whereas, in the community assemblage in the winter season, there was dominance of a few species (Figure 1b), followed by even distribution of individuals of other species.

**Resource selection function**

Resource election function (RSF) helps to understand how animals choose habitats based on resource availability. 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 2).

A total of 20 bird species had 100% selection for riverine habitat during summer, and 30 during winter. In the grassland, 10 and 13 species had 100% RSF during the summer and winter, four (4) and 13 bird species in summer and winter, respectively. Two and six bird species had 100% RSF for mixed forest in summer and winter, respectively. Ten species had 100% RSF for scrub forest in summer, and seven had 100% RSF in winter. Two species had 100% RSF for the 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 1a) and 71 bird species had 100% selection for a particular habitat in winter (Table 1b).

**Habitat specialist and generalist**

Birds were grouped into specialists or generalists based on their sighting in a particular habitat or multiple habitats (Figure 3a). It was found that there are more habitat specialists (103) than generalists (63) bird species in JJCR, and four were commensals. The

abundance of habitat generalist birds is more than that of habitat specialists (Figure 3b). The bird community was dominated by specialists (60.59%), followed by generalists (37.06%), while human commensal species constituted only 2.35% of the total recorded species. In contrast to species richness, total abundance was highest for generalists, followed by specialists, whereas human commensals showed the lowest abundance. This indicates that although specialists form the majority in terms of species number, generalists dominate numerically in the community. Riverine habitat supported the highest number of habitat specialists

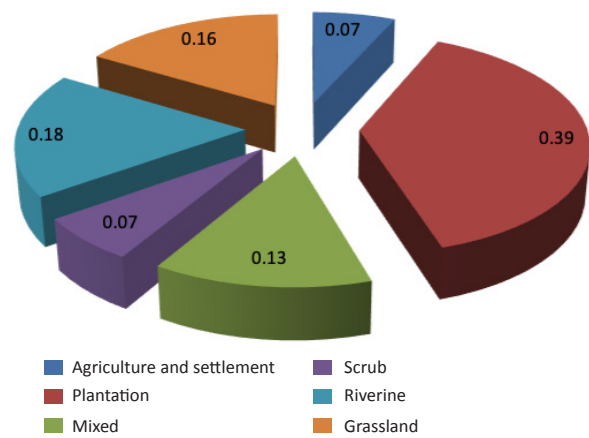


Figure 2. Proportional availability (%) of habitats of Jhilmil Jheel Conservation Reserve.

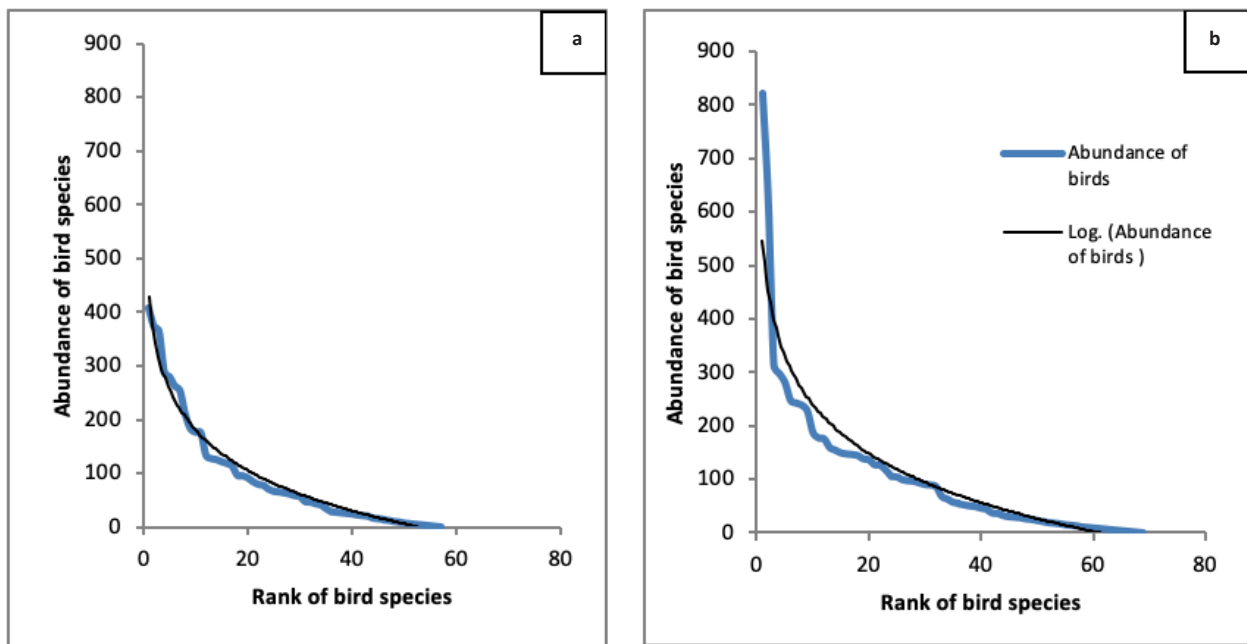


Figure 1. Rank abundance curve: a—summer | b—winter season

**Table 1a. Resource selection function during summer season (Proportion of selection for a particular habitat by a bird species).**

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

Bird species	Agriculture	Grassland	Mixed Forest	Plantation	Riverine	Scrub Forest
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

Bird species	Agriculture	Grassland	Mixed Forest	Plantation	Riverine	Scrub Forest
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

(51 species), followed by scrub forest and plantation. Scrub forest (48 species), mixed forest (47 species), and plantation (46 species) showed higher numbers of generalists. Grassland had a relatively balanced composition of specialists (31 species) and generalists (34 species). Agriculture fields showed the lowest number of specialists (5 species) but relatively higher generalists (22 species). Human commensals were recorded in very low numbers across all habitats (0–4 species), with slightly higher representation in agricultural fields.

Some of the most abundant generalist birds in JJCR are Baya Weaver *Ploceus philippinus*, Jungle Babbler *Turdoides striata*, Red-vented Bulbul *Pycnonotus cafer*, Rose-ringed Parakeet *Psittacula kramera*, and Spotted Dove *Spilopelia chinensis*. House Crow *Corvus splendens*, Rock Pigeon *Columba livia*, House Sparrow *Passer domesticus*, and Common Myna *Acridotheres tristis* are human commensals. Riverine habitat supported the maximum number of habitat specialists as it is the transition between terrestrial and wetland environments, having unique riparian vegetation and the river-created habitats such as water-edge and sandbars, sandbar scrub, river-edge forests, leading to more diversity of birds (Figure 3c).

Several birds in JJCR are habitat specialists or near habitat specialists, found more or less restricted to their habitats, making the conservation of each habitat vital for the long-term sustenance of this IBA. The JJCR has many grassland birds such as Common Stonechat *Saxicola rubicola*, White-tailed Stonechat *Saxicola leucurus*, Red Avadavat *Amandava amandava*, Zitting Cisticola *Cisticola juncidis*, Sarus Crane *Grus Antigone*, Yellow-bellied Prinia *Prinia flaviventris*, Bristled Grassbird *Chaetornis striata*, and Striated Grassbird *Megalurus palustris*. Among these White-tailed Stonechat, Yellow-bellied Prinia, Striated Grassbird, and Bristled Grassbird are considered grassland bird specialists.

Bristled Grassbird and Sarus Crane are 'Vulnerable'. Notable waterbirds in the area include the River Lapwing *Vanellus duvaucelii*, River Tern *Sterna aurantia*, Black-bellied Tern *Sterna acuticauda*, and Little Tern *Sternula albifrons*, while water-dependent species encompass the Pied Kingfisher *Ceryle rudis*, Stork-billed Kingfisher *Pelargopsis capensis*, and Great Thick-knee *Esacus recurvirostris*, with the River Lapwing and River Tern classified as 'Near Threatened' and the Black-bellied Tern as 'Endangered' by the IUCN Red List for Threatened Species. Some of the prominent scrub habitat specialists

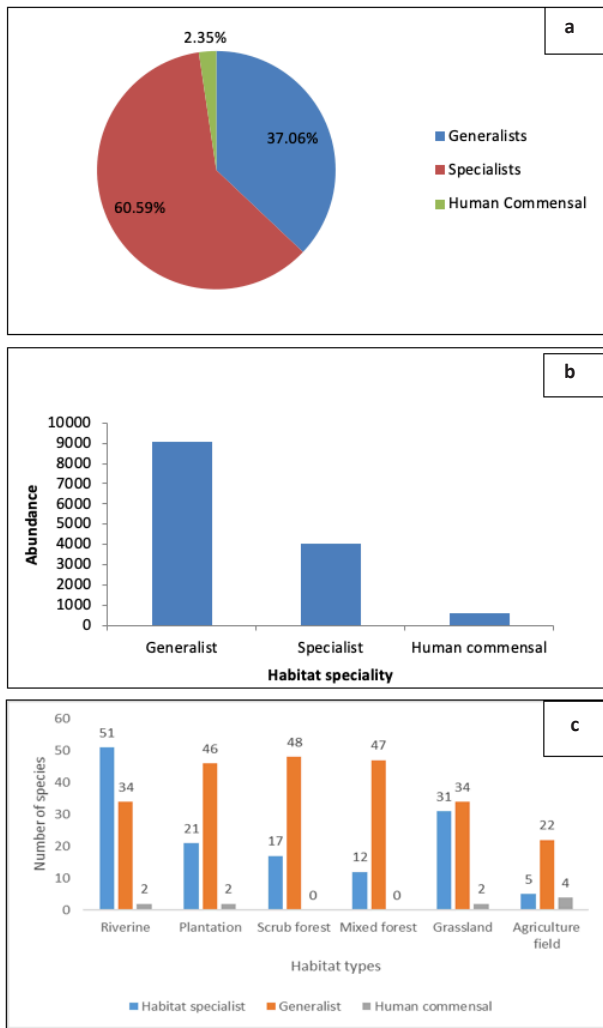


Figure 3. a—Proportion (%) of specialist-generalist birds' species in JJCR | b—Abundance of habitat specialist-generalist birds' species in JJCR | c—Number of habitat specialist-generalist in every habitat.

are Black Francolin *Francolinus francolinus* and Grey Francolin *Ortygornis pondicerianus*. In plantations of Eucalyptus and Teak, a few birds favouring open woodland habitats were more frequent, such as Black-hooded Oriole *Oriolus xanthornus* and Black Bulbul *Hypsipetes leucocephalus*. Prominent bird species of mixed deciduous forests are Red Junglefowl *Gallus gallus* and Grey Hornbill *Ocyrceros birostris*. Sarus Cranes are one of the notable species found in agricultural fields.

### Bird composition in different vertical strata (microhabitats)

The middle canopy had the highest proportion of bird species and the highest Shannon diversity in JJCR, and the upper canopy had the lowest number of bird species as compared to other vertical strata (Figure

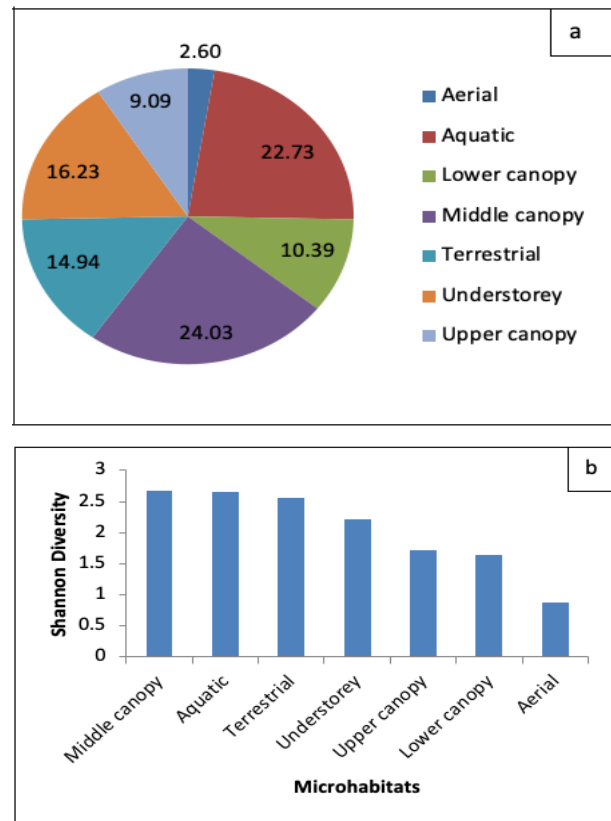


Figure 4. a—Species encountered (%) in different microhabitats | b—Shannon-Wiener diversity of birds in different microhabitats.

4a,b). There is a noticeable increase in bird species in the middle canopy in winter (Figure 5). PERMANOVA result showed a significant difference in bird composition in different vertical strata (microhabitats) 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 ( $p = 0.0001$ ) (Appendix Table 5).

### Indicator species

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 the summer season, out of 110 species, 60 species were identified as indicator species. Riverine habitat had 15 indicator species, mixed deciduous forest—12, plantation—12, grassland—11 indicator species, scrub forest—seven indicator species, and agriculture field-human settlement—three indicator species (Table 2a). In the winter season, out of 131 species, 64 were identified as indicator species for

**Table 1b. Resource selection function during winter season (Proportion of selection for a particular habitat by a bird species, 100% selection for a particular habitat is represented by value 1).**

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

Bird species	Agriculture	Grassland	mixed Forest	Plantation	Riverine	Scrub forest
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

Bird species	Agriculture	Grassland	mixed Forest	Plantation	Riverine	Scrub forest
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 Pochard	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

Bird species	Agriculture	Grassland	mixed Forest	Plantation	Riverine	Scrub forest
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

different habitats. Grassland had 10 indicator species, plantation—12, riverine—16, agriculture field-human settlement—three, mixed—seven, and scrub forest—16 indicator species (Table 2b).

#### HABITAT-WISE DETAILED DESCRIPTION

**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 *Anthus rufulus*, Common Stonechat, Red-wattled Lapwing *Vanellus indicus*, Pied Buschat *Saxicola caprata*, and 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 the 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 *Stachyris pyrrhops*, Indian Peafowl *Pavo cristatus*, Blue-tailed Bee-eater *Merops philippinus*, and Chestnut-shouldered Petronia *Gymnoris xanthocollis* were strongly associated with mixed deciduous forest during summer, while Red Junglefowl, Oriental White-eye *Zosterops palpebrosus*, and Indian Grey Hornbill were strongly associated during the winter season. Baya Weaver had the highest Indicator value (91.4%) during

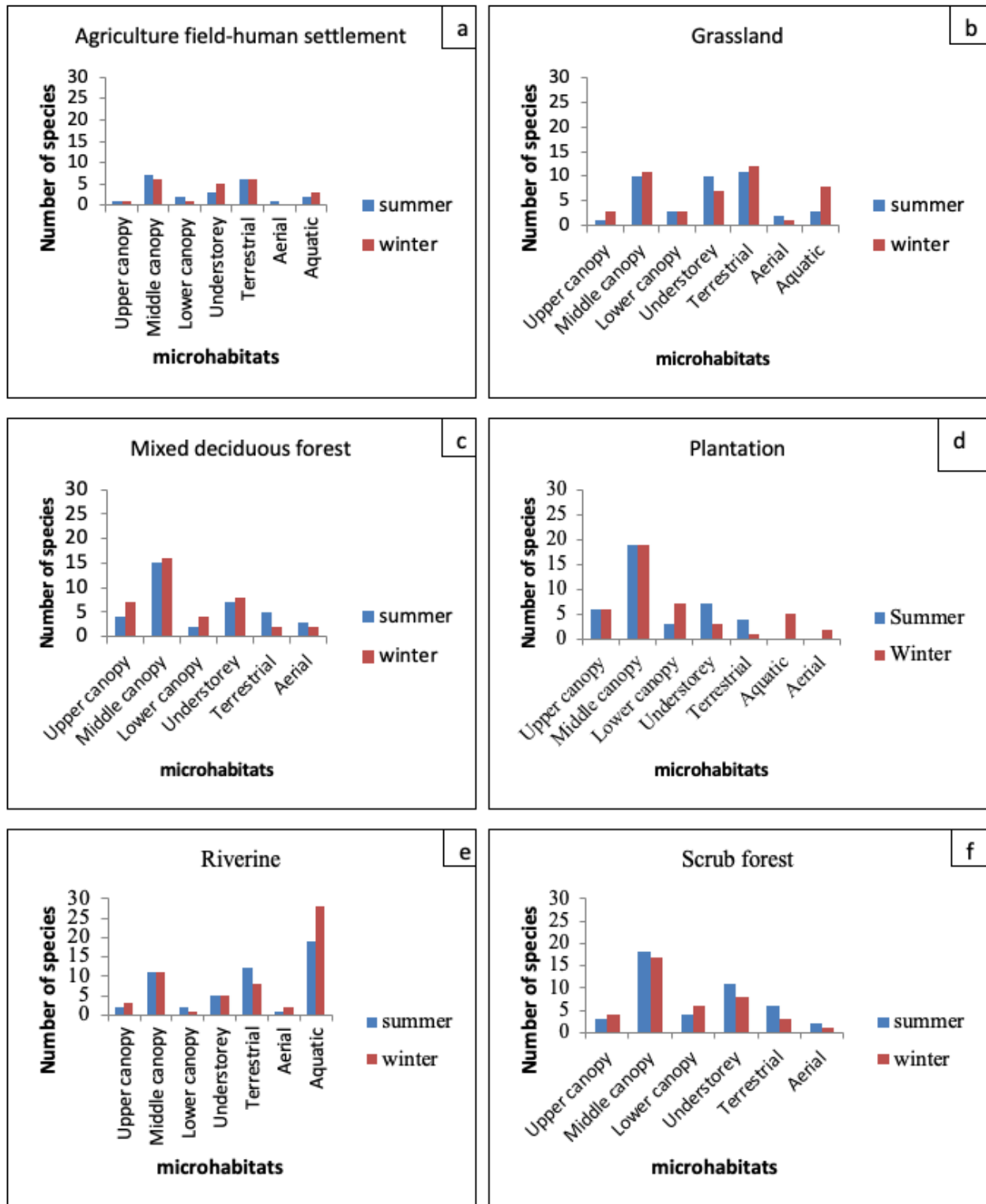


Figure 5. Vertical strata in every habitat: a—Agriculture fields-human settlements | b—Grassland | c—Mixed deciduous forest | d—Plantation | e—Riverine habitat | f—Scrub Forest.

summer and Red Junglefowl had the highest Indicator value of 70% during winter.

**Riverine habitat:** River Lapwing, River Tern, Little

Egret *Egretta garzetta*, and Little Cormorant *Microcarbo niger* had a strong association during summer and birds, namely Little Cormorant, White Wagtail *Motacilla alba*,

Table 2a. Indicator bird species in different habitats in summer season.

	A	B	Indicator value	P value	Significance codes
<b>Agriculture and settlement</b>					
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	**
<b>Grassland</b>					
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	*
<b>Mixed deciduous forest</b>					
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	*
<b>Plantation</b>					
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	*
<b>Riverine</b>					
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	***

	A	B	Indicator value	P value	Significance codes
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	*
<b>Scrub forest</b>					
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	**

A—Specificity | B—Fidelity

Significant codes: 0 '\*\*\*\*' | 0.001 '\*\*\*' | 0.01 '\*\*' | 0.05 '\*' | 0.1 '.' | 1

Citrine Wagtail *Motacilla citreola*, and Pied Kingfisher have a strong association during the winter season. River Lapwing had the highest indicator value 93.1% during the summer season and Little Cormorant had the highest Indicator value of 77.5% during winter.

**Plantation:** Black-hooded Oriole, Indian Paradise-Flycatcher *Terpsiphone paradisi*, Oriental Magpie-Robin *Copsychus saularis*, and Indian Pitta *Pitta brachyura* had a strong association with the plantation during summer, while Black-hooded Oriole, Black Bulbul, Rose-ringed Parakeet, Taiga Flycatcher *Ficedula albicilla*, and Spangled Drongo *Dicrurus bracteatus* had a strong association during the winter season. Black-hooded Oriole had a strong association with the plantation, with an indicator value of 92.8% and 81.9% during summer and winter, respectively.

**Scrub forest:** Indian Robin *Copsychus fulicatus*, Purple Sunbird *Cinnyris asiaticus*, Spotted Dove *Spilopelia chinensis*, and Green Bee-eater *Merops orientalis* were strongly associated with scrub forest during summer, while Lesser Whitethroat *Curruc curruca*, Indian Robin, Plain Prinia *Prinia inornata*, Spotted Dove, and Purple Sunbird were strongly associated during the winter season. Indian Robin had the highest indicator value (75%) during the summer season and Lesser Whitethroat

had the highest Indicator value of 83.5% during the winter season.

## DISCUSSION

The current study demonstrates that JJCR has a high species richness and diversity of bird species. The JJCR is home to a variety of habitat types that support numerous bird species. Therefore, the significance and importance of the conservation reserve for birdlife conservation is extensive. The favourable environmental conditions may have contributed to the greater species richness and diversity in JJCR. More number of bird species were found in the winter season because of the arrival of many winter visitors.

We provide here a quantitative demonstration of habitat selection in the natural assemblage of bird species using a resource selection function based on proportional use and availability. Using RSF, we found 48 bird species had 100% selection for a particular habitat in summer, and 71 bird species had 100% selection for a 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

Table 2b. Indicator bird species in different habitats in winter season.

	A	B	Indicator value	P value	Significance codes
<b>Agriculture and settlement</b>					
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	**
<b>Grassland</b>					
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	*
<b>Mixed deciduous forest</b>					
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	*
<b>Plantation</b>					
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	*
<b>Riverine</b>					
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	**

	A	B	Indicator value	P value	Significance codes
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	*
<b>Scrub forest</b>					
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	*

A—Specificity | B—Fidelity

Significant codes: 0 '\*\*\*' | 0.001 '\*\*' | 0.01 '\*' | 0.05 '' | 0.1 ' ' | 1.

of the presence of many microhabitats attracting winter migrant waterbirds. Within the bird community, some are generalists, and some are specialists in specific habitats. A larger number of habitat specialist bird species could be because of habitat heterogeneity (Surasinghe & Alwis 2010), while generalist birds were more abundant as they can adapt to a variety of environmental conditions and utilize a variety of resources. The dominance of specialists in species richness suggests that the study area supports diverse and structurally complex habitats capable of meeting specific ecological requirements. Specialist species are often sensitive to habitat alteration; therefore, their higher proportion indicates relatively good habitat quality and ecological integrity.

However, the greater abundance of generalists reflects their ecological flexibility and competitive

advantage in heterogeneous or moderately disturbed landscapes. The riverine habitat emerged as a critical refuge for specialist species, likely due to the availability of diverse microhabitats and consistent water resources. A low number of human commensals indicates that avian community composition is largely influenced by natural habitat characteristics, including vegetation structure, canopy stratification, and availability of natural food resources.

The 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 & 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; Scheffers et al. 2017; Mottl et al. 2020). 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 & Mathew 2003; Dinanti et al. 2018) showing similar results in Western Ghats, India and West Java, Indonesia. 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, openness) and biological factors (predators), and is energetically adverse for behaviours like feeding, breeding, or roosting (Turton & 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, Common Stonechat, and Yellow-bellied Prinia (Manakadan 2014; Madge et al. 2020) are commonly found in grasslands, and White-tailed Stonechat is an obligate grassland bird (Roberts 1992; Baral 2001, 2004). They can be monitored to understand the effect of management in grasslands. Subtropical grasslands in the Indian subcontinent are of international significance for biodiversity and are regarded as the most threatened habitat in the Indian subcontinent, and many grassland birds are also threatened (Grimmett et al. 1998). Lesser White Throat, Indian Robin, and Purple Sunbird were identified as indicator species of scrub forest in JJCR. Lesser White throat (Aymí & Gargallo 2021), Indian Robin (Collar & Bonan 2020), and Purple Sunbird (Cheke & Mann 2020) are usually found in scrub habitats and thus can be monitored easily. Black-hooded Oriole, Black Bulbul, and Indian Paradise-Flycatcher were obtained as indicator species in plantations in JJCR. Black-hooded Oriole (Walther & Jones 2020) and Indian Paradise-Flycatcher (Moeliker et al. 2020) are found in plantations and can be used as monitor species in 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 commensals and thus can be easily

seen in and near human settlements (Leveau & 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 agricultural fields have negative impacts on invertebrate populations, which in turn leads to the decline of the farmland bird population (Boatman et al. 2004; Hallmann et al. 2014; Stanton et al. 2018). Unsustainable agricultural practices pose threats to many forest-dependent birds (Naidoo 2004). Some of the factors responsible for degradation in agricultural fields include changes in cropping species and patterns, and the removal of semi-natural habitats (Sundar & Kittur 2013; Redhead et al. 2018). Forest specialist birds are sensitive to monoculture agricultural lands, and changes in vegetation characteristics can impact bird assemblages (Schulze & Riedl 2008; Maas et al. 2009). The intensification and expansion of agriculture threaten biodiversity (Laurance et al. 2013). There has been a long history of disturbance in the mixed deciduous forests of the Shiwalik region. Forests in these regions are under pressure from an influx of people, expanding human habitation, lopping, and grazing (Gautam et al. 2016). Baya Weaver, Red Junglefowl, and Indian Grey Hornbill can be used as indicator species for monitoring the mixed deciduous forest. Baya Weavers were observed engaging in nesting activities within these forests, using *Zizyphus mauritiana* trees for their nests. Moreover, the high indicator value of Red Junglefowl (Palei et al. 2016) and Indian Grey Hornbill (Balasubramanian et al. 2005) within deciduous forests is obvious, as, they are typically found within this habitat. Among the indicator bird species from riverine habitats, River Lapwing, and River Tern are species of conservation concern. River Lapwing is a near threatened, and River Tern is vulnerable.

Our results provide important baseline information for selecting which species to monitor as indicator species for different habitats. The present study also 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 call 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. 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 long-term monitoring of a particular habitat. All the habitats, including plantations, have their own importance for birds. Understanding the link between indicator species and habitat is important for habitat-specific management. Potential indicator species reflect the on-site ecological conditions. The analysis is based on data from six habitats representing different vegetation compositions, so the determined indicator species can be used as bio-indicators for future monitoring of the management of each habitat.

## CONCLUSION

Regular monitoring of bird populations, along with awareness programs focused on bird and habitat conservation, is essential. Despite its small size, the study area supports a remarkably rich and diverse avian community. Ongoing habitat management practices should integrate measures for the conservation of key bird species. The identified indicator species provide a valuable baseline for future monitoring efforts. Understanding the population trends and dynamics of these species can serve as an effective tool for assessing habitat and forest conditions and for refining management and conservation strategies. Caveat of the study—Though there is a possibility of non-detection of certain bird species in a particular habitat, resulting in 100% selection of certain habitats, most of the birds show multiple habitat selection through RSF analysis in the present study.

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**Appendix Table 1.** Bird species list at Jhilmil Jheel Conservation Reserve.

	Bird species	Scientific name	Family
1	Black Kite	<i>Milvus migrans</i>	Accipitridae
2	Changeable Hawk-Eagle	<i>Nisaetus cirrhatus</i>	Accipitridae
3	Cinereous Vulture	<i>Aegypius monachus</i>	Accipitridae
4	Crested Serpent-Eagle	<i>Spilornis cheela</i>	Accipitridae
5	Egyptian Vulture	<i>Neophron percnopterus</i>	Accipitridae
6	Eurasian Sparrowhawk	<i>Accipiter nisus</i>	Accipitridae
7	Himalayan Griffon	<i>Gyps himalayensis</i>	Accipitridae
8	Oriental Honey-buzzard	<i>Pernis ptilorhynchus</i>	Accipitridae
9	Shikra	<i>Tachypiza badia</i>	Accipitridae
10	Short-toed Snake-Eagle	<i>Circaetus gallicus</i>	Accipitridae
11	Slender-billed Vulture	<i>Gyps tenuirostris</i>	Accipitridae
12	White-eyed Buzzard	<i>Butastur teesa</i>	Accipitridae
13	White-rumped Vulture	<i>Gyps bengalensis</i>	Accipitridae
14	Blyth's Reed Warbler	<i>Acrocephalus dumetorum</i>	Acrocephalidae
15	Common Iora	<i>Aegithina tiphia</i>	Aegithinidae
16	Ashy-crowned Sparrow-lark	<i>Eremopterix griseus</i>	Alaudidae
17	Crested Lark	<i>Galerida cristata</i>	Alaudidae
18	Oriental Skylark	<i>Alauda gulgula</i>	Alaudidae
19	Common Kingfisher	<i>Alcedo atthis</i>	Alcedinidae
20	Pied Kingfisher	<i>Ceryle rudis</i>	Alcedinidae
21	Stork-billed Kingfisher	<i>Pelargopsis capensis</i>	Alcedinidae
22	White-throated Kingfisher	<i>Halcyon smyrnensis</i>	Alcedinidae
23	Bar-headed Goose	<i>Anser indicus</i>	Anatidae
24	Gadwall	<i>Mareca strepera</i>	Anatidae
25	Goosander	<i>Mergus Merganser</i>	Anatidae
26	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	Anatidae
27	Lesser Whistling-duck	<i>Dendrocygna javanica</i>	Anatidae
28	Northern Pintail	<i>Anas acuta</i>	Anatidae
29	Red-crested Pochard	<i>Netta rufina</i>	Anatidae
30	Ruddy Shelduck	<i>Tadorna ferruginea</i>	Anatidae
31	Cattle Egret	<i>Ardea coromanda</i>	Ardeidae
32	Great Egret	<i>Ardea alba</i>	Ardeidae
33	Grey Heron	<i>Ardea cinerea</i>	Ardeidae
34	Indian Pond-Heron	<i>Ardeola grayii</i>	Ardeidae
35	Intermediate Egret	<i>Ardea intermedia</i>	Ardeidae
36	Little Egret	<i>Egretta garzetta</i>	Ardeidae
37	Indian Grey Hornbill	<i>Ocyroceros birostris</i>	Bucerotidae
38	Oriental Pied-Hornbill	<i>Anthracoceros albirostris</i>	Bucerotidae
39	Small Minivet	<i>Pericrocotus cinnamomeus</i>	Campephagidae
40	Little Ringed Plover	<i>Charadrius dubius</i>	Charadriidae
41	Red-wattled Lapwing	<i>Vanellus indicus</i>	Charadriidae

	Bird species	Scientific name	Family
42	River Lapwing	<i>Vanellus duvaucelii</i>	Charadriidae
43	Yellow-wattled Lapwing	<i>Vanellus malabaricus</i>	Charadriidae
44	Golden-fronted Leafbird	<i>Chloropsis aurifrons</i>	Chloropseidae
45	Woolly-necked Stork	<i>Ciconia episcopus</i>	Ciconiidae
46	Ashy Prinia	<i>Prinia socialis</i>	Cisticolidae
47	Common Tailorbird	<i>Orthotomus sutorius</i>	Cisticolidae
48	Grey-breasted Prinia	<i>Prinia hodgsonii</i>	Cisticolidae
49	Plain Prinia	<i>Prinia inornata</i>	Cisticolidae
50	Yellow-bellied Prinia	<i>Prinia flaviventris</i>	Cisticolidae
51	Zitting Cisticola	<i>Cisticola juncidis</i>	Cisticolidae
52	Eurasian Collared-dove	<i>Streptopelia decaocto</i>	Columbidae
53	Laughing Dove	<i>Spilopelia senegalensis</i>	Columbidae
54	Rock Pigeon	<i>Columba livia</i>	Columbidae
55	Spotted Dove	<i>Spilopelia chinensis</i>	Columbidae
56	Yellow-footed Green-pigeon	<i>Treron phoenicopterus</i>	Columbidae
57	Indian Roller	<i>Coracias benghalensis</i>	Coraciidae
58	House Crow	<i>Corvus splendens</i>	Corvidae
59	Large-billed Crow	<i>Corvus macrorhynchos</i>	Corvidae
60	Rufous Treepie	<i>Dendrocitta vagabunda</i>	Corvidae
61	Asian Koel	<i>Eudynamis scolopaceus</i>	Cuculidae
62	Common Cuckoo	<i>Cuculus canorus</i>	Cuculidae
63	Common Hawk-cuckoo	<i>Hieracoccyx varius</i>	Cuculidae
64	Gray-bellied Cuckoo	<i>Cacomantis passerinus</i>	Cuculidae
65	Greater Coucal	<i>Centropus sinensis</i>	Cuculidae
66	Indian Cuckoo	<i>Cuculus micropterus</i>	Cuculidae
67	Pied Cuckoo	<i>Clamator jacobinus</i>	Cuculidae
68	Sirkeer Malkoha	<i>Taccocua leschenaultii</i>	Cuculidae
69	Square-tailed Drongo-cuckoo	<i>Surniculus lugubris</i>	Cuculidae
70	Pale-billed Flowerpecker	<i>Dicaeum erythrorhynchos</i>	Dicaeidae
71	Thick-billed Flowerpecker	<i>Dicaeum agile</i>	Dicaeidae
72	Ashy Drongo	<i>Dicrurus leucophaeus</i>	Dicruridae
73	Black Drongo	<i>Dicrurus macrocercus</i>	Dicruridae
74	Bronzed Drongo	<i>Dicrurus aeneus</i>	Dicruridae
75	Spangled Drongo	<i>Dicrurus hottentottus</i>	Dicruridae
76	White-bellied Drongo	<i>Dicrurus caerulescens</i>	Dicruridae
77	Indian Silverbill	<i>Euodice malabarica</i>	Estrildidae
78	Red Avadavat	<i>Amandava amandava</i>	Estrildidae
79	Yellow-breasted Greenfinch	<i>Chloris spinoides</i>	Fringillidae

	Bird species	Scientific name	Family
80	Small Pratincole	<i>Glareola lactea</i>	Glareolidae
81	Sarus Crane	<i>Antigone antigone</i>	Gruidae
82	Barn Swallow	<i>Hirundo rustica</i>	Hirundinidae
83	Plain Martin	<i>Riparia chinensis</i>	Hirundinidae
84	Bay-backed Shrike	<i>Lanius vittatus</i>	Laniidae
85	Long-tailed Shrike	<i>Lanius schach</i>	Laniidae
86	Black-bellied Tern	<i>Sterna acuticauda</i>	Laridae
87	Little Tern	<i>Sterna albifrons</i>	Laridae
88	Pallas's Gull	<i>Ichthyetus ichthyetus</i>	Laridae
89	River Tern	<i>Sterna aurantia</i>	Laridae
90	Jungle Babbler	<i>Argya striata</i>	Leiothrichidae
91	Striated Babbler	<i>Argya earlei</i>	Leiothrichidae
92	Bristled Grassbird	<i>Schoenicola striatus</i>	Locustellidae
93	Striated Grassbird	<i>Cincloramphus palustris</i>	Locustellidae
94	Brown-headed Barbet	<i>Psilopogon zeylanicus</i>	Megalaimidae
95	Coppersmith Barbet	<i>Psilopogon haemacephalus</i>	Megalaimidae
96	Great Barbet	<i>Psilopogon virens</i>	Megalaimidae
97	Asian Green Bee-eater	<i>Merops orientalis</i>	Meropidae
98	Blue-tailed Bee-eater	<i>Merops philippinus</i>	Meropidae
99	Black-naped Monarch	<i>Hypothymis azurea</i>	Monarchidae
100	Indian Paradise-flycatcher	<i>Terpsiphone paradisi</i>	Monarchidae
101	Citrine Wagtail	<i>Motacilla citreola</i>	Motacillidae
102	Grey Wagtail	<i>Motacilla cinerea</i>	Motacillidae
103	Paddyfield Pipit	<i>Anthus rufulus</i>	Motacillidae
104	White Wagtail	<i>Motacilla alba</i>	Motacillidae
105	White-browed Wagtail	<i>Motacilla maderaspatensis</i>	Motacillidae
106	Asian Brown Flycatcher	<i>Muscicapa dauurica</i>	Muscicapidae
107	Brown Rock Chat	<i>Oenanthe fusca</i>	Muscicapidae
108	Chestnut-bellied Rock-thrush	<i>Monticola rufiventris</i>	Muscicapidae
109	Common Stonechat	<i>Saxicola maurus</i>	Muscicapidae
110	Grey Bushchat	<i>Saxicola ferreus</i>	Muscicapidae
111	Indian Robin	<i>Copsychus fulicatus</i>	Muscicapidae
112	Oriental Magpie-robin	<i>Copsychus saularis</i>	Muscicapidae
113	Pied Bushchat	<i>Saxicola caprata</i>	Muscicapidae
114	Red-breasted Flycatcher	<i>Ficedula parva</i>	Muscicapidae
115	Rufous-gorgeted Flycatcher	<i>Ficedula strophiate</i>	Muscicapidae
116	Small Niltava	<i>Niltava macgrigoriae</i>	Muscicapidae
117	Taiga Flycatcher	<i>Ficedula albicilla</i>	Muscicapidae
118	Tickell's Blue Flycatcher	<i>Cyornis tickelliae</i>	Muscicapidae
119	Verditer Flycatcher	<i>Eumyias thalassinus</i>	Muscicapidae
120	White-tailed Stonechat	<i>Saxicola leucurus</i>	Muscicapidae
121	Crimson Sunbird	<i>Aethopyga siparaja</i>	Nectariniidae

	Bird species	Scientific name	Family
122	Purple Sunbird	<i>Cinnyris asiaticus</i>	Nectariniidae
123	Black-hooded Oriole	<i>Oriolus xanthornus</i>	Oriolidae
124	Maroon Oriole	<i>Oriolus traillii</i>	Oriolidae
125	Osprey	<i>Pandion haliaetus</i>	Pandionidae
126	Great Tit	<i>Parus major</i>	Paridae
127	Chestnut-shouldered Petronia	<i>Gymnoris xanthocollis</i>	Passeridae
128	House Sparrow	<i>Passer domesticus</i>	Passeridae
129	Great Cormorant	<i>Phalacrocorax carbo</i>	Phalacrocoracidae
130	Little Cormorant	<i>Microcarbo niger</i>	Phalacrocoracidae
131	Black Francolin	<i>Francolinus francolinus</i>	Phasianidae
132	Grey Francolin	<i>Francolinus pondicerianus</i>	Phasianidae
133	Indian Peafowl	<i>Pavo cristatus</i>	Phasianidae
134	Red Junglefowl	<i>Gallus gallus</i>	Phasianidae
135	Greenish Warbler	<i>Phylloscopus trochiloides</i>	Phylloscopidae
136	Grey-hooded Warbler	<i>Phylloscopus xanthoschistos</i>	Phylloscopidae
137	Hume's Warbler	<i>Phylloscopus humei</i>	Phylloscopidae
138	Lemon-rumped Warbler	<i>Phylloscopus chloronotus</i>	Phylloscopidae
139	Lesser Goldenbacked Woodpecker	<i>Dinopium benghalense</i>	Picidae
140	Streak-throated Woodpecker	<i>Picus xanthopygaeus</i>	Picidae
141	Indian Pitta	<i>Pitta brachyura</i>	Pittidae
142	Baya Weaver	<i>Ploceus philippinus</i>	Ploceidae
143	Black-breasted Weaver	<i>Ploceus benghalensis</i>	Ploceidae
144	Plum-headed Parakeet	<i>Psittacula cyanocephala</i>	Psittaculidae
145	Rose-ringed Parakeet	<i>Psittacula krameri</i>	Psittaculidae

	Bird species	Scientific name	Family
146	Black Bulbul	<i>Hypsipetes leucocephalus</i>	Pycnonotidae
147	Himalayan Bulbul	<i>Pycnonotus leucogenys</i>	Pycnonotidae
148	Red-vented Bulbul	<i>Pycnonotus cafer</i>	Pycnonotidae
149	Red-whiskered Bulbul	<i>Pycnonotus jocosus</i>	Pycnonotidae
150	White-throated Fantail	<i>Rhipidura albicollis</i>	Rhipiduridae
151	Common Greenshank	<i>Tringa nebularia</i>	Scolopacidae
152	Common Sandpiper	<i>Actitis hypoleucos</i>	Scolopacidae
153	Little Stint	<i>Calidris minuta</i>	Scolopacidae
154	Temminck's Stint	<i>Calidris temminckii</i>	Scolopacidae
155	Chestnut-bellied Nuthatch	<i>Sitta cinnamoventris</i>	Sittidae
156	Velvet-fronted Nuthatch	<i>Sitta frontalis</i>	Sittidae
157	Grey-headed Canary-Flycatcher	<i>Culicicapa ceylonensis</i>	Stenostiridae
158	Jungle Owlet	<i>Glauclidium radiatum</i>	Strigidae
159	Bank Myna	<i>Acridotheres ginginianus</i>	Sturnidae
160	Brahminy Starling	<i>Sturnia pagodarum</i>	Sturnidae
161	Common Myna	<i>Acridotheres tristis</i>	Sturnidae
162	Indian Pied Starling	<i>Gracupica contra</i>	Sturnidae
163	Jungle Myna	<i>Acridotheres fuscus</i>	Sturnidae
164	Lesser Whitethroat	<i>Curruca curruca</i>	Sylviidae
165	Red-naped Ibis	<i>Pseudibis papillosa</i>	Threskiornithidae
166	Black-chinned Babbler	<i>Cyanoderma pyrrhops</i>	Timaliidae
167	Rusty-cheeked Scimitar-babbler	<i>Erythrogonys erythrogonys</i>	Timaliidae
168	Tawny-bellied Babbler	<i>Dumetia hyperythra</i>	Timaliidae
169	Tickell's Thrush	<i>Turdus unicolor</i>	Turdidae
170	Indian White-eye	<i>Zosterops palpebrosus</i>	Zosteropidae

**Appendix Table 2. Details of point counts in every habitat at Jhilmil Jheel Conservation Reserve.**

Habitat	Area (km <sup>2</sup> )	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

**Appendix Table 3. Details of the efforts in every habitat at Jhilmil Jheel Conservation Reserve.**

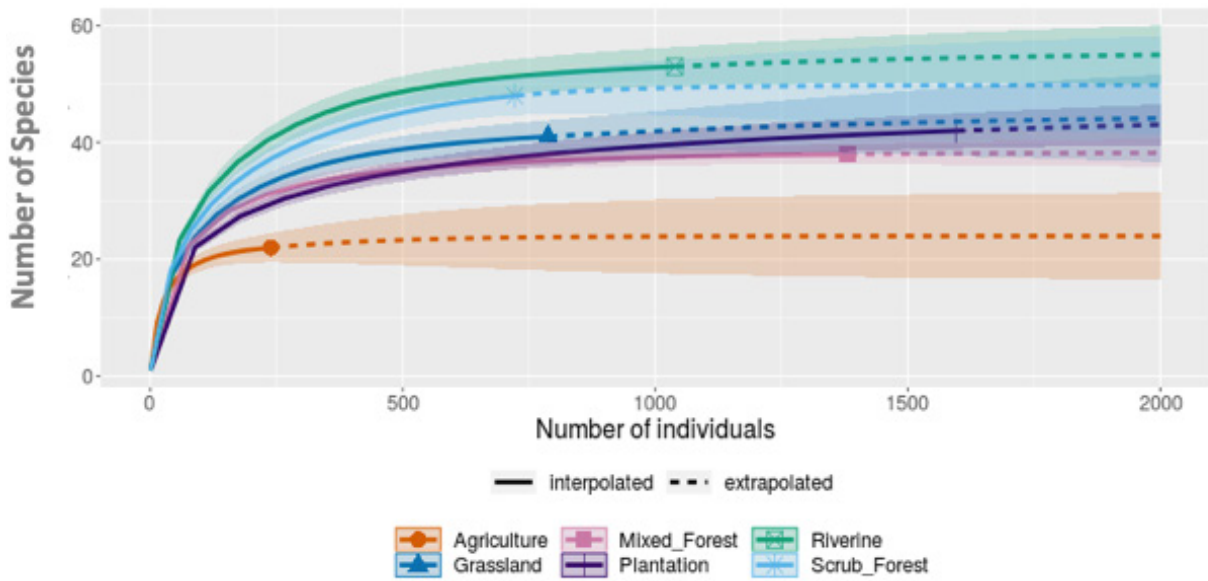
Habitat	No. of Point count	Man-Minutes	Summer (10 replications)	Winter (10 replications)
Plantation	28	280	2800	2800
Mixed deciduous forest	15	150	1500	1500
Scrub forest	12	120	1200	1200
Riverine	25	250	2500	2500
Grassland	21	210	2100	2100
Agriculture field	15	150	1500	1500

Appendix Table 4. Diversity metrics during summer and winter season at Jhilmil Jheel Conservation Reserve.

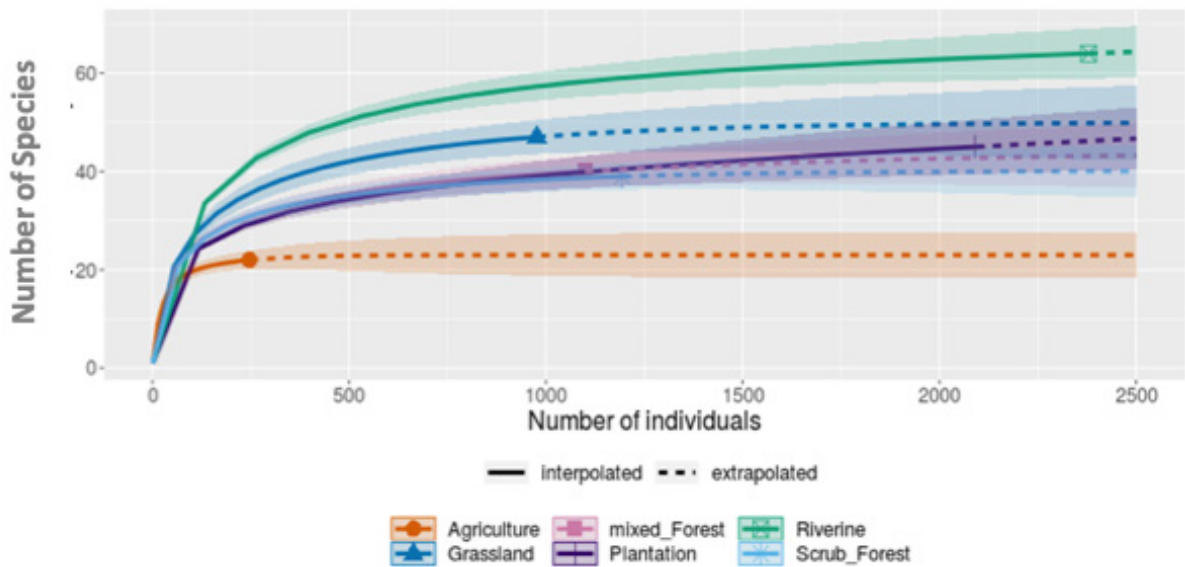
Season	Diversity Metrics	Value	Lower limit	Upper limit
Summer	Shannon_H	3.81	3.78	3.84
	Evenness_e^H/S	0.41	0.40	0.42
Winter	Shannon_H	3.99	3.96	4.02
	Evenness_e^H/S	0.39	0.38	0.40

Appendix Table 5. PERMANOVA of vertical stratification at Jhilmil Jheel Conservation Reserve.

PERMANOVA (summer)		PERMANOVA (winter)
Permutation N:	9999	9999
Total sum of squares:	23.77	31.37
Within-group sum of squares:	10.25	17.22
F:	29.04	18.26
p (same):	0.0001	0.0001



Appendix Figure 1a. Rarefaction curve for summer season.



Appendix Figure 1b. Rarefaction curve for winter season.





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– Minh Thi Anh Nguyen, Thuy Thi Bich Vo, Quy Tan Le, Vy Tran Nguyen, Vu Linh Nguyen, R.J. Timmins & Anthony J. Giordano, Pp. 28739–28749

**Rapid camera-trap assessment of mammals in Tripura, India: new records and implications for conservation**  
– Omkar Patil, Ashutosh Joshi, Rutuja Digaskar & Amey Parkar, Pp. 28750–28769

**Distribution, habitat use, and abundance of the Caracal *Caracal caracal* (Schreber, 1776) (Mammalia: Carnivora: Felidae) in a semi-arid Indian landscape**  
– Mohammad Mairaj, Dhruv Jain, Ramanand Bhakar & Ayan Sadhu, Pp. 28770–28783

**Avian richness and habitat selection patterns in Jhilmil Jheel Conservation Reserve, Uttarakhand, India**  
– Ankita Das, Soumya Dasgupta & Ramesh Krishnamurthy, Pp. 28784–28806

**Herpetofauna of the Chitwan-Annapurna Landscape, Nepal: a comprehensive species checklist including occurrence in protected areas, with suggested conservation recommendations**  
– Santosh Bhattarai, Bishal Prasad Neupane, Bivek Gautam, Prabin Shrestha, Ashley R. Olson, Fiona Hogan & Wendy Wright, Pp. 28807–28829

**Dietary assessment of tadpoles of selected rhacophorid frogs (*Polypedates*, *Rhacophorus*, *Zhangixalus*) (Amphibia: Anura: Rhacophoridae) of Kangchup, Manipur, India**  
– Yumkham Shelina Devi & Saibal Sengupta, Pp. 28830–28837

**Eastern range record of the semiaquatic freshwater earthworm *Glyphidrilus gangeticus* Gates, 1958 (Clitellata: Crassicitellata: Almidae) from West Bengal, India, with a brief key to the Indian species of the genus**  
– M. Nurul Hasan, John Warren Reynolds, Hasko F. Nesemann, Shyamasree Ghosh & Chandra Kanta Mandal, Pp. 28838–28844

**Succession of biofouling organisms on structural materials and their environmental drivers off the Kalpakkam coast, India**  
– Bandita Badakumar, D. Inbakandan & P. Sriyutha Murthy, Pp. 28845–28861

**Addition of five lesser known angiosperm species from Mizoram, India**  
– R. Lalthantluanga, Dorothy Lalbiakhluni, Vanlalawmpuia Sailo, Rose Laldinaii Darnei, R. Lalhruaitluangi, Sanatombi Devi Yumkham & Sandhyarani Devi Khomdram, Pp. 28862–28873

**Legislative and evidentiary challenges faced by the Indian law enforcement agencies in social media-enabled wildlife offences**  
– Pradipty Bhardwaj, Jayadevan S. Nair & H.V. Girisha, Pp. 28874–28885

## Communications

**Occurrence and prevalence of gastrointestinal parasites in herbivores in Dampa Tiger Reserve, Mizoram, India**  
– G.S. Solanki, Lalrinkimi & Phoebe Lalremruati, Pp. 28886–28893

**Theileriosis in a captive Indian Gaur *Bos gaurus*: a rare encounter**  
– Kaushal Kumar, Vishal Kumar Sinha, Deepak Kumar, Imran Ali, Ramesh Tiwary, Pankaj Kumar & Amit Kumar, Pp. 28894–28899

**Avifaunal diversity in agroecosystems: a case study from Uttar Pradesh, India**  
– Fatima Khan & Kaleem Ahmed, Pp. 28900–28910

**First record of the Sistan Sand Boa *Eryx sistansensis* Eskandarzadeh et al., 2020 (Reptilia: Serpentes: Erycidae) from India**  
– Vivek Sharma & Dharmendra Khandal, Pp. 28911–28918

**Population dynamics and habitat assessment of Indian Flapshell Turtle *Lissemys punctata vittata* (Reptilia: Testudines: Trionychidae) in Chawandiya, Rajasthan, India**  
– Mahaveer Prasad Vaishnav & Amol Arora, Pp. 28919–28925

**A preliminary checklist of dragonflies and damselflies (Insecta: Odonata) of Kanyakumari District, Tamil Nadu, India**  
– V. Muthukrishnan, Anand Shibu, Vinod Sadhasivan & R. Amirtha Balan, Pp. 28926–28939

**Documentation of dicotyledonous angiosperm diversity of Kanakamala, Kerala, India**  
– Marunnoli Umaiba Fitha & Puravannoor Edakkad Sreejith, Pp. 28940–28949

**Diversity of dye-yielding plants traditionally used by ethnic communities of Assam, India**  
– Bhuvan Chandra Chutia, Hena Parbin, Abhijit Chandra Roy, Krishna Kanta Medhi & Utpal Bora, Pp. 28950–28956

## Review

**Ichthyofaunal diversity and conservation status of Nagaland, India: a comprehensive review**  
– Rejuba Pongen & Pranay Punj Pankaj, Pp. 28957–28970

## Short Communications

**Preliminary observations on the breeding ecology and potential threats to Bonelli's Eagle *Aquila fasciata* in Sithagiri Malai, Tamil Nadu, India**  
– S. Naveenkumar, H. Byju & H. Maitreyi, Pp. 28971–28975

**A nesting attempt by Greater Flamingo *Phoenicopterus roseus* in an inland wetland in Kachch District, Gujarat, India**  
– Gaurav Sirola, Harindra Baraiya, Rajdeep Mitra, Anju Baroth & R. Suresh Kumar, Pp. 28976–28981

**First time in 110 years: sighting of *Gynacantha khasiaca* MacLachlan, 1896 (Odonata: Aeshnidae) in Arunachal Pradesh, India**  
– R. Mahesh, Rajesh Gopinath, Gaurav Joshi & Roshan Upadhaya, Pp. 28982–28987

## Notes

**Evidence of Rusty-spotted Cat *Prionailurus rubiginosus* (L. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in National Chambal Sanctuary, Uttar Pradesh, India**  
– Anshoo Nishad, Hiyashri Sarma, Rajib Saha, Vijay Pratap Singh, Maneesha Bhatt, Atit Rai, Qamar Qureshi & Vishnupriya Kolipakam, Pp. 28988–28990

**First photographic record of Naumann's Thrush *Turdus naumanni* Temminck, 1820 from Assam, India**  
– Pulakeswar Basumatary, Pp. 28991–28994

**New breeding record of Black-headed Ibis *Threskiornis melanocephalus* from Malappuram District, Kerala, India**  
– K.K. Junaina & A.P. Rashiba, Pp. 28995–28997

**From the heart of Urad: records of *Cyrtodactylus bapme* Kamei & Mahony, 2021 (Reptilia: Squamata: Gekkonidae) from Assam, India, with comments on the pre-loocal region in males**  
– Manmath Bharali, Pranjal Swargiary, Tejas Mariswamy, Madhurima Das, Jayaditya Purkayastha & Sanath Chandra Bohra, Pp. 28998–29002

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