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Bird Diversity and Composition across Different Habitat Types in Chittaranjan, West Bengal, India

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ABSTRACT
Anthropogenic pressures and urbanization significantly impact biodiversity patterns, profoundly affecting bird communities and their ecological functions. However, heterogeneous urban landscapes can support considerable avian diversity. To inform sustainable urban planning strategies, this study examined bird diversity across various habitat types in Chittaranjan township, West Bengal, India. Between February and May 2021, surveys recorded 112 bird species across 20 orders and 47 families. Of these, 84 species (3,331 individuals) were documented during point count surveys along road networks distributed among four habitat types: water bodies (WB), open shrub lands (OS), tree cover areas (TC), and built-up areas (BA). Initial analyses revealed the highest species richness in water bodies (54 species) followed by open shrub lands (48), tree cover (42), and built-up areas (36). However, rarefaction analysis indicated significant sampling bias, particularly in water bodies, where rarefied richness was reduced to 27.18 species. In contrast, open shrub lands retained high species richness (47.77) after rarefaction, signifying greater avian diversity independent of sampling effort. The tree cover and built-up areas exhibited rarefied richness values consistent with their raw diversity metrics. The Shannon-Wiener indices were comparable across terrestrial habitats (H' = 3.13-3.28) but significantly lower in water bodies (H' = 1.52) due to low evenness (J' = 0.08) and dominance by a few species, particularly *Dendrocygna javanica, Microcarbo niger*, and *Tadorna ferruginea*. Feeding guild analysis indicated that insectivores were the most species-rich group (39 species), while omnivores dominated numerically across all habitats, particularly in water bodies (86.7%). Most species (76) were residents, with 29 being winter visitors. Conservation assessments highlighted three species of concern: the Near Threatened *Palaeornis eupatria* and *Falco chicquera* and the Vulnerable *Aythya ferina*. The findings underscore the necessity of preserving habitat heterogeneity to maintain avian diversity in small urban landscapes, ensuring connectivity and managing invasive species that impact avian foraging and ecosystem health.

Key words: Urban avifauna, Bioindicators, Avian ecology, Species composition, Rarefaction analysis, Sustainable planning

INTRODUCTION

Cowie et al. (2022) assert that anthropogenic pressure has sparked the onset of Earth's sixth mass extinction event, resulting in a significant loss of biodiversity. This profound decline in biodiversity is driven by multiple factors operating at various trophic levels, both directly and indirectly. Key contributors include habitat loss and destruction, climate change, illegal harvesting, environmental pollution, and the invasion of alien species (Zhao et al. 2023, Anonymous 2023). The degradation of natural vegetation poses a considerable threat to many wild plant species, further diminishing habitats for fauna across the globe. This degradation is primarily attributed to increasing urbanization and agricultural expansion, which have become essential to support the growing human population worldwide. To design, plan, and manage more biodiverse urban areas, it is crucial to understand the relationships between biodiversity and the various forms of urbanization (Francis and Lorimer 2011, Soga et al. 2014). Urban populations heavily depend on scattered patches of natural vegetation within cities to maintain a connection with nature, promote a pollution-free environment, and conserve plants, wildlife, and microbial species in those areas (Thompson et al. 2022). While urbanization can homogenize landscape structures and patterns, thereby reducing diversity among native species, integrating human development with natural areas can also enhance landscape heterogeneity, fostering greater biodiversity and abundance in certain species (Lewis et al. 2015). Moreover, Stein et al. (2014) found a positive relationship between

environmental heterogeneity and species richness, indicating that it promotes species diversity by expanding niche space, providing refuges, and facilitating speciation.

Avian communities have long been recognized as bio-indicators of urbanization's impact on biodiversity within wildlife groups (Karjee et al. 2022, Fontana et al. 2011, Thompson et al. 2022). Birds offer various ecosystem services in urban green spaces, including seed dispersal, pollination, and pest control in urban forests and agricultural areas (Xu et al. 2022). The quality of a habitat can be assessed and managed by observing avian community responses to differing habitat structures and considering their representation of various trophic groups or guilds (Chettri et al. 2005, Anonymous 2023). Avian communities' prevalence, high detectability, and well-established phylogenetic relationships have made birds a focus of urban ecological research (Diaz et al. 2022). Urban avian communities are typically characterized by the dominance of a limited number of species, which may include introduced species. Their preferences often lean towards granivores, omnivores, and cavity-nesting species (Suarez-Rubio et al. 2023). Research indicates that avian communities in smaller cities and towns differ from those in larger urban centers (Sorace and Gustin 2010, Ferenc et al. 2014). Clergeau et al. (2006) observed a declining trend in avian species richness moving from peri-urban and suburban areas toward central urban regions, resulting in a greater prevalence of habitat specialist bird species in these central zones. Fontana et al. (2011) suggested that increasing tree cover within the urban matrix is the most promising and effective strategy to enhance bird species richness and diversity in urban settings. This study examined avian diversity and community structure across various habitat types in Chittaranjan township, West Bengal, India. The results provide valuable baseline data for developing sustainable management strategies to conserve bird communities and their ecological functions in small urban landscapes.

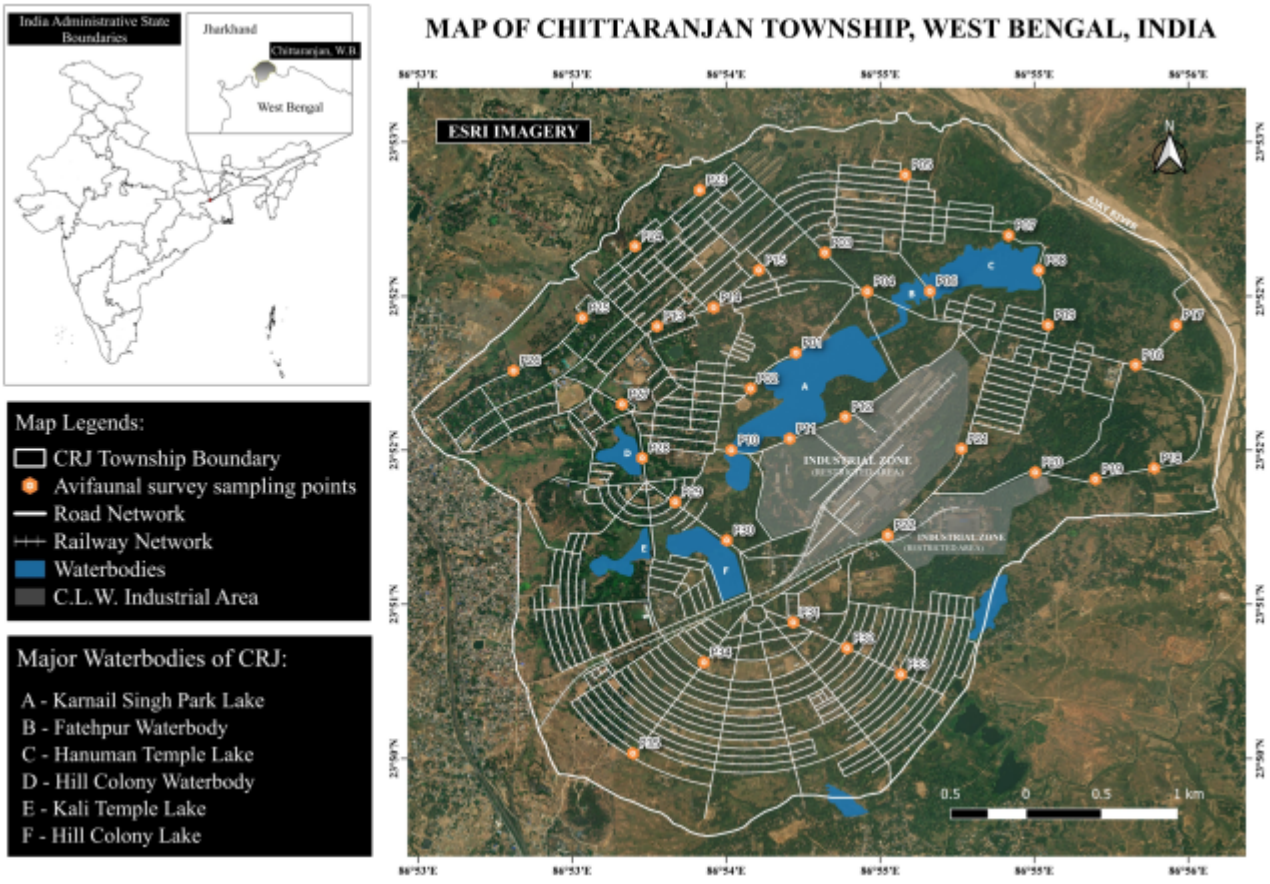

Figure 1. Study area map showing all 35 bird sampling point count locations overlaid on road networks

MATERIAL AND METHODS

Study area

An avifaunal survey was conducted in Chittaranjan township, situated between coordinates 86°54'42.05" - 86°53'55.72" N and 23°52'54.73" - 23°50'5.64" E (Fig. 1). This township is located in the Paschim Bardhaman district of West Bengal, Eastern India, at an elevation of 155 m amsl. The region experiences a tropical climate characterized by a hot and humid summer, with temperatures soaring to 37°C. Following this is a humid monsoon season averaging 32°C and a relatively cool winter with temperatures around 16°C, leading to an average annual temperature of 32°C. The winter season spans from November to February, summer from March to June, and the monsoon season from July to October. The area receives an average annual rainfall of 1400 mm. Chittaranjan Township encompasses approximately 18.34 km² and has a population of 39,098 (Anonymous 2011). The township features a variety of habitat types that support diverse bird communities, including built-up residential and administrative zones with landscaped areas, open shrub lands, regions of natural tree cover, and several wetlands ranging from small to large.

The representative tree species belong to the families Annonaceae, Moraceae, Fabaceae, Combretaceae, Cornaceae, Apocynaceae, Arecaceae, Rubiaceae, Rhamnaceae, Lythraceae, Anacardiaceae, Myrtaceae, Rutaceae, and Meliaceae. Native shrubs in the region include *Vitex negundo*, *Clerodendrum trichotomum*, *Clerodendrum indicum*, and *Calotropis gigantea*. Invasive shrubs, such as *Chromolaena odorata*, *Lantana camara*, and *Cascabela thevetia*, are prevalent in natural vegetation patches and suburban green spaces. Aquatic weed species dominate wetland areas, including *Eichhornia crassipes* and *Ludwigia adscendens*.

The wildlife and feral mammalian species observed in the township include *Macaca mulatta*, *Semnopithecus entellus*, *Sus scrofa*, *Urva auropunctata*, *Canis aureus*, *Lepus nigricollis*, *Suncus murinus*, *Hystrix indica*, *Funambulus palmarum*, and *Pteropus medius*.

We identified four habitat types for avifaunal sampling in the study area: tree covers (TC), built-up areas (BA), water bodies (WB), and open shrub lands (OS) (Table 1).

Field survey and avifaunal sampling

Avifaunal diversity and abundance were evaluated utilizing the point count method from February to May 2021 (Bibby et al. 2000, Sutherland et al. 2004). Reference data from Google Maps was employed to digitize all road networks within Chittaranjan township as line features using the vector creation tools in QGIS (Version 3.34.10 'Prizren'). A total of 35 random sampling points were subsequently generated along this road network utilizing random point generation tools (Fig. 1). The sampling points were spaced 400 m apart to reduce spatial auto-correlation and minimize the potential for double counting. Among the 35 sampling points, 11 were in tree cover areas, 9 in residential zones, 7 near water bodies, and 8 in open shrub lands. For habitats surrounding water bodies, sampling point counts were performed along the edges of reservoirs following standard protocols (Bibby et al. 2000). Each sampling point was visited twice during the survey to enhance data reliability. Given the variability in detecting birds across different habitat types, bird sightings were recorded in concentric zones around the point, up to the visible limit from the observer, for 10 minutes at each location. Birds were identified in the field using standard field guides for Indian birds (Grimmett et al. 2016, Grewal et al. 2018). All birds identified as individuals, based on visual or auditory cues, with clear evidence of utilizing the habitat, were included in the count. Surveys were conducted during peak bird activity periods: four hours after sunrise and four hours before sunset, with no surveys performed under adverse weather conditions. Opportunistic bird sightings between sampling points were documented for the final bird checklist but were not included in the analysis. Additionally, overflying birds were excluded from the counts.

Diversity analysis and community structure

The avian community structure was analyzed using various diversity indices, including the Shannon Diversity Index (H'), Evenness (J'), Margalef Richness (D_{Mg}), Equitability (J), Simpson 1-D Index (D'), all implemented through the 'BiodiversityR' package in R version 4.4.2. Additionally, rank

Table 1. Description of the different habitat types and their vegetation characteristics in the study area.

Habitat	Points	GPS coordinates		Vegetation characteristics
		Lat (N)	Long (E)	
Tree cover	P03	23° 52' 22.19"	86° 54' 23.08"	Characterized by both natural and artificial tree plantations featuring tree species such as *Albizia saman*, *Albizia lebbeck*, *Terminalia arjuna*, *Senna siamea*, *Peltophorum pterocarpum*, *Pithecellobium dulce*, *Delonix regia*, *Mitragyna parviflora*, *Butea monosperma*, *Bismarckia nobilis*, *Ziziphus mauritiana*, *Ziziphus spina-christi*, *Plumeria alba*, *Pongamia pinnata*, *Cassia fistula*, *Dalbergia sissoo*, *Ficus religiosa*, *Mangifera indica*, *Monoon longifolium, Pongamia pinnata*, *Ficus racemosa*, *Syzygium cumini*, *Suregada multiflora, Streblus asper, Eucalyptus globulus*, *Ficus benghalensis*, *Azadirachta indica*, and *Borassus flabellifer*
	P04	23° 52' 13.12"	86° 54' 33.01"	
	P07	23° 52' 26.22"	86° 55' 6.06"	
	P12	23° 51' 43.81"	86° 54' 27.83"	
	P18	23° 51' 31.82"	86° 55' 40.04"	
	P19	23° 51' 29.23"	86° 55' 26.29"	
	P20	23° 51' 30.85"	86° 55' 12.25"	
	P22	23° 51' 16.16"	86° 54' 37.8"	
	P25	23° 52' 6.96"	86° 53' 26.38"	
	P26	23° 51' 54.61"	86° 53' 10.32"	
	P27	23° 51' 46.8"	86° 53' 35.66"	
Built-up area	P09	23° 52' 5.27"	86° 55' 15.24"	Built-up residential areas and administrative blocks comprising tree species such as *Mangifera indica*, *Polyalthia longifolia*, *Phoenix sylvestris, Artocarpus heterophyllus, Psidium guajava, Aegle marmelos, Ficus racemosa*, *Aegle marmelos*, *Syzygium cumini*, *Azadirachta indica*, *Dalbergia sissoo*, *Ziziphus mauritiana*, and *Roystonea regia*
	P13	23° 52' 5.02"	86° 53' 43.87"	
	P24	23° 52' 23.74"	86° 53' 38.72"	
	P29	23° 51' 23.9"	86° 53' 48.12"	
	P31	23° 50' 55.79"	86° 54' 15.7"	
	P32	23° 50' 49.78"	86° 54' 28.26"	
	P33	23° 50' 43.66"	86° 54' 40.86"	
	P34	23° 50' 46.46"	86° 53' 54.82"	
	P35	23° 50' 25.22"	86° 53' 38.22"	
Water bodies	P01	23° 51' 58.79"	86° 54' 16.31"	Waterbodies containing aquatic flora such as *Eichhornia crassipes*, *Ludwigia adscendens*, and *Nymphaea* spp.
	P06	23° 52' 13.19"	86° 54' 47.63"	
	P08	23° 52' 18.12"	86° 55' 13.08"	
	P10	23° 51' 36.04"	86° 54' 1.22"	
	P11	23° 51' 38.74"	86° 54' 14.87"	
	P28	23° 51' 34.2"	86° 53' 40.38"	
	P30	23° 51' 14.98"	86° 54' 0.14"	
Open shrub lands	P02	23° 51' 50.47"	86° 54' 5.72"	Small to large patches of land with scattered trees, predominantly covered with grasses and native shrubs such as *Vitex negundo*, *Clerodendrum trichotomum*, *Clerodendrum indicum*, and *Calotropis gigantea*, also including invasive shrubs such as *Lantana camara*, *Chromolaena odorata*, and *Cascabela thevetia*
	P05	23° 52' 40.3"	86° 54' 41.87"	
	P14	23° 52' 9.37"	86° 53' 57.08"	
	P15	23° 52' 18.16"	86° 54' 7.63"	
	P16	23° 51' 55.94"	86° 55' 35.69"	
	P17	23° 52' 5.23"	86° 55' 45.23"	
	P21	23° 51' 36.36"	86° 54' 55.01"	
	P23	23° 52' 36.77"	86° 53' 53.84"	

abundance plots were created using the 'vegan' package to assess bird species abundance distributions and visualize species dominance patterns across different habitat types. This analysis facilitates a comparative examination of community structure among various habitats.

Assessing sampling efforts across habitats

Species accumulation curves were generated using the 'vegan' package to evaluate the sampling efforts

across different habitat types. This was based on site-by-species abundance matrices created for each habitat type individually. The `specaccum()` function was utilized with the random method and 100 permutations to estimate the average species richness and the associated standard deviation as a function of sampling effort, which refers to the number of sampling points.

Standardizing sampling bias using rarefaction analysis

To address variations in sampling effort across different habitat types, we conducted a rarefaction analysis utilizing the 'vegan' package in R. We created a community matrix containing species abundance data for each habitat using the 'dplyr' and 'tidyr' packages. The sampling effort was standardized to the lowest number of individuals observed across habitats (320) by employing the 'rarefy' function in 'vegan', following Gotelli and Colwell (2001). This approach estimates the expected species richness under equal sampling effort, enabling unbiased diversity comparisons across habitats. We calculated raw and rarefied species richness values to evaluate the impact of sampling bias on the observed diversity patterns.

Feeding guild, migratory status, population trend and IUCN category

In this study, we adopted a simplified food guild classification based on the diverse feeding habits observed in Indian birds. We categorized the birds into various guilds according to their primary feeding behaviours: carnivorous/piscivorous (C/P), frugivorous (F), granivorous (G), omnivorous (O), herbivorous (H), insectivorous (I), and nectarivorous (N). This classification of feeding guilds is derived from standard references (Anonymous n.d.). Information regarding the seasonality and migratory status of the birds identified within the study area was obtained from established field guides (Grimmett et al. 2016, Grewal et al. 2018). Additionally, the global population trends and conservation status of the birds were sourced from the IUCN Red List website (Anonymous 2025).

RESULTS

Species richness, abundance and diversity indices

During the survey period, a total of 112 bird species were recorded, belonging to 20 orders and 47 families, which includes observations from both the point count survey and opportunistic sightings (Appendices I and II). Focusing on the species identified solely during the point count sampling, we documented 3,331 individual birds representing 84 species across 18 orders and 41 families within all four habitat types. The highest avian richness was noted in water bodies, with 54 species, although bird evenness was low (J' = 0.08), characterized by a few dominating species. Areas with tree cover exhibited greater bird richness (42 species) compared to built-up areas (36 species), but both habitats demonstrated similar intermediate levels of species evenness (J' = 0.54 and 0.55, respectively). Open shrub lands recorded a bird richness of 48 species, surpassing tree cover and built-up areas, with an evenness value of J' = 0.62. The Shannon–Wiener Index revealed almost identical values across the three terrestrial habitats: tree cover (H' = 3.13), built-up areas (H' = 3.12), and open shrub lands (H' = 3.28), with water bodies registering the lowest value (H' = 1.52). Additionally, the Simpson Index (1-D) reflected that built-up areas and open shrub lands had the same diversity score (D' = 0.94), slightly higher than that of tree cover (D' = 0.93). In comparison, water bodies exhibited a lower diversity score (D' = 0.50) (Table 2).

Rank-abundance

A total of 3,331 individuals representing 84 bird species were recorded during the point count survey. This included 2,332 individuals in WB (70%), 320 in TC (9.61%), 320 in BA (9.61%), and 359 in OS (10.78%). The most dominant species in the water bodies were the Lesser Whistling-Duck (*Dendrocygna javanica*), Little Cormorant (*Microcarbo niger*), and Ruddy Shelduck (*Tadorna ferruginea*) (Fig. 2). In contrast, terrestrial habitats were primarily occupied by generalist bird species such as the Jungle Babbler (*Argya striata*), Common Myna (*Acridotheres tristis*), Indian Pied Starling (*Gracupica contra*), Rose-ringed Parakeet (*Psittacula krameri*), Eurasian Collared Dove

Table 2. Bird diversity profiles across different habitat types in Chittaranjan, West Bengal

Diversity profiles	Open shrub land	Built-up areas	Tree cover	Water bodies
Taxa	48	36	42	54
Individuals	359	320	320	2332
Simpson (1-D)	0.94	0.94	0.93	0.50
Shannon (H')	3.28	3.12	3.13	1.52
Margalef Richness (D_{Mg})	7.99	6.07	7.10	6.83
Evenness (J')	0.55	0.63	0.54	0.08
Equitability (J)	0.85	0.87	0.84	0.38
Dominance (D)	0.06	0.06	0.07	0.50

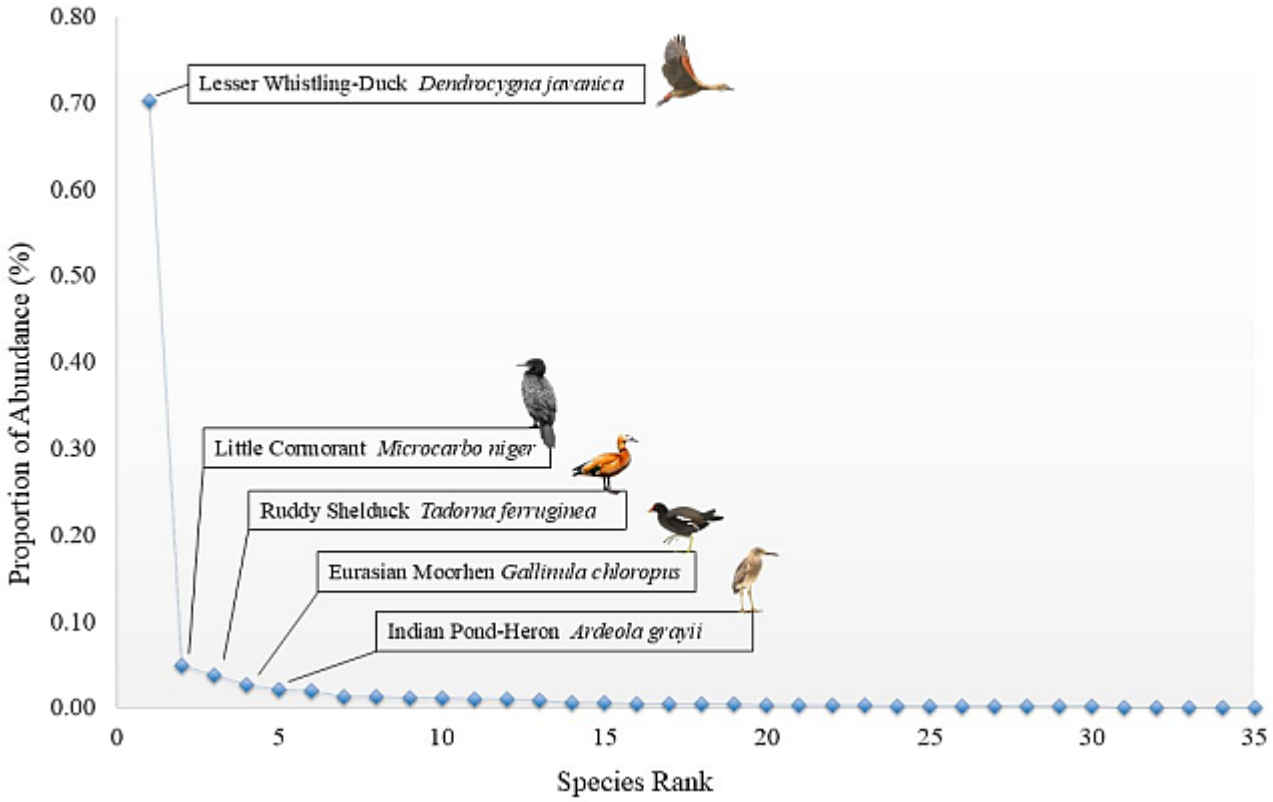

Figure 2. Species rank abundance plot for the water body habitat in Chittaranjan

(*Streptopelia decaocto*), and House Crow (*Corvus splendens*) (Fig. 3). These species, recognized for their adaptability, thrive in diverse environments, including both urban and rural areas, often capitalizing on human-altered landscapes and resources.

Species accumulation curve by habitat

The species accumulation curve revealed distinct patterns of species richness among the four habitat types (Fig. 4). Tree cover displayed the steepest curve and the highest asymptote, indicating the greatest species richness and a relatively high rate of species discovery as sampling effort increased. In contrast, built-up areas exhibited a much flatter curve with an early plateau, suggesting limited species diversity and diminished returns from additional sampling. Open shrub lands and water bodies demonstrated intermediate patterns, showcasing moderate accumulation rates and species richness, which reflect their transitional or resource-dependent roles in supporting avian diversity.

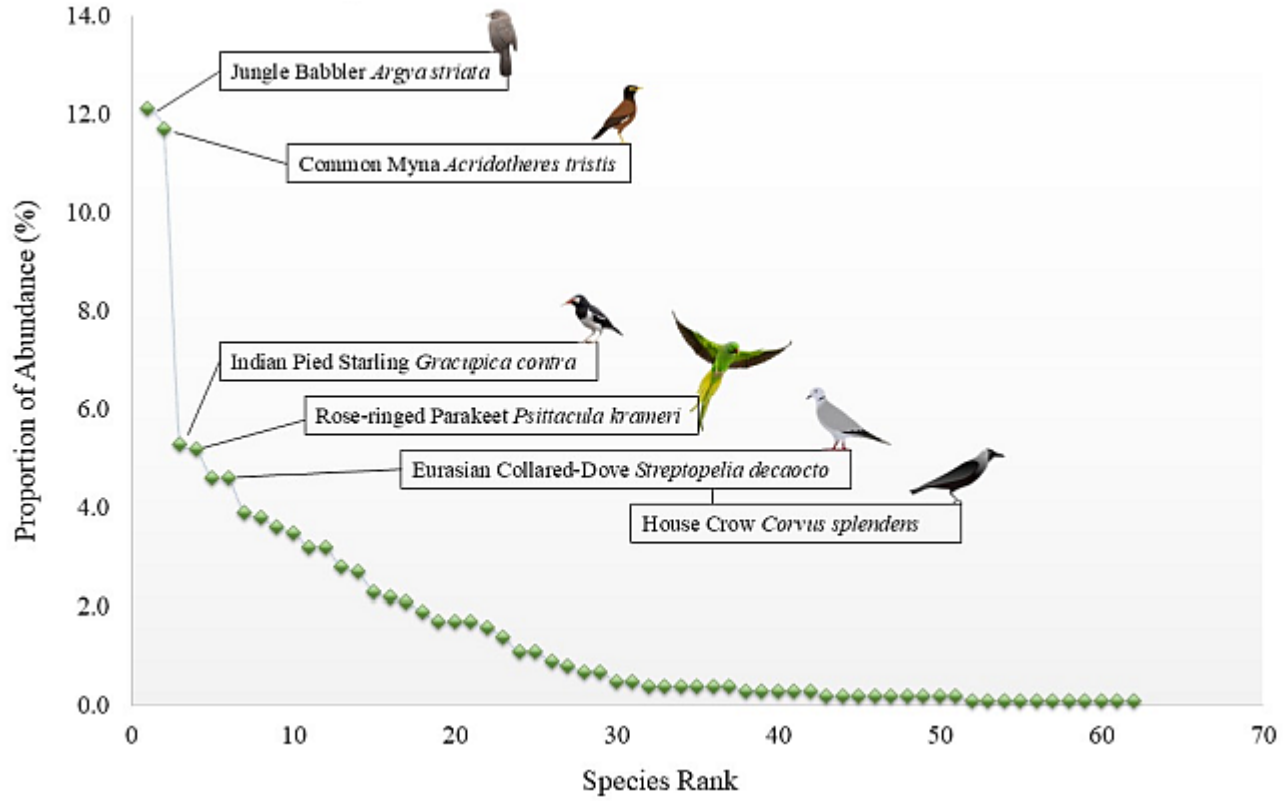

Figure 3. Species rank abundance plot for the terrestrial habitat in Chittaranjan

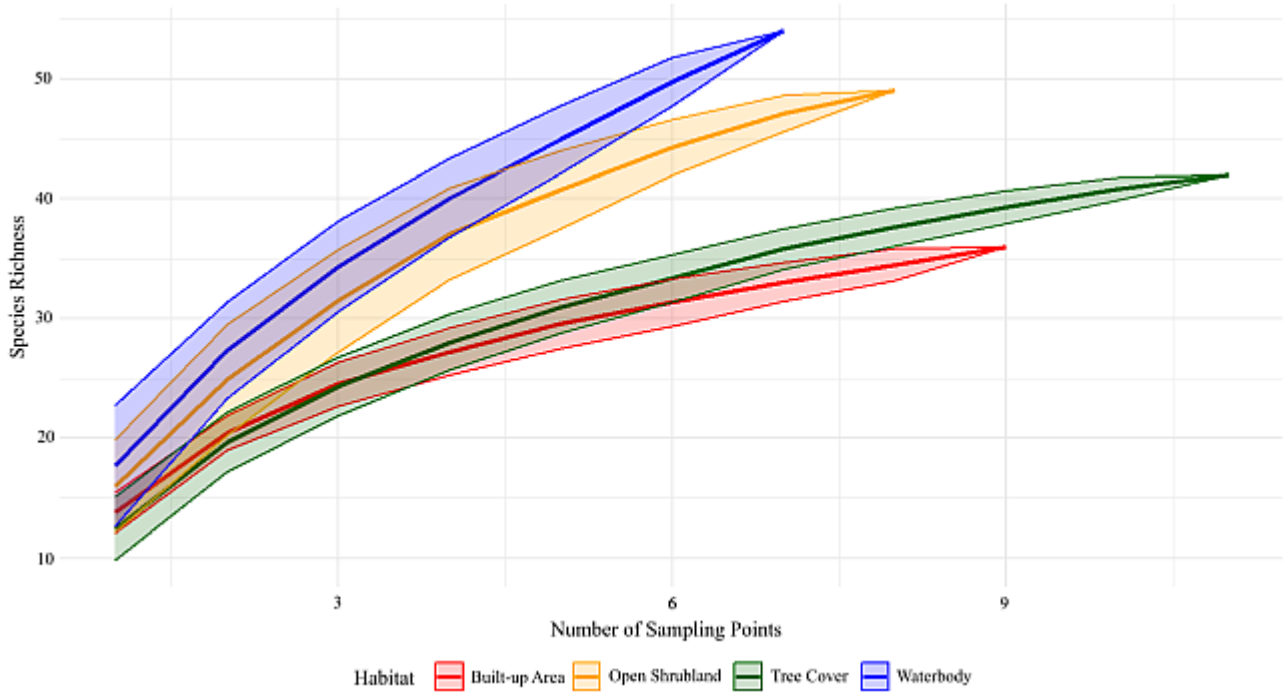

Figure 4. Species accumulation curves by habitat types

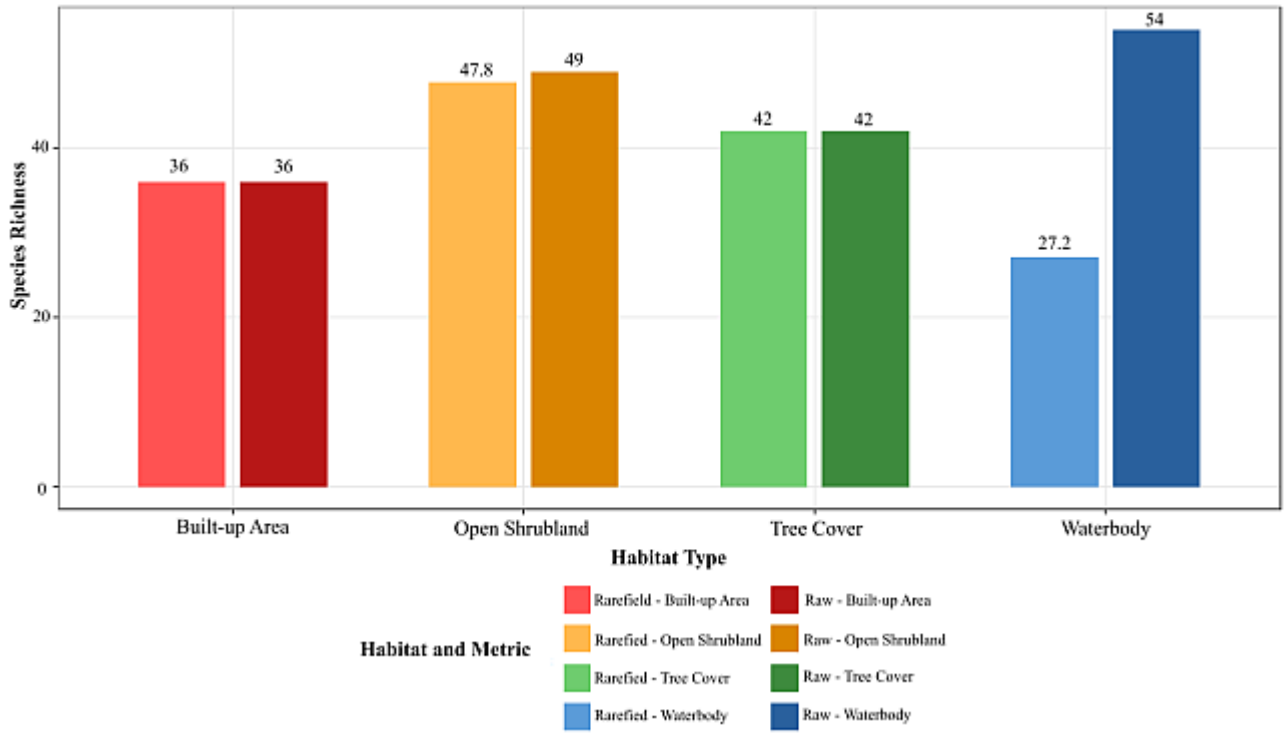

Figure 5. Comparison of raw and rarefied species richness by habitat

Rarefaction analysis for standardizing sampling bias

Rarefaction analysis revealed notable differences in avian species richness across various habitat types after controlling for sampling effort (Fig. 5). Although water bodies exhibited the highest observed species richness (n = 54), their rarefied richness significantly declined to 27.18 after standardization of sampling effort. This suggests that the initially high diversity metric was mainly due to sampling intensity rather than the intrinsic characteristics of the habitat. In contrast, Open shrub land retained high species richness values post-rarefaction, with the rarefied estimate (47.77) closely aligning with the raw observation value (49). This indicates genuinely higher avian diversity that is independent of sampling effort. Tree cover and built-up areas, both with equal sample sizes (320 individuals per habitat), exhibited rarefied richness values that were consistent with their raw diversity metrics (42 and 36, respectively), confirming that these estimates accurately reflect the relative avian diversity patterns between these habitat types without the influence of sampling bias.

Feeding guilds and migratory status

During the survey, 112 bird species were recorded and categorized into seven feeding guilds. The insectivores emerged as the most diverse group, comprising 39 species, followed by omnivores with 33 species and carnivores/piscivores with 21 species. Nine species represented frugivores, while granivores and herbivores included four species each. Only two nectarivorous species were observed: the Purple Sunbird (*Cinnyris asiaticus*) and the Purple-rumped Sunbird (*Leptocoma zeylonica*). An analysis of the abundance of 84 bird species identified during point count surveys revealed distinct distributions of feeding guilds across different habitat types. In aquatic environments, omnivores dominated, accounting for 86.7% of the bird population, followed by carnivores/piscivores at 10.2% and insectivores at 2.1%. Frugivores and herbivores collectively represented just 1% of birds in these habitats. However, terrestrial habitats exhibited greater feeding guild heterogeneity, with omnivores accounting for 51.5% of the bird population alongside a more diverse arry of other feeding guilds. Insectivores comprised 18% of the terrestrial bird population, followed by frugivores at 14.7%,

granivores at 9.6%, nectarivores at 3.6%, and carnivores/piscivores at 2.6%. Most bird species (76 species) were classified as residents in the study area, followed by winter visitors (29 species). Only one species, the Asian Brown Flycatcher (*Muscicapa dauurica*), was identified as an autumn/spring visitor. In comparison, two species, the Black-headed Ibis (*Threskiornis melanocephalus*) and the Indian Golden Oriole (*Oriolus kundoo*), were considered summer/monsoon visitors. Additionally, the seasonal patterns of four bird species - the Indian Gray Hornbill (*Ocyceros birostris*), Orange-breasted Green Pigeon (*Treron bicinctus*), Red-necked Falcon (*Falco chicquera*), and Slender-billed Oriole (*Oriolus tenuirostris*) - remained undetermined in the study area.

Conservation status and population trend

Based on the IUCN Red List, a total of 108 bird species occurring in the study area are classified as Least Concern (LC). Additionally, two species - the Alexandrine Parakeet (*Palaeornis eupatria*) and the Red-necked Falcon (*Falco chicquera*) - are designated as Near Threatened (NT), while the Common Pochard (*Aythya ferina*) is categorized as Vulnerable.

DISCUSSION

Sustainable planning is crucial in the rapid urbanization occurring worldwide, particularly in small urban and suburban areas. To maintain avian diversity in these regions, it is essential to foster habitat heterogeneity in terms of type and structure (Dong et al. 2023). Species richness increases when various habitat types remain interconnected, avoiding isolation in small urban environments (Evans et al. 2009). Our study identifies distinct patterns of avian community structure across four habitat types in Chittaranjan, offering valuable insights into habitat-specific biodiversity dynamics and the ecological implications of habitat heterogeneity within small urban landscapes. The significant variations in species richness, evenness, and functional guild composition among different habitats highlight the ecological complexity of these environments and their differing abilities to support avifaunal diversity.

Habitat-specific diversity patterns

The initial analysis of raw species richness data indicated that water bodies are biodiversity hotspots, hosting 54 species, followed by open shrub lands with 48 species, tree cover areas with 42 species, and the built-up regions with 36 species. However, our rarefaction analysis uncovered significant sampling bias, particularly regarding water bodies, where the standardized species richness dropped notably from 54 to 27.18 species. This finding underscores the critical importance of standardizing sampling efforts when comparing habitats with varying sampling intensities (Gotelli and Colwell 2001). In contrast, open shrub lands retained a high species richness of 47.77 even after rarefaction, suggesting a genuinely greater avian diversity not influenced by sampling effort. The Shannon-Wiener diversity indices reinforce these patterns, revealing comparable diversity values across terrestrial habitats (H' = 3.13–3.28) while showing significantly lower diversity in water bodies (H' = 1.52). This difference is primarily due to the low evenness (J' = 0.08) observed in water bodies, where the community is dominated by a few abundant species such as the Lesser Whistling-Duck (*Dendrocygna javanica*), Little Cormorant (*Microcarbo niger*), and Ruddy Shelduck (*Tadorna ferruginea*). Conversely, open shrub lands exhibited the highest evenness (J' = 0.62) among all habitats, indicating a more equitable distribution of individuals across species.

Ecological implications of species accumulation and community structure

The species accumulation curves provide valuable insights into sampling effectiveness and habitat-specific diversity patterns. Areas with tree cover displayed the steepest curves and the highest asymptote, indicating considerable species richness and ongoing potential for species discovery with further sampling efforts. This trend suggests that tree cover areas likely offer a complex vertical structure and a variety of microhabitats that can support diverse avian assemblages (MacArthur and MacArthur 1961). In contrast, built-up areas exhibited a flatter curve with an early plateau, reflecting lower species diversity and diminished returns from additional sampling. This pattern aligns with habitat simplification commonly associated with

urbanization (McKinney 2008). The rank-abundance distributions reveal a distinct ecological signature of urban adaptation across terrestrial habitats. The prevalence of generalist species such as the Jungle Babbler (*Argya striata*), Common Myna (*Acridotheres tristis*), Indian Pied Starling (*G racupica contra*), and House Crow (*Corvus splendens*) in these areas aligns with the biotic homogenization hypothesis. This hypothesis suggests that urbanization promotes community convergence by proliferating adaptable, human-commensal species (McKinney 2006, Le Viol et al. 2012, Kale et al. 2018, Pal et al. 2019). These species exhibit behavioural flexibility, dietary versatility, and tolerance to human disturbance, which allow them to exploit resources in landscapes altered by human activity (Sol et al. 2013).

Functional guild distribution and ecological processes

The distribution of feeding guilds across different habitats offers valuable insights into avian community structure and resource use. The high prevalence of omnivores in water bodies (86.7%) underscores the feeding habits of the dominant aquatic bird species and may point to a compromised trophic structure. The presence of invasive water hyacinth (*Eichhornia crassipes*) in these water bodies, noted during the survey, is likely to impact this pattern by modifying habitat structure and altering resource availability for more specialized foraging guilds (Villamagna and Murphy 2010). In contrast, terrestrial habitats exhibited a more balanced representation of feeding guilds, although omnivores still represented the majority (51.5%). The increased proportions of insectivores (18%) and frugivores (14.7%) in these areas suggest a greater diversity of available resources and a more effective niche partitioning. The relatively low numbers of specialized feeding guilds, such as nectarivores (<4%), may indicate competition from the more dominant generalist species (Whelan et al. 2015).

Conservation implications and anthropogenic impacts

While the majority of recorded species were classified as Least Concern (108 species), the presence of Near Threatened species, such as the Alexandrine Parakeet (*Palaeornis eupatria*) and the Red-necked Falcon (*Falco chicquera*), along with the Vulnerable Common Pochard (*Aythya ferina*), underscores the conservation significance of these habitats. Our observations of wetland degradation, particularly the spread of *Eichhornia crassipes*, raise considerable conservation concerns. This invasive species not only impedes the movement of water birds but also diminishes foraging efficiency (Basaula et al. 2021) and appears to cause direct mortality to both hatchlings and adult birds due to removal activities conducted by administrative authorities. Furthermore, the fish mortality observed in Karnail Singh Park Lake during the survey, primarily attributed to the overwhelming presence of *Eichhornia crassipes*, points to broader ecosystem impacts such as deoxygenation and altered thermal regimes (Getahun and Kefale 2023). These changes may disrupt aquatic food webs and adversely affect piscivorous birds. The significant proportion of resident species (76 species) compared to seasonal migrants (32 species) indicates that the study area provides year-round habitat resources. Nevertheless, the seasonal influx of winter visitors highlights the area's critical role in supporting broader migratory networks, reinforcing the necessity of maintaining habitat quality throughout the year.

CONCLUSIONS

This study highlights the importance of maintaining avian diversity in small urban landscapes through habitat heterogeneity and connectivity across various habitat types. A broader range of bird species can thrive by mimicking natural ecosystems by promoting habitat diversity with multi-layered greenery that includes trees, shrubs, and ground cover alongside undisturbed wetlands. Urban development should prioritize habitat mosaics over uniform built environments, emphasizing preserving native vegetation supporting specialist and generalist species. Conservation efforts must focus on maintaining the structural complexity of tree-covered areas and open shrublands, vital for diverse avian communities. Moreover, managing invasive vegetation in wetland and terrestrial environments is essential for restoring habitat functionality, especially for seasonal migrants. Habitat

management should be carefully planned and timed to minimize nesting species disruptions and incorporate monitoring protocols to evaluate bird responses to these management practices. Future research should encompass year-round sampling to capture seasonal dynamics, assess the effects of vegetation structure on bird diversity, and experimentally evaluate management interventions, particularly concerning invasive species control in aquatic environments. This integrated approach will enhance the ecological framework for sustainable urban planning in Chittaranjan and similar small urban landscapes, ultimately fostering more biodiversity-friendly urban settings.

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Appendix I. List of birds observed during the point count survey in Chittaranjan, West Bengal

	Species	Scientific name	Frequency of occurrence	Relative frequency (%)	Order	Family	Feeding guild	Seasonality in CRJ	Population trend	IUCN Red List category
1	Alexandrine Parakeet	*Palaeornis eupatria*	3	0.46	Psittaciformes	Psittaculidae	F	R	↓	NT
2	Ashy Drongo	*Dicrurus leucophaeus*	1	0.15	Passeriformes	Dicruridae	I	WV	?	LC
3	Ashy Prinia	*Prinia socialis*	5	0.77	Passeriformes	Cisticolidae	I	R	↔	LC
4	Ashy Woodswallow	*Artamus fuscus*	2	0.31	Passeriformes	Artamidae	I	R	↔	LC
5	Asian Brown Flycatcher	*Muscicapa dauurica*	2	0.31	Passeriformes	Muscicapidae	I	AV/SV	↔	LC
6	Asian Green Bee-eater	*Merops orientalis*	2	0.31	Coraciiformes	Meropidae	I	R	↑	LC
7	Asian Koel/ Western Koel	*Eudynamys scolopaceus*	27	4.17	Cuculiformes	Cuculidae	O	R	↔	LC
8	Asian Openbill	*Anastomus oscitans*	10	1.55	Ciconiiformes	Ciconiidae	C/P	R	?	LC
9	Asian Palm Swift	*Cypsiurus balasiensis*	3	0.46	Apodiformes	Apodidae	I	R	↓	LC
10	Bank Myna	*Acridotheres ginginianus*	4	0.62	Passeriformes	Sturnidae	O	R	↑	LC
11	Barn Swallow	*Hirundo rustica*	2	0.31	Passeriformes	Hirundinidae	I	WV	↓	LC
12	Black Drongo	*Dicrurus macrocercus*	27	4.17	Passeriformes	Dicruridae	I	R	?	LC
13	Black Kite	*Milvus migrans*	4	0.62	Accipitriformes	Accipitridae	C/P	R	↔	LC
14	Black-crowned Night Heron	*Nycticorax nycticorax*	1	0.15	Pelecaniformes	Ardeidae	O	R	↓	LC
15	Black-headed Ibis	*Threskiornis melanocephalus*	2	0.31	Pelecaniformes	Threskiornithidae	C/P	SV/MV	↑	LC
16	Black-hooded Oriole	*Oriolus xanthornus*	21	3.25	Passeriformes	Oriolidae	I	R	↔	LC
17	Black-rumped Flameback	*Dinopium benghalense*	8	1.24	Piciformes	Picidae	I	R	↓	LC
18	Black-winged Stilt	*Himantopus himantopus*	1	0.15	Charadriiformes	Recurvirostridae	O	WV	↑	LC
19	Blyth's Reed Warbler	*Acrocephalus dumetorum*	1	0.15	Passeriformes	Acrocephalidae	I	WV	↑	LC
20	Booted Warbler	*Iduna caligata*	4	0.62	Passeriformes	Acrocephalidae	I	WV	↑	LC
21	Brahminy Starling	*Sturnia pagodarum*	11	1.70	Passeriformes	Sturnidae	O	R	?	LC
22	Bronze-winged Jacana	*Metopidius indicus*	9	1.39	Charadriiformes	Jacanidae	O	R	?	LC
23	Brown Shrike	*Lanius cristatus*	5	0.77	Passeriformes	Laniidae	O	WV	↓	LC
24	Cattle Egret	*Bubulcus ibis*	9	1.39	Pelecaniformes	Ardeidae	O	R	↑	LC
25	Chestnut-tailed Starling	*Sturnia malabarica*	15	2.32	Passeriformes	Sturnidae	O	R	?	LC
26	Cinnamon Bittern	*Ixobrychus cinnamomeus*	1	0.15	Pelecaniformes	Ardeidae	C/P	R	?	LC
27	Common Hawk-Cuckoo	*Hierococcyx varius*	1	0.15	Cuculiformes	Cuculidae	I	R	↓	LC
28	Common Iora	*Aegithina tiphia*	1	0.15	Passeriformes	Aegithinidae	I	R	?	LC
29	Common Myna	*Acridotheres tristis*	39	6.03	Passeriformes	Sturnidae	O	R	↑	LC
30	Common Tailorbird	*Orthotomus sutorius*	1	0.15	Passeriformes	Cisticolidae	I	R	↔	LC
31	Coppersmith Barbet	*Psilopogon haemacephalus*	8	1.24	Piciformes	Megalaimidae	F	R	↑	LC
32	Cotton Pygmy-Goose	*Nettapus coromandelianus*	4	0.62	Anseriformes	Anatidae	O	R	?	LC
33	Eurasian Collared-Dove	*Streptopelia decaocto*	35	5.41	Columbiformes	Columbidae	G	R	↑	LC
34	Eurasian Coot	*Fulica atra*	1	0.15	Gruiformes	Rallidae	O	R	↑	LC
35	Eurasian/ Common Hoopoe	*Upupa epops*	3	0.46	Bucerotiformes	Upupidae	I	R	↓	LC
36	Eurasian/ Common Moorhen	*Gallinula chloropus*	12	1.85	Gruiformes	Rallidae	O	R	↔	LC
37	Eurasian Wigeon	*Mareca penelope*	1	0.15	Anseriformes	Anatidae	H	WV	↓	LC
38	Gray-breasted Prinia	*Prinia hodgsonii*	1	0.15	Passeriformes	Cisticolidae	I	R	↓	LC
39	Great Cormorant	*Phalacrocorax carbo*	4	0.62	Suliformes	Phalacrocoracidae	C/P	WV	↑	LC
40	Greater Coucal	*Centropus sinensis*	7	1.08	Cuculiformes	Cuculidae	O	R	↓	LC

	Species	Scientific name	Frequency of occurrence	Relative frequency (%)	Order	Family	Feeding guild	Seasonality in CRJ	Population trend	IUCN Red List category
41	Greenish Warbler	*Phylloscopus trochiloides*	2	0.31	Passeriformes	Phylloscopidae	I	WV	↑	LC
42	Grey Francolin	*Ortygornis pondicerianus*	5	0.77	Galliformes	Phasianidae	O	R	↔	LC
43	Grey Heron	*Ardea cinerea*	5	0.77	Pelecaniformes	Ardeidae	C/P	R	?	LC
44	Grey-headed Lapwing	*Vanellus cinereus*	1	0.15	Charadriiformes	Charadriidae	O	WV	↔	LC
45	House Crow	*Corvus splendens*	17	2.63	Passeriformes	Corvidae	O	R	↔	LC
46	Indian Pied Starling	*Gracupica contra*	13	2.01	Passeriformes	Sturnidae	O	R	↑	LC
47	Indian Pond-Heron	*Ardeola grayii*	11	1.70	Pelecaniformes	Ardeidae	C/P	R	?	LC
48	Indian Roller	*Coracias benghalensis*	2	0.31	Coraciiformes	Coraciidae	O	R	↑	LC
49	Intermediate Egret	*Ardea intermedia*	6	0.93	Pelecaniformes	Ardeidae	C/P	R	↓	LC
50	Jungle Babbler	*Argya striata*	32	4.95	Passeriformes	Leiothrichidae	O	R	↔	LC
51	Lesser Whistling-Duck	*Dendrocygna javanica*	15	2.32	Anseriformes	Anatidae	O	R	↓	LC
52	Lesser Whitethroat	*Curruca curruca*	1	0.15	Passeriformes	Sylviidae	I	WV	↔	LC
53	Lineated Barbet	*Psilopogon lineatus*	11	1.70	Piciformes	Megalaimidae	F	R	↓	LC
54	Little Cormorant	*Microcarbo niger*	7	1.08	Suliformes	Phalacrocoracidae	C/P	R	?	LC
55	Little Egret	*Egretta garzetta*	2	0.31	Pelecaniformes	Ardeidae	C/P	R	↑	LC
56	Little Grebe	*Tachybaptus ruficollis*	7	1.08	Podicipediformes	Podicipedidae	O	R	↓	LC
57	Little Swift	*Apus affinis*	1	0.15	Apodiformes	Apodidae	I	R	↑	LC
58	Northern Pintail	*Anas acuta*	2	0.31	Anseriformes	Anatidae	O	WV	↓	LC
59	Olive-backed Pipit	*Anthus hodgsoni*	3	0.46	Passeriformes	Motacillidae	I	WV	↔	LC
60	Oriental Magpie-Robin	*Copsychus saularis*	15	2.32	Passeriformes	Muscicapidae	I	R	↔	LC
61	Paddyfield Warbler	*Acrocephalus agricola*	2	0.31	Passeriformes	Acrocephalidae	I	WV	↓	LC
62	Pheasant tailed-jacana	*Hydrophasianus chirurgus*	5	0.77	Charadriiformes	Jacanidae	O	R	?	LC
63	Purple Heron	*Ardea purpurea*	1	0.15	Pelecaniformes	Ardeidae	C/P	R	↑	LC
64	Purple Sunbird	*Cinnyris asiaticus*	28	4.33	Passeriformes	Nectariniidae	N	R	↔	LC
65	Purple Swamphen	*Porphyrio porphyrio*	8	1.24	Gruiformes	Rallidae	O	R	?	LC
66	Purple-rumped Sunbird	*Leptocoma zeylonica*	1	0.15	Passeriformes	Nectariniidae	N	R	↓	LC
67	Red-naped Ibis	*Pseudibis papillosa*	2	0.31	Pelecaniformes	Threskiornithidae	C/P	WV	↓	LC
68	Red-vented Bulbul	*Pycnonotus cafer*	16	2.47	Passeriformes	Pycnonotidae	I	R	↑	LC
69	Red-whiskered Bulbul	*Pycnonotus jocosus*	14	2.16	Passeriformes	Pycnonotidae	I	R	↓	LC
70	Rock Dove	*Columba livia*	4	0.62	Columbiformes	Columbidae	G	R	↓	LC
71	Rose-ringed Parakeet	*Alexandrinus krameri*	19	2.94	Psittaciformes	Psittaculidae	F	R	↑	LC
72	Ruddy Shelduck	*Tadorna ferruginea*	2	0.31	Anseriformes	Anatidae	O	WV	?	LC
73	Rufous Treepie	*Dendrocitta vagabunda*	16	2.47	Passeriformes	Corvidae	O	R	↓	LC
74	Shikra	*Accipiter badius*	3	0.46	Accipitriformes	Accipitridae	C/P	R	↔	LC
75	Spotted Dove	*Spilopelia chinensis*	25	3.86	Columbiformes	Columbidae	G	R	↑	LC
76	Spotted Owlet	*Athene brama*	2	0.31	Strigiformes	Strigidae	C/P	R	↔	LC
77	Stork-billed Kingfisher	*Pelargopsis capensis*	4	0.62	Coraciiformes	Alcedinidae	C/P	R	↓	LC
78	White Wagtail	*Motacilla alba*	1	0.15	Passeriformes	Motacillidae	I	WV	↔	LC
79	White-breasted Waterhen	*Amaurornis phoenicurus*	17	2.63	Gruiformes	Rallidae	O	R	?	LC
80	White-browed Wagtail	*Motacilla maderaspatensis*	1	0.15	Passeriformes	Motacillidae	I	R	↔	LC
81	White-throated Kingfisher	*Halcyon smyrnensis*	2	0.31	Coraciiformes	Alcedinidae	C/P	R	↑	LC
82	Wire-tailed Swallow	*Hirundo smithii*	3	0.46	Passeriformes	Hirundinidae	I	R	↑	LC

	Species	Scientific name	Frequency of occurrence	Relative frequency (%)	Order	Family	Feeding guild	Seasonality in CRJ	Population trend	IUCN Red List category
83	Yellow-eyed Babbler	*Chrysomma sinense*	1	0.15	Passeriformes	Paradoxornithidae	I	R	↔	LC
84	Yellow-footed Green-Pigeon	*Treron phoenicopterus*	14	2.16	Columbiformes	Columbidae	F	R	↑	LC

Feeding guilds: C/P = Carnivorous/Piscivorous, F = Frugivorous, G = Granivorous, H = Herbivorous, I = Insectivores, Nectarivorous (N) and O = Omnivores;
Seasonality in CRJ: AV/SV = Autumn/Spring Visitor, R = Resident, WV = winter visitors and SV/MV = Summer/Monsoon Visitor;
Population trend: Decreasing = ↓, Increasing = ↑, Stable = ↔, Unknown =?; IUCN Red List status: LC = Least Concern (LC), NT = Near Threatened

Appendix II. List of opportunistic bird sightings during the survey period in Chittaranjan, West Bengal

	Common name	Scientific name	Order	Family	Feeding guild	Status in CRJ	Population trend	IUCN category
1	Black-winged Kite	*Elanus caeruleus*	Accipitriformes	Accipitridae	C/P	R	↔	LC
2	Citrine Wagtail	*Motacilla citreola*	Passeriformes	Motacillidae	I	WV	↑	LC
3	Clamorous Reed Warbler	*Acrocephalus stentoreus*	Passeriformes	Acrocephalidae	I	WV	↔	LC
4	Common Pochard	*Aythya ferina*	Anseriformes	Anatidae	H	WV	↓	VU
5	Common Sandpiper	*Actitis hypoleucos*	Charadriiformes	Scolopacidae	O	WV	↓	LC
6	Common Snipe	*Gallinago gallinago*	Charadriiformes	Scolopacidae	O	WV	↓	LC
7	Gadwall	*Mareca strepera*	Anseriformes	Anatidae	H	WV	↑	LC
8	Gray Wagtail	*Motacilla cinerea*	Passeriformes	Motacillidae	I	WV	↔	LC
9	Great Crested Grebe	*Podiceps cristatus*	Podicipediformes	Podicipedidae	C/P	WV	?	LC
10	Great White Egret	*Ardea alba*	Pelecaniformes	Ardeidae	O	R	?	LC
11	Green Sandpiper	*Tringa ochropus*	Charadriiformes	Scolopacidae	O	WV	↑	LC
12	Indian Golden Oriole	*Oriolus kundoo*	Passeriformes	Oriolidae	F	SV/MV	?	LC
13	Indian Gray Hornbill	*Ocyceros birostris*	Bucerotiformes	Bucerotidae	F	U	↔	LC
14	Indian Nightjar	*Caprimulgus asiaticus*	Caprimulgiformes	Caprimulgidae	I	R	↔	LC
15	Indian Thick-knee	*Burhinus indicus*	Charadriiformes	Burhinidae	I	R	?	LC
16	Northern Shoveler	*Spatula clypeata*	Anseriformes	Anatidae	O	WV	↓	LC
17	Orange-breasted Green-Pigeon	*Treron bicinctus*	Columbiformes	Columbidae	F	U	↓	LC
18	Oriental Honey-buzzard	*Pernis ptilorhynchus*	Accipitriformes	Accipitridae	C/P	R	↓	LC
19	Paddyfield Pipit	*Anthus rufulus*	Passeriformes	Motacillidae	I	R	↔	LC
20	Pied Kingfisher	*Ceryle rudis*	Coraciiformes	Alcedinidae	C/P	R	?	LC
21	Plain Prinia	*Prinia inornata*	Passeriformes	Cisticolidae	I	R	↔	LC
22	Plaintive Cuckoo	*Cacomantis merulinus*	Cuculiformes	Cuculidae	I	R	↔	LC
23	Red-crested Pochard	*Netta rufina*	Anseriformes	Anatidae	H	WV	?	LC
24	Red-necked Falcon	*Falco chicquera*	Falconiformes	Falconidae	C/P	U	↓	NT
25	Scaly-breasted Munia	*Lonchura punctulata*	Passeriformes	Estrildidae	G	R	↔	LC
26	Slender-billed Oriole	*Oriolus tenuirostris*	Passeriformes	Oriolidae	F	U	↓	LC
27	Taiga Flycatcher	*Ficedula albicilla*	Passeriformes	Muscicapidae	I	WV	↓	LC
28	Yellow-crowned Woodpecker	*Leiopicus mahrattensis*	Piciformes	Picidae	I	R	↔	LC

Feeding guilds: C/P = Carnivorous/Piscivorous, F = Frugivorous, G = Granivorous, H = Herbivorous, I = Insectivores and O = Omnivores;
Seasonality in CRJ: AV/SV = Autumn/Spring Visitor, R = Resident, WV = winter visitors, SV/MV = Summer/Monsoon Visitor, and U = Unknown;