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Caption: *Cyrtodactylus myintkyawthurai*, endemic to Myanmar. Medium: Water colours on watercolor sheet. © Aakanksha Komanduri

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ARTICLE

Comparison of bird diversity in protected and non-protected wetlands of western lowland of Nepal

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Abstract: Protected areas are considered important for biodiversity conservation, however, studies have shown that habitats outside protected areas can also support high diversity and are important for biodiversity conservation. In this context, we compared the bird diversity between protected (Rani Taal in Shuklaphanta National Park) and non-protected (Sati Karnali Taal) wetlands in western Nepal. Bird surveys were conducted from February to August 2019, using open width point count method in 100 m intervals along transects. A total of 122 species belonging to 18 orders and 44 families were recorded from the protected wetland, and 107 species belonging to 16 orders and 41 families from the non-protected wetland area. Insectivores had high abundance in both wetlands (43% and 47% in protected and non-protected wetlands, respectively). Forest-dependent birds were more abundant in protected wetland compared to non-protected wetland. Our study showed that both protected and non-protected wetlands along with agricultural landscapes, support a richness of birds. Hence priority should be given to both wetlands for the conservation of birds.

Keywords: Aves, conservation, protected and non-protected areas, threatened birds.

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INTRODUCTION

Protected area (PA) is a key strategy for in situ conservation of biodiversity. Evidence has shown PAs that are crucial in conserving forests, natural environments, biodiversity, and ecosystem services (Rodrigues et al. 2004; Dahal et al. 2014; Watson et al. 2016). In the past, PAs surged globally, and Nepal has also made notable progress in increasing PA coverage (UNEP-WCMC et al. 2018; DNPWC 2020). By the end of 2020 over 15% of the earth's terrestrial surface was covered by PAs (Terborgh et al. 2002; UNEP-WCMC et al. 2018). In spite of increase in PAs, their efficacy in protecting overall biodiversity is contested (Rodrigues et al. 2004; Chape et al. 2005). Several important species remain outside the jurisdiction of PAs (Chakravarty et al. 2012), and some geographical areas are under-represented (Shrestha et al. 2010), incuding some global biodiversity hotspots and agro-ecosystems that support rich biodiversity (Sharma & Vetaas 2015). Researchers have argued and demonstrated that areas outside formal PAs are worth conserving, as they provide alternative habitats and refuges for maintaining viable populations of residential and migratory bird species (Shrestha et al. 2010; Cox & Underwood 2011; Dudley et al. 2014; DNPWC 2020) and thus complement PAs in achieving biodiversity goals.

Freshwater ecosystems are among the most productive ecosystems, and they provide countless services to both the human and ecological communities (Dudgeon et al. 2006). Yet they remain vulnerable to various stresses and pressures (Geist 2011). Freshwater constitutes about 2.5% of the area of all water on Earth (Ostfeld et al. 2012) and approximately 5% (743,500 ha) in Nepal (Siwakoti & Karki 2009). In the global context, wetlands support more than 40% of the birds and 12% of other animals (Kumar 2005; Paracuellos 2006). More than 20% of threatened bird species, both migratory and resident, are supported by the wetlands of Asia (Paracuellos 2006; Grimmett et al. 2016a).

Birds are important indicators of the health of freshwater ecosystems (Zakaria & Rajpar 2010; Inskipp et al. 2017; Baral & Inskipp 2020; Brotherton et al. 2020). Past studies have highlighted that Nepal's freshwater diversity has been threatened by different factors, including construction of dams, point source and non-point source pollution, habitat encroachment by invasive species, overharvesting, and recent global environmental changes (Khatiwada et al. 2021).

Many wetlands outside protected areas are important for conserving biodiversity, but are not given due attention for conservation. Past studies of bird species have been mostly concentrated in the protected areas and Ramsar sites. The difference in bird diversity between protected and non-protected areas is not well documented. In this study, we compared bird diversity between wetlands within a PA (Rani Taal in Shuklaphanta National Park) and outside it (Sati Karnali Taal), and asked following questions: (i) is there a difference in bird richness between protected and non-protected wetlands? (ii) is there a difference in conservation value for birds inside and outside protected area? (iii) do birds in protected and non-protected wetland differ in their feeding guilds? Understanding the distribution of bird diversity in and outside PAs can be useful to conservation managers and planners to formulate conservation strategies.

MATERIALS AND METHODS

Study area

This study was conducted in two wetlands, one in Shuklaphanta National Park (Rani Taal, hereafter referred to as protected and undisturbed wetland) and one in a nearby agricultural landscape (Sati Karnali Taal, hereafter non-protected and disturbed wetland), selected to compare bird diversity and distribution (Image 1). These wetlands share similar geography and climatic conditions, but differ in terms of management and disturbance (Table 1).

Bird survey

A bird survey was carried out following the "point count" method along transects near the bank of lake/wetland, following detailed instructions provided by Bibby et al. (2000) from February to September 2019 two times a day at 0600–1000 h and 1600–1800 h. A total of five transects were laid in each wetland and bird study was carried out during the winter and summer seasons. The length of the transect walks varied from 500 m to 1,000 m depending upon the shape of the wetland and forest patch. The points were fixed in every 100-m intervals along the transects, then the birds were scanned and counted with the aid of binoculars (Nikon 20 × 50 and Bushnell 10 × 40) within the 50 m circular radius.

Four observers scanned for birds in all directions for five minutes. The observed birds were counted and listed, and data from all observers were pooled for each transect. To ensure a comprehensive species list for each survey site, calls of birds were also recorded with a cell phone in MP3 format. All the observed species were

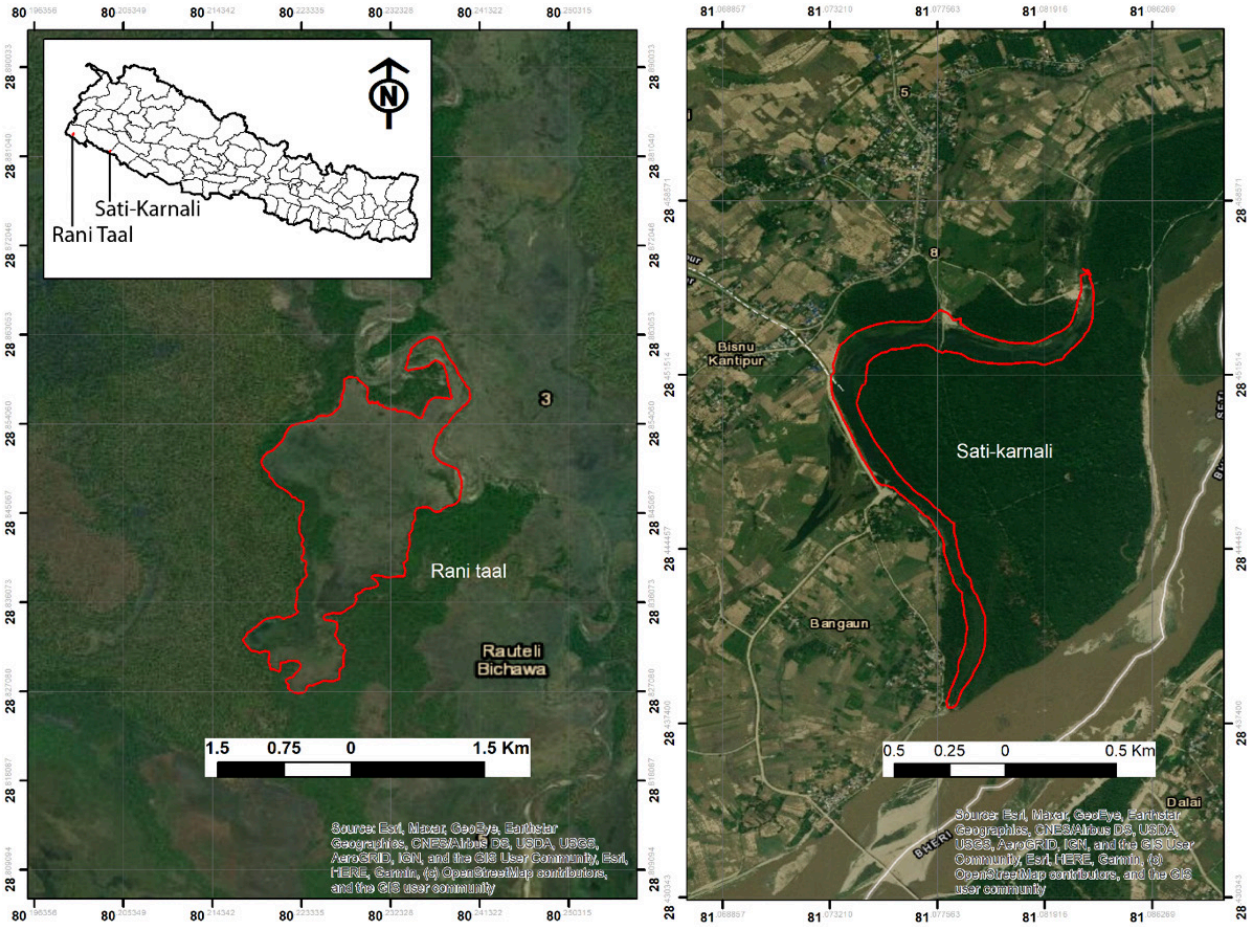

Figure 1. Map of the study area showing protected and non-protected wetlands.

recorded with abundance by visual and auditory aids, with habitat and environmental variables. Birds were identified using Grimmett et al. (2016a,b). Calls were identified using the bird song database of Xeno-Canto (https://www.xeno-canto.org/). Foraging behavior was grouped into five different trophic structures based on the feeding habit of birds and availability of food resources in the study area (Zakaria & Rajpar 2010). These trophic structures are: insectivores, omnivores, piscivores, herbivores, and carnivores. We also carried out a questionnaire survey and literature review to record migratory and other rare bird species in the area.

Data analysis

We classified birds based on their feeding guilds, habitats and migratory behavior (BCN & DNPWC 2016; Grimmett et al. 2016). We also categorized bird conservation status using IUCN Red List (https://www.iucnredlist.org). Species richness refers to the number of species, and abundance means the number of individuals of each species. We used two measures of richness, one for transects and another for sites. We also calculated the diversity indices of birds in protected and non-protected sites.

Shannon Weiner diversity index (H) was used to determine species diversity in a community (Shannon 1948).

Shannon index (H) = $\frac{1}{\sum_{i=1}^{s} p_i^2}$

Where, p_i is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

Simpson index was determined to measure community diversity in relation to habitats (Simpson 1949).

Simpson index (D) = $- \sum_{i=1}^{s} p_i \ln p_i$

Where *p* is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is the sum of the calculations, and *s* is the number of species.

Evenness (e) was used to determine distribution of

individuals of a species in a community.

Evenness = H'/Hmax

Where H' is Shannon diversity index and Hmax is the maximum possible value. E is constrained between 0 and 1.0. As with H', evenness assumes that all species are represented within the sample.

Jacob's equitability (J) was used to measure the evenness with which individuals are divided among the taxa present. Equitability (J) = H'/lnS

Where, H' = Shannon's index of diversity, S = number of taxa

Fisher's index describes mathematically the relation between the number of species and the number of individuals in those species (Fisher & Yates 1943). Fisher diversity index, defined implicitly by the formula.

$$S = a \times \ln\left(1 + \frac{n}{a}\right)$$

Where, S is number of taxa, n is number of individuals and a is the Fisher's alpha.

Differences in species richness and abundance between the protected and non-protected areas were tested using a student *t* test. Data were checked for normality before conducting the *t* test. All statistical analyses were carried out in R version. 3.6.1 (R Development Core Team 2019).

RESULTS

Diversity and distribution of birds in protected and non-protected wetlands

We recorded a total of 1,693 individuals (winter= 961; summer= 732) belonging to 122 species (winter= 118; summer= 104) from 18 orders and 44 families in the protected wetland, and 1,672 individuals (winter= 791; summer= 881) belonging to 107 species (winter= 94; summer= 86) from 16 orders and 41 families in non-protected wetland (Appendix 1). The most abundant species were from order Passeriformes (37%) followed by Coraciiformes (9.8%), Psittaciformes (7.2%), and Galliformes (6.3%) in the protected wetland whereas Passeriformes (43%) was the most abundant followed by Coraciiformes (11%), Pelecaniformes (6.9%), and Psittaciformes (6.8%) in the non-protected wetland.

In terms of cumulative abundance, Common Peafowl (4.9%) was the most abundant species in the protected wetland, followed by House Swift (4.7%), Blue-tailed Bee-eater (4.3%), and Wire-tailed Swallow (3.0%), whereas House Sparrow (4.2%) was the most abundant species followed by Cattle Egret (4.0%), Blue-tailed Bee-eater (3.5%), Lesser Whistling Duck (3.3%), and Slaty-headed Parakeet (3.2%) in non-protected wetland (Appendix 1).

Overall, there was higher richness of birds in protected wetland (n= 122 compared to non-protected wetland (n= 107, t= 8.623, p <0.004). Similarly, species richness was also higher in both summer (t= 4.01, p= 0.004) and winter (t= 4.726, p= 0.001) seasons (Figure 1) in protected wetland. However, there was no significant difference in species abundance between protected and non-protected wetlands (t= 0.140, p= 0.870). But the mean abundance of the birds was higher in summer season than winter in protected wetland (Figure 1).

The overall Shannon index of diversity (H), and Fisher alpha (α) in protected wetland was higher than from the non-protected wetland (Table 2). Similarly, the species diversity of protected wetland was more in winter season than summer. But there was no variation in species dominance index (D) during winter and summer seasons (D= 0.019, in winter and D= 0.021, in summer season) (Table 2). Similarly, the species diversity of birds in non-protected wetland was more winter (H= 4.21, α= 31.0) than in summer (H= 4.19, α= 27.43) (Table 2).

Categorization of birds according to habitat types

A total of 49 species of wetland dependent birds, followed by 43 species of forest, 17 species of open area birds, and 13 species of bush birds were recorded from protected wetland, whereas 41 species of wetland birds, 37 species of forest birds, 18 species of open area birds, and 11 species of bush dependent birds were recorded from human dominated non-protected lake (Figure 2).

Feeding guilds of birds

The proportion of insectivorous birds was higher in both wetlands (protected 43.5% and non-protected 47.41%) followed by omnivores, piscivores, herbivores, and carnivores, respectively (Figure 3).

Bird species with conservation concern

We recorded a globally Endangered species: Egyptian Vulture *Neophron percnopterus*; two Vulnerable species: Common Pochard *Aythya ferina* & Great Slaty Woodpecker *Mulleripicus pulverulentus*; and seven Near Threatened species: Grey-headed Fish Eagle *Icthyophaga ichthyaetus*, Lesser Fish Eagle *Icthyophaga humilis*, River Lapwing *Vanellus duvaucelii,* Red-headed Falcon *Falco chicquera*, Painted Stork *Mycteria leucocephala,* Asian Woollyneck *Ciconia episcopus*, & Oriental Darter *Anhinga melanogaster* in protected wetland. In non-protected wetland and its vicinity we reported three Vulnerable species: Common Pochard *Aythya ferina*, Great Slaty Woodpecker *Mulleripicus*

Table 1. Comparative information about the study area: Protected and non-protected wetlands of lowland Terai western Nepal.

Parameters	Protected wetland	Non-protected wetland
Location	Inside Shuklaphanta National Park, Kanchanpur	Inside Sati Karnali Community Forest User Group, Tikapur, Kailali
Geographic location	N28.922883/ E80.176317	N28.453533/ E81.07378
Elevation	175 m	158 m
River basin	Mahakali	Karnali
Nature of lake	Oxbow	Oxbow
Area	369 hector	25 hector
Temperature	Average temperature 25.9 °C (14.3–32 °C, warmest month May and coldest month January)	Average temperature 24.6 °C (15.6–32 °C, warmest month May and coldest month January)
Rainfall	1,579 mm	1,757 mm
Feeder	Rainwater	Rani Kulo
Vegetation	Surrounded by dense Sal (*Shorea robusta*) forest. Associated tree species are Kusum (*Scheleira oleosa*), Saaj (*Terminalia alata*), Rohini (*Mallotus phillipensis*), Jamun (*Syzygium cuminii*), Bhellar (*Trewia nudiflora*) Common shrub species: Rudilo (*Pogostemon bengalensis*), Asare (*Murraya koenighii*) and Bhati (*Clerodendrum viscosum*). The lake is surrounded by elephant grass (*Saccharum spontaneum*), Narenga (*Narenga porphyrocoma*) on south, west and east Khatiwada et al. (2019)	Surrounded by riverine type and dominated by Sissoo (*Dalbergia sissoo*), Simal (*Bombax ceiba),* Vellar *(Trewia nudiflora)* and Khayer (*Acacia catechu)*. Sindhure (*Mallotus phillipensis)* and Shirish (*Albizia chinensis)* Common shrub species: Asare (*Murraya keonighii)*, Bhati (*Clerodendron viscosum)*. This area is well known for rattan cane (*Calamus tenuis)*. Khatiwada et al. (2019)
Disturbance	No human impact, Natural eutrophication and siltation is common. More than 80% of the total area of this lake is converted into grassland and marshy land	Anthropogenic activities such as fishing, collection of snails, other aquatic products, grazing are very common.
Management authority	Shuklaphanta National Park	Sati Karnali Community Forest User Group

Table 2. The diversity and dominance indices of birds in protected and non-protected wetlands.

	Winter		Summer		Total	
	Protected	Non-protected	Protected	Non-protected	Protected	Non-protected
Species richness	118	94	104	86	122	107
Dominance_D	0.019	0.03	0.021	0.03	0.019	0.018
Shannon_H	4.512	4.21	4.29	4.19	4.47	4.38
Evenness_e^H/S	0.68	0.69	0.69	0.67	0.66	0.672
Equitability_J	0.917	0.921	0.921	0.92	0.92	0.921
Fisher_alpha	37.21	31	34.51	27.43	31.54	27.31

pulverulentus, & Lesser Adjutant *Leptoptilos javanicus*; and six Near Threatened species: Grey-headed Fish-eagle *Icthyophaga ichthyaetus*, River Lapwing *Vanellus duvaucelii,* Asian Woollyneck *Ciconia episcopus*, Painted Stork *Mycteria leucocephala*, Oriental Darter *Anhinga melanogaster*, and Alexandrine Parakeet *Psittacula eupatria* (Figure 4, Image 2).

DISCUSSION

The present study examined diversity of wetland-associated bird species from the lowlands of western Nepal. Our results indicate that bird community structure (i.e., species richness, abundance, composition) varied notably between protected and non-protected wetland and associated areas. Nevertheless, wetlands outside the protected area system also support a large number of important birds.

Bird diversity in protected and non-protected areas

The wetlands in both protected and non-protected areas support a considerable bird diversity of different feeding guilds. Overall, higher bird diversity was found in protected areas, signifying the importance of these areas for species conservation. Similar results were reported by Dahal et al. (2014) from forests of lowland Nepal. Abundance of forest specialist bird species such as Lesser Yellownape *Picus chlorolophus* and Common Peafowl *Pavo cristatus* was higher around the protected

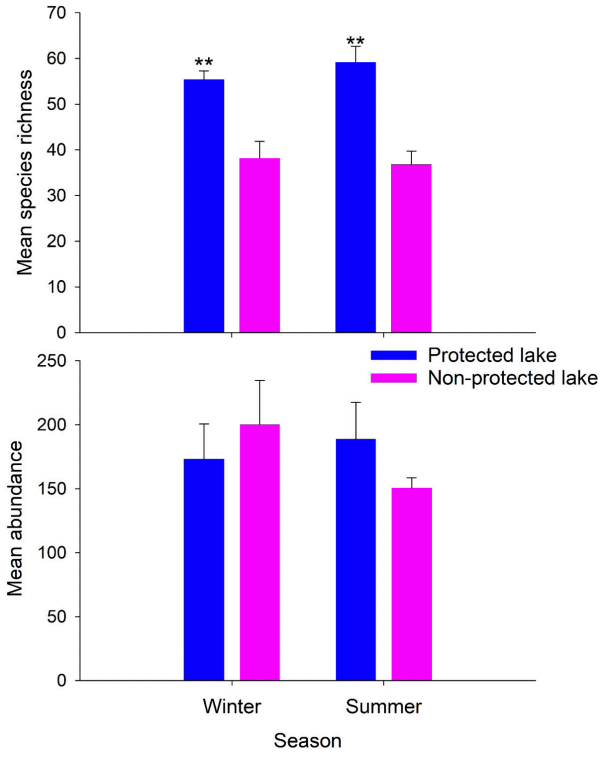

Figure 1. Mean richness and abundance of bird species on the protected and non-protected wetlands. The level of significance is from t-test (** <0.01).

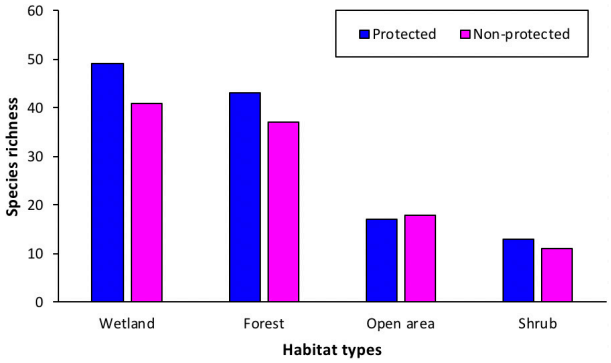

Figure 2. Habitat-wise species richness of birds.

wetland compared to non-protected wetland and surrounding areas (Appendix 1).

Our results showed an important dynamic in the wetlands in and outside the protected area. Increasing in richness in PA within the wetlands during summer, there is not distinct change in wetlands outside the PA (Figure 1). Slight increase of bird richness inside the PA might be because it provides a safe refuge for breeding birds and the disturbance is very low. Similarly, the higher abundance of the birds outside the PA during

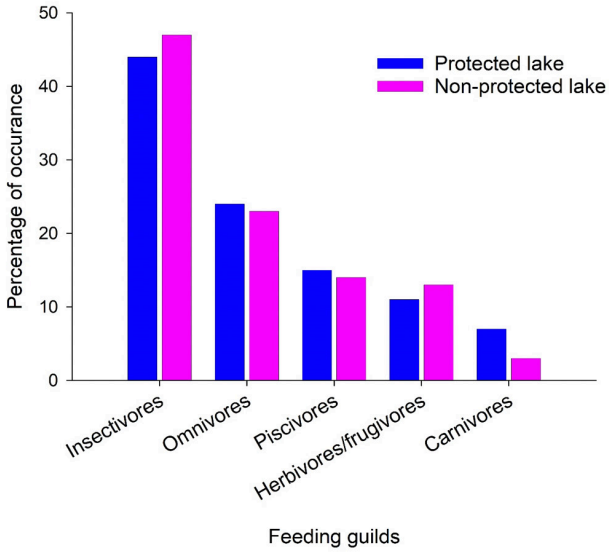

Figure 3. Percentage of bird species recorded for the different feeding guilds.

winter indicates that open and more disturbed nature of the wetlands are equally important to provide habitat for birds. Agriculture landscapes around the wetlands outside the protected area also provide bird feeding grounds. Abundance in wetlands outside PA decreases noticeably, indicating that winter migrants would have left and some resident species may also leave seeking safer habitat to breed. During March-June, water resources inside the PA become dry and the birds concentrate in this lake, hence it shows greater abundance during summer than in winter.

Our study reports higher species richness in wetland followed by forest birds (Figure 2). The species richness of birds is comparatively higher in and around the protected wetland. Lowland protected areas support old and mature forests and harbor the highest richness of forest specialist bird species (Dahal et al. 2014). Similarly, some of the wetland-dependent and associated bird species like Lesser Fish Eagle *Icthyophaga humilis*, Osprey *Pandion haliaetus*, Mallard *Anas platyrhynchos*, Ruddy Shelduck *Tadorna ferruginea*, and Gadwall *Mareca strepera* were reported only from the protected wetland and associated areas. Higher richness of birds in protected wetland areas may be attributed to lower anthropogenic disturbance (Khatri et al. 2019; Lamsal et al. 2019), supporting birds that require undisturbed forests.

National Park are surrounded by Sal forest and grassland that support many globally threatened birds. Nepal's wetlands provide an important habitat for many wetland dependent and grassland birds including 15

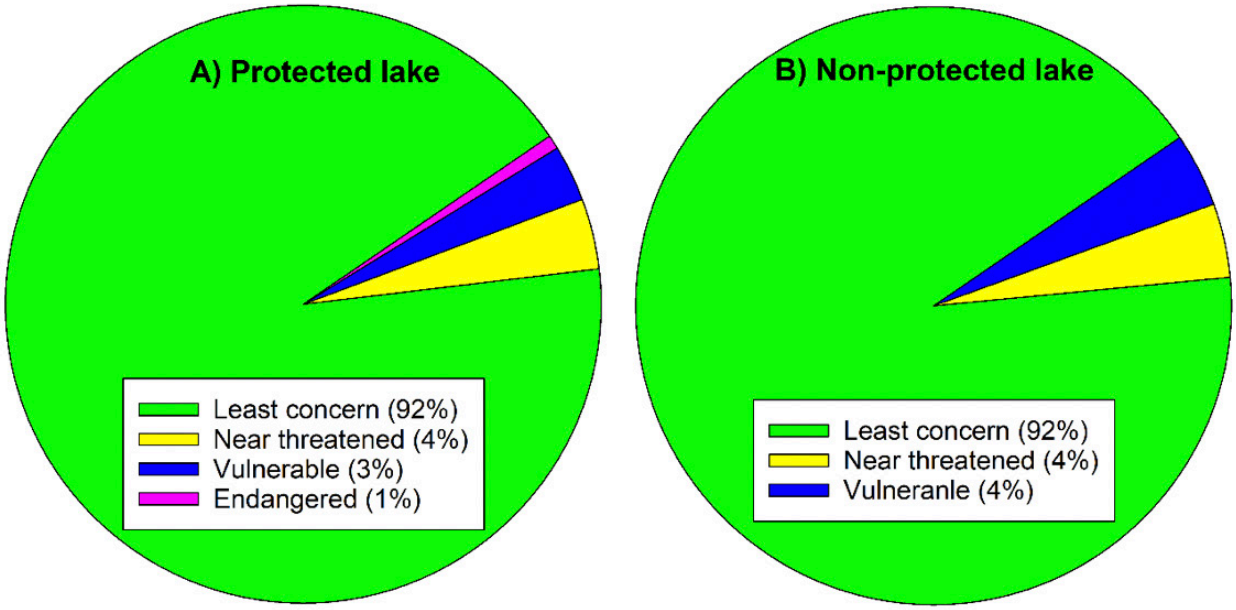

Figure 4. Pie chart showing the percentage of bird species according to IUCN Category.

globally threatened and 13 near threatened bird species (Baral & Inskipp 2009). During our study, we recorded one Endangered species of bird: Egyptian Vulture *Neophron percnopterus,* two globally Vulnerable birds: Great Slaty Woodpecker *Mulleripicus pulverulentus* Common Pochard *Aythya ferina* and five globally Near Threatened birds in and around the protected lake.

Habitat heterogeneity is greater inside the Shuklaphanta National Park in and around the protected wetland. Higher the habitat heterogeneity favours higher the species diversity (Tamme et al. 2010). Hence higher number of forest specific birds and wetland birds were recorded in the protected wetland. But the non-protected wetland is surrounded by small patch of forest and agriculture landscape. The exploitation of natural resources and impact of human pressure was more in non-protected wetland which may be a cause of lower abundance of forest and wetland specialist birds. Nevertheless, due to diverse habitats, agricultural landscape supported higher richness and abundance of open area birds. Elsen et al. (2017) reported that low intensity agriculture supports higher bird diversity during winter in Himalayan montane landscape.

The wetland outside the protected area also supported considerable bird diversity. The birds reported here included several species listed as Vulnerable (VU) in IUCN Red List. Non-protected wetland and adjoining areas provide the suitable habitats for several vulnerable and near threatened bird species. During this study, we reported three Vulnerable and six Near Threatened bird species. The adjoining area of this wetland is surrounded by paddy fields and swampy areas, which are the foraging ground to several species (de Silva et al. 2015; Adhikari et al. 2019). The tree species present in paddy field and adjoining community forest provide the nesting and foraging places for birds. The study on the responses of birds with tree species in agricultural landscape found larger population sizes of birds with low intensity farming as they share same land for foraging (Hulme et al. 2013). Hence, land sharing would result in better bird conservation outcomes (Hulme et al. 2013; Edwards et al. 2014; Schulte et al. 2016) but land sparing has greater potential biodiversity benefits for large mammals, cats and large birds than land sharing (Lamb et al. 2019; Finch et al. 2020). Several studies show that agricultural land is an important driver that effect the wild nature directly or indirectly which is very common in developing countries (Green et al. 2005; Haslem & Bennett 2008; Šálek et al. 2018; Chaudhary et al. 2020).

Difference in feeding guilds

The results showed that wetlands are suitable for avifauna as they offer shelter, food, suitable nesting, and roosting sites for different groups of birds (Giosa et al. 2018). The habitat preference of the bird could be due to the availability of food they feed on such as insects, fishes, frogs, lizards, mouse, grains, fruits, vegetable matter (Katuwal et al. 2016; Harisha & Hosetti 2018). We identified five different foraging guilds such as insectivores, omnivores, piscivores, herbivores, and

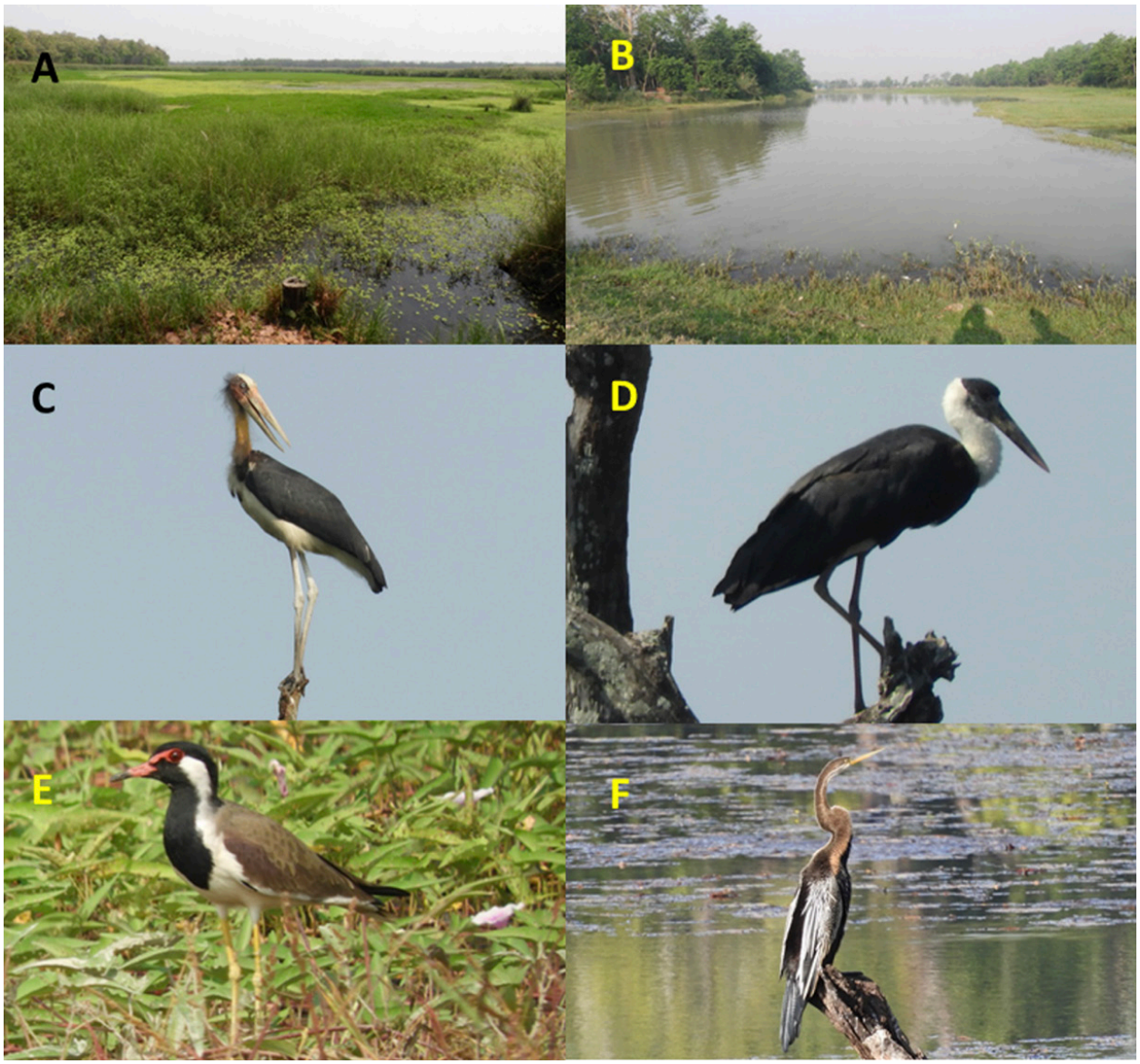

Image 2. A—protected wetland (Rani Taal) inside the Shuklaphanta National Park, western Nepal | B—non-protected wetland (Sati Karnali Taal) of Kailali district | C—Lesser Adjutant (*Leptoptilos javanicus*), globally Vulnerable, recorded from non-protected wetland | D—Asian Woolly-neck (*Ciconia episcopus*), globally Near threatened, recorded from both wetlands | E—Red-wattled Lapwing (*Vanellus indicus*), globally Least Concern, recorded from both wetlands | F—Oriental Darter (*Anhinga melanogaster*), globally near threatened recorded from both wetlands. © Jagan Nath Adhikari

carnivores of birds. Among them, insectivores were highly abundant in both wetland systems. Dahal et al. (2014) identified seven main foraging guilds of birds. Insectivores are the most dominant group of birds as compared to other birds in the globe (Zakaria & Rajpar 2010; Datta 2011; Dahal et al. 2014; Basnet et al. 2016; Adhikari et al. 2018a,b). The main reason for the selection of different habitats by birds could be the presence of different vegetation types. The vegetation surrounding the protected wetland was dense and relatively mature compared to non-protected wetland. The agricultural fields around the non-protected wetland also supported more insectivore birds. Hence, both protected and non-protected wetlands are very important from conservation aspects of birds.

CONCLUSION

This study demonstrates that both protected and non-protected wetlands have comparable richness, though the composition of birds slightly differed.

Protected areas supported some forest and wetland specialist birds. The study reported the same common bird species on both protected and non-protected wetlands, hence, wetlands outside protected areas are also important for species conservation. This result suggests that the habitats outside protected areas also play an important complementary role to conservation of bird species which are worth conserving. Mosaics of habitat patches in low-intensity agricultural landscape favored considerable bird diversity which supports the idea that food production and biodiversity conservation can be reconciled in same landscape unit. Wetlands rich in biodiversity and sources of ecosystem goods and services are dwindling faster due to increased human activities related with agriculture, land use change and infrastructure development. We underscore call for action to extend program for the protection of ecosystem outside protected areas while emphasizing the management of protected areas for enhanced in situ conservation.

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Appendix 1. Bird species with their abundance observed in protected and non-protected wetlands in Winter and Summer. Relative abundance (RA) refers total percentage contribution of each species to the total sample. 0 indicated the species were not recorded during field study, here, EN= Endangered, VU= Vulnerable, NT= Near threatened and LC= Least Concern.

	Order/Family/ Common name	Zoological name	RA in Winter		RA in Summer		Total RA(%)		IUCN category
			Protected	Non-protected	Protected	Non-protected	Protected	Non-protected	
Order ACCIPITRIFORMES									
Family Accipitridae									
1	Black Kite	*Milvus migrans* (Boddaert, 1783)	0.004	0.5	0.007	0.554	0.524	0.53	LC
2	Crested Serpent-eagle	*Spilornis cheela* (Latham, 1790)	0.002	0.125	0.001	0.111	0.175	0.117	LC
3	Grey-headed Fish-eagle	*Icthyophaga ichthyaetus* (Horsfield, 1821)	0.002	0.503	0.001	0.443	0.175	0.47	NT
4	Lesser Fish-eagle	*Icthyophaga humilis* (Müller & Schlegel, 1841)	0.604	0	0.005	0	0.466	0	NT
5	Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)	0.001	0	0.001	0	0.117	0	EN
Family Pandionidae									
6	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	0.002	0	0.003	0	0.233	0	LC
Order ANSERIFORMES									
Family Anatidae									
7	Bar-headed Goose	*Anser indicus* (Latham, 1790)	0.005	0	0	0	0.291	0	LC
8	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	1.915	1.509	0	0	0.874	0.707	LC
9	Common Shelduck	*Tadorna tadorna (*Linnaeus, 1758)	1.017	1.509	0	0	0.932	0.7	LC
10	Common Teal	*Anas crecca* Linnaeus, 1758	0.004	0.628	0	0	0.233	0.294	LC
11	Gadwall	*Mareca strepera* (Linnaeus, 1758)	0.004	0	0	0	0.233	0	LC
12	Lesser Whistling-duck	*Dendrocygna javanica (*Horsfield, 1821)	0.91	6.92	0	0	0.583	3.241	LC
13	Mallard	*Anas platyrhynchos* Linnaeus, 1758	0.002	0	0	0	0.117	0	LC
14	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	0.002	0	0	0	0.117	0	LC
Order BUCEROTIFORMES									
Family Bucerotidae									
15	Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	0.002	0	0.003	0.111	0.233	0.05	LC
Family Upupidae									
16	Common Hoopoe	*Upupa epops* Linnaeus, 1758	0.006	0.25	0.008	0.222	0.699	0.235	LC
Order CAPRIMULGIFORMES									
Family Apodidae									
17	House Swift	*Apus nipalensis* (Hodgson, 1836)	2.052	2.77	3.04	2.328	4.662	2.533	LC
Order CHARADRIIFORMES									
Family Charadriidae									
18	Grey-headed Lapwing	*Vanellus cinereus* (Blyth, 1842)	0.004	0.251	0.005	0	0.466	0.118	LC
19	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	0.004	0.503	0.007	0.665	0.524	0.589	LC
20	River Lapwing	*Vanellus duvaucelii* (Lesson, 1826)	0.004	0.628	0.004	0.665	0.408	0.648	NT
21	Yellow-wattled Lapwing	*Vanellus malabaricus* (Boddaert, 1783)	0.004	1.006	0.005	1.219	0.466	1.119	LC
Family Jacanidae									
22	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	0.81	0.628	1.019	0.332	1.399	0.471	LC

	Order/Family/ Common name	Zoological name	RA in Winter		RA in Summer		Total RA(%)		IUCN category
			Protected	Non-protected	Protected	Non-protected	Protected	Non-protected	
Family Scolopacidae									
23	Common Sandpiper	*Actitis hypoleucos* Linnaeus, 1758	0.004	0	0.003	0	0.35	0	LC
24	Green Sandpiper	*Tringa ochropus* Linnaeus, 1758	0.012	0.503	0.007	0.554	0.991	0.53	LC
25	Marsh Sandpiper	*Tringa stagnatilis* (Bechstein, 1803)	0.004	0.503	0.003	0.443	0.35	0.471	LC
26	Wood Sandpiper	*Tringa glareola* Linnaeus, 1758	0.002	0	0	0	0.117	0	LC
Order CICONIIFORMES									
Family Ciconiidae									
27	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	0.71	1.509	0.009	1.77	0.991	1.649	LC
28	Asian Woollyneck	*Ciconia episcopus* (Boddaert, 1783)	0.002	0.125	0.003	0.886	0.233	0.53	NT
29	Black Stork	*Ciconia nigra* (Linnaeus, 1758)	0.002	0	0.003	0	0.233	0	LC
30	Lesser Adjutant	*Leptoptilos javanicus* (Horsfield, 1821)	0	0.252	0	0	0	0.117	VU
31	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	0.002	0.252	0	0	0.117	0.117	NT
Order COLUMBIFORMES									
Family Columbidae									
32	Grey-capped Emerald Dove	*Chalcophaps indica* (Linnaeus, 1758)	0.008	1.006	1.011	0.997	0.932	1.001	LC
33	Oriental Turtle-dove	*Streptopelia orientalis* (Latham, 1790)	0.004	0.503	0.005	0.443	0.466	0.47	LC
34	Red Turtle-dove	*Streptopelia tranquebarica* (Hermann, 1804)	0.004	0.503	0.005	0.554	0.466	0.53	LC
35	Rock Dove	*Columba livia* Gmelin, 1789	0.005	0	0.004	0	0.466	0	LC
36	Western Spotted Dove	*Spilopelia suratensis* (Gmelin, 1789)	0.019	0.628	0.008	4.212	1.399	2.53	LC
Order CORACIIFORMES									
Family Alcedinidae									
37	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	0.005	0.628	0.007	0.554	0.583	0.589	LC
38	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	0	0.252	0.001	0	0.058	0.117	LC
39	Stork-billed Kingfisher	*Pelargopsis capensis* (Linnaeus, 1766)	0.002	0	0	0	0.117	0	LC
40	White-breasted Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	0.07	0.88	0.012	2.1	0.932	1.532	LC
Family Coraciidae									
41	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	0.05	0.628	0.007	0.554	0.583	0.589	LC
Family Meropidae									
42	Asian Green Bee-eater	*Merops orientalis* Latham, 1802	1.018	2.138	2.013	2.106	1.573	2.121	LC
43	Blue-tailed Bee-eater	*Merops philippinus* Linnaeus, 1766	2.038	3.899	3.048	3.215	4.254	3.535	LC
44	Chestnut-headed Bee-eater	*Merops leschenaulti* Vieillot, 1817	0.004	0.503	0.005	0.222	0.466	0.353	LC
Order CUCULIFORMES									
Family Cuculidae									
45	Banded Bay Cuckoo	*Cacomantis sonneratii* (Latham, 1790)	0.002	0.252	0.003	0.222	0.233	0.23	LC
46	Common Hawk-cuckoo	*Hierococcyx varius* (Vahl, 1797)	0.002	0.252	0.003	0.222	0.233	0.23	LC
47	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	0.002	0.252	0.003	0.222	0.233	0.23	LC
48	Indian Cuckoo	*Cuculus micropterus* Gould, 1837	0.003	0.377	0.004	0	0.35	0.176	LC

	Order/Family/ Common name	Zoological name	RA in Winter		RA in Summer		Total RA(%)		IUCN category
			Protected	Non-protected	Protected	Non-protected	Protected	Non-protected	
49	Lesser Coucal	*Centropus bengalensis* (Gmelin, 1788)	0.008	1.006	0.009	0.776	0.874	0.88	LC
50	Western Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	0.002	0	0.003	0	0.233	0	LC
Order FALCONIFORMES									
Family Falconidae									
51	Red-headed Falcon	*Falco chicquera* Daudin, 1800	0.002	0	0.003	0	0.233	0	NT
Order GALLIFORMES									
Family Phasianidae									
52	Black Francolin	*Francolinus francolinus* (Linnaeus, 1766)	0.004	0.252	0.003	0.221	0.35	0.23	LC
53	Common Peafowl	*Pavo cristatus* Linnaeus, 1758	3.052	2.767	4.047	2.328	4.953	2.53	LC
54	Common Quail	*Coturnix coturnix* (Linnaeus, 1758)	0.004	0	0.008	0	0.583	0	LC
55	Red Junglefowl	*Gallus gallus* (Linnaeus, 1758)	0.804	0.503	0.005	0.443	0.466	0.471	LC
56	Common Coot	*Fulica atra* Linnaeus, 1758	0.01	0	0	0.554	0.583	0.294	LC
Order GRUIFORMES									
Family Rallidae									
57	Ruddy-breasted Crake	*Zapornia fusca* (Linnaeus, 1766)	0.015	0	0.017	0	1.632	0	LC
58	Watercock	*Gallicrex cinerea* (Gmelin, 1789)	0.01	1.258	0.004	0	0.758	0.58	LC
59	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	0.003	0.377	0	0	0.175	0.17	LC
Order PASSERIFORMES									
Family Alaudidae									
60	Rufous-winged Lark	*Mirafra assamica* Horsfield, 1840	0.715	1.88	2.017	1.33	1.632	1.591	LC
61	Sand Lark	*Alaudala raytal* (Blyth, 1844)	0.002	0.25	0	0.221	0.117	0.23	LC
Family Campephagidae									
62	Scarlet Minivet	*Pericrocotus flammeus* (Forster, 1781)	0.006	0.754	0.009	0.665	0.758	0.7	LC
Family Cisticolidae									
63	Jungle Prinia	*Prinia sylvatica* Jerdon, 1840	0.005	0.628	0.005	0	0.524	0.294	LC
64	Zitting Cisticola	*Cisticola juncidis* (Rafinesque, 1810)	0.004	0.503	0.004	0.443	0.408	0.471	LC
Family Corvidae									
65	Grey Treepie	*Dendrocitta formosae* Swinhoe, 1863	0.002	0	0.003	0	0.233	0	LC
66	House Crow	*Corvus splendens* Vieillot, 1817	0.915	1.88	1.012	2.439	1.399	2.18	LC
67	Large-billed Crow	*Corvus macrorhynchos* Wagler, 1827	0.004	0.503	0.008	1.441	0.583	1	LC
68	Red-billed Blue Magpie	*Urocissa erythroryncha* (Boddaert, 1783)	0.002	0.25	0.003	0.221	0.233	0.235	LC
69	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	0.004	0.503	0.004	0.554	0.408	0.53	LC
Family Dicruridae									
70	Ashy Drongo	*Dicrurus leucophaeus* Vieillot, 1817	0.005	0.628	0.007	0.55	0.583	0.58	LC
71	Black Drongo	*Dicrurus macrocercus* Vieillot, 1817	1.015	1.88	2.017	1.88	1.632	1.885	LC
72	Greater Racquet-tailed Drongo	*Dicrurus paradiseus* (Linnaeus, 1766)	0.004	0.503	0.003	0.44	0.35	0.47	LC
73	Lesser Racquet-tailed Drongo	*Dicrurus remifer* (Temminck, 1823)	0.002	0.252	0.003	0.221	0.233	0.23	LC

	Order/Family/ Common name	Zoological name	RA in Winter		RA in Summer		Total RA(%)		IUCN category
			Protected	Non-protected	Protected	Non-protected	Protected	Non-protected	
74	White-bellied Drongo	*Dicrurus caerulescens* (Linnaeus, 1758)	0	0	0	0.332	0	0.176	LC
Family Estrildidae									
75	Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	0.005	0.628	0.007	0.554	0.583	0.589	LC
Family Hirundinidae									
76	Barn Swallow	*Hirundo rustica* Linnaeus, 1758	1.023	2.642	2.028	2.771	2.506	2.71	LC
77	Wire-tailed Swallow	*Hirundo smithii* Leach, 1818	2.026	3.144	3.036	2.771	3.03	2.946	LC
Family Laniidae									
78	Grey-backed Shrike	*Lanius tephronotus* (Vigors, 1831)	0	0	0.33	0.001	0.176	0.058	LC
Family Leiotrichidae									
79	Common Babbler	*Argya caudata* (Dumont, 1823)	0.004	0.503	0.005	0.665	0.466	0.589	LC
80	Jungle Babbler	*Turdoides striata* (Dumont, 1823)	1.014	1.761	2.016	1.33	1.515	1.53	LC
81	Large Grey Babbler	*Argya malcolmi* (Sykes, 1832)	0	0	0.005	0	0.233	0	LC
Family Monarchidae									
82	Black-naped Monarch	*Hypothymis azurea* (Boddaert, 1783)	0.905	0.628	0.807	0.554	0.583	0.589	LC
83	White Wagtail	*Motacilla alba* Linnaeus, 1758	0	0	0	1.108	0	0.589	LC
84	White-browed Wagtail	*Motacilla maderaspatensis* Gmelin, 1789	0.004	0.503	0.005	0.554	0.466	0.53	LC
Family Muscicapidae									
85	Black Redstart	*Phoenicurus ochruros* (Gmelin, 1774)	0	0.629	0	0	0	0.294	LC
86	Common Stonechat	*Saxicola torquatus* (Linnaeus, 1766)	1.017	1.761	1.015	1.108	1.573	1.41	LC
87	Grey Bushchat	*Saxicola ferreus* Gray, 1846	0.002	0.251	0.003	0.221	0.233	0.23	LC
88	Indian Robin	*Saxicoloides fulicatus* (Linnaeus, 1766)	0.002	0.251	0.003	0.221	0.233	0.23	LC
89	Oriental Magpie-robin	*Copsychus saularis* (Linnaeus, 1758)	1.017	1.257	0.915	1.219	1.573	1.237	LC
90	Pied Bushchat	*Saxicola caprata* (Linnaeus, 1766)	0	0	0	0.332	0	0.176	LC
91	White-capped Water-redstart	*Phoenicurus leucocephalus* (Vigors, 1831)	0.005	0.628	0.001	0.554	0.35	0.589	LC
92	White-tailed Stonechat	*Saxicola leucurus* (Blyth, 1847)	0.004	0.503	0	0.443	0.233	0.471	LC
Family Oriolidae									
93	Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	0.004	0.503	0.004	1.33	0.408	0.942	LC
Family Passeridae									
94	Chestnut-shouldered Bush-sparrow	*Gymnoris xanthocollis* (Burton, 1838)	1.015	1.257	1.615	1.662	1.515	1.473	LC
95	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	1.026	3.144	2.028	5.21	2.681	4.242	LC
Family Ploceidae									
96	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	0.01	1.257	0.016	0.776	1.282	1	LC
Family Pycnonotidae									
97	Black Bulbul	*Hypsipetes leucocephalus* (Gmelin, 1789)	1.01	1.257	2.015	1.108	1.224	1.17	LC
98	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	0.006	0	0.008	0.665	0.699	0.35	LC
99	Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus, 1758)	1.017	2.012	1.019	1.995	1.748	2	LC

	Order/Family/ Common name	Zoological name	RA in Winter		RA in Summer		Total RA(%)		IUCN category
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Family Scotocercidae									
100	Pale-footed Bush-warbler	*Hemitesia pallidipes* (Blanford, 1872)	0.002	0.251	0.003	0.221	0.233	0.235	LC
Family Sturnidae									
101	Asian-pied Starling	*Gracupica contra* (Linnaeus, 1758)	0	0	0	0.886	0	0.471	LC
102	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	1.015	1.886	2.019	1.99	1.69	1.944	LC
103	Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)	1.012	1.509	1.015	2.1	1.34	1.826	LC
Family: Zosteropidae									
104	Indian White-eye	*Zosterops palpebrosus* (Temminck, 1824)	0.002	0.251	0.003	0.221	0.233	0.235	LC
Order PELECANIFORMES									
Family Ardeidae									
105	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	0.805	0.628	0.005	7.649	0.524	4.36	LC
106	Great White Egret	*Ardea alba* Linnaeus, 1758	0.006	0	0.007	0	0.641	0	LC
107	Grey Heron	*Ardea cinerea* Linnaeus, 1758	0.004	0.503	0.005	0.443	0.466	0.471	LC
108	Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	0	0	0.04	0.332	1.748	0.176	LC
109	Intermediate Egret	*Ardea intermedia* Wagler, 1829	0.003	0.628	0.004	0.554	0.35	0.589	LC
110	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	0.004	0.503	0.005	0.997	0.466	0.766	LC
111	Purple Heron	*Ardea purpurea* Linnaeus, 1766	0.004	0	0.005	0.443	0.466	0.235	LC
Family Threskiornithidae									
112	Red-naped Ibis	*Pseudibis papillosa* (Temminck, 1824)	0.004	0.503	0.005	0.11	0.466	0.294	LC
Order PICIFORMES									
Family Megalaimidae									
113	Brown-headed Barbet	*Psilopogon zeylanicus* (Gmelin, 1788)	0.002	0.251	0.003	0.221	0.233	0.235	LC
114	Coppersmith Barbet	*Psilopogon haemacephalus* (Müller, 1776)	0.005	0.628	0.005	0.55	0.524	0.589	LC
Family Picidae									
115	Brown-capped Pygmy Woodpecker	*Picoides nanus* (Vigors, 1832)	0	1.509	0	1.77	0	1.649	LC
116	Great Slaty Woodpecker	*Mulleripicus pulverulentus* (Temminck, 1826)	0.002	0.251	0.003	0	0.233	0.117	VU
117	Indian Pygmy Woodpecker	*Picoides nanus* (Vigors, 1832)	1.012	0.503	1.012	0	1.224	0.235	LC
118	Lesser Yellownape	*Picus chlorolophus* Vieillot, 1818	0.004	0	0.005	0	0.466	0	LC
119	Greater Flameback	*Chrysocolaptes guttacristatus* (Tickell, 1833)	0.808	0.503	0.78	0.44	0.816	0.471	LC
120	Yellow-crowned Woodpecker	*Leiopicus mahrattensis* (Latham, 1801)	0.005	0.628	0.004	0.554	0.466	0.589	LC
Order PSITTACIFORMES									
Family Psittacidae									
121	Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	2.021	1.257	2.025	0.997	2.273	1.119	LC
122	Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus, 1766)	2.019	1.257	0	0.886	1.049	1.06	NT
123	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	1.01	1.509	2.016	1.33	1.282	1.414	LC
124	Slaty-headed Parakeet	*Psittacula himalayana* (Lesson, 1832)	3.031	4.02	2.02	2.439	2.622	3.18	LC

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Order STRIGIFORMES									
Family Strigidae									
125	Jungle Owlet	*Glaucidium radiatum* (Tickell, 1833)	0.001	0	0.001	0	0.117	0	LC
126	Spotted Owlet	*Athene brama* (Temminck, 1821)	0.001	0	0.001	0	0.117	0	LC
Order SULIFORMES									
Family Anhingidae									
127	Oriental Darter	*Anhinga melanogaster* Pennant, 1769	0.002	0.125	0	0	0.117	0.058	NT
Family Phalacrocoracidae									
128	Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	0.01	0.503	0	0.443	0.583	0.47	LC
129	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	1.017	1.006	1.019	0.997	1.748	1	LC

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Author's contributions: JNA designed the study, carried out the fieldwork, analysed the data and prepare draft, JRK designed the study, analysed the data and revised the draft, DA carried out the fieldwork and revised the final draft, SS carried out the fieldwork and revised the final draft, BPB prepared map and revised the final draft, DR revised the final draft, LNS designed the study, helped in fieldwork, analysed and helped for the preparation of manuscript and revised the draft.

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