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

Jagan Nath Adhikari 1 5, Janak Raj Khatiwada 2, Dipendra Adhikari 3, Suman Sapkota 4, Bishnu Prasad Bhattarai 5 6, Deepak Rijal 6 & Lila Nath Sharma 7

1 Central Department of Zoology, Institute of Science and Technology, Tribhuvan University, Kathmandu, Nepal.
2 Department of Zoology, Birendra Multiple Campus, Bharatpur, Chitwan, Nepal.
3 Small Mammals Conservation and Research Foundation, PO Box 9092, Kathmandu, Nepal.
4 Friends of Nature (FON), Kathmandu, Nepal.
5 USAID Program for Aquatic Natural Resource Improvement, Paani Program, Baluwatar, Kathmandu, Nepal.
6 Forest Action Nepal, Bagdol Lalitpur, Nepal.
7 Forest Action Nepal, Bagdol Lalitpur, Nepal.

1 jagan.adhikari@bimc.tu.edu.np (corresponding author), 2 janakrajkhatiwada@gmail.com, 3 dipenadk2005@gmail.com,
4 suman.palpa99.ss@gmail.com, 5 bishnu.bhattarai@cdz.tu.edu.np, 6 deepak_rijal@dai.com, 7 lilanathsharma@gmail.com

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.
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 (Chakravarthy et al. 2012), and some geographical areas are under-represented (Shrestha et al. 2010), including 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 x 50 and Bushnell 10 x 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
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).

\[
H = -\sum_{i=1}^{s} p_i \ln p_i
\]

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, \( \Sigma \) 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).

\[
D = -\sum_{i=1}^{s} p_i \ln p_i
\]

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), \( \Sigma \) is the sum of the calculations, and \( s \) is the number of species.

Evenness (e) was used to determine distribution of

![Figure 1. Map of the study area showing protected and non-protected wetlands.](image)
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.

Jacobs’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 × ln (1 + 5

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 (a) 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 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 ichthyaeus, Lesser Fish Eagle Icthyophaga humilis, River Lapwing Vanellus duvaealci, 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
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pulverulentus, & Lesser Adjutant Leptoptilos javanicus; and six Near Threatened species: Grey-headed Fish-eagle Ichthyophaga 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 Yellowwax Picus chlorolophus and Common Peafowl Pavo cristatus was higher around the protected

| 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 hectar        | 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 (Shorea olesse), Saaz (Terminalia aflat), Rohini (Mallotus philippensis), Jamun (Syzygium cuminii), Bhelar (Treia nudiflora) Common shrub species: Rudilo (Pogostemon bengalensis), Asare (Murraya koenighii) and Bhati (Clorodendron 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 Sisoo (Dalbergia sissoo), Simal (Bombax ceiba), Vellar (Treia nudiflora) and Khayer (Azoca catechu). Sinduure (Mallotus philippensis) and Shirish (Albizia chinensis) Common shrub species: Asare (Murraya koenighii), Bhati (Clorodendron 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 1. Comparative information about the study area: Protected and non-protected wetlands of lowland Terai western Nepal.**

| Parameters                  | Protected Non-protected | Protected Non-protected | Winter | Summer | Total |
|-----------------------------|-------------------------|-------------------------|--------|--------|-------|
| **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                   | 0.92   | 0.92   | 0.92  | 0.921 |
| **Fisher_alpha**            | 37.21                   | 31                      | 34.51  | 27.43  | 31.54 | 27.31 |

**Table 2. The diversity and dominance indices of birds in protected and non-protected wetlands.**
Protected and non-protected wetland birds of Nepal

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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 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 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.

Figure 3. Percentage of bird species recorded for the different feeding guilds.
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...
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  |
| Order ACCIPITRIFORMES      |                 |              |              |             |                |
| Family Accipitridae        |                 |              |              |             |                |
| 1 Black Kite               | Milvus migrans  | 0.004        | 0.5          | 0.007   | 0.554        | 0.524         | 0.53          | LC       |
| 2 Crested Serpent-eagle    | Spilornis cheela | 0.002        | 0.125        | 0.001   | 0.111        | 0.175         | 0.117        | LC       |
| 3 Grey-headed Fish-eagle   | Icthyophaga ichthyaeus (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                  | Moreoa strepera (Linnaeus, 1758) | 0.004 | 0 | 0 | 0 | 0.233 | 0 | LC |
| 12 Lesser Whistling-duck   | Dendrocopos javanicus (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    | Ocyxera 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 (Boddart, 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 (Boddart, 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 | 0.312 | 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   |
|                           |                 |              |             |             | category     |
| **Family Scopoliidae**    |                 |              |             |             |              |
| 23 Common Sandpiper       | Actitis hypoleucus Linnaeus, 1758 | 0.004         | 0.003       | 0.35        | 0 LC         |
| 24 Green Sandpiper        | Tringa ochropus Linnaeus, 1758 | 0.012        | 0.007       | 0.991       | 0.53 LC      |
| 25 Marsh Sandpiper        | Tringa stagnatilis (Bechstein, 1803) | 0.004 | 0.003 | 0.443 | 0.35 0.471 LC |
| 26 Wood Sandpiper         | Tringa glareola Linnaeus, 1758 | 0.002        | 0.003       | 0.117       | 0 LC         |
| **Order CICONIIFORMES**  |                 |              |             |             |              |
| 27 Asian Openbill         | Anastomus ascitans (Beddaert, 1783) | 0.71        | 1.509       | 0.991       | 1.649 LC     |
| 28 Asian Woollyneck       | Ciconia episcopus (Beddaert, 1783) | 0.002 | 0.125 | 0.03 | 0.233 | 0.53 NT |
| 29 Black Stork            | Ciconia nigra (Linnaeus, 1758) | 0.002        | 0.003       | 0.233       | 0 LC         |
| 30 Lesser Adjutant        | Leptoptilus javanicus (Horsfield, 1821) | 0 | 0.252 | 0 | 0 | 0.117 VU |
| 31 Painted Stork          | Mycteria leucocephala (Pennant, 1769) | 0.002 | 0.252 | 0 | 0 | 0.117 NT |
| **Order COLUMBIFORMES**  |                 |              |             |             |              |
| 32 Grey-capped Emerald Dove | Chalcophaps indica (Linnaeus, 1758) | 0.008 | 1.006 | 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 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 | 0.466 | 0 LC |
| 36 Western Spotted Dove   | Spilopelia capensis (Gmelin, 1789) | 0.019 | 0.628 | 0.008 | 4.212 1.399 2.53 LC |
| **Order CORACIIFORMES**  |                 |              |             |             |              |
| 37 Common Kingfisher      | Alcedo atthis (Linnaeus, 1758) | 0.005 | 0.628 | 0.007 | 0.554 0.583 0.589 | LC |
| 38 Pied Kingfisher        | Ceyx erithacus (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**    |                 |              |             |             |              |
| 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|               |
| 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 |

**Order GRUIFORMES**

Family Rallidae

| 57 Ruddy-breasted Crane    | Zapornia fusca (Linnaeus, 1766) | 0.015 | 0 | 0.017 | 0 | 1.632 | 0 | 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 |

Family Cisticolidae

| 63 Jungle Prinia           | Prinia sylvatica Jerdon, 1840 | 0.005 | 0.628 | 0.005 | 0 | 0.524 | 0.294 | LC |

Family Corvidae

| 65 Grey Treepie            | Dendrocitta formosae Swinhoe, 1863 | 0.002 | 0 | 0.003 | 0 | 0.233 | 0 | 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 macroscepus 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            | 0.33        | 0             | 0.176        | LC           |
| 75 Scaly-breasted Munia   | Lonchura punctulata (Linnaeus, 1758) | 0.005       | 0.628        | 0.007       | 0.554         | 0.583        | 0.589        | LC           |
| 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           |
| 78 Grey-backed Shrike     | Lanius tephronotus (Vigors, 1831) | 0           | 0            | 0.33        | 0.001         | 0.176        | 0.058        | LC           |
| 79 Common Babbler         | Argya coudata (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           |
| 82 Black-naped Monarch    | Hypothymis azurea (Boddart, 1783) | 0.905       | 0.628        | 0.807       | 0.554         | 0.583        | 0.589        | LC           |
| 83 White Wagtail          | Motacilla alba Linnaeus, 1758 | 1.017       | 1.257        | 1.215       | 1.573         | 1.237        | 1.233        | LC           |
| 84 White-browed Wagtail   | Motacilla madaraspotensis Gmelin, 1879 | 0.004      | 0.503        | 0.005       | 0.554         | 0.466        | 0.53         | LC           |
| 85 Black Redstart         | Phoenicurus ochruros (Gmelin, 1774) | 0           | 0.629        | 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 Gmelin, 1846 | 0.002       | 0.251        | 0.003       | 0.221         | 0.233        | 0.23         | LC           |
| 88 Indian Robin           | Saxicola fulicata (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           | 0.323         | 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           |
| 93 Black-hooded Oriole    | Oriolus xanthornus (Linnaeus, 1758) | 0.004      | 0.503        | 0.004       | 1.33          | 0.408        | 0.942        | LC           |
| 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, 1766) | 1.026      | 3.144        | 2.028       | 5.21          | 2.681        | 4.242        | LC           |
| 96 Baya Weaver            | Ploceus philippinus (Linnaeus, 1766) | 0.01       | 1.257        | 0.016       | 0.776         | 1.282        | 1            | LC           |
| 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 sinensis (Linnaeus, 1766) | 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 |
|---------------------------|-----------------|--------------|--------------|-------------|---------------|
|                           | Protected       | Non-protected | Protected    | Non-protected | Protected     | Non-protected |
| Family Scotocercidae      |                 |              |              |             |               |               |
| 100 Pale-footed Bush-     | Hemitesia      | 0.002        | 0.251        | 0.003       | 0.221         | 0.233         | 0.235         | LC           |
| warbler                   | pollidipes     | (Blanford,  |              |             |               |               |               |              |
|                           |                 | 1872)        |              |             |               |               |               |              |
| Family Sturnidae          |                 |              |              |             |               |               |               |              |
| 101 Asian-pied Starling   | Gracupica      | 0            | 0            | 0.886       | 0             | 0.471         | LC           |
|                           | contra (Linnaeus, |              |              |             |               |               |               |              |
|                           | 1758)          |              |              |             |               |               |               |              |
| 102 Common Myna           | Acridotheres    | 1.015        | 1.886        | 2.019       | 1.99          | 1.69          | 1.944         | LC           |
|                           | tristis        | (Linnaeus,   |              |             |               |               |               |              |
|                           |                 | 1766)        |              |             |               |               |               |              |
| 103 Jungle Myna           | Acridotheres    | 1.012        | 1.509        | 1.015       | 2.1           | 1.34          | 1.826         | LC           |
|                           | fuscus (Wagler, |              |              |             |               |               |               |              |
|                           | 1827)          |              |              |             |               |               |               |              |
| Family: Zosteropidae      |                 |              |              |             |               |               |               |              |
| 104 Indian White-eye      | Zosterops      | 0.002        | 0.251        | 0.003       | 0.221         | 0.233         | 0.235         | LC           |
|                           | palpebrosus    | (Temminck,   |              |             |               |               |               |              |
|                           |                 | 1824)        |              |             |               |               |               |              |
| Order PELECANIFORMES     |                 |              |              |             |               |               |               |              |
| Family Ardeidae          |                 |              |              |             |               |               |               |              |
| 105 Cattle Egret          | Bubulcus ibis  | 0.805        | 0.628        | 0.005       | 7.649         | 0.524         | 4.36          | LC           |
|                           | (Linnaeus, 1758)|              |              |             |               |               |               |              |
| 106 Great White Egret     | Ardea alba     | 0.006        | 0            | 0.007       | 0             | 0.641         | 0             | LC           |
|                           | Linnaeus, 1758 |              |              |             |               |               |               |              |
| 107 Grey Heron            | Ardea cinerea  | 0.004        | 0.503        | 0.005       | 0.443         | 0.466         | 0.471         | LC           |
|                           | Linnaeus, 1758 |              |              |             |               |               |               |              |
| 108 Indian Pond Heron     | Ardea grayii   | 0            | 0            | 0.04        | 0.332         | 1.748         | 0.176         | LC           |
|                           | (Sykes, 1832)  |              |              |             |               |               |               |              |
| 109 Intermediate Egret    | Ardea intermedia | 0.003        | 0.628        | 0.004       | 0.554         | 0.35          | 0.589         | LC           |
|                           | Wagler, 1829   |              |              |             |               |               |               |              |
| 110 Little Egret          | Eretro 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 |
| Order Threskiornithidae   |                 |              |              |             |               |               |               |              |
| 112 Red-naped Ibis        | Pseudibis      | 0.004        | 0.503        | 0.005       | 0.11          | 0.466         | 0.294         | LC           |
|                           | papillosa (Temminck, 1824) |              |              |             |               |               |               |              |
| Order PICIFORMES         |                 |              |              |             |               |               |               |              |
| Family Megalaimidae       |                 |              |              |             |               |               |               |              |
| 113 Brown-headed Barbet   | Psilopagan      | 0.002        | 0.251        | 0.003       | 0.221         | 0.233         | 0.235         | LC           |
|                           | zeylanicus (Gmelin, 1788) |              |              |             |               |               |               |              |
| 114 Coppersmith Barbet    | Psilopagan      | 0.005        | 0.628        | 0.005       | 0.55          | 0.524         | 0.589         | LC           |
|                           | haemacephalus (Müller, 1776) |              |              |             |               |               |               |              |
| Family Picidae            |                 |              |              |             |               |               |               |              |
| 115 Brown-capped Pygmy    | Picoidecus      | 0            | 1.509        | 0           | 1.77          | 0             | 1.649         | LC           |
| Woodpecker                | nanus (Vigors, 1832) |              |              |             |               |               |               |              |
| 116 Great Slaty           | Mulleripicus    | 0.002        | 0.251        | 0.003       | 0             | 0.233         | 0.117         | VU           |
| Woodpecker                | pulvulentus (Temminck, 1826) |              |              |             |               |               |               |              |
| 117 Indian Pygmy Woodpecker| Picoidecus  | 1.012        | 0.503        | 1.012       | 0             | 1.224         | 0.235         | LC           |
|                           | nanus (Vigors, 1832) |              |              |             |               |               |               |              |
| 118 Lesser Yellowmite     | Picus chlorolophus Vieillot, 1818 | 0.004 | 0 | 0.005 | 0 | 0.466 | 0 | LC |
| 119 Greater Flameback     | Chrysocolaptes  | 0.808        | 0.503        | 0.78        | 0.44          | 0.816         | 0.471         | LC           |
|                           | guttacristatus (Tickell, 1813) |              |              |             |               |               |               |              |
| 120 Yellow-crowned        | Leipticus       | 0.005        | 0.628        | 0.004       | 0.554         | 0.466         | 0.589         | LC           |
| Woodpecker                | mahrottenis (Latham, 1801) |              |              |             |               |               |               |              |
| Order PSITTACIFORMES      |                 |              |              |             |               |               |               |              |
| Family Psittacidae        |                 |              |              |             |               |               |               |              |
| 121 Plum-headed Parakeet  | Pittacula      | 2.021        | 1.257        | 2.025       | 0.997         | 2.273         | 1.119         | LC           |
|                           | cyanocephala   | (Linnaeus, 1766) |              |             |               |               |               |              |
| 122 Alexandrine Parakeet  | Pittacula      | 2.019        | 1.257        | 0           | 0.886         | 1.049         | 1.06          | NT           |
|                           | eupatria (Linnaeus, 1766) |              |              |             |               |               |               |              |
| 123 Rose-ringed Parakeet  | Pittacula      | 1.01         | 1.509        | 2.016       | 1.33          | 1.282         | 1.414         | LC           |
|                           | krameri (Scopoli, 1769) |              |              |             |               |               |               |              |
| 124 Slaty-headed Parakeet | Pittacula      | 3.031        | 4.02         | 2.02        | 2.439         | 2.622         | 3.18          | LC           |
|                           | himalayana (Lesson, 1832) |              |              |             |               |               |               |              |
Protected and non-protected wetland birds of Nepal

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Authors details: JAGAN NATH ADHIKARI has a keen interest in the ecology, behavior and conservation of birds, large mammals and herpetofauna. Jagan has authored or co-authored more than ten peer-reviewed papers on birds, mammals, and human-wildlife interactions and three textbooks of zoology for undergraduate level. JANAK RAJ KHATIWADA, PhD is a wildlife biologist with extensive field experience in Himalayan region. He has authored or co-authored more than 15 peer-reviewed papers on taxonomy, thermal ecology, composition, distribution, and conservation status of the herpetofauna of different parts of Nepal, India and China. To date, he has described four new species of amphibians for science from Nepal and India. DIPENDRA ADHIKARI is a wildlife biologist with field experience in lowland to highland of Nepal. His research interests include diversity and distribution patterns of small mammals, birds and photographic capture recapture of megafauna such as tigers, elephants. SUMAN SAPKOTA’s research interests include ecology of frogs, bioacoustics, endemic and threatened frogs and effect of climate change on frogs. He has been involved in different researches related to herpetofauna and presented his work in different national and international conferences. He is currently working as Conservation Officer in Friends of Nature (FON), Nepal. BISHNU PRASAD BHATTARAI, PhD is a conservation biologist His research interests include the conservation of large carnivores, their habitats, and prey, biogeography of Himalayan flora and fauna (e.g., birds, mammals, herpetofauna, and orchids), forest and wildlife habitat management. DEEPAK RIJAL, PhD is nationally reputed scholar of biodiversity. Over 30 years Deepak with specialist expertise in ecological adaptation has been actively involved in research and conservation of agriculture, forest, and freshwater resources. He has been a prolific writer and has been the lead and co-author for knowledge products published nationally and internationally. Deepak as a Board Chair of the nationally reputed research and development non-government organization consistently provides strategic direction that contributes to knowledge and benefit to various end-users in Nepal and abroad. LILA NATH SHARMA, PhD is a researcher at ForestAction Nepal. He is an ecologist and undertakes action research related to biodiversity conservation, forest restoration, and invasive species management.

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.

| Order/Family/ Common name | Zoological name | RA in Winter | RA in Summer | Total RA(%) | IUCN category |
|--------------------------|----------------|-------------|-------------|-------------|---------------|
| RA in Winter | RA in Summer | Protected | Non-protected | Protected | Non-protected | Protected | Non-protected |
| Protected | Non-protected | Protected | Non-protected | Protected | Non-protected |
| Protected | Non-protected | Protected | Non-protected | Protected | Non-protected |
| 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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