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Research Article

Influence of environmental factors on bird diversity in and around Kahundanda Hillscape, Pokhara, Nepal

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Abstract

Birds are the indicators of the ecosystem health. Several environmental variables affect the diversity, distribution and migration of birds. Kahundanda of Pokhara Valley is one of the important hillscapes having different habitat types such as human settlements, forest, farmland, wetland and open areas. This study explored the factors affecting the diversity and distribution of birds in Kahundanda. The direct observation by "point count" method was used for the bird survey. A total of 49 points were fixed along the nine transects in every 200–250 m distance of the Kahundanda (elevation ranges from 700 m to 1424 m). In each point, we also recorded habitat types and disturbance factors. A total of 101 species of birds belonging to 18 orders and 41 families were reported from the study area. The species diversity was the highest in forest habitat (H' = 3.558) and least in open area (H' = 2.365). Among them, 58.42% of birds were resident and 41.58% were migratory, that included two globally threatened (one critically endangered, one endangered) and one near threatened species. Other factors such as the number of livestock present, distance from roads and settlement, environmental factors such as distance from the water resources, elevation and number of fruiting trees significantly affected the distribution of the birds at Kahundanda. Thus, environmental factors such as habitat types, human disturbance and proximity to water resources are important for bird species conservation in the human-dominated landscape.

Keywords: Disturbance; Habitat; Kahundanda; Threatened birds

1 | Introduction

Nepal is rich in avifauna (891 species, 8.87% of the global species) due to physiography, geography and climatic differences (DNPWC & BCN 2019; BCN 2022). Elevation, land use and land cover patterns, settlements, anthropogenic disturbance, etc. determine the diversity and abundance of the birds. Small ranged species are habitat and topography specific than large ranged birds (Pan et al. 2016; Pan et al. 2019). Habitat heterogeneity hypothesis states that where there is a greater variety of habitat types per unit area with complexity of vegetation structures (Kim et al. 2018) that increases faunal diversity by providing good space for birds in an area (Kim et al. 2018; Iswandaru et al. 2020). Alpine habitat, forest and scrub, wetlands, grassland, agricultural land and human settlements are the key habitats found in Nepal (Basnet et al. 2016, Grimmett et al. 2016; Baral & Inskipp 2020). Diversity of habitats ranging from bare rock and scrub in the alpine zone to tropical forest in the lowlands, support the diverse bird species. In the agriculture land, excessive use of agrochemicals, intensive crop rotations, removal of non-crop plants from the agriculture field directly or indirectly affect the resource availability and habitat

density in agroecosystem (Redlich et al. 2018). The food availability is an example of good habitat quality, for example, food availability in the wetland environment increases the diversity of wetland birds (Inskipp et al. 2017; Meer & Mirza 2017; Baral & Inskipp 2020)

Birds and their diversity provide bio-indication of that ecosystem or landscape and also indicate the health and quality of ecosystem (Bregman et al. 2014). Anthropogenic drivers such as habitat destruction, fragmentation and degradation are responsible for the change in the bird's community and diversity. These factors are directly affecting their breeding, feeding and nesting grounds that lead to local threats to the birds and their conservation (Bregman et al. 2014).

Out of the 891 bird species recorded in Nepal, 19% (n = 168 species) have been assessed as nationally threatened of which 64 species are Critically Endangered, 44 Endangered, 64 Vulnerable and 22 are Data Deficient (Inskipp et al. 2016). A total of 43 species of birds are globally threatened; 43 are globally near threatened species followed by nine Critically Endangered (CR), nine Endangered (EN), 25 Vulnerable (VU) and eight are Regionally Extinct (RE) species: jungle bush quail (*Perdicula asiatica*), rufous-necked hornbill (*Aceros nipalensis*), silver-breasted broadbill (*Serilophus lunatus*), green cochoa (*Cochoa viridis*), black-breasted parrotbill (*Paradoxornis flavirostris*), pink-headed duck (*Rhodonessa caryophyllacea*) and white-bellied heron (*Ardea insignis*) in Nepal (Inskipp et al. 2016; DNPWC & BCN 2019; BCN 2022). Spiny babbler (*Acanthoptila nipalensis)* is the only endemic bird of Nepal. Nine species; Himalayan monal, cheer pheasant, satyr tragopan, Bengal florican, lesser florican, great hornbill, sarus crane, black stork and white stork are protected birds of Nepal according to NPWC act 1973. Currently, 71 species of birds are accepted as a vagrant bird species in Nepal (Inskipp et al. 2020). Over half (53%) of Nepal's nationally threatened birds inhabit in forests, 27% inhabit in wetlands and 15% inhabit grasslands (DNPWC & BCN 2019).

Various anthropogenic changes and developmental process in these days in Nepal are affecting the diversity/richness of the avifauna and their habitats. Several environmental variables change the diversity and distribution of the birds. Seasonal migration of the birds is one of the important evolutionary hypotheses that explains birth and death as well as life process (Ferreira & Perbiche-Neves 2021; Ghimire et al. 2021). Migratory birds can adapt with the residential birds and share the same habitat, food and breeding ground (Ghimire et al. 2021). Therefore, the interrelationship between migrant and resident birds plays as an important role in the breeding season. The heterospecific attraction hypothesis states that migrants use residents as a signal to identify suitable sites for breeding as the resident birds already occupy the higher quality sites (Kim et al. 2018). Hence, increasing migration may positively affect the species richness and density of the given sites (Ferreira & Perbiche-Neves 2021). Previous studies have shown that habitat of the birds such as forest, wetlands, grasslands, bush area have been threatened by various anthropogenic activities such as development of infrastructures, roads, dams in wetlands, pollutions, habitat encroachments, habitat degradation by invasive and alien species (Junk et al. 2013). Food and water scarcity, overgrazing and use of pesticides, pollution from households and industrial discharges and agricultural run-off is seriously degrading the habitat of birds which are posing serious threats to birds of Nepal (Inskipp et al. 2016). Though various studies have looked at diversity of birds but they have focused on lake system, habitats (Khatri et al. 2019). Studies on altitudinal gradients of the human-dominated landscape of the surrounding hills of Pokhara Valley are scarce.

The study of the diversity of bird community in different habitats is essential to find out the community structure and composition. This type of study is also important for regional or local landscapes for avian conservation Kahundanda is the stepping stone habitat for the long-range migratory birds that migrate through the Annapurna Conservation Area (ACA) to the Chitwan National Park (CNP) in the lowlands. Besides, it also provides the refugium and nesting habitats for different species of birds of lake clusters of Pokhara Valley- a Ramsar site. It is also an important ecotourism destination of Pokhara Valley for nature and cultural tourists. The conservation status and distribution of birds in different environmental gradients in this area are still scarce. Thus, we aimed to explore (i) the community structure of birds of the Kauhdanda area (ii) environmental factors affecting the diversity and distribution of birds.

2 | Materials and methods

2.1 | Study area

Pokhara is the largest metropolitan city of Nepal in terms of area and second-largest in terms of populations. This valley is situated in the western part of Nepal and one of the most popular tourist

destinations in Nepal. Many tourists visit this valley to see the Himalayan range, biodiversity, caves and lakes. The study site Kahundanda is located in the north-east of the main city of Pokhara at 28.218800°N to 28.250745°N and 84.016812°E to 84.012913°E from 838m to 1424m asl and covers an area of 9.27 km² (Fig. 1). Kamalpokhari, a part of the lake clusters of Pokhara Valley- Ramsar site is located at the southern base of the Kahundanda. The study area is drained by Kahun *Khola* (stream ~ *Khola* in Nepali), Kali *Khola* and Seti River. The motorable roads and human settlement fragment the southern part of the study area. The northern part of this area is covered with evergreen broad leaf forest that provide the shelter to mammals, birds, herpetofauna. The forest patches in the settlement area are important for many birds, herpetofauna and urban mammals.

The study area has a humid subtropical climate; however, the elevation keeps temperatures moderate. Temperatures in summer average between 25 and 35 °C; in winter around −2 to 15 °C. Pokhara and nearby areas receive a high amount of precipitation (the annual rainfall 4851mm) (DHM 2019). Vegetation found in the southern and northern face area are *Schima wallichi* (Chilaune), *Castanopsis indica* (Katus), *Alnus nepalensis* (Uttis), *Ficus bengalensis* (Bar) *Ficus religiosa* (Peepal), *Acacia catechu* (Khair), *Bombax ceiba* (Simal), *Emblica officinalis* (Amala), *Aegle marmelos* (Bel), etc. and northern face have Rhododendrons and associated forest. *Lantana camara* (Banmara) is the dominant invasive species of this area. The fruiting plants such as *Rubus idaeus* (Ainselu), *Choerospondias axillaris* (Lapsi), *Berberis* sp. (Chutro), *Myrica esculenta* (Khafal), *Ziziphus mauritiana* (Bayar), *Psidium guajava* (Amba), *Prunus cerasoides* (Paiyun), *Citrus jambhiri* (Jyamir), *Diospyros kaki* (Tiju), *Phyllanthus emblica* (Amala), *Morus* sp. (Mulberry), *Musa acuminata* (Banana), *Prunus persica* (Peach), *Limonia acidissima* (Wood apple), *Ficus religiosa* (Peepal), *Mangifera indica* (Mango) scattered in the open area (settlements) and forest area attract the frugivorous and herbivore as well as insectivore birds.

2.2 | Methods

The study of birds of in and around Kahundanda Hillscape was carried out for three months from August 2019 to October 2019. There were nine transects laid randomly that covered different habitat types, slopes, elevation and aspects for data collection. A total of 49 points were fixed along transects at the interval of 200–250m. The birds were reported within 25m radius and spent 20 minutes for each point (Five minutes for settlements and 15 minutes for observation) at 6.30–11.00 AM and 3.30–5.30 PM by using binoculars (Olympus, 20×50 magnification) and photographed the

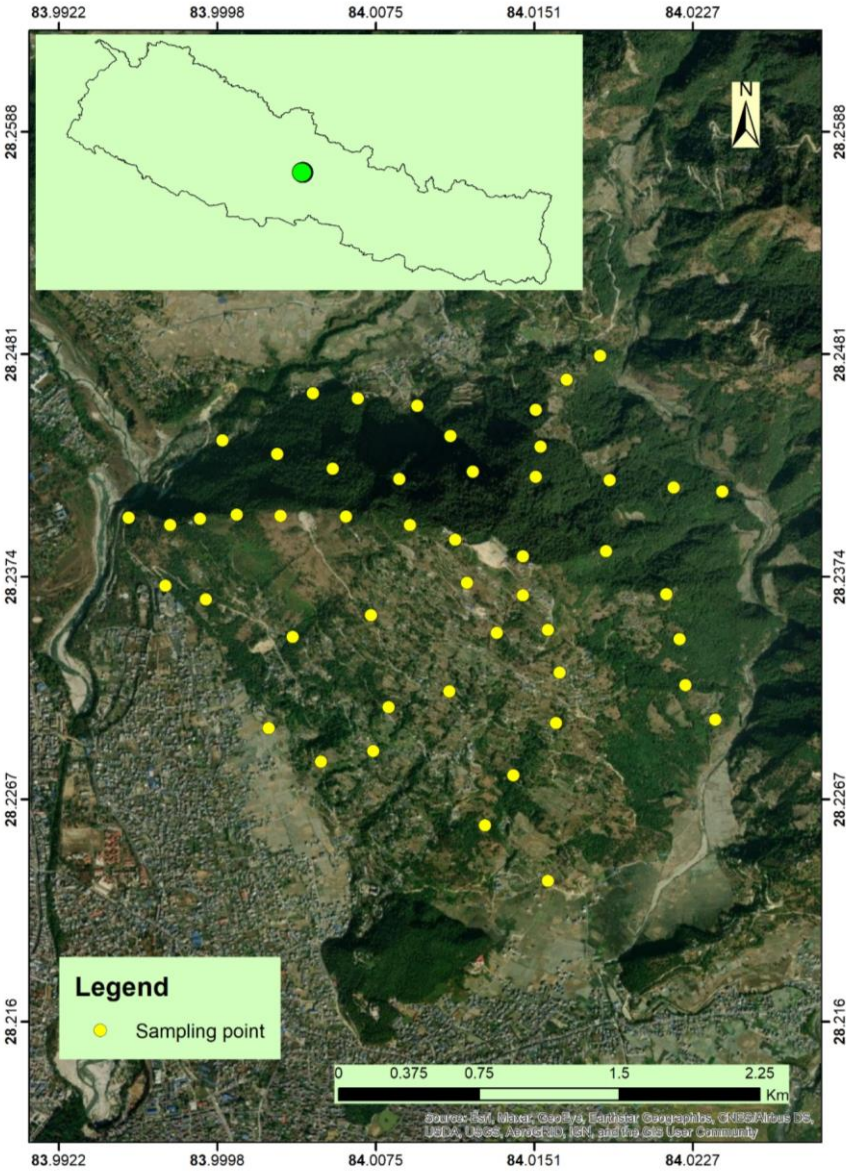

Figure 1. Map of the study area showing sampling locations

Table 1. The variables and parameters recorded during field study

SN	Variables	Descriptions
1	Species variables	All the bird species recorded during field study
2	Habitat variables	Types of habitats (forest area, bush, open (include grassland and open area or settlement area), wetlands)
3	Conservation status	IUCN category of threatened status Threatened status as National Redlist Data Book (NRDB)
4	Migratory status	Residential and migratory
5	Feeding guilds	Carnivores, herbivores, omnivores, piscivores and insectivores
6	Environmental variables	Distance to road (RV), distance to village or settlements (DV), distance to water resources (DW), number of livestock present (Nliv), number of fruiting trees present (NFT), elevation (Ele)

birds by using Nikon P900 (80x) camera. The point count method helps to cover the range of bird species, maximize bird detection and increase identification accuracy (Ralph et al. 1995). Global positioning system (GPS) was used to record geographic location of the sampling points. We collected bird's data along with number of individuals reported, activities of the birds, time, and weather conditions by developing standard data sheet. We also recorded the sound of the birds which were not visible but singing. We used the field guide book "Birds of Nepal" Grimmett et al. (2016) for bird identification. Photographs of unidentified species were identified with the help of bird experts. During bird survey, we also recorded different environmental factors such as distance to road, distance to settlements, distance to water sources, number of livestock present, number of fruiting trees including habitat and disturbance (Table 1).

The scientific name, family, order, conservation and migratory status were identified with the help of IUCN Red List of Threatened Species and The Status of Nepal's Birds: The National Red List Series Birds of Nepal (https://www.iucnredlist.org/, https://www.hi-alyanature.org/page/red-data-birds). The recorded sound of the birds was identified by using the bird song database of Xeno-Canto (https://www.xeno-canto.org/). The feeding guilds of the birds was grouped into four groups as Carnivores, herbivores, omnivores and insectivores based on primary food they uptake as described by Grimmett et al. (2016). Environmental variables such as distance to road, distance to village or settlements, distance to nearest water sources were measured as Euclidian distance from sampling points to nearest road, settlement or water resources using ArcGIS 10.7. Other variables such as the number of livestock present, number of fruiting plants present were reported in the sampling points through the direct observation method.

The collected data were analyzed by diversity index, Simpson index of diversity and evenness. We calculated the diversity indices of birds as their habitat types.

Shannon Index (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, Σ is the sum of the calculations, and s is the number of species.

Simpson index was used to show community diversity in relation to different habitat types (Simpson 1949).

Simpson Index (1-D) = $\frac{1}{\sum_{i=1}^{s} p_i^2}$

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) determined the distribution of individuals of a species in a community.

Evenness = H'/H_{max}

Where H' is the Shannon diversity index and H_{max} 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.

Species discovery curve was developed to test whether the sampling effort was enough for the detection of all the species that reported from the study area. This curve was plotted in between cumulative number of species reported and the sampling effort (Willott 2001). The cumulative number of species was placed in Y-axis and sampling unit placed in X-axis. We used species Rank Abundance Curve (RAC) or Whittaker plot to show the relative abundance of the birds (Izsák & Pavoine 2012; Avolio et al. 2019). For this curve, the species reported were ranked according to their abundance. The most abundant species is given rank 1, the second most abundant is 2 and so on. The abundant rank is placed

in X-axis and the relative abundance (RA) is placed on Y-axis. The relative abundance was simply calculated, dividing number of individuals of species by the total a number of individuals reported.

The Data were analyzed using CANOCO 4.56 to show the relation between birds and habitat types (Ter Braak & Šmilauer 2009). We used Canonical Correspondence Analysis (CCA) because the gradient length was greater than 3 in all cases with species abundance data. Univariate generalized linear model (GLM) with Poisson distribution (identity function) was used to find out the relation between the species richness and different environmental parameters using R 4.0.0 version (R Core Team 2020).

3 | Results

3.1 | Bird community structure in Kahundada

A total of 589 individuals of birds under 101 species, belonging to 41 families and 19 orders were recorded in the study area. Order Passeriformes is the largest order (n=52 species) followed by Piciformes (n = 9 species)

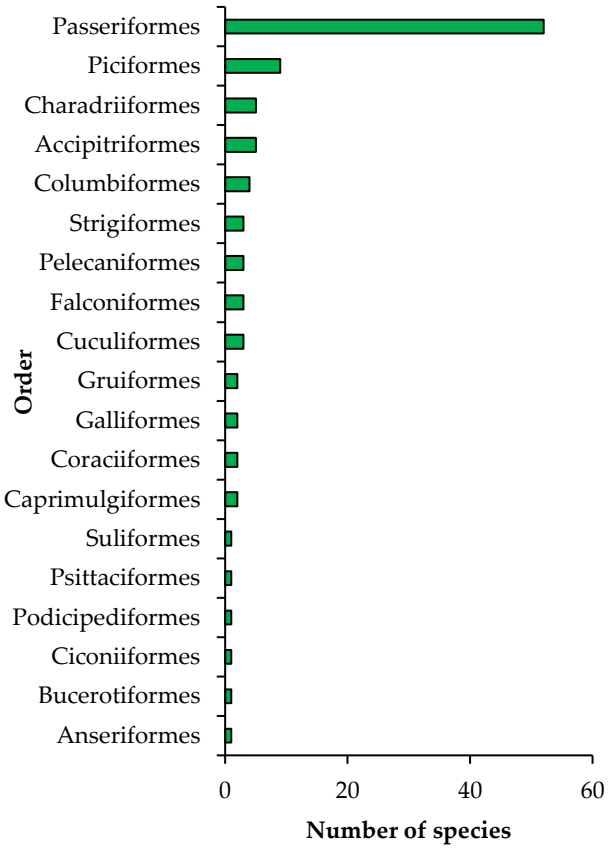

Figure 3. Order-wise species of birds in Kahundada area

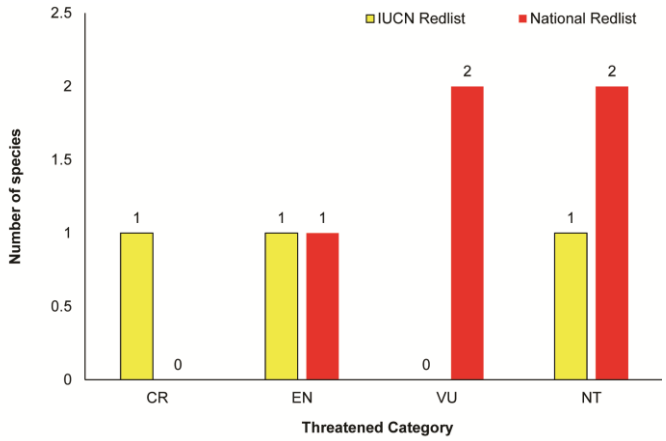

Figure 3. Conservation status of birds (global and national status) as Redlist Data Book, here, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened (NT)

(Fig. 2). Among the reported species 41.58% (n = 41) were migrant and 58.42% (n = 59) were resident birds (Table S1).

We reported one globally Critically Endangered (CR)- red-headed vulture (*Sarcogyps calvus*), one Endangered (EN)- steppe eagle (*Aquila nipalensis*), and one Near Threatened (NT) species- river lapwing (*Vanellus duvaucelii*). Similarly, one species was categorized as nationally Endangered (E) species- red-headed vulture (*Sarcogyps calvus*), two Vulnerable (V)- steppe eagle (*Aquila nipalensis*), black stork (*Ciconia nigra*) and two nationally Near Threatened categories- river lapwing (*Vanellus duvaucelii*) and watercock (*Gallicrex cinerea*) (Figs. 3 and 4). The results showed that most of the birds were least concerned category. We also reported only one endemic bird spiny babbler (*Acanthoptila nipalensis*) from Kahundanda area.

The Shannon index of diversity (H'), Simpson index (1-D) and evenness (e) was the highest in forest habitat (H' = 3.55, 1-D = 0.96, e = 0.83) followed by wetlands (H' = 2.81, 1-D= 0.92, e = 0.72), bush habitat (H' = 2.66, 1-D = 0.87, e = 0.69) and the least diversity and evenness was in open area (H' = 2.36, 1-D = 0.76, e = 0.65) (Table 2). But, species dominance index (D) was the highest in open area habitat followed by bush (D = 0.92), wetland (D = 0.79) and forest area (D = 0.031) (Table 2).

The species discovery curve based on cumulative number of species present in the sampling points showed linear trends and a greater number of species were reported with increasing the number of sampling points (Fig. 5).

A total of 101 species reported were ranked into 22 different ranks depending the number of individuals reported of each species. The rank abundance curve

Figure 4. Birds reported from Kahundanda and associated area, A. red-headed vulture (*Sarcogyps calvus*), B. steppe eagle (*Aquila nipalensis*), C. common kestrel (*Falco tinnunculus*) and D. black stork (*Ciconia nigra*) (Photo credit: Subash Bastola).

(RAC) showed the steep gradient up to rank 6 and gentle slope after that (Fig. 6). The steep slope showed the low evenness as the high-ranking species have much higher abundances than the low-ranking species. A shallow gradient indicates high evenness as the abundances of the different species are similar.

3.2 | Influence of environmental factors to the birds

Bird species richness in Kahundanda area was the highest in forest followed by open area, wetlands, bush and lowest in grassland habitat (Fig. 7).

Table 2. Diversity and dominance indices of birds in different habitats of Kahundanda

	Forest	Wetland	Open	Bush
Dominance index (D)	0.032	0.079	0.13	0.09
Simpson index (1-D)	0.97	0.92	0.76	0.87
Shannon index (H)	3.56	2.81	2.36	2.66
Evenness (e)	0.84	0.72	0.65	0.69

The Monte-Carlo permutation test of significance of all canonical axes (ordination diagram (biplot)) showed the omnivores birds were significantly reported more from the open areas (agriculture fields, residential areas and grassland) than wetlands, forest area and bush habitat ($F = 1.546$, $P = 0.002$, Trace = 0.909, with 499 permutations). Similarly, insectivore birds were significantly associated with open area and forest area

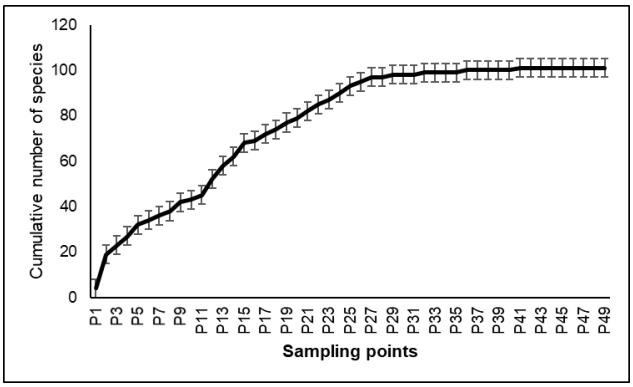

Figure 5. Species discovery curve of birds reported from Kahundanda area

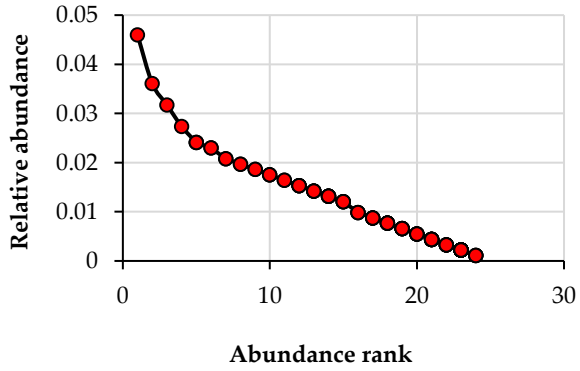

Figure 6. Rank abundance curve (RAC) of bird species recorded in Kahundanda, Pokhara

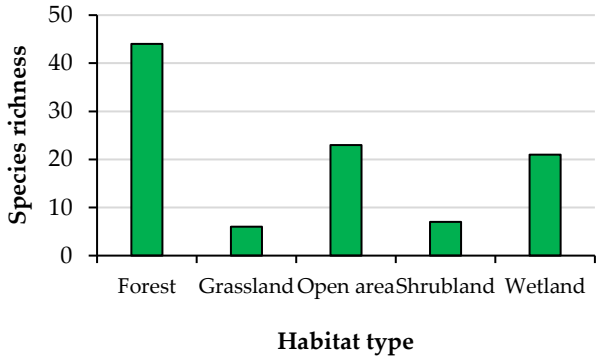

Figure 7. Bird species richness in different habitat types

(F= 2.616, P=0.002, Trace= 2.206, with 499 permutations (Fig. 8).

Likewise, CCA ordination diagram (biplot) of carnivores birds with different habitat types of Kahundanda significantly showed relation with forest, open area and wetland habitat (F = 2.616, P = 0.002, Trace=2.206, with 499 permutations) and herbivores were reported more in forest and open area mainly agriculture fields and grassland area (F = 1.478, P = 0.08, Trace=1.282, with 499 permutations) (Fig. 9).

The results of univariate GLM shows that birds were significantly reported far from the roads (showed the negative association with roads, Z = 3.097, P = 0.001). Similarly, distance to village shows the significant association with distance to settlements or village.

Likewise, number of livestock present in the study area was the major indicator of the habitat use of birds. They showed significantly negative relation with number of livestock in the study area (Z = -6.061, P < 0.000) (Table 3). Water resources played a vital role for the occurrence of wetland and wetland dependent birds (Z = -1.378, p=0.16). Number of fruiting trees present in the study area was also the best predictor for the occurrence of bird species. Most of the omnivores and herbivore birds depend upon the fruits and flowers of the fruiting plants and GLM showed the significantly positive association with number of fruiting trees (Z = -6.061, P < 0.000). Our study area ranges from 838 m to 1424 m altitude. The result shows the positive association of bird species richness with elevation of Kauhndanda (Table 3, Fig. 10).

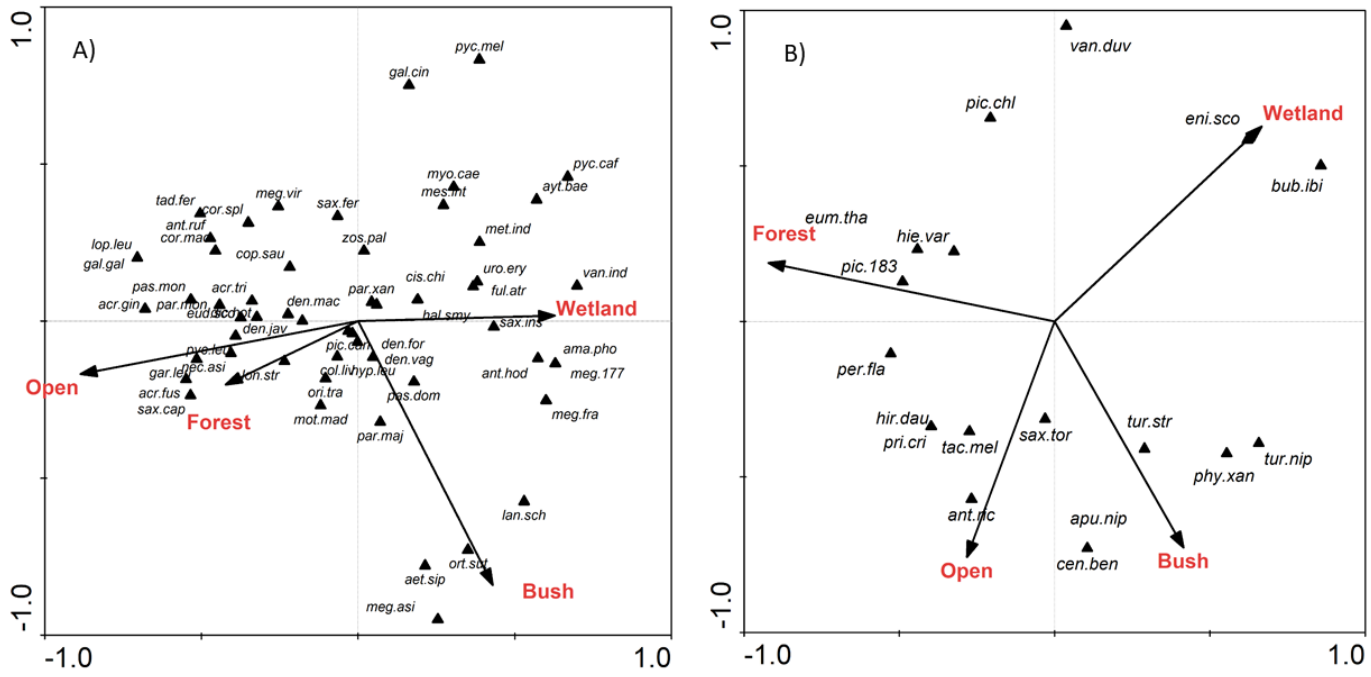

Figure 8. CCA ordination diagram (biplot) showing the bird species association with different habitats A) omnivore and B) insectivore birds of Kahundanda.

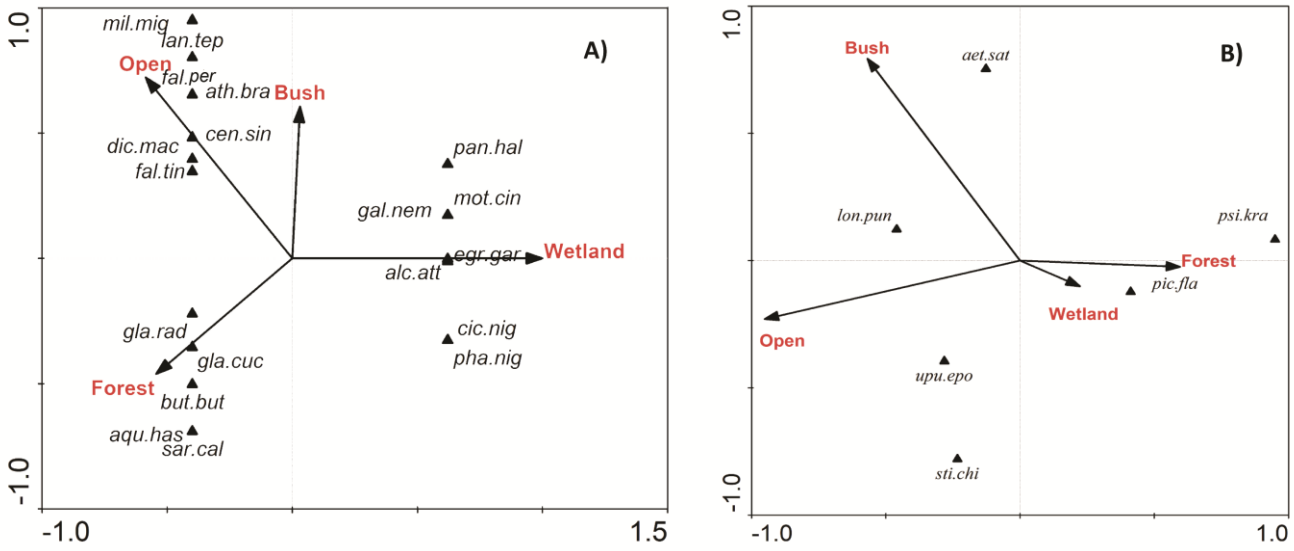

Figure 9. CCA ordination diagram (biplot) showing the bird species association with different habitats A) carnivore and B) herbivore birds of Kahundanda

4 | Discussion

Environmental variables such as habitat types, number of fruiting trees present and other anthropogenic activities affect the distribution and species richness of the birds. Habitat types and number of fruiting trees provide the appropriate nesting and feeding sites to the birds. This study examined the status of birds in and around Kahundanda Hillscape, Pokhara Valley, Nepal. Our results indicated that the species richness of birds varied with the habitat types. The Kamalpokhari wetland and associated wetlands and streams supported a large number of wetland birds. The lake clusters of Pokhara Valley including Kamalpokhari are listed in Ramsar site. The Kahundanda supported a considerable bird species (n = 101). Overall, higher bird diversity was found in forests and open areas as these areas are very close to the city area and one of the important tourist areas. Agriculture lands and residential areas supported a large number of urban and open area dependent birds. The forest patches scattered in the Kahundanda also support diverse bird species. Similar types of studies in and around Phewa Lake of the Pokhara valley reported 148 species of birds belonging to 44 families and 11 orders (Khatri et al. 2019). Similarly, Dhakal et al. (2020) reported 101 species of birds in Khaste Lake Complex, Pokhara Valley. The species diversity of the birds was higher in the terrestrial ecosystem (H' = 3.27) including forest than wetland of Phewa Lake (H' = 3.07) (Khatri et al. 2019), a similar type of results was found in our study.

Habitat heterogeneity of the Kahundanda supported a large number of bird species. Omnivore birds were reported more from the open and forest areas, likewise, insectivores and herbivores were reported from the agriculture landscape and in and around Kamalpokhari Lake complex. Wetlands of Kamalpokhari and associated areas supported 21 species of wetland birds that highlighted the importance of such small lakes for the conservation of wetland birds. Similar type of study

Table 3. Univariate Generalized Linear Model (GLM) with Poisson distribution and identity link function test showing the effects of different environmental and disturbance factors on abundance of birds in Kauhndanda.

Model	Estimate	Std. Error	z value	Pr(>|z|)	AIC
DR	0.003	0.001	3.097	0.001**	273.3
DW	-0.002	0.001	-1.378	0.168	281.42
DV	0.003	0.001	2.604	0.009**	276.42
Ele	0.007	0.003	2.051	0.04*	279.19
NFT	1.144	0.187	6.118	<0.000***	243.77
Nliv	-0.681	0.112	-6.061	<0.000***	249.91

Note: Significance codes: 0 '***', 0.001 '**', 0.01 '*'; DR= Distance to road, DW= Distance to water, DV= Distance to village or settlements, Ele= Elevation, NFT= Number of fruiting trees, Nliv=Number of livestock

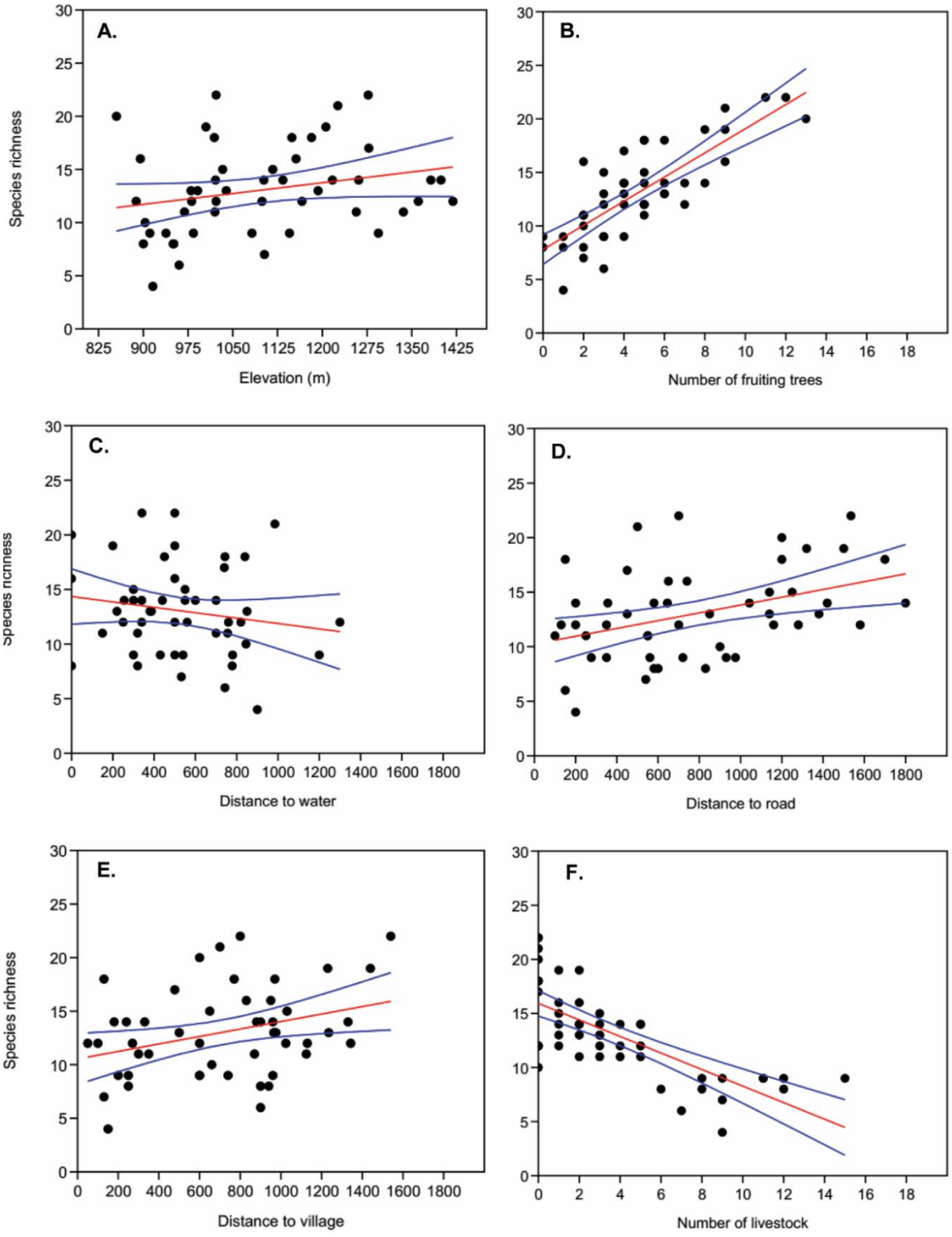

Figure 10. Relationship between bird species richness and different environmental factors (A) elevation (R^2 = 0.07), (B) number of fruiting plants (R^2 = 0.63), (C) distance to water (R^2 = 0.03), (D) distance to motorable roads (R^2 = 0.16), (E) distance to village (R^2 = 0.11) and (F) number of livestock present (R^2 = 0.52) in Kahundanda Hillscape.

conducted by Khadka et al. (2017) from the wetlands of Chitwan National Park reported 46 species of wetland birds. Adhikari et al. (2018) reported 44 wetland birds from Beeshhazari Lake system, one of the Ramsar sites of Nepal. Khatri et al. (2019) reported 63 wetland dependent birds from Phewa Lake (one of the parts of Ramsar site: the lake cluster of Pokhara Valley) whereas Thapa and Saund (2012) reported 77 species of wetland birds in Jagadishpur Reservoir (one of the Ramsar sites from lowland Nepal).

Our study reported two globally threatened birds and one Near-Threatened bird according to the IUCN

category. Likewise, five species of birds were listed in the nationally threatened category including two nationally near threatened birds. Hence, this area played an important role in bird conservation. A study by Khatri et al. (2019) reported seven globally threatened birds from in and around the Phewa Lake. Dhakal et al. (2020) reported six globally threatened birds from Khaste Lake complex, Pokhara. Hence, conservation priorities should be given for such type of wetland habitat for the conservation of birds. Ingesting pesticides directly or indirectly by eating pesticide-contaminated grains, fruits, worms and insects may adversely affect the birds. Due to lack of public awareness about the importance of wetland resources, the area has been found misused by the local villagers. Lack of proper wetland management and overgrazing are the existing major problems.

A species discovery curve is a quantitative analysis that evaluates the minimum number of sampling size necessary to define the number of species that represent a community (Willott 2001; Mendes et al. 2020). The species discovery curve for Kahundanda clearly showed the sufficient sampling efforts for the birds. Similar type of species discovery curve was also used in the study of birds by La Sorte & Somveille (2020) and Pandey et al. (2021). The relative species abundance is a major component of biodiversity and indicate how common and rare species are relative to other species. Relative species abundances indicate the specific patterns that provide the scenario and effects of the macro ecosystems on the species distribution (Izsák & Pavoine 2012; Avolio et al. 2019). A rank abundance curve or Whittaker plot is a graphical tool that help to visualize species richness and species evenness (Izsák & Pavoine 2012; Yin et al. 2018; Avolio et al. 2019; Pandey et al. 2021). In this study, we used RAC to show the relation between the relative abundance of the birds and their abundance rank in the Kahundanda area.

Habitat heterogeneity of the Kahundanda supported a large number of bird species. Omnivore birds were reported more from the open and forest areas, while insectivore and herbivore birds were reported from the agriculture landscapes and in and around Kamal-pokhari Lake. Birds are confined to specific habitats that provide feeding and breeding grounds (Martin & Fahrig 2018; Adhikari et al. 2019). Abundance and richness of birds are limited by the food available to the habitat (Kim et al. 2018).

The abundance of herbivore birds was higher in the open areas, agricultural fields and forests. Number of fruiting trees present in the forest or agriculture or human settlement areas added more food availability for the herbivore birds. Hence, specific fruiting seasons increased the abundance of herbivore birds (Pandey et al. 2021). The avian research conducted by Herzog et al. (2005) in the Swiss agricultural landscape reported the pastureland didn't contribute to bird diversity but our study found that agriculture along with settlements and grassland supported higher omnivores and insectivore bird diversity. Insectivorous birds are the habitat specialists but they used agriculture fields and residential areas for foraging as the insect diversity is high in agriculture fields (Redhead et al. 2018; Schumm et al. 2020). Carnivore birds (birds of prey and scavengers) were significantly reported in open and wetland areas while piscivores birds were reported in wetland habitats. Similar types of results reported also reported from Kennya (Virani et al. 2011), India (Chettri et al. 2018; Mazumdar 2019; Kakati et al. 2021), China (Zhang et al. 2019), Bhutan (Mazumdar 2019), Indonesia (Krisanti et al. 2017).

The distribution and abundance of birds depend upon different environmental and disturbance variables. Elevation of the landscape is one of the major factors that influence the distribution of the birds (Basnet et al. 2016; Katuwal et al. 2016; Neupane et al. 2020; Pandey et al. 2020; Ghimire et al. 2021). Distance to village or settlements, distance to roads, number of livestock present are the major disturbance determinant of the birds. The agriculture land and home garden also provide the nesting and feeding ground to the open area birds (Pandey et al. 2021). The fruiting trees also increases the richness of the birds (Pandey et al. 2021). Our results also showed a significant relation with distance to roads and settlements and a negative association with the number of livestock present. Similar type of results were also found on the study of Adhikari et al. (2019) in Chitwan National Park, Nepal; Basnet et al. (2016) in the hilly region of Central Himalaya, Nepal; Andradas et al. (2019) in Northern Iberian Peninsula; Altaf et al. (2018) in Panjab, Pakisthan; Panigrahi and Jins (2018) in Kerela, India. Hence, presence of different environmental factors including disturbance are the important driver for the occurrence of birds in and around Kahundanda Hillscape, Pokhara, Nepal.

5 | Conclusions

Different types of habitats of the Kahundanda Hillscape supported a total of 101 terrestrial and wetland dependent birds. Most of the birds were reported from

forest areas and wetlands. The habitats of human dominated mountainous landscape play an important role to the conservation of birds. Mosaics of habitat patches with agricultural landscape favored the high species richness within a small area. Presence of fruiting trees near the open area and settlement supported higher bird diversity. Habitat types, human disturbance and proximity to water resources are important for bird species conservation and ecotourism in human dominated landscape like Kahundanda.

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Authors' contributions

SCB designed research and collected data; SCB and HD identified the birds, JNA and BPB analyzed the data, JNA and SCB wrote draft of the article, SCB, JNA, HD and BPB revised the manuscript. All authors approved the final manuscript for publication.

Conflicts of interest

Authors declare no conflict of interest.

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Supplementary Table S1. Checklist of the birds reported from Kahundada

SN	Common name	Scientific name	Codes used in Canacoo	Order	Family	IUCN Redlist	National Redlist	Feeding guild
1	Himalayan buzzard	*Buteo refectus* (Portenko, 1929)	But.ref	Accipitriformes	Accipitridae	LC	LC	Carnivore
2	Black kite	*Milvus migrans* (Boddaert, 1783)	Mil.mig	Accipitriformes	Accipitridae	LC	LC	Carnivore
3	Red-headed vulture	*Sarcogyps calvus* (Scopoli, 1786)	Sar.cal	Accipitriformes	Accipitridae	CR	EN	Carnivore
4	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	Pan.hal	Accipitriformes	Pandionidae	LC	LC	Pisivore
5	Little grebe	*Tachybaptus ruficollis* (Pallas, 1764)	Tac.ruf	Podicipediformes	Podicipedidae	LC	LC	Pisivore
6	Lesser whistling-duck	*Dendrocygna javanica* (Horsfield, 1821)	Den.jav	Anseriformes	Anatidae	LC	LC	Omnivore
7	Common sandpiper	*Actitis hypoleucos* Linnaeus, 1758	Act.hyp	Charadriiformes	Scolopacidae	LC	LC	Omnivore
8	Common hoopoe	*Upupa epops* (Linnaeus, 1758)	Upu.epo	Bucerotiformes	Upupidae	LC	LC	Granivore
9	House swift	*Apus nipalensis* (Hodgson, 1837)	Apu.nip	Caprimulgiformes	Apodidae	LC	LC	Insectivore
10	Alpine swift	*Tachymarptis melba* (Linnaeus, 1758)	Tac.mel	Caprimulgiformes	Apodidae	LC	LC	Insectivore
11	River lapwing	*Vanellus duvaucelii* (Lesson, 1826)	Van.duv	Charadriiformes	Charadriidae	NT	NT	Insectivore
12	Red-wattled lapwing	*Vanellus indicus* (Boddaert, 1783)	Van.ind	Charadriiformes	Charadriidae	LC	LC	Omnivore
13	Bronze-winged jacana	*Metopidius indicus* (Latham, 1790)	Met.ind	Charadriiformes	Jacanidae	LC	LC	Omnivore
14	Little-ringed plover	*Charadrius dubius* (Scopoli, 1786)	Cha.dub	Charadriiformes	Charadriidae	LC	LC	Insectivore
15	Black stork	*Ciconia nigra* (Linnaeus, 1758)	Cic.nig	Ciconiiformes	Ciconiidae	LC	VU	Carnivore
16	Rock dove	*Columba livia* (Gmelin 1789)	Col.liv	Columbiformes	Columbidae	LC	LC	Omnivore
17	Spotted dove	*Spilopelia suratensis* (Gmelin, 1789)	Spi.sur	Columbiformes	Columbidae	LC	LC	Granivore
18	Oriental turtle-dove	*Streptopelia orientalis* (Latham, 1790)	Str.ori	Columbiformes	Columbidae	LC	LC	Herbivore
19	Yellow-footed green pigeon	*Treron phoenicopterus* (Latham, 1790)	Tre.pho	Columbiformes	Columbidae	LC	LC	Omnivore
20	Common kingfisher	*Alcedo atthis* (Linnaeus, 1758)	Alc.att	Coraciiformes	Alcedinidae	LC	LC	Carnivore
21	White-throated kingfisher	*Halcyon gularis* (Kuhl, 1820)	Hal.gul	Coraciiformes	Alcedinidae	LC	LC	Omnivore
22	Steppe eagle	*Aquila nipalensis* (Hodgson, 1833)	Aqu.nip	Falconiformes	Accipitridae	EN	VU	Carnivore
23	Greater coucal	*Centropus sinensis* (Stephens, 1815)	Cen.sin	Cuculiformes	Cuculidae	LC	LC	Carnivore
24	Western koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	Eud.sco	Cuculiformes	Cuculidae	LC	LC	Omnivore
25	Common hawk-cuckoo	*Hierococcyx varius* (Vahl, 1797)	Hie.var	Cuculiformes	Cuculidae	LC	LC	Insectivore
26	Shikra	*Accipiter badius* (Gmelin, 1788)	Acc.bad	Accipitriformes	Accipitridae	LC	LC	Carnivore
27	Peregrine falcon	*Falco peregrinus* Tunstall, 1771	Fal.per	Falconiformes	Falconidae	LC	LC	Carnivore
28	Common kestrel	*Falco tinnunculus* (Linnaeus, 1758)	Fal.tin	Falconiformes	Falconidae	LC	LC	Carnivore
29	Red junglefoul	*Gallus gallus* (Linnaeus, 1758)	Gal.gal	Galliformes	Phasianidae	LC	LC	Omnivore
30	Kalij pheasant	*Lophura leucomelanos* (Latham, 1790)	Lop.leu	Galliformes	Phasianidae	LC	LC	Omnivore
31	White-breasted waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	Ama.pho	Gruiformes	Rallidae	LC	LC	Omnivore
32	Brown shrike	*Lanius cristatu* (Linnaeus, 1758)	Lan.cri	Passeriformes	Laniidae	LC	LC	Insectivore
33	Watercock	*Gallicrex cinerea* (Gmelin, 1789)	Gal.cin	Gruiformes	Rallidae	LC	NT	Omnivore
34	Cattle egret	*Bubulcus ibis* (Linnaeus, 1758)	Bub.ibi	Passeriformes	Ardeidae	LC	LC	Insectivore
35	Large cuckooshrike	*Coracina javensis* (Horsfield, 1821)	Cor.jav	Passeriformes	Campephagidae	LC	LC	Omnivore
36	Scarlet minivet	*Pericrocotus flammeus* (Forster, 1781)	Per.fla	Passeriformes	Campephagidae	LC	LC	Insectivore

37	Common tailorbird	*Orthotomus sutorius* (Pennant, 1769)	Ort.sut	Passeriformes	Cisticolidae	LC	LC	Omnivore
38	Striated prinia	*Prinia crinigera* (Hodgson, 1836)	Pri.cri	Passeriformes	Cisticolidae	LC	LC	Insectivore
39	Common green magpie	*Cissa chinensis* (Boddaert, 1783)	Cis.chi	Passeriformes	Corvidae	LC	LC	Omnivore
40	House crow	*Corvus splendens* (Vieillot, 1817)	Cor.spl	Passeriformes	Corvidae	LC	LC	Omnivore
41	Grey treepie	*Dendrocitta formosae* (Swinhoe, 1867)	Den.for	Passeriformes	Corvidae	LC	LC	Omnivore
42	Rufous treepie	*Dendrocitta vagabunda* (Latham, 1790)	Den.vag	Passeriformes	Corvidae	LC	LC	Omnivore
43	Red-billed blue magpie	*Urocissa erythrorhyncha* (Boddaert, 1783)	Uro.ery	Passeriformes	Corvidae	LC	LC	Omnivore
44	Spangled drongo	*Dicrurus bracteatus* (Gould, 1842)	Dic.bra	Passeriformes	Dicruridae	LC	LC	Omnivore
45	Black drongo	*Dicrurus macrocercus* (Vieillot, 1817)	Dic.mac	Passeriformes	Dicruridae	LC	LC	Carnivore
46	Scaly-breasted munia	*Lonchura punctulata* (Linnaeus, 1758)	Lon.pun	Passeriformes	Estrildidae	LC	LC	Herbivore
47	White-rumped munia	*Lonchura striata* (Linnaeus 1766)	Lon.str	Passeriformes	Estrildidae	LC	LC	Omnivore
48	Red-rumped swallow	*Cecropis daurica* Linnaeus, 1771)	*Cec.dau*	Passeriformes	Hirundinidae	LC	LC	Insectivore
49	Long-tailed shrike	*Lanius schach* (Linnaeus, 1758)	Lan.sch	Passeriformes	Laniidae	LC	LC	Omnivore
50	Grey-backed shrike	*Lanius tephronotus* (Vigors, 1837)	Lan.tep	Passeriformes	Laniidae	LC	LC	Carnivore
51	White-crested laughingthrush	*Garrulax leucolophus* (Hardwicke, 1815)	Gar.leu	Passeriformes	Leiotrichidae	LC	LC	Omnivore
52	Spiny babbler	*Turdoides nipalensis* (Hodgson, 1836)	Tur.nip	Passeriformes	Leiotrichidae	LC	LC	Insectivore
53	Jungle babbler	*Turdoides striata* (Dumont, 1823)	Tur.str	Passeriformes	Leiotrichidae	LC	LC	Omnivore
54	Olive-backed pipit	*Anthus hodgsoni* (Richmond, 1907)	Ant.hod	Passeriformes	Motacillidae	LC	LC	Omnivore
55	Richard's pipit	*Anthus richardi* (Vieillot, 1818)	Ant.ric	Passeriformes	Motacillidae	LC	LC	Insectivore
56	Paddyfield pipit	*Anthus rufulus* (Vieillot, 1818)	Ant.ruf	Passeriformes	Motacillidae	LC	LC	Omnivore
57	Grey wagtail	*Motacilla cinerea* (Tunstall, 1771)	Mot.cin	Passeriformes	Motacillidae	LC	LC	Carnivore
58	White-browed wagtail	*Motacilla maderaspatensis* (Gmelin, 1789)	Mot.mad	Passeriformes	Motacillidae	LC	LC	Omnivore
59	Oriental magpie robin	*Copsychus saularis* (Linnaeus, 1758)	Cop.sau	Passeriformes	Muscicapidae	LC	LC	Omnivore
60	Little forktail	*Enicurus scouleri* (Vigors, 1832)	Eni.sco	Passeriformes	Muscicapidae	LC	LC	Insectivore
61	Verditer flycatcher	*Eumyias thalassinus* (Swainson, 1838)	Eum.tha	Passeriformes	Muscicapidae	LC	LC	Insectivore
62	Blue whistling thrush	*Myophonus caeruleus* (Scopoli, 1786)	Myo.cae	Passeriformes	Muscicapidae	LC	LC	Omnivore
63	Pied bushchat	*Saxicola caprata* (Linnaeus, 1766)	Sax.cap	Passeriformes	Muscicapidae	LC	LC	Omnivore
64	Grey bushchat	*Saxicola ferreus* (Gray 1846)	Sax.fer	Passeriformes	Muscicapidae	LC	LC	Omnivore
65	Taiga flycatcher	*Ficedula albicilla* (Pallas, 1811)	Fic.alb	Passeriformes	Muscicapidae	LC	LC	Insectivore
66	Common stonechat	*Saxicola torquatus* (Linnaeus, 1766)	Sax.tor	Passeriformes	Muscicapidae	LC	LC	Insectivore
67	Indian golden oriole	*Oriolus kundoo* (Sykes, 1832)	Aet.sip	Passeriformes	Oriolidae	LC	LC	Omnivore
68	Crimson sunbird	*Aethopyga siparaja* (Raffles, 1822)	Aet.sip	Passeriformes	Nectariniidae	LC	LC	Omnivore
69	Purple sunbird	*Cinnyris asiatica* (Latham, 1790)	Cin.asi	Passeriformes	Nectariniidae	LC	LC	Omnivore
70	Maroon oriole	*Oriolus traillii* (Vigors, 1832)	Ori.tra	Passeriformes	Oriolidae	LC	LC	Omnivore
71	Great tit	*Parus major* (Linnaeus, 1757)	Par.maj	Passeriformes	Paridae	LC	LC	Omnivore
72	Green-backed tit	*Parus monticolus* (Vigors, 1831)	Par.mon	Passeriformes	Paridae	LC	LC	Omnivore
73	Black-lored tit	*Parus xanthogenys* (Vigors, 1831)	Par.xan	Passeriformes	Paridae	LC	LC	Omnivore
74	House sparrow	*Passer domesticus* (Linnaeus, 1758)	Pas.dom	Passeriformes	Passeridae	LC	LC	Omnivore
75	Eurasian tree sparrow	*Passer montanus* (Linnaeus, 1758)	Pas.mon	Passeriformes	Passeridae	LC	LC	Omnivore

76	Grey-hooded warbler	*Phylloscopus xanthoschistos* (Gray, 1846)	Phy.xan	Passeriformes	Phylloscopidae	LC	LC	Insectivore
77	Black bulbul	*Hypsipetes leucocephalus* (Gmelin, 1789)	Hyp.leu	Passeriformes	Pycnonotidaetaiga	LC	LC	Omnivore
78	Red-vented bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	Pyc.caf	Passeriformes	Pycnonotidae	LC	LC	Omnivore
79	Himalayan bulbul	*Pycnonotus leucogenys* (Gray, 1837)	Pyc.leu	Passeriformes	Pycnonotidae	LC	LC	Omnivore
80	Black-crested bulbul	*Rubigula flaviventris* (Tickell, 1833)	Rub.fla	Passeriformes	Pycnonotidae	LC	LC	Omnivore
81	Jungle myna	*Acridotheres fuscus* (Wagler, 1827)	Acr.fus	Passeriformes	Sturnidae	LC	LC	Omnivore
82	Bank myna	*Acridotheres ginginianus* (Latham, 1790)	Acr.gin	Passeriformes	Sturnidae	LC	LC	Omnivore
83	Common myna	*Acridotheres tristis* (Linnaeus,1766)	Acr.tri	Passeriformes	Sturnidae	LC	LC	Omnivore
84	Indian white-eye	*Zosterops palpebrosus* (Temminck, 1824)	Zos.pal	Passeriformes	Zosteropidae	LC	LC	Omnivore
85	Great cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	Pha.car	Suliformes	Phalacrocoracidae	LC	LC	Omnivore
86	Intermediate egret	*Ardea intermedia* Wagler, 1829	Ard.int	Pelecaniformes	Ardeidae	LC	LC	Omnivore
87	Indian pond-heron	*Ardeola grayi* (Sykes, 1832)	Ard.gra	Pelecaniformes	Ardeidae	LC	LC	Pisivore
88	Little egret	*Egretta garzetta* (Linnaeus, 1767)	Egr.gar	Pelecaniformes	Ardeidae	LC	LC	Carnivore
89	Blue-throated barbet	*Megalaima asiatica* (Latham, 1790)	Meg.asi	Piciformes	Megalaimidae	LC	LC	Omnivore
90	Golden-throated barbet	*Psilopogon franklinii* (Blyth, 1842)	Psi.fra	Piciformes	Megalaimidae	LC	LC	Omnivore
91	Coppersmith barbet	*Psilopogon haemacephalus* (Müller, 1776)	Psi.hae	Piciformes	Megalaimidae	LC	LC	Omnivore
92	Great barbet	*Psilopogon virens* (Boddaert, 1783)	Psi.vir	Piciformes	Megalaimidae	LC	LC	Omnivore
93	Greater yellownape	*Chrysophlegma flavinucha* (Gould, 1834)	Chr.fla	Piciformes	Picidae	LC	LC	Hervibore
94	Fulvous-breasted woodpecker	*Dendrocopos macei* (Veillot, 1818)	Den.mac	Piciformes	Picidae	LC	LC	Omnivore
95	Grey-headed woodpecker	*Dendropicos spodocephalus* (Bonaparte, 1850)	Den.spo	Piciformes	Picidae	LC	LC	Omnivore
96	Lesser yellownape	*Picus chlorolophus* (Vieillot, 1818)	Pic.chl	Piciformes	Picidae	LC	LC	Insectivore
97	Scaly-bellied woodpecker	*Picus squamatus* (Vigors, 1831)	Pic.squ	Piciformes	Picidae	LC	LC	Insectivore
98	Rose-ringed parakeet	*Alexandrinus krameri* (Scopoli, 1769)	Ale.kra	Psittaciformes	Psittacidae	LC	LC	Herbivore
99	Spotted owlet	*Athene brama* (Temminck, 1821)	Ath.bra	Strigiformes	Strigidae	LC	LC	Carnivore
100	Asian barred owlet	*Glaucidium cuculoides* (Vigors, 1831)	Gla.cuc	Strigiformes	Strigidae	LC	LC	Carnivore
101	Jungle owlet	*Glaucidium radiatum* (Tickell, 1833)	Gla.rad	Strigiformes	Strigidae	LC	LC	Carnivore