BIRD DIVERSITY AND FACTORS AFFECTING THE BIRD ABUNDANCE ALONG THE BAGMATI RIVER CORRIDOR, NEPAL

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Submitted to

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Kirtipur, Kathmandu

Nepal

August 2022

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award for any degree. All sources of information have been specifically acknowledged by reference to author(s) or institution(s).

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This is to recommend that the thesis entitled "Bird diversity and factors affecting the bird abundance along the Bagmati River corridor, Nepal" has been carried out by Ms. Neelam Mahata for the partial fulfillment of the degree of Master of Science in Zoology with special paper Ecology and Environment. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institution.

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LETTER OF APPROVAL

On the recommendation of the supervisor, Assoc. Prof. Dr. Hari Prasad Sharma, this thesis submitted by Ms. Neelam Mahata entitled "Bird diversity and factors affecting the bird abundance along the Bagmati River corridor, Nepal" is approved for the examination for the partial fulfillment of the requirements for the degree of Master of Science in Zoology with special paper Ecology and Environment.

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CERTIFICATE OF ACCEPTANCE

The thesis work submitted by Ms. Neelam Mahata entitled "Bird diversity and factors affecting the bird abundance along the Bagmati River corridor, Nepal" has been accepted as partial fulfillment for the requirements of the degree of Master of Science in Zoology with special paper Ecology and Environment.

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LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
GLM	Generalized Linear Model
AIC	Akaike Information Criterion

ABSTRACT

Bagmati River is considered a potential biodiversity conservation area due to its unique and diversified habitat near to human settlement. However, little information is available on the bird diversity, their abundance and factor affecting on bird species. This study generated data using a point count method along the Bagmati River corridor between Sundarijal to Chovar between October 2021 and April 2022. This study identified 67 bird species belonging to 11 orders and 28 families along the Bagmati River corridor. Passeriformes and Muscicapidae were the most prevalent orders and families among the birds that were observed. Rock Dove (*Columba livia*) was recorded as the most abundant resident bird species in the study area. Among the feeding guilds of birds, insectivores were recorded as the highest bird species and followed by omnivores, carnivores, frugivores and granivores. The Shannon-Wiener diversity index of bird species was 3.35, while the Pielou's evenness index was 0.796. Various variables such as the tree, nearest distance to the water source, road, settlement, open land, sewage, temperature and elevation had a significant effect on the bird abundance. The bird abundance was increased in presence of tree, near the settlement, nearer to sewage, at low temperatures, increasing distance to water source and road whereas decreased with the distance to open land and at a higher elevation. These data can be used for developing bird conservation policy in an urban area, and the research can be used as a replicate of other cities like Kathmandu Valley.

1. INTRODUCTION

1.1 Background

Nepal is home to 1.1% and 3.2% of the known flora and fauna of the globe respectively, and has high biodiversity (MoFSC 2014). Among the faunal species, 886 bird species are found in Nepal, which is about 9% of the global total bird species (BCN and DNPWC 2018). Around 44 bird species enlisted in the IUCN Red List of threatened species are identified as globally threatened, and 167 as nationally threatened species (BCN and DNPWC 2019). The CITES Appendix I lists 12 bird species, Appendix II lists 95 species, and Appendix III has 5 species (BCN and DNPWC 2019). Of the majority of nationally threatened bird species, 53% are found inhabiting forests, 27% in wetlands, 15% in grasslands, 8% in cultivated land, 5% in scrubland, 9% in open country, 3% in near human settlement and 1% in semi-desert habitat (BCN and DNPWC 2011).

Birds are key components of the earth's biodiversity and play a vital role in aquatic ecosystems for the ecological functioning of the environment such as indicators of pollination (Tabur and Ayvaz 2010, Sekercioglu et al. 2016, Chain-Guadarrama et al. 2019), seed dispersal, scavenging and as predators of insect pests (Sekercioglu 2006, Whelan et al. 2008, Aynalem and Bekele 2009, Gatesire et al. 2014, Meles and Bogale 2018). They are ecologically important as they reflect the state of the environment (Juliana and Soladoye 2018) and also can be used for the stability of wetlands (Morrison 1986, Bhat et al. 2009, Amat and Green 2010, Bensizerara et al. 2013).

The River corridor is an important system for the conservation of species and provides suitable habitat for breeding and roosting birds (Knopf and Samson 1994, Rosenberg et al. 1997, Maciusik et al. 2010). It provides vegetation, riparian zones and debris with abundant food for the occurrence of species (Rosenberg et al. 1997). It also causes a large effect on the diversity of birds within an area (Bennett et al. 2014), therefore, the corridor represents important areas for the conservation of species (Miller et al. 1998). The corridor across the urban areas becomes the priority area for developing green spaces (Beatley 2000), which provides semi-natural habitats (Jim and Chen 2003), and a space for species observation. Green spaces are

important for the provision of ecosystem services and can have a positive impact on quality of life, human health and wellbeing (Fuller et al. 2007). It also helps in promoting interest in nature conservation issues (Miller 2005). These spaces help to improve the ecological and recreational values and wildlife movement as well as increase biodiversity (Hepcan et al. 2009).

Kathmandu accounts for about one-third of the country's urban population (Muzzini and Aparicio 2013). Due to wastes, the Bagmati River water within the Kathmandu valley was not suitable for drinking, recreational use and irrigation purposes (Stanley International et al. 1994). Sewage disposal and waste deposition degraded the water quality of Bagmati riparian Kathmandu Valley (Bajracharya and Tamrakar 2007). Human encroachment has been the root cause of the deterioration of religious and cultural heritage sites along the river banks (Platman 2014, Shrestha 2015). The regular campaign also called the Bagmati River conservation campaign which was initiated by Bagmati River Festival is going on since 1991, based that the habitat is supposed to be suitable for different bird species. Bagmati River area is considered a potential Important Bird's Area (Baral and Inskipp 2005).

As urban habitats are rich in avian species (Panda et al. 2020), knowledge of the conservation of habitat use is important to determine high-priority areas (Zhao et al. 2013, Reiley 2017, Kong et al. 2018, Zhu et al. 2021). Habitat conditions determine the variation of species richness from region to region (Recher 1969, Pearson 1977). Habitat characteristics such as the presence of forest edges and shrubs play an important role in driving species composition (Basnet et al. 2016). Bird distribution, diversity and abundance of the ecosystem are determined by seasonality, human disturbances and resource availability (Roy et al. 2011, Shah and Sharma 2022). Bird species occurrence and population are declining due to increased anthropogenic activities, and changes in vegetation structure and climatic factors (Chace and Walsh 2006, Barber et al. 2010, Sheta et al. 2011, Asefa et al. 2015, Nepal and Thapa 2018, Jha and Sharma 2019). Urbanization is a major driver of degradation and biodiversity loss of riparian habitats (Mills et al. 1989, McKinney 2006, Magura et al. 2010, Katuwal et al. 2018, Cao and Natuhara 2019). Due to the exceeding human population, the vegetation structure and composition in urban environments are primary reasons for creating unsuitable habitats for many avian species (Beissinger and Osborne 1982, Germaine et al. 1998). The presence of livestock and people and

distance from roads and village cause a significant negative impact on the presence, distribution, diversity and abundance of birds (Adhikari et al. 2019).

As bird conservation is deeply rooted in Nepali people's culture, tradition and religion, the Government of Nepal has initiated many important conservation commitments from time to time (Baral et al. 2012). Knowledge of the composition of the bird along with its protection and conservation provides a habitat for a diversity of birds (Dahal and Bhuju 2008). Protection of community-managed forests can also play a vital role in increasing the diversity of birds and helps in attracting avifaunal tourism which is beneficial for the local communities (Poudel et al. 2021). Monitoring of birds provides valuable information on the ecological status of avifauna and can be a vital tool for developing awareness regarding the conservation value of those species (Kumar and Gupta 2013, Manohara et al. 2016). Biodiversity conservation strategies and implementation of awareness program at the local level against anthropogenic threats also helps in the conservation of species (Lamsal et al. 2014). Therefore, understanding the diversity of birds and factors affecting them helped in recognizing the status of birds in the Bagmati River corridor which is important for the exploration of avifauna as well as for the management and conservation of species of birds.

1.2 Objectives of the study

1.2.1 General objective

The general objective of this study was to explore the diversity of birds and factors affecting the bird abundance along the Bagmati River corridor.

1.2.2 Specific objectives

The specific objectives were:

- To explore the diversity of birds along the Bagmati River corridor.
- To analyze the factors affecting the bird abundance along the Bagmati River corridor.

1.3 Rationale of the study

Birds play an important role in ecosystem balance by providing various ecological services such as provisioning, regulating, cultural and supporting services (Sekercioglu 2006, Whelan et al. 2008, Whelan et al. 2010, Wenny et al. 2011, Mahendiran and Azeez 2018, Michel et al. 2020). Bagmati River is considered the main habitat for a variety of bird species (Thapa et al. 2008). In Nepal, several studies on bird diversity were found to specialize in conservation areas but the conservation of species in river corridors is little known. Riparian areas offer food to birds and support to many species living there (Rosenberg et al. 1997, Bennett et al. 2014). However these days, they are facing issues because of human disturbances, habitat loss and degradation, pollution, and overuse of pesticides (Mengesha and Bekele 2008, Thapa et al. 2008, Gorghate et al. 2015, Girma et al. 2017, Adhikari et al. 2018, Kandel et al. 2018). In the valley, due to infrastructural works, the green places are being changed into human settlements that have degraded the chance of survival of species. However, their distribution and effects of variables such as pollution, unplanned urbanization, habitat degradation and sewage disposal on the abundance of birds are little known. Since 2001, the Bagmati River Festival has been going on continuously to overcome the problem of the river. Enriching the habitats by increasing green spaces around the river may support the greater abundance of birds along the Bagmati River corridor. The data generated from this study can be used further for the conservation of bird species as well as for establishing bird watching places in the Kathmandu Valley.

2. LITERATURE REVIEW

2.1 Bird diversity

The diversity of birds varies consistent with food, season and the sort of environment during which they survive. Urban areas have a high bird abundance than non-urban habitats and additionally offer breeding sites for varied urban bird species that help in deciding the high diversity of these areas (Chace and Walsh 2006). The high avian diversity and richness were due to the complicated vegetation structure that provides shelter, varied niches, microhabitats and appropriate hunting grounds for birds (Debnath et al. 2018). The Bagmati River corridor is the richest area for a diversity of birds and supports high species of birds because of the diverse environment (Thapa et al. 2008). In most areas, terrestrial habitats additionally support diverse bird species (Sethy et al. 2015), for example, it may be a home for several residential and migratory birds (Chaudhari et al. 2009). Town landscapes affected the richness and relative abundance of birds which revealed that residential neighborhoods, institutional grounds and informal settlements had the best species diversity as compared to alternative small landscape varieties (Gatesire et al. 2014). However, the rapidly growing urbanization become a major threat to birds and should cause the extinction of species (Filloy et al. 2019).

Urban birds have a high tolerance to environmental conditions than rural birds so they can survive in urban habitats (Bonier et al. 2007). Urban green spaces facilitate increasing the richness of birds (Carbó-Ramírez and Zuria 2011). A proper supply of food has great importance in increasing the diversity of birds in urban areas (Rosenberg et al.1997, Bennett et al. 2014, Galbraith et al. 2015, Plummer et al. 2019). Riparian corridors support a high richness and abundance of birds (Cooke and Zack 2008). The riparian forest also supports an enormous richness and abundance of birds (De Oliveira Ramos and dos Anjos 2014).

2.2 Habitat use

Understanding the diversity of birds in several habitats helps to know the structure of a community and also helps in the conservation of species (Singh et al. 2013). The rise in residential development in urban areas is the primary reason for a change in

habitat and affects avian communities. Species richness also differs according to the kind of habitat. Habitat conditions confirm the distribution of species in different niches (Basnet et al. 2016). Disturbed and indigenous forests supported high bird richness than plantation forests and farmlands (Bett et al. 2016). The season determines the shifting of habitat utilization and width of a niche due to which grasslands had high habitat utilization rate (Zhao et al. 2013).

2.3 Factors affecting the bird diversity

Knowledge of factors determining the distribution of species is important for protecting the diversity of birds in a specific area. Various factors affect the diversity and distribution of species of birds. Factors such as environmental, ecological and social factors, morphological and vegetation characteristics, climatic conditions and anthropogenic disturbances were responsible for bringing change in the abundance and diversity of birds (Mengesha et al. 2011, Thapa and Saund 2012, Ferger et al. 2014, Asefa et al. 2017, Goddard et al. 2017, Imai et al. 2017, Wehenkel et al. 2017). Variation in breeding species of birds takes place due to vegetation factors (Mills et al. 1989). Urbanization was responsible for decreasing species richness and diversity which was due to the loss of greenery habitats in urban areas (Beissinger and Osborne 1982). Asefa et al. (2015) reported that assemblages of birds differed between sites and showed significant positive relationships with shrub and grass height. Availability of food, water and canopy were the major factors deciding the variety and abundance of birds. Development works in the surrounding landscapes affect the habitat of birds (Miller et at. 2003). Similarly, the presence of trees and shrubs also causes variation in the richness of birds (Juliana and Soladoye 2018).

Other factors such as the presence of livestock and people, distance from the road, settlement, water source, human disturbance, construction activities, noise, sewage, temperature and elevation also cause affect the abundance and diversity of birds (Able and Noon 1976, Herbers et al. 2004, Tuljapurkar and Bhagwat 2007, McCain 2009, Rais et al. 2011, Morelli et al. 2014, Zeleke 2015, Girma et al. 2017, Adhikari et al. 2018, Adhikari et al. 2019, Ceresa et al. 2021, Shah and Sharma 2022).

From the study, it was found that the abundance of birds was affected by various factors including the presence of tree, road distance, nearest water source, the nearest settlement, nearest open land, nearest sewage, temperature and elevation. Mostly the

birds inhabit near the human settlement and adapt to the urban habitat. Similarly, the presence of tree within the plot and increasing distance to the water source and road additionally favor more abundance of bird species. At higher elevations, few numbers of birds could be due to weather conditions. As a number of the birds were found feeding on waste the abundance of birds was discovered a lot in those areas.

3. MATERIALS AND METHODS

3.1 Study Area

Kathmandu valley is situated at the elevation of 1,350 m and surrounded by mountains. Kathmandu is a circular basin occupying about 525 km^2. The Bagmati is only the major river system in the valley. The study was conducted in the Bagmati River corridor from Sundarijal to Chovar (Figure 1). The river originates from Baghdwar at the elevation of 2,732 m. It is situated around 15 km northeast of Bagmati which flows down to various parts of the valley and finally exits from Katuwal Daha at the elevation of 1,140 m.

The Bagmati geographic area lies between the latitudes and longitudes of 26º23′18″ to 27º49′11″N and 85º1′25″ to 85º57′10″E. The River drains 3,500 km^2 before crossing the lower Tarai plain and also the international boundary into the Indian state of Bihar and eventually exhausting into the Ganges (BIWMP 2003). The very high population growth in the valley over the last 30 years has created problems with the amount and quality of water supplies due to high demand and inadequate waste disposal systems. The composition of the river suggests that sewage material effluent coming back into the river has a serious impact on the quality of water (Jüttner et al. 2003). A temperate climate prevails in the capital of Nepal. The mean annual temperature is 18°C. The coldest month is January with a mean temperature of 10°C. The warmest months are July and August. The yearly rainfall in Kathmandu is 1,400 mm. The wettest is July month with a mean rainfall of about 370 mm. The floras of the study area were Pine (*Pinus roxburghii*), Neem (*Azadirachta indica*), Jamun (*Syzygium cumini*), Simal (*Bombax ceiba*), Bojho (*Acorus calamus*), Lapsi (*Choerospondias axillaries*), Lahare pipal (*Populas deltoids*), Rhododendron (*Rhododendron arboreum*), etc. (Pandey and Bajracharya 2010). The fauna of the study area were Rhesus Monkey (*Macaca mulatta*), and free ranging Cow (*Bos indicus*) and Goat (*Capra hircus*), etc. (Wada 2005).

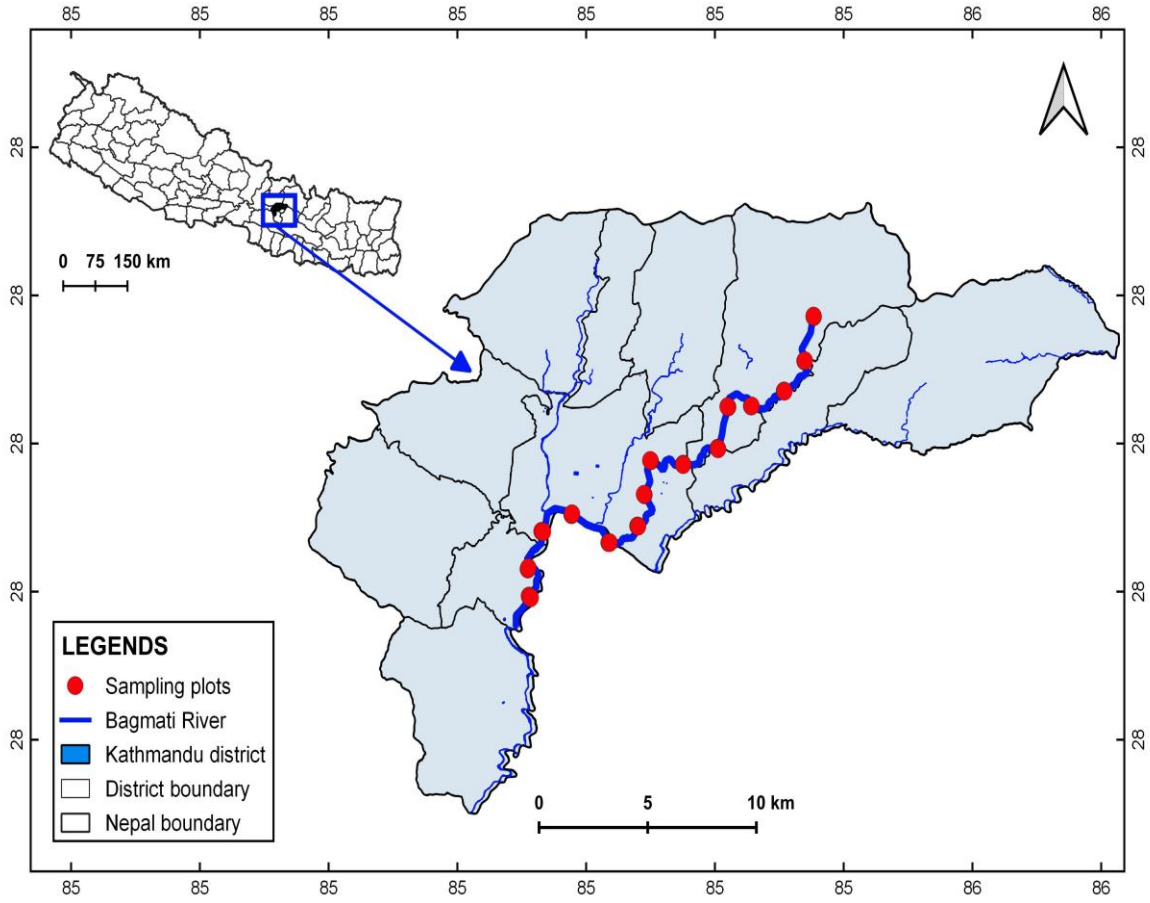

Figure 1: Map of the study area from Sundarijal to Chovar, Nepal

3.2 Materials

- Record papers
- Camera: Nikon D5600 with 55-300mm telens
- Binocular: Bushnell Falcon 10×50
- Measuring tape
- Field guide book: "Birds of Nepal" (Grimmett et al. 2016)
- Global Positioning System (GPS): Garmin Etrex 10

3.3 Methods

3.3.1 Bird observation

The study was carried out from 10 October 2021 to 9 April 2022. A point count method was applied to identify the number and type of bird species and their habitat use along the Bagmati River corridor between Sundarijal to Chovar. The river corridor was divided into 30 sampling points at 15 locations for bird observation. Birds were observed on either side of the river. The interval between the two sampling points was approximately 2 km. The sampling point for the bird was fixed at the bank of the river which was accessed through the Bagmati road corridor. At each point, the bird species were observed within a 50 m radius. The bird observation was carried out early in the morning from 6:00 am to 11:00 am in the designed framework. Bird counting/observation at each sampling point was started after staying quietly for 10 minutes. Altogether 11 visits were done in the field. The bird count was performed every five-minute interval for 30 minutes at each station. The highest numbers of birds for each species recorded during 30 minutes were used for data analysis. Birds were observed using Bushnell Falcon 10×50 binocular. Birds were identified in the field and unidentified bird pictures were taken using Nikon D5600 with a 55-300 mm telens camera for reference. A field guidebook of Grimmett et al. (2016) was used for bird identification.

3.3.2 Factors affecting bird abundance

The habitat characteristics of each sampling station such as the presence of tree, nearest distance from the center of each plot to the water source, road, settlement, open land and sewage were measured using a tape measure. If a single tree is present and the height is above five meters in the sampling plot, the plot is known as tree presence. The average temperature of each sampling plot was recorded during the observation period.

3.3.3 Data analysis

Ecological analyses such as Shannon-Wiener diversity, Pielou's evenness index, abundance and richness were calculated from the collected data. All the recorded species of birds in the study area were categorized into five feeding guilds based on

the field guidebook “Birds of Nepal” (Grimmett et al. 2016). The classification was done based on food as insectivores (feeding on insects, larva, spiders, worms, crustaceans, mollusks, etc.), omnivores (feeding on both plants and animals), carnivores (feeding on fishes, amphibians, reptiles, birds and mammals), frugivores (feeding on fruits, berries and drupes) and granivores (feeding on seeds and grains).

Shannon-Wiener diversity index

Shannon-Wiener diversity index was used to calculate the diversity of species.

$$H' = -\Sigma pilnpi$$

where,

H' = Shannon diversity index

Pi = Proportion of individual species

Pielou's evenness index

An evenness index was calculated from the collected data.

$$E = H'/ \log S$$

where,

H'=Shannon-Wiener's diversity index

S=Species richness

Poisson distribution was used to find the effect of the presence of a tree, road distance (m), nearest water source (m), nearest settlement (m), nearest open land (m), nearest sewage (m), temperature (^{0}C) and elevation (m) on the bird abundance. Variables were analyzed and GLM (Generalized Linear Model) was done in the R program (R Core Team 2019) for the analysis of data. Models were ranked by using the Akaike Information Criterion (AICc) and weight was used to estimate the strength of evidence for each model (Mazerolle 2006). Model averaging was done using all models for each variable to estimate 95% confidence intervals and statistical significance was accepted.

4. RESULTS

4.1 Bird Diversity

A total of 11,853 individuals of 67 bird species belonging to 11 orders and 28 families with their feeding guild category were recorded from the study area of the Bagmati River corridor (Appendix 1). Among the observed birds, Passeriformes was the most dominant order (47 species, 70%), and followed by Columbiformes (4 species, 6%), Charadriiformes (4 species, 6%), Accipitriformes (3 species, 4%), Pelecaniformes (2 species, 3%), Psittaciformes (2 species, 3%) while remaining each order Bucerotiformes, Coraciiformes, Galliformes, Gruiformes and Piciformes with single species (1% for each) (Figure 2).

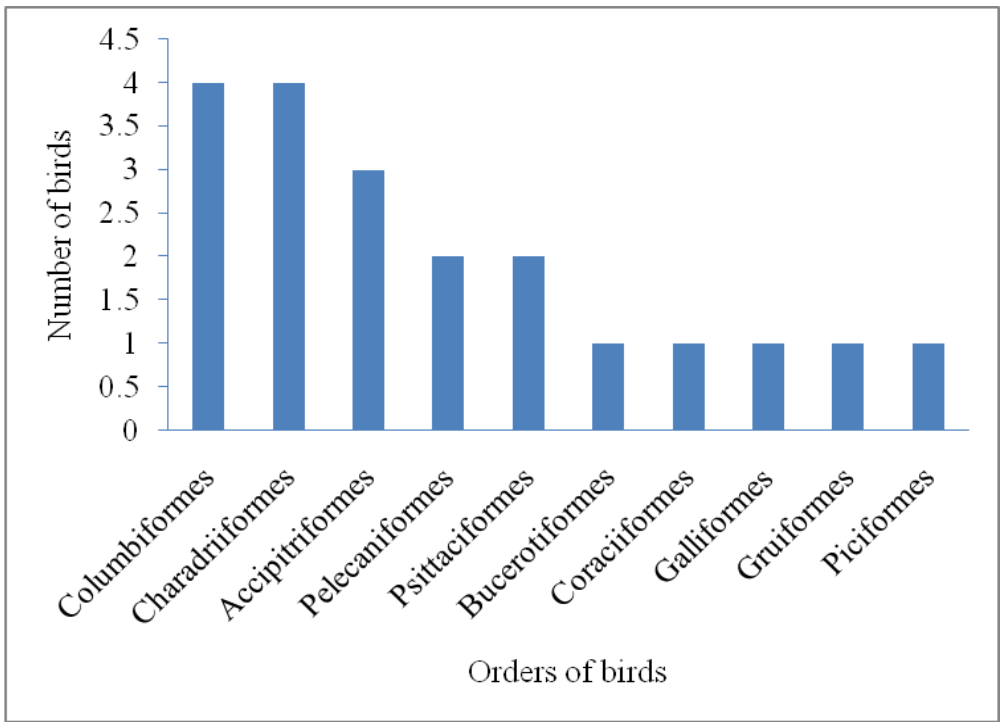

Figure 2: Bird species according to orders in the Bagmati River corridor between October 2021 and April 2022 (Order Passeriformes was excluded in the figure).

Among the recorded 28 families, the family Muscicapidae had the highest number of bird species (14 species, 21%) followed by Motacillidae (6 species, 8.95%), Columbidae and Pycnonotidae (4 species with 5.97% each), Accipitridae, Corvidae and Phylloscopidae (3 species with 4.47% each), Ardeidae, Campephagidae, Charadriidae, Dicruridae, Laniidae, Passeridae, Psittaculidae, Scolopacidae and

Sturnidae (2 species with 2.98% each) while remaining each family Alcedinidae, Aegithalidae, Cisticolidae, Hirundinidae, Megalaimidae, Paridae, Phasianidae, Rallidae , Rhipiduridae, Sylviidae, Turdidae and Upupidae were single species with 1.49% each (Figure 3).

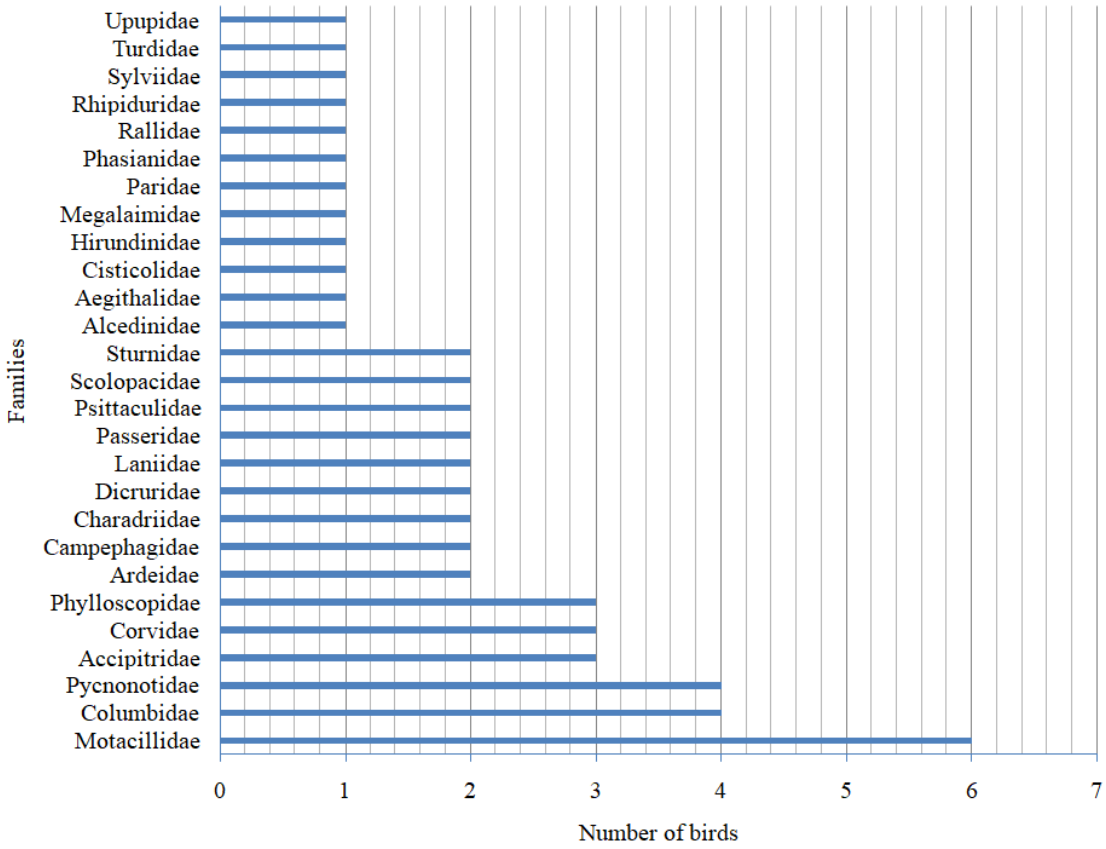

Figure 3: Observed birds according to families in the Bagmati River corridor between October 2021 and April 2022 (Family Muscicapidae was excluded in the figure).

The Shannon-Wiener diversity index and evenness were found 3.35 and 0.796, respectively. The feeding guild of birds along the Bagmati River corridor revealed that the highest number of birds was recorded for insectivores (52%, n = 35), and followed by omnivores (21%, n = 14), the equal percentage for carnivores, frugivores and granivores (9%, n=6) (Figure 4).

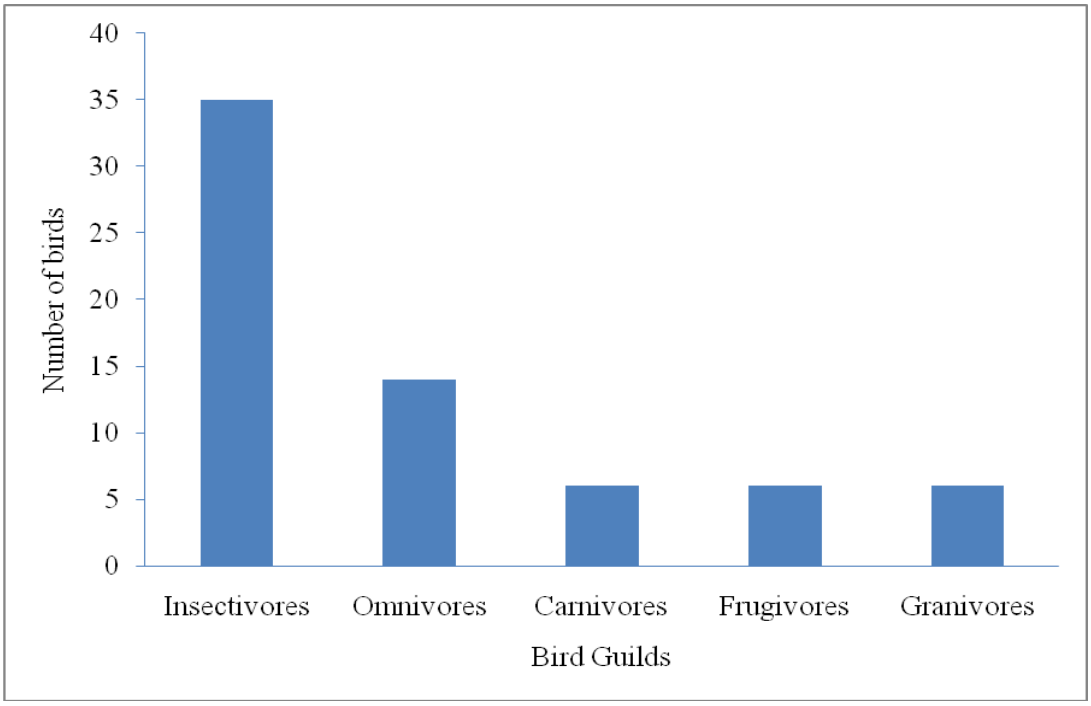

Figure 4: Bird species according to guilds in the Bagmati River corridor between October 2021 and April 2022.

4.2 Factors affecting the bird abundance

The 90% of plots had trees. The average distance from the observation plots was measured for nearest water source [average: 5.867 ± 3.711 (SD); range: 2 to 20 m], road [average: 56.4 ± 83.398 (SD); range: 5 to 270 m], settlement [average: 65.97 ± 108.427 (SD); range: 7 to 500 m], open land [average: 8.067 ± 5.57 m (SD); range: 2 to 25 m] and sewage [average: 2.5 ± 1.042213 (SD); range: 1 to 5 m].The average elevation of the study plot was 1312 ± 80.144 (SD) [range: 1253 to 1595 m]. The average temperature during the study period at the sampling plot was 8.667 ± 2.264 (SD) [range: 5 to 13^{0}C].

The bird abundance was increased in presence of tree. Poisson distribution models were described for the occurrence of species of birds along the Bagmati River corridor where models such as the presence of tree, distance to water source (m), distance to road (m), distance to settlement (m), distance to open land (m), distance to sewage (m), temperature (^{0}C) and elevation (m) were described as predictive variables and abundance of species of birds as response variables. The best model of abundance of species of birds includes elevation, and the second best model includes elevation and nearest water source (Appendix 2). Furthermore, the bird abundance

decreased with the distance to open land and at higher elevation (Table 1). In addition, the higher bird abundance was found at near to settlement, sewage and at lower temperature (Table 1). The bird abundance was also increased with increasing the distance to water source and road (Table 1).

Table 1: Model-averaged variables estimate with a lower and upper limit at 95 % Confidence Limits (CL) describing the diversity of birds and effects of factors on the abundance of birds along the Bagmati River corridor, Nepal (Figure1) between October 2021 to April 2022. Model-averaged variables include the presence of tree, distance to water source (m), distance to road (m), distance to settlement (m), distance to open land (m), distance to sewage (m), temperature (^{0}C) and elevation (m). Significant effects are in bold.

Variables	**Estimate**	**SE**	**Lower CL**	**Upper CL**	**Z**	**P**
(Intercept)	8.6492	1.0432	6.6540	10.7516	8.291	**<0.0001**
Tree	-0.2916	0.1467	-0.5757	-0.0002	-1.988	**0.0468**
Distance to water source	0.0240	0.0143	-0.0043	0.0518	1.680	0.0930
Distance to road	0.0005	0.0005	-0.0005	0.0015	1.038	0.2992
Distance to settlement	-0.0002	0.0006	-0.0014	0.0009	-0.385	0.6999
Distance to open land	-0.0123	0.0088	-0.0296	0.0049	-1.394	0.1634
Distance to sewage	-0.0323	0.0350	-0.1009	0.0363	-0.923	0.3559
Temperature	-0.0063	0.0181	-0.0419	0.0290	-0.353	0.7241
Elevation	-0.0036	0.0007	-0.0052	-0.0021	-4.677	**0.0001**

5. DISCUSSION

This study explores abundant bird diversity along the Bagmati River corridor. Generally, the results of this study indicate that the area is home to a large number of bird species. This could be due to suitable habitat as well as food for the birds. The presence of tree indicates the change in the number of species along the river corridor. The local government emphasized the greenery in the valley including along the river (Goutam 2018). This is because of the high number of species like Rock Dove recorded during the study which contributed to a large proportion of the overall abundance. This might be due to the availability of food in the river corridor that provides abundant food for the occurrence of species (Rosenberg et al. 1997, Bennett et al. 2014). The highest number of birds was recorded for the order Passeriformes. Globally, the order Passeriformes has a wider distribution and higher population. As the study area, Kathmandu is an urban area so the accessibility of food in such area is a primary driver of regulating the population of birds (Galbraith et al. 2015, Plummer et al. 2019). Not only in this area but the birds of this order were also recorded as dominant order in other areas too (Chaudhari et al. 2009, Singh 2015, Kharel 2018, Kiros et al. 2018, Husein and Sultan 2019, Neupane et al. 2020). Muscicapidae family supports a higher number of species which might be due to the favorable place for the survival of species.

The basic requirements of birds are adequate food supply and safety (Lakshmi 2006). Availability of proper supply of food plays a major role in higher survival, increase reproductive rates, helping in rapid digestion of food, facing physiological challenges of migration and maintaining a high rate of metabolism in the body (Stevenson 1933, McWilliams and Karasov 2001) whereas scarcity of food lowers their breeding success (Chamberlain et al. 2009, Meyrier et al. 2017, Seress et al. 2020). Urban areas provide breeding sites for many urban bird species and attract insectivores (Chace and Walsh 2006). It is evident from the study that insectivore birds constitute a majority of the species of birds which might be due to the presence of waste disposal and dumps of garbage as a source of adequate food supply to a wide variety of birds (Tuljapurkar and Bhagwat 2007, Mehra et al. 2017). Some of the species forage on soil for food whereas some depend on the water column for living. However, a similar study on feeding guilds was shown by Kumar and Gupta (2013), Basnet et al.

(2016) and Katuwal et al. (2018) where most of the birds forage on insects for food. The omnivores bird species were recorded more because these are generalist species, with a broad range of diets and more tolerance to humans (Samia et al. 2015). Less number of fruiting trees was the reason for the low number of frugivores birds in the study area.

Various factors such as environmental factors (Sethy et al. 2015), climatic factors (Ferger et al. 2014, Wehenkel et al. 2017) and morphological and vegetation characteristics (Mengesha et al. 2011, Thapa and Saund 2012) might be responsible for bringing change in the abundance, distribution and diversity of birds. Due to the fluctuation in the number of individuals of species, the species richness of birds changes according to seasons or months (Giri and Chalise 2008, Lamsal et al. 2014). Habitat characteristics such as the presence of trees play an important role in driving bird species composition. The tree presence, nearest distance to the water source, road, settlement, open land, sewage, temperature and elevation played a vital role in bringing the change in the bird abundance along the Bagmati River corridor. The bird abundance increases with increasing the distance to the road (Morelli et al. 2014) and at the nearest distance to the water source as the corridor supports abundant food for the species. Settlement areas also provide high avian species which was due to the accessibility of heterogeneous habitats for forage and nesting (Zeleke 2015). Studies elsewhere have indicated a low abundance of birds in settlement areas because of high disturbances, construction activities and noise due to vehicles which cause a threat to birds (Kafle et al. 2008, Rais et al. 2011, Inskipp et al. 2017, Adhikari et al. 2018, Adhikari et al. 2019). Temperature is another driver affecting bird abundance. The results of this study indicated that low temperature favors the more availability of bird species and high temperature lowers their number which indicates that temperature harms the bird abundance (Ceresa et al. 2021). Bird abundance becomes low with the distance to open land and decreased with an increase in elevation (Able and Noon 1976, Herbers et al. 2004, McCain 2009), which might be due to decreased availability of food and nesting sites in the open areas (Burke and Nol 1998, Ford et al. 2001).

The present study revealed that the area is rich in avian species due to favorable climatic conditions for the occurrence of species. The Rock Dove (*Columba livia*) was the most dominant species. Probably, the Rock Dove is an invasive bird species

in Nepal as they are well adapted to living in an urban environment and its excreta contain highly acidic material which corrodes metals and damage buildings (Bernardi et al. 2009, Spennemann et al. 2017). This might be due to the adaptation of the species to diverse habitat conditions. Commonly seen species House Sparrow (*Passer domesticus*), House Crow (*Corvus splendens*), Indian Pond-heron (*Ardeola grayii*), Cattle Egret (*Bubulcus ibis*), Common Sandpiper (*Actitis hypoleucos*), White Wagtail (*Motacilla alba*), etc. were observed mostly in groups. Among them, insectivores and omnivores species were found nearer to the water sources due to the availability of a variety of food.

Bagmati River corridor is a home for various types of urban-adapted avian species which indicates that the habitat is suitable and supports immense food resources to them (Ferger et al. 2014). As dumping ground consists of a great variety of food, some of the birds were found feeding on the carcass and disposal wastes but the majority were found searching for insects and worms as food during the study. A higher abundance of birds was found in presence of tree, near the settlement, sewage, at lower temperature, increasing the distance to water source and road whereas decreased with the distance to open land and at a higher elevation. Sewage also causes an increase in the abundance of birds (Tuljapurkar and Bhagwat 2007).

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study indicates that the Bagmati River corridor is rich in biodiversity as it supports more number of avian species. Most bird species are under the order Passeriformes and the family Muscicapidae in the Bagmati River corridor. Among the bird guilds, the insectivores have a higher number of bird species. Various factors such as the presence of tree, distance to the water source, road, settlement, open land, sewage, temperature and elevation affect the bird diversity and abundance. The abundance of birds was increased in presence of tree, near the settlement, sewage, at low temperature, increasing distance to water source and road whereas decreased with the distance to open land and at a higher elevation. Thus, knowledge on the conservation of habitat and minimizing the factors that affect the birds helps in protecting the status of avian species.

6.2 Recommendations

The findings from this study could lead to the following suggestions:

1. Due to lack of time, seasonal variation of bird diversity could not be explored. So, future research should be conducted in the autumn, winter, spring and summer season to understand the seasonal variation of birds.
2. Further research should be conducted to explore new bird species to know the birds' status in the study area for designing the bird watching station.

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APPENDICES

Appendix 1: Bird species of Bagmati River corridor and their taxonomic position, feeding guild category and IUCN Status

S.N.	Common Name	Scientific Name	Order	Family	Feeding Guild	IUCN Status
1	Black Kite	*Milvus migrans*	Accipitriformes	Accipitridae	Carnivore	Least Concern
2	House Crow	*Corvus splendens*	Passeriformes	Corvidae	Omnivore	Least Concern
3	Large-billed Crow	*Corvus macrorhynchos*	Passeriformes	Corvidae	Omnivore	Least Concern
4	Rock Dove	*Columba livia*	Columbiformes	Columbidae	Granivore	Least Concern
5	House Sparrow	*Passer domesticus*	Passeriformes	Passeridae	Granivore	Least Concern
6	Jungle Myna	*Acridotheres fuscus*	Passeriformes	Sturnidae	Omnivore	Least Concern
7	Cattle Egret	*Bubulcus ibis*	Pelecaniformes	Ardeidae	Insectivore	Least Concern
8	White Wagtail	*Motacilla alba*	Passeriformes	Motacillidae	Insectivore	Least Concern
9	Grey-headed Lapwing	*Vanellus cinereus*	Charadriiformes	Charadriidae	Insectivore	Least Concern
10	Common Sandpiper	*Actitis hypoleucos*	Charadriiformes	Scolopacidae	Insectivore	Least Concern

11	Red-vented Bulbul	*Pycnonotus cafer*	Passeriformes	Pycnonotidae	Omnivore	Least Concern
12	Oriental Magpie Robin	*Copsychus saularis*	Passeriformes	Muscicapidae	Insectivore	Least Concern
13	White-breasted Kingfisher	*Halcyon smyrnensis*	Coraciiformes	Alcedinidae	Carnivore	Least Concern
14	Dusky Warbler	*Phylloscopus fuscatus*	Passeriformes	Phylloscopidae	Insectivore	Least Concern
15	Rosy Pipit	*Anthus roseatus*	Passeriformes	Motacillidae	Omnivore	Least Concern
16	Rose-ringed Parakeet	*Alexandrinus krameri*	Psittaciformes	Psittaculidae	Frugivore	Least Concern
17	Green Sandpiper	*Tringa ochropus*	Charadriiformes	Scolopacidae	Insectivore	Least Concern
18	Common Stonechat	*Saxicola torquatus*	Passeriformes	Muscicapidae	Insectivore	Least Concern
19	Indian Pond- heron	*Ardeola grayii*	Pelecaniformes	Ardeidae	Insectivore	Least Concern
20	Hodgson's Redstart	*Phoenicurus hodgsoni*	Passeriformes	Muscicapidae	Insectivore	Least Concern
21	White-capped Water-redstart	*Chaimarrornis leucocephalus*	Passeriformes	Muscicapidae	Insectivore	Least Concern
22	Common Tailorbird	*Orthotomus sutorius*	Passeriformes	Cisticolidae	Insectivore	Least Concern
23	Long-tailed Shrike	*Lanius schach*	Passeriformes	Laniidae	Carnivore	Least Concern

24	Pied Bushchat	*Saxicola caprata*	Passeriformes	Muscicapidae	Insectivore	Least Concern
25	Plumbeous Water-redstart	*Phoenicurus fuliginosus*	Passeriformes	Muscicapidae	Insectivore	Least Concern
26	Black Drongo	*Dicrurus macrocercus*	Passeriformes	Dicruridae	Insectivore	Least Concern
27	Booted Eagle	*Hieraaetus pennatus*	Accipitriformes	Accipitridae	Carnivore	Least Concern
28	Black Redstart	*Phoenicurus ochruros*	Passeriformes	Muscicapidae	Insectivore	Least Concern
29	Grey Wagtail	*Motacilla cinerea*	Passeriformes	Motacillidae	Insectivore	Least Concern
30	Common Myna	*Acridotheres tristis*	Passeriformes	Sturnidae	Omnivore	Least Concern
31	Barn Swallow	*Hirundo rustica*	Passeriformes	Hirundinidae	Insectivore	Least Concern
32	Olive-backed Pipit	*Anthus hodgsoni*	Passeriformes	Motacillidae	Insectivore	Least Concern
33	Black-throated Tit	*Aegithalos concinnus*	Passeriformes	Aegithalidae	Insectivore	Least Concern
34	Mountain Bulbul	*Ixos mcclellandii*	Passeriformes	Pycnonotidae	Frugivore	Least Concern
35	Blue Whistling- thrush	*Myophonus caeruleus*	Passeriformes	Muscicapidae	Omnivore	Least Concern
36	Western Spotted Dove	*Spilopelia suratensis*	Columbiformes	Columbidae	Granivore	Least Concern
37	Kalij Pheasant	*Lophura leucomelanos*	Galliformes	Phasianidae	Omnivore	Least Concern

38	Black Bulbul	*Hypsipetes leucocephalus*	Passeriformes	Pycnonotidae	Insectivore	Least Concern
39	Eurasian Tree Sparrow	*Passer montanus*	Passeriformes	Passeridae	Granivore	Least Concern
40	Tree Pipit	*Anthus trivialis*	Passeriformes	Motacillidae	Insectivore	Least Concern
41	Himalayan Bulbul	*Pycnonotus leucogenys*	Passeriformes	Pycnonotidae	Omnivore	Least Concern
42	Red- throated Flycatcher	*Ficedula albicilla*	Passeriformes	Muscicapidae	Omnivore	Least Concern
43	Grey-backed Shrike	*Lanius tephronotus*	Passeriformes	Laniidae	Carnivore	Least Concern
44	Blue-throated Barbet	*Psilopogon asiatica*	Piciformes	Megalaimidae	Frugivore	Least Concern
45	Spotted Forktail	*Enicurus maculatus*	Passeriformes	Muscicapidae	Insectivore	Least Concern
46	Alexandrine Parakeet	*Palaeornis eupatria*	Psittaciformes	Psittaculidae	Frugivore	Near Threatened
47	Oriental Turtle- dove	*Streptopelia orientalis*	Columbiformes	Columbidae	Granivore	Least Concern
48	Slaty-backed Flycatcher	*Ficedula erithacus*	Passeriformes	Muscicapidae	Omnivore	Least Concern
49	Steppe Eagle	*Aquila nipalensis*	Accipitriformes	Accipitridae	Carnivore	Endangered
50	Little Forktail	*Enicurus scouleri*	Passeriformes	Muscicapidae	Insectivore	Least Concern
51	Yellow-bellied Fairy-	*Chelidorhynx hypoxantha*	Passeriformes	Rhipiduridae	Insectivore	Least Concern

	fantail					
52	Grey Treepie	*Dendrocitta formosae*	Passeriformes	Corvidae	Frugivore	Least Concern
53	Greenish Warbler	*Phylloscopus trochiloides*	Passeriformes	Phylloscopidae	Insectivore	Least Concern
54	White-collared Blackbird	*Turdus albocinctus*	Passeriformes	Turdidae	Frugivore	Least Concern
55	Paddyfield Pipit	*Anthus rufulus*	Passeriformes	Motacillidae	Insectivore	Least Concern
56	Common Hoopoe	*Upupa epops*	Bucerotiformes	Upupidae	Insectivore	Least Concern
57	Lesser Whitethroat	*Curruca curruca*	Passeriformes	Sylviidae	Omnivore	Least Concern
58	Eurasian Collared- dove	*Streptopelia decaocto*	Columbiformes	Columbidae	Granivore	Least Concern
59	Hume's Leaf Warbler	*Phylloscopus humei*	Passeriformes	Phylloscopidae	Insectivore	Least Concern
60	Grey Bushchat	*Saxicola ferreus*	Passeriformes	Muscicapidae	Insectivore	Least Concern
61	Scarlet Minivet	*Pericrocotus flammeus*	Passeriformes	Campephagidae	Insectivore	Least Concern
62	Great Tit	*Parus major*	Passeriformes	Paridae	Insectivore	Least Concern
63	Little Pied Flycatcher	*Ficedula westermanni*	Passeriformes	Muscicapidae	Insectivore	Least Concern
64	Ashy Drongo	*Dicrurus leucophaeus*	Passeriformes	Dicruridae	Insectivore	Least Concern

65	Eurasian Coot	*Fulica atra*	Gruiformes	Rallidae	Omnivore	Least Concern
66	Red-wattled Lapwing	*Vanellus indicus*	Charadriiformes	Charadriidae	Omnivore	Least Concern
67	Long-tailed Minivet	*Pericrocotus ethologus*	Passeriformes	Campephagidae	Insectivore	Least Concern

IUCN= International Union for Conservation of Nature

Appendix 2: Poisson distribution models describing the occurrence of species of birds along Bagmati River corridor, Nepal between October 2021 and April 2022 (Figure 1). Model variables include the presence of tree, distance to water source (m), distance to road (m), distance to settlement (m), distance to open land (m), distance to sewage (m), temperature (^{0}C) and elevation (m) as predictive variables and abundance of species of birds as response variables. K is parameter, wi is the Akaike model weight.

Models	K	logLik	AICc	ΔAICc	wi
Elevation	2	-97.812	200.069	0	0.103
Elevation + Nearest water source	3	-96.903	200.729	0.659	0.074
Distance to settlement+ Elevation	3	-97.164	201.251	1.181	0.057
Elevation + Nearest water source + Presence of tree	4	-96.061	201.723	1.654	0.045
Elevation + Presence of tree	3	-97.503	201.930	1.860	0.040
Distance to road + Elevation	3	-97.727	202.378	2.309	0.032
Distance to sewage + Elevation	3	-97.754	202.432	2.362	0.031
Elevation + Temperature	3	-97.776	202.475	2.405	0.030
Distance to open land + Elevation	3	-97.812	202.547	2.477	0.029

Distance to sewage + Elevation + Nearest water source	4	-96.725	203.050	2.981	0.023
Distance to settlement + Elevation + Presence of tree	4	-96.789	203.179	3.109	0.021
Distance to road + Elevation + Nearest water source	4	-96.842	203.284	3.214	0.020
Distance to settlement + Elevation + Nearest water source	4	-96.880	203.361	3.291	0.019
Elevation + Nearest water source + Temperature	4	-96.882	203.364	3.294	0.019
Distance to open land + Elevation + Nearest water source + Presence of tree	5	-95.445	203.391	3.321	0.019
Null	1	-126.233	254.610	54.540	1.48E-13
Distance to open land	2	-125.223	254.890	54.820	1.29E-13

PHOTO PLATES

Himalayan Bulbul

Black Drongo

Alexandrine Parakeet

Barn Swallow

Common Myna

Rock Dove

Hodgson´s Redstart (♂)

Hodgson´s Redstart (♀)

Common Sandpiper

Common Stonechat

Blue Whistling-thrush

Indian Pond-heron

Grey-headed Lapwing

House Crow

Long-tailed Shrike

Olive-backed Pipit

Jungle Myna

Large-billed Crow

Oriental Turtle-dove

Oriental Magpie Robin

Plumbeous Water-redstart

White-capped Water-redstart

Steppe Eagle

Red-vented Bulbul

Western Spotted Dove

Black Kite