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Tribhuvan University area serves as a greenspace for birds in the Kathmandu Valley, Central Nepal

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Abstract

The Kathmandu Valley, encompassing the capital city of Nepal, is one of the fastest growing metropolitan areas in South Asia. Rapid population growth and urbanization in Kathmandu have degraded the urban environment affecting the native biota. Therefore, a detailed assessment of avian species richness and its distribution in potential green spaces of the Kathmandu Valley is essential. We assessed the avian diversity in different habitats of the Tribhuvan University area, a potential refuge for birds in the urban landscape, by the point count method in the winter and summer of 2020. A total of 71 bird species from 39 genera and 32 families comprising 10 orders - 'including the globally endangered Steppe eagle (*Aquila nipalensis*)' - were recorded. Of the 10 orders, Passeriformes (44 species), had the highest richness followed by Columbiformes, Piciformes and Cuculiformes (with four species in each). Among the feeding guilds, the insectivorous guild (with 28 species) had the highest species richness followed by omnivores and carnivores. A higher Shannon's diversity index was recorded in forest habitats (3.51) than built-up areas (3.45) or farmland (3.42). Despite the small size, our study has shown that the Tribhuvan University area is an important greenspace for birds in the Kathmandu Valley. An extensive exploration, monitoring and management of greenspaces are crucial for maintaining the ecological integrity of the urban landscape of the Kathmandu Valley.

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Key words: Avian fauna, greenspace, Kirtipur, Passeriformes, urbanization

Introduction

By 2050, the majority of the world's population is expected to be living in cities (United Nations, 2014). More and more natural land has been replaced by tall buildings and concrete surfaces as urbanization has progressed (Ferenc et al., 2014) resulting in loss or alteration of the biotic community. Biodiversity loss as a result of urbanization is a serious issue that has sparked global concern (Grimm et al., 2008). Birds are one of the most common and ecologically functional wildlife in urban areas, contributing as ecosystem bio-indicators (Sekercioglu, 2006), plant pollinators (García, 2016), flagship species (Veríssimo et al., 2014), waste biomass recyclers and disease vector regulators (Muñoz-Pedreros et al., 2016; Plaza et al., 2019). Biodiversity loss due to rapid urbanization may be ameliorated to some extent by management of green areas like gardens and parks (Fernández-Juricic, 2004).

Urban green areas are able to support a large number of birds due to the availability of sufficient sources of food, water and shelter (Dale, 2018). In built-up areas, urban parks form habitat islands, which connect to other vegetation patches to build a habitat network (Chen et al., 2006). Furthermore, urban parks along the major migratory bird flyways provide important stopover places for migratory

birds (Matthews and Rodewald, 2010; Seewagen and Newhouse, 2018).

Nepal is home to 886 bird species representing 23 orders and 97 families (DNPWC and BCN, 2018). Kathmandu Valley, and the surrounding hills has two Important Bird and Biodiversity Areas (IBAs) - Phulchowki Mountain Forest and Shivapuri-Nagarjun National Park, and one potential IBA (Bagmati Valley), demonstrating its importance for bird diversity (Baral and Inskipp, 2005). The Kathmandu Valley is the most populated urban region of Nepal, and is growing at a rate of 6.5% per year, indicating one of the fastest growing metropolitan areas in the South Asia (Ishtiaque et al.; 2017; Timsina et al., 2020). Haphazard and unplanned urbanization in the valley continues to exponentially engulf forest patches, grasslands and agricultural lands (Muzzini and Aparicio, 2013; Ishtiaque et al., 2017).

Green areas, like forest patches, parks, gardens and grasslands, may minimize the effects of urbanization on urban wildlife, including birds. Previous studies on some green spaces of the Kathmandu Valley, such as forest patches (Pashupatinath, Swyambhunath, Ranibari, etc.) (Katuwal 2016), grassland (a portion of the Tribhuvan International Airport) (Dahal and Bhuju, 2008), and parks (Bagmati River Nature Park) (Thapa et al., 2008) revealed that these spaces hold significant numbers of birds and provide suitable habitat for migratory and threatened species.

To understand the importance of green spaces in minimizing the effects of degraded urban environments, a detailed assessment of bird richness, and its distribution at different habitats in potential green space of the Kathmandu Valley, is essential. The Tribhuvan University (TU) area on the south-western side of the valley holds diverse habitats including forests, agricultural fields and built-up areas, and could be a stronghold of local biodiversity. However, there has been no comprehensive documentation of flora and fauna in the area. Therefore, this study aimed to assess: i) bird community structure, and ii) seasonal richness, abundance and diversity of birds in the TU area.

Material and Methods

Study area

Tribhuvan University is situated in Kirtipur, an ancient town located about five kilometers south-west of Kathmandu Valley's major metropolis. It is the oldest university in Nepal and covers an area of 1.57 km^2. The study area has a sub-tropical climate with cool and dry winters (October-February), hot and dry summers (March-May) and a hot and humid monsoon (June-September). The entire area can be categorized into three habitat types, i.e. building areas, forest areas and farmland areas. Administrative and academic buildings, playgrounds and hostel areas were included in the building area habitat.

Seasonal cultivation is done by locals in certain portions of the university area. Commonly cultivated crops are rice (monsoon) and maize. These seasonally cultivated areas, along with a few adjoining grassland patches, were included in the farmland habitat. Within the study area, there lies a man-made garden, the Coronation garden. The Coronation garden, and adjoining forest patches, were included in the forest habitat. Common vegetation recorded in the study area are *Alnus nepalensis* (Betulaceae), *Bauhinia variegata* (Fabaceae), *Castonopsis indica* (Fagaceae), *Celtis* spp. (Cannabaceae), *Cinnamomum camphora* (Lauraceae), *Cotoneaster bacillaris* (Rosaceae), *Jasminum humile* (Oleaceae), *Juniperus* spp. (Cupressaceae), *Lantana camara* (Verbenaceae), *Largerstroemia indica* (Lythraceae), *Legustrum confusum* (Oleaceae), *Quercus lanata* (Fagaceae), *Rubus biflorus* (Rosaceae), *Rubus ellipticus* (Rosaceae), *Salix babylonica* (Salicaceae), *Schima wallichi* (Theaceae), *Thuja orientalis* (Cupressaceae), *Zizyphyus jujuba* (Rhamnaceae), among others.

Bird survey

In order to record the seasonal variation in bird diversity, two seasonal surveys were conducted in winter (December 2019 - January 2020) and summer (June - July) of 2020. The bird survey was conducted on every alternate day for two months in each season. Data collection was done using the point count method (Bibby et al., 2000). Birds observed and heard within a 50 m radius were recorded from a fixed point (Jasmani et al., 2017; Zhang et al., 2021) and the distance between two points was maintained at 150 m. The point count entailed an observer sitting quietly for 5 minutes at the start of each observation and then recording birds for another 10 minutes (Paker et al., 2014). Observations were done at a constant time in the morning 30 minutes after dawn to 10:00 AM and again from 3:30 PM until 30 minutes before sunset, to increase the probability of detecting more birds. A total of 54 point count stations (18 point count stations in each habitat type) were surveyed. However, observations were not conducted when the weather was unfavorable for observation.

Birds were scanned with the help of Bushnell Falcon 10x50 wide-angle binoculars and photographs were taken using a Nikon p900 camera. For species identification, the standard field book 'Birds of Nepal' (Grimmett et al., 2016) was used. A map of the study area was prepared using ArcGIS 10.4. The image of the study area was extracted from google earth and geo-referenced.

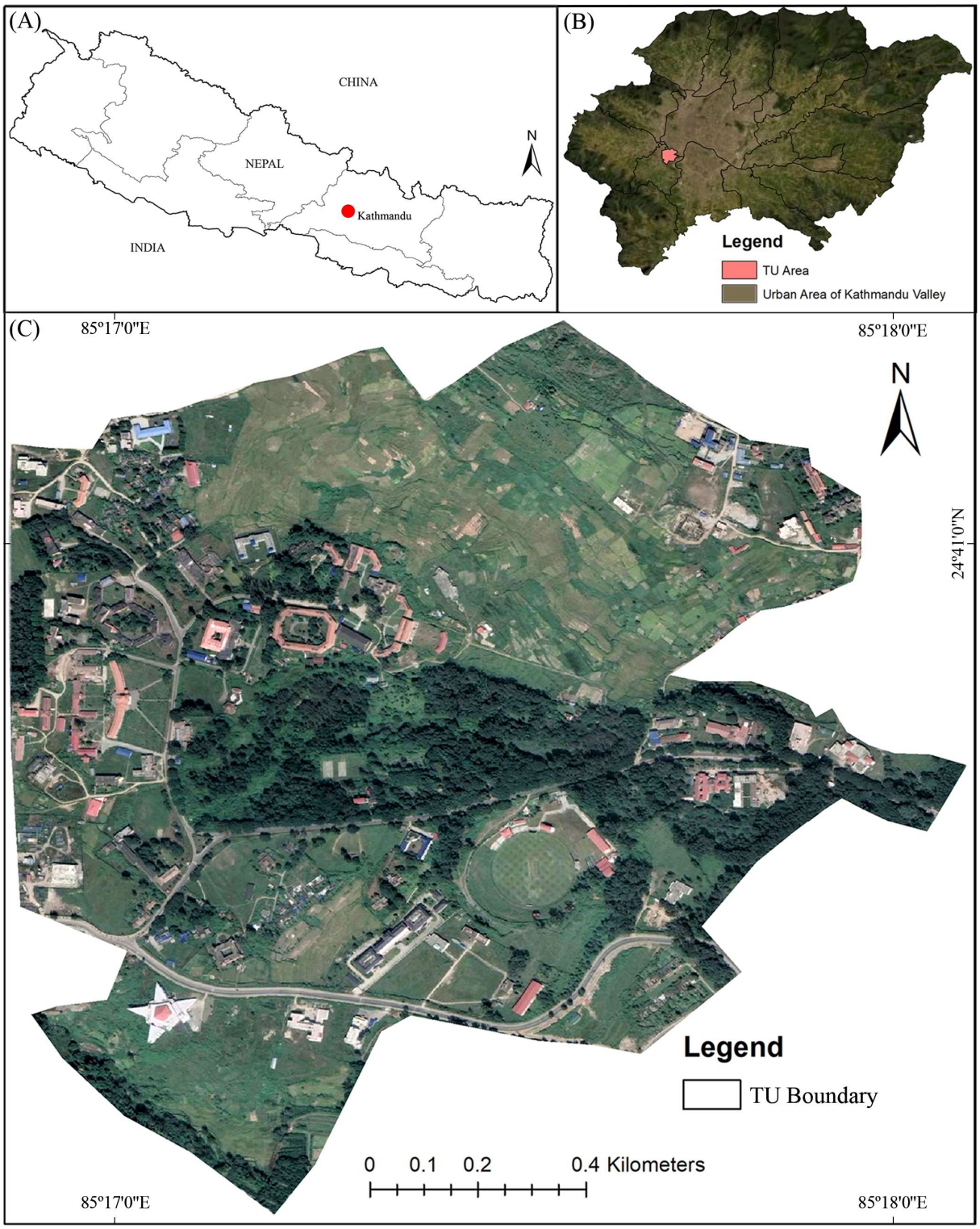

Figure 1: Map of the study area. A- Map of Nepal showing the Kathmandu Valley; B- Map of Kathmandu Valley showing the Tribhuvan University area; C- Map of Tribhuvan University area showing different habitat types. The map was prepared using ArcGIS 10.4.

Data management and analysis

Based on the diet descriptions from Grimmett et al. (2016), the observed birds were categorized into five feeding guilds: Carnivorous, Granivorous, Insectivorous, Frugivorous and Omnivorous. Various community parameters, such as species richness, abundance and diversity indices, were then calculated to quantify biological diversity. Species richness represented the cumulative list of species observed during the sampling and abundance represented the total number of individuals (Chettri et al., 2018). Species diversity was determined using the Shannon-Weiner index, Simpson's index and Pielou's evenness index.

The Shannon-Weiner Diversity Index (H') was calculated for each area using the formula

$$H' = -\sum_{i=1}^{s}[p_i (\ln p_i)]$$

where p_i is the number of observed individuals of the i^{th} species divided by the total number of all birds (Shannon 1948).

The Simpson's Diversity Index (D) was calculated for each habitat type using the equation

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$$

where n is the number of individuals of a species and N is a total number of individuals in total species.

The Pielou's measure of species evenness (E) was used to assess the relative abundance of the different species making up the richness of an area (Krebs, 1978). It compares the similarity of the population size of each of the species present, using the formula

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

where H' is the diversity index and S is the number of species.

The criteria used in the Shannon-Wiener diversity index were: (i) H< 1 represented a low diversity of bird species; (ii) H values 1–3 represented a moderate diversity of species; and (iii) H> 3 represented a high diversity of bird species (Iswandaru et al., 2020).

The criteria for the Pielou's evenness index are that, low E values (closer to 0) represented low evenness while high E values (closer to 1) represented relatively uniform evenness. The Simpson Diversity Index (D) values range between 0 and 1, with high values representing higher diversity (Poudel et al., 2021).

To test whether the sampling effort was enough to detect all the species that occur in the study area, a species accumulation curve was produced, by plotting the cumulative number of species detected against the sampling effort (Deng et al., 2015). All the calculations were done using the R Studio (R Core Team, 2017) and Microsoft Excel.

Results

A total of 3126 individual birds belonging to 11 orders, 32 families and 71 species were recorded. Some of the most abundant bird species were the House crow (*Corvus splendens*), Spotted dove (*Stigmatopelia chinensis*), Common pigeon (*Columba livia*), and Common myna (*Acridotheres tristis*). The globally endangered Steppe eagle (*Aquila nipalensis*) was the only threatened species observed in the study area. The Black stork, a nationally protected bird species in Nepal, was also recorded from the area.

Bird community structure

The Order Passeriformes was the most dominant (n= 47) and the orders Ciconiiformes, Galliformes, Coraciiformes and Strigiformes were represented by a single species each (Table 1, Fig. 2). The highest number of species were recorded from family Muscicapidae (n= 7). The majority of the recorded bird species were resident birds (n= 57), the remaining 14 species were migratory birds.

In both study seasons, the species accumulation curve almost achieved a linear curve, indicating the possibility of encountering a few more species with increasing sampling efforts (Fig. 3).

Seasonal variation of birds by habitat

The maximum bird abundance was recorded in the forest areas (1141 individual birds) followed by the building areas (1050 individuals) and the minimum was from the farm areas (935 individuals). The number of individuals recorded varied between the seasons. In the summer season, the number of individuals recorded from all habitat types were greater than in the winter season (Fig. 4).

Seasonal variation of birds by feeding guild

The highest number of species (28 species) was observed from the insectivorous feeding guild in the summer season. The lowest richness (4 species) was from the granivores in both seasons. Omnivores were the most abundant (n= 703 individual birds) and frugivores (n= 71 individuals) were the least abundant among the feeding guilds. The bird abundance showed significant variation between seasons (χ^2= 10.54, df= 4, p< 0.0001). However, the bird richness did not show significant variation (χ^2= 0.256, df= 4, p= 0.992) (Fig. 5).

Table 1: List of birds recorded from the Tribhuvan University area in winter and summer of 2019–2020 in different habitat types with their migratory status and feeding specialization.

Common Name	Scientific Name	Orders	Families	Summer			Winter			Migratory Status	Feeding Guild
				Fa.	Bu.	Fo.	Fa.	Bu.	Fo.		
Shikra	*Accipiter badius* Gmelin, 1788	Accipitriformes	Accipitridae	-	-	+	-	-	+	R	C
Steppe eagle	*Aquila nipalensis* (Hodgson, 1833)	Accipitriformes	Accipitridae	+	-	-	+	-	+	WV	C
Black kite	*Milvus migrans* (Boddaert, 1783)	Accipitriformes	Accipitridae	+	+	+	+	+	+	R	C
Black stork	*Ciconia nigra* (Linnaeus, 1758)	Ciconiiformes	Ciconiidae	-	-	-	+	-	-	PV	C
Common pigeon	*Columba livia* Gmelin, 1789	Columbiformes	Columbidae	+	+	+	+	+	+	R	G
Spotted dove	*Stigmatopelia chinensis* (Scopoli 1786)	Columbiformes	Columbidae	+	+	+	+	+	+	R	F
Eurasian-collard dove	*Streptopelia decaocto* (Frivaldszky, 1838)	Columbiformes	Columbidae	-	+	+	+	-	+	R	G
Oriental turtle dove	*Streptopelia orientalis* (Latham, 1790)	Columbiformes	Columbidae	+	+	+	+	+	+	R	G
White-throated kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	Coraciiformes	Alcedinidae	+	+	+	+	+	+	R	C
Greater coucal	*Centropus sinensis* (Stephens, 1815)	Cuculiformes	Cuculidae	+	-	+	-	+	+	R	C
Eurasian cuckoo	*Cuculus canorus* Linnaeus, 1758	Cuculiformes	Cuculidae	+	+	+	-	-	-	SV	I
Asian koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	Cuculiformes	Cuculidae	+	+	+	-	-	-	SV	O
Green-billed malkhoa	*Rhopodytes tristis* (Lesson, 1830)	Cuculiformes	Cuculidae	-	-	+	-	-	+	SV	O
Kalij pheasant	*Lophura leucomelanos* (Latham, 1790)	Galliformes	Phasianidae	-	-	+	-	-	+	R	O
Large cuckooshrike	*Coracina macei* (Lesson, 1830)	Passeriformes	Campephagidae	-	+	+	-	-	-	R	I
Scarlet minivet	*Pericrocotus flammeus* Forster, 1781	Passeriformes	Campephagidae	-	-	-	-	+	+	R	I
Common tailorbird	*Orthotomus sutorius* (Pennant, 1769)	Passeriformes	Cisticolidae	+	+	+	+	+	+	R	I
Large-billed crow	*Corvus macrorhynchos* Wagler, 1827	Passeriformes	Corvidae	+	+	+	+	+	+	R	O
House crow	*Corvus splendens* Vieillot, 1817	Passeriformes	Corvidae	+	+	+	+	+	+	R	O
Rufous treepie	*Dendrocitta vagabunda* (Latham, 1790)	Passeriformes	Corvidae	-	+	+	+	+	+	R	F
Red-billed blue magpie	*Urocissa erythroryncha* (Boddaert, 1783)	Passeriformes	Corvidae	+	+	+	-	-	+	R	F
Plain flowerpecker	*Dicaeum minullum* (R. Swinhoe, 1870)	Passeriformes	Dicaeidae	-	-	+	-	-	+	R	F
Ashy drongo	*Dicrurus leucophaeus* Vieillot, 1817	Passeriformes	Dicruridae	+	+	+	+	+	+	R	I
Black drongo	*Dicrurus macrocercus* (Vieillot, 1817)	Passeriformes	Dicruridae	+	+	+	+	+	+	R	I
Barn swallow	*Hirundo rustica* Linnaeus, 1758	Passeriformes	Hirundinidae	+	+	+	+	+	+	R	I
Red-rumped swallow	*Cecropis daurica* (Laxmann, 1769)	Passeriformes	Hirundinidae	+	+	+	+	+	+	R	I
Grey-backed shrike	*Lanius tephronotus* (Vigors, 1831)	Passeriformes	Laniidae	+	-	-	+	-	+	WV	C
Long-tailed shrike	*Lanius schach* Linnaeus, 1758	Passeriformes	Laniidae	+	+	+	+	+	+	R	C
Olive-backed pipit	*Anthus hodgsoni* (Richmond, 1907)	Passeriformes	Motacillidae	+	+	+	+	-	+	WV	I
Paddy-field pipit	*Anthus rufulus* (Vieillot, 1818)	Passeriformes	Motacillidae	+	+	+	+	+	+	R	I
White wagtail	*Motacilla alba* Linnaeus, 1758	Passeriformes	Motacillidae	+	+	+	+	+	+	WV	I
Grey wagtail	*Motacilla cinerea* Tunstall, 1771	Passeriformes	Motacillidae	+	+	-	+	+	+	WV	I
White-browed wagtail	*Motacilla maderaspatensis* Gmelin, 1789	Passeriformes	Motacillidae	+	+	+	+	+	-	R	I
Oriental magpie robin	*Copsychus saularis* (Linnaeus, 1758)	Passeriformes	Muscicapidae	+	+	+	+	+	+	R	I
Verditer flycatcher	*Eumyias thalassinus* (Swainson, 1838)	Passeriformes	Muscicapidae	-	-	+	-	-	-	SV	I
Taiga flycatcher	*Ficedula albicilla* (Pallas, 1811)	Passeriformes	Muscicapidae	-	-	-	+	+	+	WV	I

Table 1. (Continued)

Common Name	Scientific Name	Orders	Families	Summer			Winter			Migratory Status	Feeding Guild
				Fa.	Bu.	Fo.	Fa.	Bu.	Fo.		
Siberian ruby-throat	*Luscinia calliope* (Pallas, 1776)	Passeriformes	Muscicapidae	-	-	+	-	-	+	WV	I
Blue whistling thrush	*Myophonus caeruleus* (Scopoli, 1786)	Passeriformes	Muscicapidae	+	+	+	+	+	+	R	O
Pied bushchat	*Saxicola caprata* (Linnaeus, 1766)	Passeriformes	Muscicapidae	+	+	+	+	+	+	R	I
Grey bushchat	*Saxicola ferreus* Gray & Gray, 1847	Passeriformes	Muscicapidae	+	+	-	+	+	-	R	I
Common stonechat	*Saxicola torquatus* (Linnaeus, 1766)	Passeriformes	Muscicapidae	+	+	+	+	+	+	R	I
Crimson sunbird	*Aethopyga siparaja* (Raffles, 1822)	Passeriformes	Nectariniidae	-	-	+	-	+	+	R	F
Purple sunbird	*Cinnyris asiaticus* Latham, 1790	Passeriformes	Nectariniidae	-	-	+	-	+	+	R	O
Indian golden oriole	*Oriolus oriolus* Sykes, 1832	Passeriformes	Oriolidae	-	+	+	-	-	-	SV	O
Great tit	*Parus major* Linnaeus, 1758	Passeriformes	Paridae	+	+	+	+	+	+	R	I
Black-lored tit	*Parus xanthogenys* (Vigors, 1831)	Passeriformes	Paridae	+	+	+	+	+	+	R	I
House sparrow	*Passer domesticus* (Linnaeus, 1758)	Passeriformes	Passeridae	+	+	+	+	+	+	R	G
Eurasian tree sparrow	*Passer montanus* (Linnaeus, 1758)	Passeriformes	Passeridae	+	+	+	+	+	+	R	G
Grey-hooded warbler	*Phylloscopus xanthoschistos* (Gray and Gray, 1846)	Passeriformes	Phylloscopidae	+	+	+	+	+	+	R	I
Baya weaver	*Ploceus philippinus* (Linnaeus, 1766)	Passeriformes	Ploceidae	+	-	+	+	+	+	R	O
Black bulbul	*Hypsipetes leucocephalus* (Gmelin, 1789)	Passeriformes	Pycnonotidae	-	+	+	+	+	+	R	O
Red-vented bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	Passeriformes	Pycnonotidae	+	+	+	+	+	+	R	O
Himalayan bulbul	*Pycnonotus leucogenys* (Gray, JE, 1835)	Passeriformes	Pycnonotidae	-	-	-	+	+	+	R	O
Chestnut bellied nuthatch	*Sitta cinnamoventris* Blyth, 1842	Passeriformes	Sittidae	+	+	+	-	+	+	R	I
Velvet-fronted nuthatch	*Sitta frontalis* Swainson, 1820	Passeriformes	Sittidae	+	+	+	-	+	+	R	I
Grey-headed canary flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)	Passeriformes	Stenostiridae	-	-	+	-	-	+	R	I
Jungle myna	*Acridotheres fuscus* (Wagler, 1827)	Passeriformes	Sturnidae	+	+	+	+	+	+	R	O
Common myna	*Acridotheres tristis* (Linnaeus, 1766)	Passeriformes	Sturnidae	+	+	+	+	+	+	R	O
Chestnut-tailed starling	*Sturnia malabarica* (Gmelin, 1789)	Passeriformes	Sturnidae	+	+	+	-	-	-	SV	O
Brahmany starling	*Sturnia pagodarum* (Gmelin, 1789)	Passeriformes	Sturnidae	-	+	-	-	-	-	R	O
Oriental white eye	*Zosterops palpebrosus* (Temminck, 1824)	Passeriformes	Zosteropidae	+	+	+	+	+	+	R	O
Indian pond heron	*Ardeola grayii* (Sykes, 1832)	Pelecaniformes	Ardeidae	+	+	+	+	+	+	R	C
Cattle egret	*Bubulcus ibis* (Linnaeus, 1758)	Pelecaniformes	Ardeidae	+	+	+	+	+	+	R	C
Little egret	*Egretta garzetta* (Linnaeus, 1766)	Pelecaniformes	Ardeidae	+	-	-	+	-	-	R	C
Blue-throated barbet	*Megalaima asiatica* (Latham, 1790)	Piciformes	Megalaimidae	+	+	+	+	+	+	R	F
Coppersmith barbet	*Megalaima haemacephalus* (Statius Müller, 1776)	Piciformes	Megalaimidae	-	+	+	-	+	+	R	F
Fulvous-breasted woodpecker	*Dendrocopos macei* (Vieillot, 1818)	Piciformes	Picidae	+	+	+	+	+	+	R	I
Great barbet	*Megalaima virens* (Boddaert, 1783)	Piciformes	Megalaimidae	-	+	+	-	-	-	R	F
Alexandrine parakeet	*Psittacula eupatria* (Linnaeus, 1766)	Psittaciformes	Psittaculidae	+	+	+	+	+	+	R	F
Rose-ringed parakeet	*Psittacula krameri* (Scopoli, 1769)	Psittaciformes	Psittaculidae	+	+	+	+	+	+	R	F
Spotted owlet	*Athene brama* (Temminck, 1821)	Strigiformes	Strigidae	-	+	+	-	+	-	R	C

Notes: Fa.- Farmland, Bu.- Building, Fo.- Forest, R- Residential, PV-Passage visitor, SV- Summer visitor, WV- Winter visitor, '+'- presence, '-'- absence

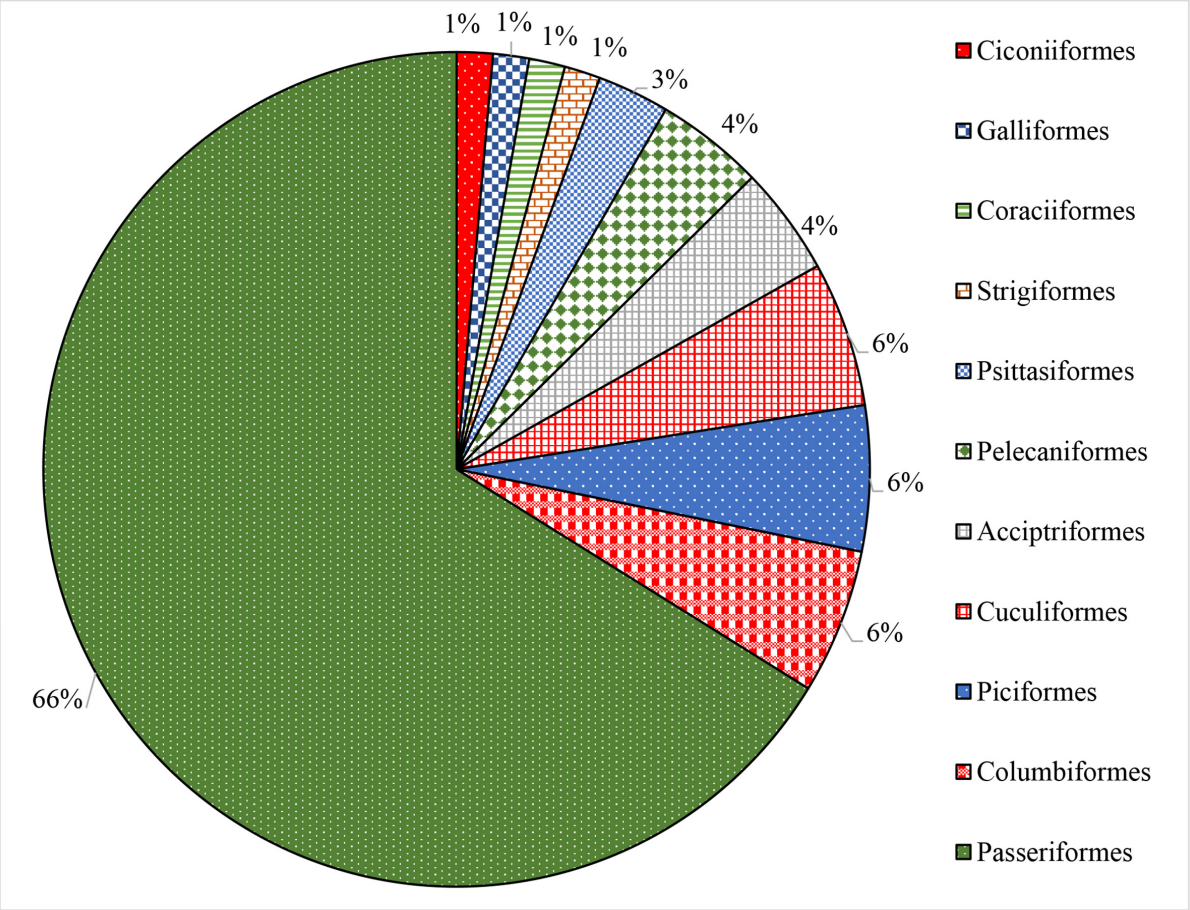

Figure 2: Number of bird species among different orders observed in Tribhuvan University area, Kirtipur of the present study.

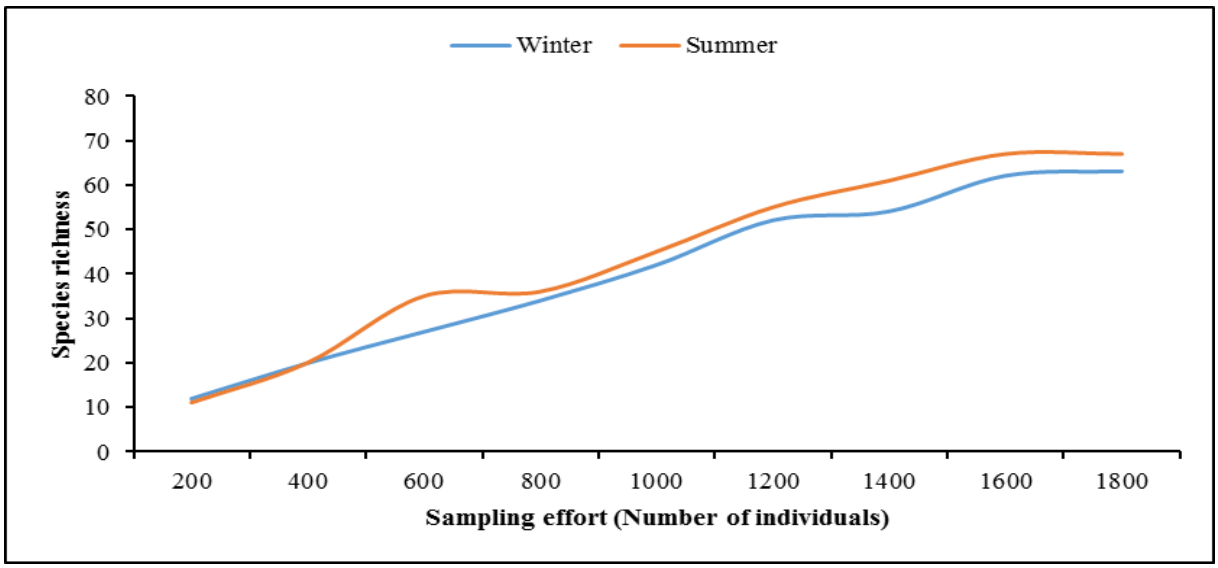

Figure 3: Species accumulation curve of birds for the winter and summer seasons in Tribhuvan University area showing the increasing species richness with additional sampling efforts.

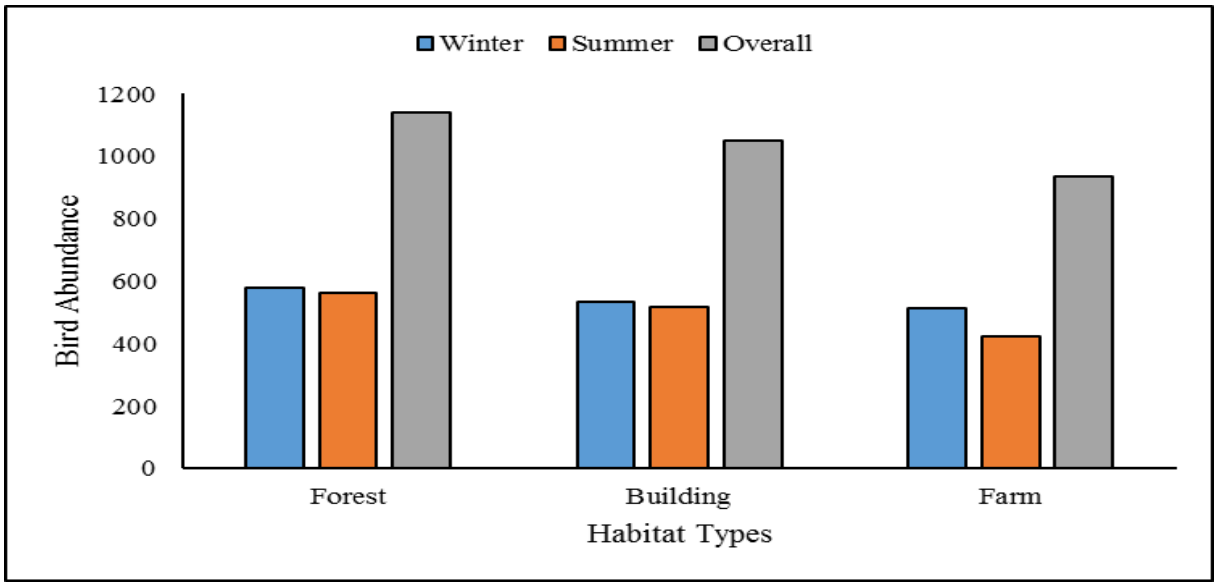

Figure 4: Bird abundance by habitat for two seasons recorded in the Tribhuvan University area.

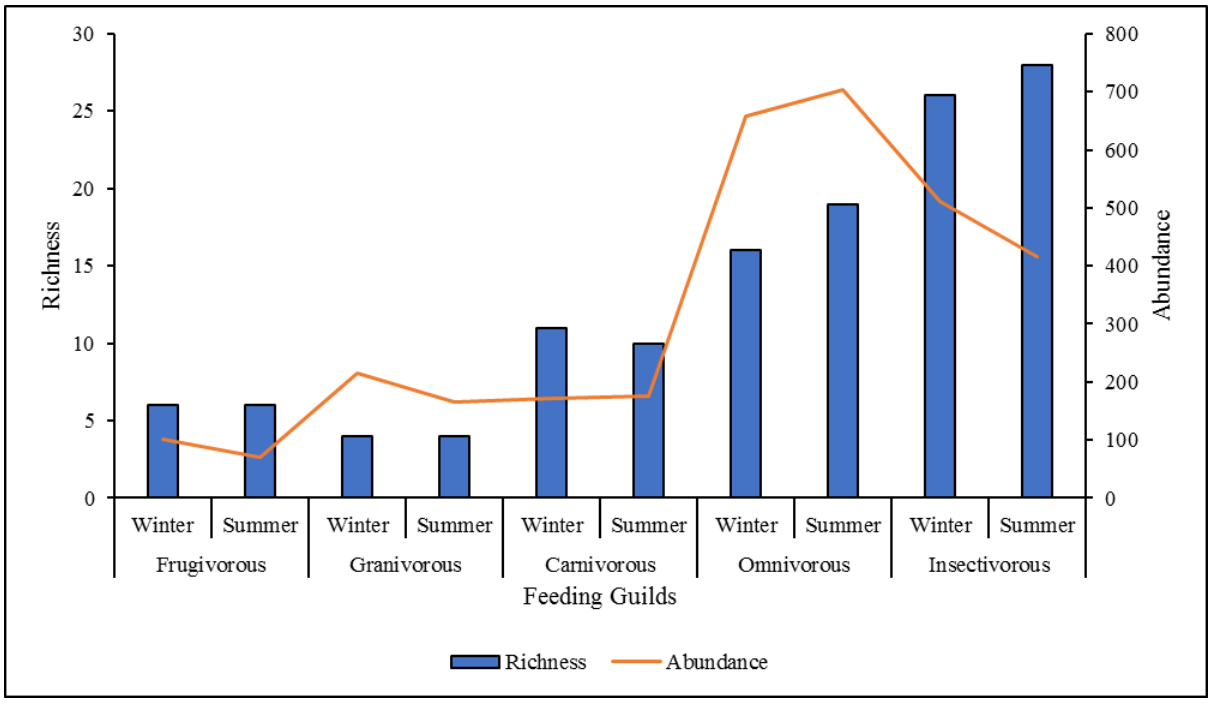

Figure 5: Bird species richness and abundance by feeding guild for two seasons recorded in Tribhuvan University area.

Bird diversity in the TU area by habitat

The bird diversity by habitat indices were calculated for both seasons (Table 2). Overall, the Shannon-Weiner index was found to be 3.46. All the seasonal and habitat values of Shannon-Weiner indices were greater than 3. In the winter season, the highest diversity (3.50) was observed in the forest areas and the lowest was found in the building areas. Similarly, in the summer season, the highest diversity (3.52) was observed in the building areas and lowest (3.41) was found in the farm areas. In all habitat types, the Simpson's index was close to 1, indicating a high diversity in the study area. Simpson's indices were maximum in the farm areas during the winter and in the building areas during the summer.

The average evenness index in different habitat types was 0.62, indicating a high degree of evenness. In the winter season, the highest value was recorded from the farm areas and lowest (0.59) was from the forest areas. Similarly, in the summer season, the highest value was recorded from the building areas and lowest was (0.5) from the forest areas (Table 2).

Table 2: Bird diversity and average density by habitat and season in the Tribhuvan University area.

Habitat Type	Shannon's Index		Simpson's Index		Evenness		Density (Individuals/ha)
	Winter	Summer	Winter	Summer	Winter	Summer	
Forest areas	3.50	3.52	0.95	0.93	0.59	0.50	15.42
Building areas	3.44	3.47	0.95	0.96	0.65	0.64	14.21
Farm areas	3.43	3.41	0.96	0.95	0.68	0.62	12.69

Discussion

Although urban gardens and parks are planned basically for the benefit of people, their secondary role of maintaining urban species diversity is essential for healthy ecosystems too. Therefore, the necessity of greenspaces for urban birds is increasingly recognized, as evidenced by several studies (MacGregor-Fors et al., 2010; Carbó-Ramírez and Zuria, 2011). Our study of bird diversity in the Tribhuvan University area has revealed that urban greenspaces can serve as suitable habitat for many bird species other than the urban-exploiter species which are very common in cities (Fig. 6). Therefore, understanding bird species richness, diversity and community structure in different habitats of urban greenspace, and their seasonal variation, is very important in designing more bird-friendly gardens in urban areas. Our study suggests the Tribhuvan University area is an important urban greenspace in the landscape of the Kathmandu Valley supporting high bird diversity.

The study area is habitat for 71 bird species. The Steppe eagle (*Aquila nipalensis*) recorded from the area is categorized as endangered by the IUCN Red List of Threatened Species (BirdLife International, 2020). Threatened and rare birds mostly prefer habitat with high canopy cover and protected areas with minimal disturbed core (Lešo et al., 2019; Inskipp et al., 2020) with these threatened bird species showing a lower tolerance for human modified habitats (BirdLife International, 2017). The study area lacks natural forest with high canopy cover and undisturbed core which might be the reason for the scarcity of many rare and threatened birds.

A linear species accumulation curve indicates the possibility of encountering additional species with increased sampling effort. The chances of encountering additional species with increased sampling effort might be attributed to the short isolation distance of the TU area from the Chandragiri Forest, a potential regional species pool in the Kathmandu Valley. The Chandragiri Forest, a natural forest fragment of 11 km^2 is located about 1.4 km away from the TU area and harbors 199 bird species (Katuwal et al., 2020), including almost all species found in our study area. Studies have revealed that bird richness and abundance of small urban parks and greenspaces are greatly affected by isolation distance from local and regional species pools (Fernández-Juricic, 2000; Wang et al., 2013; Yang et al., 2020).

Passeriformes is the most species-rich ordinal clade of birds, with >6,000 species around the globe (Ricklefs, 2012). Passerines have a wide range of distribution from arid to wet, and temperate to tropical climates, including natural and urban environments (Johnson and Holt, 2015). Species in the Passeriformes dominate the bird community in the TU area. Similar results were shown by other bird research from the Kathmandu Valley (Katuwal et al., 2018) and the Shivapuri Nagarjun National Park (Jha, 2020). Passeriformes have also been recorded as the dominant order of birds in other natural habitats of Nepal (Dangaura et al., 2020; Pandey et al., 2020).

Our results are in agreement with other studies on bird species composition in which richness and abundance of different feeding guilds varied seasonally in urban green space (Caula et al., 2008; Zhou and Chu, 2012; Katuwal et al., 2018). From the perspective of feeding guilds, the most dominant feeding category at TU is insectivorous and the minority of bird species are granivorous. Similar ecological studies at the University of Lampung (Iswandaru et al., 2020), Musanze's urban landscape (Gatesire et al., 2014) and urban landscapes from Bhubaneswar (Panda et al., 2021), revealed that insectivore is the most dominant feeding guild. Insectivorous birds eat a large variety of arthropods (Nyffeler et al., 2018; Tallamy and Shriver, 2021) and the variety of microhabitats and seasonal agricultural practices within the study area might be responsible for supporting more insectivorous birds. Research conducted around the world has shown that urban greenspaces support insect populations by offering nectar and pollen for adults and providing reproductive resources (Black, 2011; Frey and LeBuhn, 2016; Philpott et al., 2019). In addition , greenspaces also serve as refuge for urban insect pollinators (Hall et al., 2017). Although the insectivore guild had the highest number of species, the omnivore guild had the highest abundance.

High abundance of omnivorous birds in the study area, especially in the building habitats and areas near to buildings, might be due to the availability of a variety of anthropogenic food sources (e.g. household waste, food centers, markets, restaurants). This might be the reason behind the high abundance of *Corvus splendens*, *Acridotheres tristis* and *Corvus macrorhynchos* in our research. Our results corroborate other studies in small urban parks in Malaysia (Jasmani et al., 2017) and round the world (Ottoni et al., 2009; de Bonilla et al., 2012). The low occurrence of the frugivorous species in the study area may be due to insufficient fruiting trees as observed in several previous studies (Menon and Mohanraj, 2016; Schneiberg et al., 2020).

Figure 6: Photographs of some birds recorded from the Tribhuvan University area, Kathmandu, Nepal. A- Blue-throated barbet (*Megalaima asiatica*); B- Cattle egret (*Bubulcus ibis*); C- Himalayan bulbul (*Pycnonotus leucogenys*); D- Kalij Pheasant (*Lophura leucomelanos*); E- Red-vented bulbul (*Pycnonotus cafer*); F- Rose-ringed parakeet (*Psittacula krameri*); G- Scarlet minivet (*Pericrocotus flammeus*); H- Spotted owlet (*Athene brama*); I- Black kite (*Milvus migrans*); and J- Verditer flycatcher (*Eumyias thalassinus*).

Different habitats in the TU area were assessed in terms of seasonal diversity indices. In our study, there was a slight difference in the species diversity index between the habitat types. Generally, the Shannon-Weiner diversity ranges in between 1.5 to 3.5 (< 1.5 represents very low diversity and > 3.5 represents very high diversity) and therefore, the average index value of 3.46 from our study illustrates significantly high bird diversity in the TU area. The range of the Simpson's diversity index is 0 to 1 and an index value closer to 1 represents high diversity. In this study, the average value of Simpson's index is 0.95 which indicates high bird diversity in the different habitat types of the TU. There was only moderately uniform species distribution for the whole study area, with an Evenness Index (E) of 0.61, and for the different habitats the value lies between 0.50 and 0.68.

There were similar ecological studies done in the agroforestry industry of Indonesia (Withaningsih and Alham, 2020), the urban landscapes of India (Panda et al., 2021) and Indonesian urban habitats (Pudyatmoko and Nurvianto, 2009) that showed high alpha diversity values. Similarly, bird density in different habitats of the TU was calculated and we found that higher density was observed in the forest habitat. Various diversity indices and density results clearly demonstrate that the forest habitat is the most desirable habitat followed by the building habitat for birds in the TU area. The least number of species was observed in the farm habitat. Several bird studies in urban gardens and parks have shown similar results, indicating that forest sections have a high diversity (Pudyatmoko and Nurvianto, 2009; Panda et al., 2021).

During the present study, we observed that most of the birds recorded in the forest habitats were found in shrubs. High shrub species richness in the forest habitat of the study area might have made the forest habitat favorable for diverse bird species. Shrubs offer birds shelter from extreme weather condition and predators, along with providing food in the form of insects, seeds and fruits. This result is consistent with previous studies showing shrubs are essential for many forest birds in urban gardens (Daniels and Kirkpatrick, 2006; Bino et al., 2008; Paker et al., 2014).

Conclusions

The study from Tribhuvan University, Kathmandu found that the family Muscicapidae and order Passeriformes were found dominant in the bird community. Diversity indices revealed that higher bird diversity exists in forested areas during the summer season. The study area has a diverse avian community and is home to many bird species, including globally threatened species. Despite its small size, but because of its important role in urban ecological diversity, it can be considered as a potential greenspace in the Kathmandu Valley. Moreover, further identification, management, and regular monitoring of such greenspace is necessary.

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Conflicts of interest

All the authors declare that there are no conflicting issues related to this research article.

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