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Research Article

Urbanization Favors Some Over Others: Bird Diversity Pattern in the Suburban-Urban Gradient of Butwal City, Central Lowland of Nepal

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BA and LK conceptualized the study. BA and NP performed the fieldworks, analyzed data and prepared the manuscript. LK supervised the research and finalized the manuscript. All authors approved the manuscript for submission.

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Abundance, Bird diversity, Human footprint, Species richness, Urban exploiters

Abstract | Urbanization results in habitat modification causing alteration in the assemblage of biological diversity. Bird diversity serves as a good ecological indicator; hence, this study examined the effects of urbanization on bird species richness and diversity in Butwal Sub-Metropolitan City, one of the rapidly expanding cities in the central lowland Nepal. Bird surveys were conducted during the winter and post-monsoon seasons of 2020 along eight transects each of 2 km length by positioning the point count stations at every 200 m interval. The associations of bird richness and abundance with NDVI as the proxy of productivity and human footprint data as the proxy of human disturbance were established. A total of 3,297 birds belonging to 69 species from 33 families in 14 orders were observed. The order Passeriformes was the most dominant order, while insectivore was the most dominant feeding guild. The suburban sites had higher bird diversity and richness than urban sites; whereas, the abundance of urban exploiter birds was higher in the urban area. Vegetation cover showed a positive association with the bird species richness. Conversely, human disturbance showed negative effects. In an urban setting, green spaces and parks shelter more diverse species. Thus, cities should focus on developing green city concept simultaneously with other developmental projects.

Novelty Statement | This is a comprehensive study using rigorous bird surveys, and analyzing the bird richness and abundance with high-resolution data on vegetation and anthropogenic pressure. Our findings could be instrumental in the proper management of urban biodiversity.

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Introduction

Global human population shift from rural to urban areas is increasing (Anderies *et al*., 2007) possessing threats to biodiversity conservation (Goddard *et al*., 2010). This leads to increased intensity of urbanization resulting in habitat fragmentation or alteration (Marzluff and Ewing, 2008) and causing loss of biodiversity (Callaghan *et al*., 2018). Hence, such areas require specific attention to biodiversity conservation (Blair and Johnson, 2008). Urbanization ranks as the most common factor causing species endangerment and extinction second to interactions with invasive species (Czech *et al*., 2000). However, the impact of urbanization is not the same to all the taxa as it favors abundance of some urban exploiter species but reduces the richness and diversity (Marzluff, 2001).

Birds serve as good ecological indicators showing sensitiveness to environmental degradation (Clergeau *et al*., 2001; Lin *et al*., 2008). Habitat degradation is a detrimental consequence of urbanization affecting bird communities (McKinney, 2006). Bird community structure and composition changes with urbanization gradients as species richness decreases with urbanization, while

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abundance and density of some of the species increases (Chace and Walsh, 2006; Sandström *et al.*, 2006). Urban adapted species, commonly known as urban exploiters, tend to utilize a wide range of resources found in urban sites because of their generalist behavior and can thrive well even in altered habitat (Menon and Rangaswamy, 2016; Rodrigues *et al.*, 2018; Palacio, 2020). The suburban areas with moderate levels of disturbances provide heterogeneity in habitats and support higher bird diversity (Chace and Walsh, 2006). Habitat heterogeneity beyond the threshold also results in habitat fragmentation and in turn supports less biodiversity. Therefore, it is important to know compositional and configurational heterogeneity of a habitat which affects the diversity that it can support.

Built area and building density is one of the main factors altering natural habitats and negatively affecting bird richness in urban areas. Other anthropogenic and ecological factors like noise, human disturbances, predators, etc. escalate the effects (MacGregor-Fors and Schondube, 2011; Menon and Rangaswamy, 2016; Rodrigues *et al.*, 2018). Conversely, vegetative components, mainly trees, positively influence bird diversity and richness (Fontana *et al.*, 2011; Menon *et al.*, 2015). With increasing urbanization, the natural habitat is degraded, so, urban green spaces in cities are major factors for determining diversity and richness (Dale, 2018) and a good indicator for bird heterogeneity (Callaghan *et al.*, 2018). Urban surroundings alter the natural flow of food (Fuller *et al.*, 2012), influence feeding guilds, favor habitat generalists like omnivores, rather than food and habitat specialists (Evans *et al.*, 2011; Silva *et al.*, 2016; Altaf *et al.*, 2018). All bird species are not equally and negatively influenced by the urbanization as it favors abundance of some selected species which can exploit the urban environment. For example, bird species that nest in cavities/buildings and have wider dietary adaptation may have an advantage in living and settling in urban areas (Jokimaki *et al.*, 2016).

Butwal City, a rapidly expanding metropolis in central lowland Nepal, is the current capital of Lumbini Province. It is pressurized by population surge and anthropogenic development increasing the intensity of urbanization. Most importantly, Butwal City lies along the north-south migration route of trans-Himalayan birds along the Kaligandaki River Valley (Prins and Namgail, 2017; Neupane *et al.*, 2020). Hence, it is important to know the bird species composition and effects of that rampant urbanization poses to the bird in Butwal City. Environmental variables like vegetation cover, human footprint index, and land use land cover data could be used to analyze the habitat heterogeneity and assess their influence on the bird diversity. Additionally, climatic variables like temperature and precipitation and their seasonal variations may also have their effects in bird community structure. The intermediate disturbance hypothesis posits that moderate level of habitat heterogeneity supports higher diversity. Hence, we aimed to examine bird community structure at different level of human disturbance in a rapidly urbanizing city. This study assessed the pattern of bird species richness and abundance along the urbanization gradient (measured in terms of vegetation cover and human footprint index) in Butwal City, central lowland Nepal during winter and post-monsoon seasons of 2020.

Materials and Methods

Study area

Butwal Sub-Metropolitan City lies in Rupandehi District of Lumbini Province at the central lowland of Nepal. It lies between 83.36° to 83.50°E and 27.61° to 27.74°N (Figure 1) and covers an area of 101.61 square km (Thapa and Poudel, 2018). This city stands beside the bank of the Tinau River at the northern edge of the Terai plain below the Siwalik Hills. The elevation of the city ranges from around 100 m in the south-western lowland to 1,229 m in the northern hills (Thapa and Poudel, 2018). The climate of this region is tropical type. The summer is hotter and dry with temperature rising up to 45°C whereas the winter is cold with temperature declining below to 8°C. Major precipitation takes place during the monsoon that usually begins in June. About 65% of the surface area of Butwal Metropolitan City is covered by the forest (Thapa and Poudel, 2018). Dominant vegetation in urban and suburban areas of Butwal City include *Ficus religiosa*, *Ficus benghalensis*, *Azadirachta indica*, *Bombax ceiba*, *Aegle marmelos*, *Dalbergia sissoo*, *Garuga pinnata*, *Saraca asoca*, *Neolamarckia cadamba*, *Eucalyptus camaldulensis*, *Melia azedarach*, *Ficus benjamina*, *Premna barbata*, *Tamarindus indica*, *Ficus racemose*, *Morus alba*, etc.

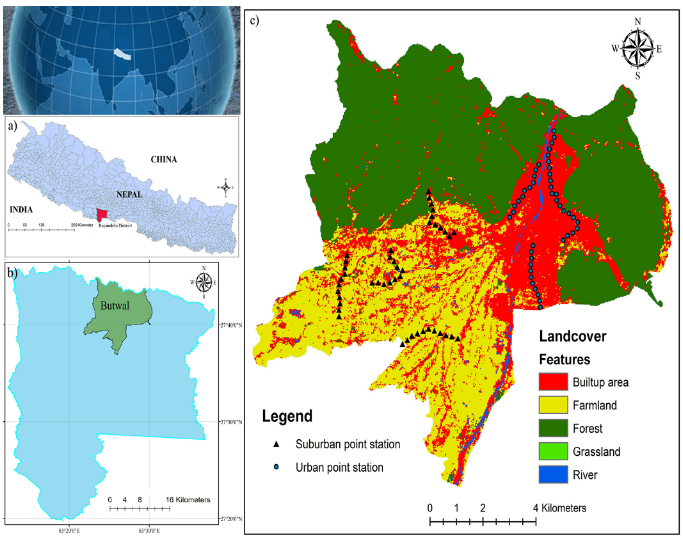

Figure 1: Map of the study area. (a) Map of Nepal showing Rupandehi District; (b) Map of Rupandehi District showing Butwal Sub-Metropolitan City; and, (c) Land-use-land-cover map of Butwal Sub-Metropolitan City with point count stations for the bird survey.

Study design and bird survey

Urban area was defined as the area with high population densities and higher built surfaces (Pickett *et al*., 2011). Considering this, Butwal City was categorized into two levels of urbanization i.e. urban and suburban areas. Urban and suburban sites were illustrated through supervised classification Lansat-8 image of the city on the basis of land cover (Figure 1c) combining band images (2, 3, 4). Landsat-8 imageries were layer stacked and Butwal City area was extracted. Next, the images were then classified by object-based image classification by defining training areas or samples such as built-up area, farmland, etc. that led to development of signature file. At last, interactive supervised and maximum likelihood classification was applied and post-classification processing was done. Urban and suburban demarcation was done on the basis of Normalized Difference Vegetation Index (NDVI) data. A median value of the NDVI data (0.143) was calculated after processing Landsat-8 OLI/TIRS image downloaded from the US Geological Survey (https://espa.cr.usgs.gov) and through visual inspection. An area with greater NDVI than the median value was regarded as the suburban area and that with lower NDVI was regarded as urban area.

Point count method has been described to be more efficient method for urban habitat, requiring less effort per count, having less potential for error than transect count (Mortimer and Clark, 2013) and is better method for population with high density like that of urban exploiter birds (Gibbons and Gregory, 2006). Eight transects (four in urban areas and four in suburban areas), each of 2 km length with point station at every 200 m (Filloy *et al*., 2019) were deployed representing the study area. It resulted a total of 88 point-count stations. The urban transects run through major residential areas, fewer trees and green spaces and creeks while suburban transects run through dispersed residential areas, farmlands and rivers.

The bird survey was conducted on 01–18 February and 06–23 October 2020, from 7 AM to 11 AM. Birds observed in the radius of 50 m from the count station were noted for 10 minutes. Distance between the observer and the birds was measured using the range-finder (Leica Range master CRF 2400-R). The birds were identified using binoculars and field guide book (Grimmett *et al*., 2016). Birds were categorized to their feeding guilds following Katuwal *et al*. (2018) and Pandey *et al*. (2021).

Habitat characteristics and environmental variables

The NDVI data obtained from processing Landsat-8 OLI/TIRS images for both the study seasons were used as the proxy of vegetation cover or the productivity. The human footprint index (Venter *et al*., 2018) was also used as the proxy of human disturbance. Both the NDVI values and footprint index were extracted for each point stations. The average monthly temperature and average monthly precipitation for respective seasons were also extracted for point count stations from the WorldClim database (https://www.worldclim.org/bioclim). Extraction and processing of images and environmental variables were done on ArcGIS 10.2.

Data analysis

Diversity indices (Shannon-Weiner index and Simpson's index) were calculated for the bird diversity in both the urban and suburban areas as follows:

$$\text{Shannon} - \text{Weiner Diversity Index (H)} = -\sum p_i \,.\ln p_i$$

$$\text{Simpson' Index of diversity (D)} = 1 - \sum p_i^2$$

Where, p_i is the proportion (n/N) of a species obtained as individuals of one particular species (n) divided by the total number of individuals of all species (N).

The relative abundance (RA) of bird species was calculated by dividing the number of records of each species by the total number of records of all species in both urban and suburban areas.

Difference in species richness between the urban and suburban areas was tested for significance by the t-test. Regression analysis was performed to establish relationship of species richness with NDVI and human footprint index for each season. The effect of NDVI and human footprint on species richness and abundance were modelled singularly. General Linear Model (GLM) was used to assess association of bird richness/abundance with environmental variables (NDVI, temperature and precipitation). These statistical analyses were done on R program (R Core Team, 2013) using vegan package (Oksanen *et al*., 2019).

Results and Discussion

A total of 3,297 birds of 69 species were observed from 33 families under 14 orders. Among the 69 species, 60 were residents and 09 were migrants (Table 1). The species count was higher in winter (n=56) than in post-monsoon (n=52). In both seasons, suburban area recorded higher species richness than the urban area (Table 2). The species accumulation curve revealed a linear relationship with the possibility of finding more species with increasing sampling efforts (Figure 2).

Passeriformes was the most dominant order represented by 38 species followed by Pelecaniformes (n=6) and Psittaciformes (n=4) (Table 1). House sparrow (*Passer domesticus*) was the most abundant species followed by House crow (*Corvus splendens*) and Common pigeon (*Columba livia*) (Table 1). Insectivore was the most

Table 1: Checklist of birds recorded in Butwal Sub-Metropolitan City, Nepal with their residential status, feeding guild, relative abundance and IUCN Red List status.

English name	Scientific name	Order	Family	Status	Feeding guild	RA (%)		IUCN Status
						Urban	Suburban	
Black Kite	*Milvus migrans*	Accipitriformes	Accipitridae	R	Carnivorous	0.80	0.72	LC
House Swift	*Apus affinis*	Apodiformes	Apodidae	R	Insectivorous	2.08	-	LC
Common Hoopoe	*Upupa epops*	Bucerotiformes	Upupidae	R	Insectivorous	0.06	0.06	LC
Indian Grey Hornbill	*Ocyceros birostris*	Bucerotiformes	Bucerotidae	R	Omnivorous	0.31	0.24	LC
Common Sandpiper	*Actitis hypoleucos*	Charadriiformes	Scolopacidae	WM	Insectivorous	0.06	0.44	LC
Little-ringed Plover	*Charadrius dubius*	Charadriiformes	Charadridae	R	Carnivorous	-	0.12	LC
Red-wattled Lapwing	*Vanellus indicus*	Charadriiformes	Charadridae	R	Carnivorous	-	0.12	LC
Asian Openbill	*Anastomus oscitans*	Ciconiiformes	Ciconiidae	R	Carnivorous	-	0.06	LC
Asian Woolly-neck	*Ciconia episcopus*	Ciconiiformes	Ciconiidae	R	Carnivorous	-	0.18	NT
Lesser Adjutant	*Leptoptilos javanicus*	Ciconiiformes	Ciconiidae	R	Carnivorous	-	0.12	VU
Common Pigeon	*Columba livia*	Columbiformes	Columbidae	R	Granivorous	15.8	4.63	LC
Spotted Dove	*Stigmatopelia chinensis*	Columbiformes	Columbidae	R	Granivorous	0.67	2.82	LC
Yellow-footed pigeon	*Treron phoenicoptera*	Columbiformes	Columbidae	R	Frugivorous	0.73	-	LC
White-throated King-fisher	*Halcyon smyrnensis*	Coraciiformes	Alcedinidae	R	Carnivorous	-	0.36	LC
Green Bee eater	*Merops orientalis*	Coraciiformes	Meropidae	R	Insectivorous	-	0.12	LC
Greater Coucal	*Centropus sinensis*	Cuculiformes	Cuculidae	R	Carnivorous	0.06	0.36	LC
Asian Koel	*Eudynamys scolopaceus*	Cuculiformes	Cuculidae	SM	Omnivorous	-	0.06	LC
Common Hawk Cuckoo	*Hierococcyx varius*	Cuculiformes	Cuculidae	R	Insectivorous	0.06	0.06	LC
Ashy Prinia	*Prinia socialis*	Passeriformes	Cisticolidae	R	Insectivorous	-	0.66	LC
Black Drongo	*Dicrurus macrocercus*	Passeriformes	Dicruridae	R	Insectivorous	0.37	3.13	LC
Black-hooded Oriole	*Oriolus xanthornus*	Passeriformes	Oriolidae	R	Omnivorous	0.06	0.24	LC
Brown Rockchat	*Cercomela fusca*	Passeriformes	Muscicapidae	R	Insectivorous	0.92	0.12	LC
Oriental Magpie Robin	*Copsychus saularis*	Passeriformes	Muscicapidae	R	Insectivorous	0.43	0.90	LC
Verditer Flycatcher	*Eumyias thalassinus*	Passeriformes	Muscicapidae	WM	Insectivorous	-	0.06	LC
Red-breasted Flycatcher	*Ficedula parva*	Passeriformes	Muscicapidae	WM	Insectivorous	-	0.06	DD
Black Redstart	*Phoenicurus ochruros*	Passeriformes	Muscicapidae	WM	Insectivorous	0.06	0.18	LC
Common Stonechat	*Saxicola torquatus*	Passeriformes	Muscicapidae	R	Insectivorous	-	0.18	LC
Black-throated Thrush	*Turdus atrogularis*	Passeriformes	Turdidae	WM	Omnivorous	-	0.42	LC
Jungle Myna	*Acridotheres fuscus*	Passeriformes	Sturnidae	R	Omnivorous	0.31	0.54	LC
Common Myna	*Acridotheres tristis*	Passeriformes	Sturnidae	R	Omnivorous	5.14	4.81	LC
Asian Pied Starling	*Gracupica contra*	Passeriformes	Sturnidae	R	Omnivorous	1.16	3.73	LC
Brahminy Starling	*Sturnia pagodarum*	Passeriformes	Sturnidae	R	Omnivirous	-	0.18	LC
Brown Shrike	*Lanius cristatus*	Passeriformes	Laniidae	WM	Insectivorous	-	0.36	LC
Common Tailorbird	*Orthotomus sutorius*	Passeriformes	Cisticolidae	R	Insectivorous	0.55	2.88	LC
Greater Racket-tailed Drongo	*Dicrurus paradiseus*	Passeriformes	Dicruridae	R	Insectivorous	-	0.24	LC
Grey Wagtail	*Motacilla cinerea*	Passeriformes	Motacillidae	WM	Insectivorous	0.37	0.24	LC
Indian Jungle Crow	*Corvus culminatus*	Passeriformes	Corvidae	R	Carnivorous	0.18	1.98	LC
House Crow	*Corvus splendens*	Passeriformes	Corvidae	R	Omnivorous	16.23	4.27	LC
Rufous Treepie	*Dendrocitta vagabunda*	Passeriformes	Corvidae	R	Frugivorous	0.37	0.36	LC
House Sparrow	*Passer domesticus*	Passeriformes	Passeridae	R	Granivorous	41.95	32.21	LC
Jungle Babbler	*Turdoides striata*	Passeriformes	Leiothrichi-dae	R	Omnivorous	0.61	0.84	LC
Long-tailed Shrike	*Lanius schach*	Passeriformes	Laniidae	R	Carnivorous	0.67	1.32	LC
Paddy-field Pipit	*Anthus rufulus*	Passeriformes	Motacillidae	R	Insectivorous	-	1.08	LC
Plain Prinia	*Prinia inornata*	Passeriformes	Cisticolidae	R	Insectivorous	-	0.12	LC

Table continue on next page................

English name	Scientific name	Order	Family	Status	Feeding guild	RA (%) Urban	RA (%) Suburban	IUCN Status
Purple Sunbird	*Cinnyris asiaticus*	Passeriformes	Nectariniidae	R	Nectarivorous	0.06	0.12	LC
Red Avadavat	*Amandava amandava*	Passeriformes	Estrildidae	R	Granivorous	-	0.06	LC
Red-vented Bulbul	*Pycnonotus cafer*	Passeriformes	Pycnonotidae	R	Omnivorous	2.45	3.49	LC
Red-whiskered bulbul	*Pycnonotus jocosus*	Passeriformes	Pycnonotidae	R	Omnivorous	3.8	9.50	LC
Scaly-breasted Munia	*Lonchura punctulata*	Passeriformes	Estrildidae	R	Granivorous	0.18	2.94	LC
Scarlet Minivet	*Pericrocotus flammeus*	Passeriformes	Campephagidae	R	Insectivorous	0.37	-	LC
Hair-crested Drongo	*Dicrurus hottentottus*	Passeriformes	Dicruridae	R	Insectivorous	0.37	-	LC
Tickell's Leaf Warbler	*Phylloscopus affinis*	Passeriformes	Phylloscopidae	R	Insectivorous	-	0.06	LC
White-bellied Drongo	*Dicrurus caerulescens*	Passeriformes	Dicruridae	R	Insectivorous	0.06	0.36	LC
White Wagtail	*Motacilla alba*	Passeriformes	Motacillidae	WM	Insectivorous	0.31	1.2	LC
White-browed Wagtail	*Motacilla maderaspatensis*	Passeriformes	Motacillidae	R	Insectivorous	0.73	0.72	LC
Intermediate Egret	*Ardea intermedia*	Pelecaniformes	Ardeidae	R	Carnivorous	-	0.06	LC
Indian Pond Heron	*Ardeola grayii*	Pelecaniformes	Ardeidae	R	Carnivorous	0.37	1.20	LC
Cattle Egret	*Bubulcus ibis*	Pelecaniformes	Ardeidae	R	Carnivorous	-	3.55	LC
Little Egret	*Egretta garzetta*	Pelecaniformes	Ardeidae	R	Carnivorous	-	0.06	LC
Red-napped Ibis	*Pseudibis papillosa*	Pelecaniformes	Threskiornithidae	R	Omnivorous	-	0.06	LC
Coppersmith Barbet	*Megalaima haemacephala*	Piciformes	Megalaimidae	R	Frugivorous	0.12	-	LC
Brown-headed Barbet	*Megalaima zeylanica*	Piciformes	Megalaimidae	R	Frugivorous	-	0.12	LC
Plum-headed Parakeet	*Psittacula cyanocephala*	Psittaciformes	Psittaculidae	R	Herbivorous	-	0.66	LC
Alexandrine Parakeet	*Psittacula eupatria*	Psittaciformes	Psittaculidae	R	Herviborous	1.04	-	NT
Slaty-headed Parakeet	*Psittacula himalayana*	Psittaciformes	Psittaculidae	R	Frugivorous	-	0.90	LC
Rose-ringed Parakeet	*Psittacula krameri*	Psittaciformes	Psittaculidae	R	herbivorous	-	0.78	LC
Spotted Owlet	*Athene brama*	Strigiformes	Strigidae	R	Carnivorous	-	0.06	LC
Little Cormorant	*Microcarbo niger*	Suliformes	Phalacrocoracidae	R	Carnivorous	-	0.12	LC

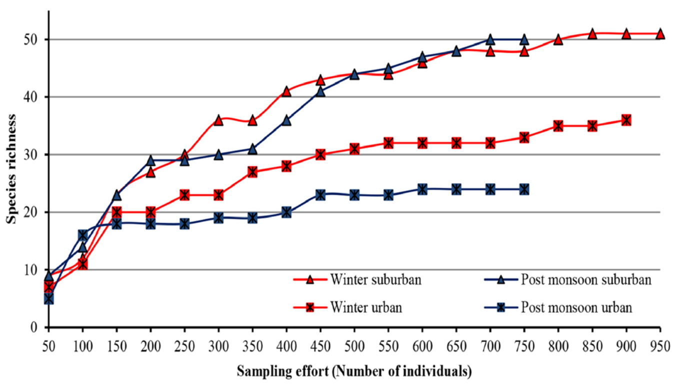

Figure 2: Species accumulation curve of birds recorded in Butwal Sub-Metropolitan City, Nepal.

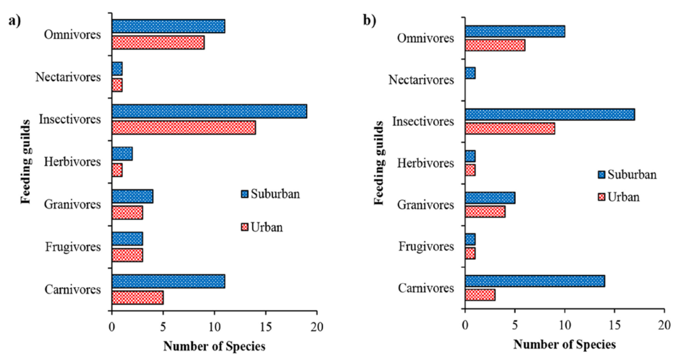

Figure 3: Feeding guild-wise richness of birds; (a) in the winter; and (b) in the post-monsoon season.

dominant feeding guild in both seasons followed by omnivores whereas, herbivores and nectarivores were least dominant (Figure 3). Similarly, insectivores were also the dominant guild in both urban and suburban areas in each season.

Species richness was lower in urban area (n=39) than the suburban area (n=63) (Table 2). Significant difference was observed in species richness between urban and suburban areas for winter (t=3.40, $p<0.05$) as well as the post-monsoon (t=5.12, $p<0.05$). The overall abundance of birds in two areas did not differ significantly, however,

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some urban exploiter species like House sparrow (*Passer domesticus*), House crow (*Corvus splendens*) and Common pigeon (*Columba livia*) had much higher abundance in the urban habitat (Table 1). The evenness indices were lower in urban areas for both the seasons. Diversity indices were higher in suburban habitats than in urban areas irrespective of the seasons (Table 3). Species richness, abundance, as well as both the Simpson's and Shannon-Weiner diversity indices were higher in winter than that of post-monsoon.

Table 2: Diversity in urban and sub-urban areas for both the study seasons.

Measures	Winter		Post-monsoon		Overall	
	Urban	Sub urban	Urban	Sub urban	Urban	Sub urban
Richness	36	51	24	49	39	63
Simpson's 1-D	0.6	0.71	0.57	0.68	0.66	0.77
Shannon's H	1.16	1.51	1.04	1.42	1.39	1.88
Abundance	869	935	764	729	1633	1664
Evenness	0.74	0.77	0.81	0.79	0.677	0.767

The regression analysis between NDVI and overall species richness for respective seasons showed statistically significant positive association ($p<0.05$) (Figures 4a, b). There was negative association between species richness and human foot print index for both seasons ($p<0.05$) (Figures 4c, d). Among the environmental variables examined, the GLM showed their differential relations with bird richness for the two seasons. For the winter, the richness varied significantly in urban areas with the NDVI and precipitation; whereas in suburban areas it varied with the temperature. For the post-monsoon, only the temperature in suburban area appeared to shape the bird richness. Bird abundance in suburban area varied with temperature in winter and with both temperature and precipitation in post-monsoon season.

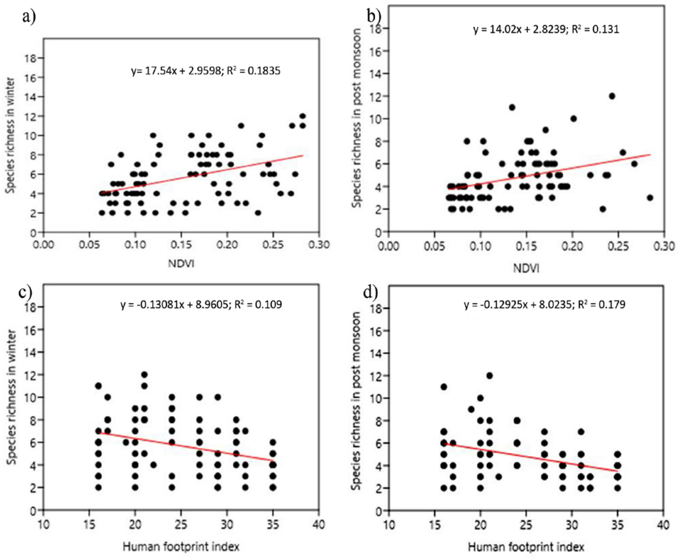

Figure 4: Relationship of species richness with NDVI and human footprint index for respective seasons; (a) richness vs. NDVI in the winter, (b) richness vs. NDVI in the post-monsoon, (c) richness vs. human footprint index in the winter, (d) richness vs. human footprint index in the post-monsoon.

We assessed the bird community structure for winter and post-monsoon seasons in Butwal Sub-Metropolitan City at central lowland Nepal and tested the effects of urbanization on bird assemblage along the rural-urban gradient. The findings followed the rural-urban gradient trend as illustrated by Chace and Walsh (2006) and Filloy *et al*., (2019). Higher diversity and richness was recorded in the suburban area than in the urban area, which supports the intermediate disturbance theory as depicted in multiple other studies (Tratalos *et al*., 2007; Katuwal *et al*., 2018; Gillings, 2019).

Table 3: Summary of the GLM between environmental variables and species richness and abundance for winter and post monsoon seasons.

Season	Area	Variable	Avian richness			Avian abundance		
			Slope (a)	Intercept (b)	P value	Slope (a)	Intercept (b)	P value
Winter	Urban	NDVI	19.439	2.748	0.024	72.87	12.076	0.344
		Precipitation	-0.725	9.329	0.018	-2.464	35.15	0.374
		Temperature	2.181	-34.616	0.078	10.666	-172.99	0.325
	Sub-urban	NDVI	15.833	3.317	0.083	42.707	12.603	0.287
		Precipitation	0.538	3.769	0.678	1.7487	12.308	0.754
		Temperature	-21.884	405.96	0.003	-92.69	1713.1	0.004
Post-monsoon	Urban	NDVI	8.5919	2.858	0.060	-11.58	18.597	0.774
		Precipitation	-0.205	21.226	0.372	0.159	3.803	0.935
		Temperature	1.060	-23.705	0.129	1.330	-17.12	0.826
	Sub-urban	NDVI	0.267	5.704	0.972	11.694	14.581	0.736
		Precipitation	-0.602	55.065	0.157	-6.684	563.52	< 0.001
		Temperature	9.00	-241.51	0.049	54.054	-1403.1	0.008

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The most dominant feeding guild was insectivores, which was also observed in other studies (MacGregor-Fors and Schondube, 2011; Katuwal *et al*., 2018; Dangaura *et al*., 2020). On the contrast, this finding is opposite to some other studies because generalist such as omnivorous species can exploit different resources and are most abundant (Clergeau *et al*., 1998; Chace and Walsh, 2006; Silva *et al*., 2016); however, omnivores were second most abundant guild in this study. Similarly, insectivores and other feeding guilds assemblage were most in suburban habitats owing to the habitat heterogeneity that altogether fosters insect richness and bird assemblage (Aronson *et al*., 2017).

In the context of Nepal, seasonality plays crucial role in determining bird species distribution as one-third of birds are summer and winter migratory where winter migrants exceed summer migrants (Grimmett *et al*., 2000; Inskipp *et al*., 2016). This might be the reason the study recorded higher species richness in winter than in post-monsoon. Higher species richness in winter was also illustrated by Carbó-Ramírez and Zuria, (2011) and Katuwal *et al*., (2018) in their respective research. But Keten *et al*. (2020) recorded low richness in winter while Verma and Murmu (2015) recorded high richness in spring that are in contrast with this study. These seasonal fluctuations in species diversity is associated with resources availability, climatic conditions and seasonal movement (Katuwal *et al*., 2016; Pandey *et al*., 2020).

Urbanization affects the species diversity and richness as a result of landscape manipulation that alters habitat and resources (Blair and Johnson, 2008; Grimm *et al*., 2008). Species diversity and richness both decrease but abundance of urban exploiters increases with urban expansion (Reis *et al*., 2012; Rodrigues *et al*., 2018). This reduction in richness and diversity indices may be due to environmental pollution, and lack of green spaces and fruiting trees (Crooks *et al*., 2004). Urban expansion supports urban dwellers or generalist species compensating the loss of other species (Fontana *et al*., 2011; MacGregor-Fors and Schondube, 2011; Oliveira Hagen *et al*., 2017) as the urban adapters are well adapted to the residential and open areas (Keten *et al*., 2020) while specialist species are the least urban tolerant (Callaghan *et al*., 2019). The most abundant bird species observed during this study were House sparrow, House crow and Common pigeon which are known to be commensals with human (Jokimäki and Suhonen, 1998). Abundance of such urban exploiters was much higher in urban areas than in the suburban periphery. The ability to feed on diverse food, nesting, roosting on urban built structures (building, poles and wires) and withstand anthropogenic pressure are the major causes of abundant presence of urban dwellers (MacGregor-Fors and Schondube, 2011; Rodrigues *et al*., 2018).

Human built infrastructures or sealed areas (houses and buildings) exert the major effects on bird diversity and richness (MacGregor-Fors and Schondube, 2011; Menon and Mohanraj, 2016; Filloy *et al*., 2019). Anthropogenic pressure is second to none when it comes to decreasing richness and diversity (Zhou and Chu, 2012), which negative influence was also found in this study but the supplementary feeding habits somehow compensate the bird communities (Lepczyk *et al*., 2008; Galbraith *et al*., 2015). Similarly, noise of any kind, either vehicular or anthropogenic, are also detrimental to bird richness (Rodrigues *et al*., 2018; Filloy *et al*., 2019). Vegetative cover, mainly trees, is the most prominent factor to increase diversity and richness (Fontana *et al*., 2011; Haedo *et al*., 2017) be it either in urban or suburban areas. The positive association of NDVI with richness in this study also supports this view. In urban sites, green spaces or areas hosted more diverse species including urban adapters. These vegetative covers provide the species with nesting, roosting, shelter and foraging, ultimately uplifting the species richness and diversity (Marzluff and Ewing, 2008; Menon *et al*., 2015). Suburban areas characterized by the presence of more open or green spaces, farmlands and less impervious surfaces provided heterogeneous habitat, increasing the bird diversity and richness of the area as reported in multiple other studies (Verma and Murmu, 2015; Ferenc *et al*., 2016).

Conclusions and Recommendations

Land cover and seasonality exert influence upon bird community assemblage and distribution. Suburban sites host more diverse species and higher feeding guild distribution. Bird species richness and diversity has positive association with the vegetation cover whereas the same has negative association with human pressure. Cities experiencing decline in bird richness should focus on increasing green spaces and parks. In urban settings, urban green spaces are pivotal to foster the bird richness.

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Conflict of interests

The authors have declared no conflict of interest.

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