AVIAN DIVERSITY ALONG URBANIZATION GRADIENT OF BUTWAL SUB-METROPOLITAN CITY, NEPAL

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A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Zoology with special paper ecology and environment.

Submitted to

Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu,
Nepal

Chaitra, 2077 (April 2021)

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 of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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RECOMMENDATION

This is to recommend that the thesis entitled **"AVIAN DIVERSITY ALONG URBANIZATION GRADIENT OF BUTWAL SUB-METROPOLITAN CITY, NEPAL"** has been carried out by Bibek Aryal for the partial fulfillment of Master's Degree of Science in Zoology with special paper ecology and environment. This is his/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 institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor Laxman Khanal, PhD, this thesis submitted by Bibek Aryal entitled "**AVIAN DIVERSITY ALONG URBANIZATION GRADIENT OF BUTWAL SUB-METROPOLITAN CITY, NEPAL**" is approved for the examination in partial fulfilment of the requirements for Master's Degree of Science in Zoology with special paper ecology and environment.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Bibek Aryal entitled "**AVIAN DIVERSITY ALONG URBANIZATION GRADIENT OF BUTWAL SUB-METROPOLITAN CITY, NEPAL**" has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special paper ecology and environment.

EVALUATION COMMITTEE

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LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
VU	Vulnerable
NT	Near Threatened
DD	Data Deficient
LC	Least Concern
GLM	General Linear Modeling
NDVI	Normalized Difference Vegetation Index

ABSTRACT

Global population shift from rural to urban areas intensifies the urbanization which causes changes in the species composition. Butwal Sub-Metropolitan City in the central lowland Nepal is also facing the rapid changes in land use and land cover, due to urbanization. In this regards, this study was undertaken in the Butwal Sub-Metropolitan City aiming to know the effects of urbanization on avian diversity. The area was categorized as urban and suburban on the basis of NDVI (Normalized Difference Vegetation Index) value, the median value taken as the threshold for the demarcation. Altogether, 8 transects (4 in urban and 4 in sub-urban areas) each of 2 km length were deployed. Point count stations were positioned at every 200 m interval along transects. Avian surveys were conducted during the winter and post monsoon seasons of 2020. The avian community structure in the study area was characterized. The associations of avian richness and abundance with NDVI as the proxy of productivity and human footprint data as the proxy of human disturbance were established. Overall, 69 bird species were recorded from 33 families under 14 orders, where Passeriformes was the most dominant order, while insectivores was the most dominant feeding guild. Species richness was higher in winter than in post monsoon. The suburban sites had higher bird diversity and richness than urban sites. This study also illustrated rural–urban gradient effect, supporting the intermediate disturbance hypothesis. Vegetative cover showed positive effects on species richness; on the contrary, human pressure showed negative effects on bird species richness. Temperature and precipitation influenced the avian species richness and abundance. This study clearly demonstrates the importance of vegetative cover and urban greenery for checking the species decline in urban areas, thus, urban policy makers should focus on increasing green spaces in and around the city.

1. INTRODUCTION

1.1 Background

Avian fauna have striking diversity in their bodily features, mode of feeding, habitat and adaptation. Class Aves comprises a total of 29 different orders consisting about 10,000 bird species (IUCN 2016). They live and breed on all seven continents while tropics home the greatest biodiversity of birds. In Nepal, 886 species are recorded which comprise 9% of total world bird diversity (BCN 2018). Among these, 168 species are nationally threatened; out of which 40% are Critically Endangered, 23% are Endangered and 37% are Vulnerable (Inskipp et al. 2017).

Global population shift from rural to urban areas is increasing (Anderies et al. 2007, Tippetts 2018) possessing threats to biodiversity conservation (Goddard et al. 2010). City wildlife diversity can have a major impact on regional, national and even global biodiversity management (Owen 1978). While urbanization and sub-urbanization alters habitats, such areas are becoming increasingly important to biodiversity conservation (Blair and Johnson 2008). Environmental changes result while land is transformed to build cities and to maintain the demands of increasing urban populations which lead to over consumption of resources (Turner et al. 1990, Grimm et al. 2008) . Urbanization ranks the most common factor causing species endangerment and extinction second to interactions with invasive species (Czech et al. 2000) affecting geomorphological and hydrological processes and modifying natural ecosystem resulting in the emergence of unique and taxonomically different communities of organisms, occupying diverse matrix in the urban settings (Arnold Jr and Gibbons 1996, Machlis et al. 1997). Human population along with fragmentation of natural habitats, alteration of energy flow due to urbanization hamper the ecological systems that have been supporting the biodiversity (Alberti and Marzluff 2004).

Birds serve as good ecological indicators and are highly defined and widely surveyed taxon and show sensitiveness to environmental degradation (Clergeau et al. 2001, Lin et al. 2008). Urbanization is known to change bird community structure and composition while increasing urban exploiters abundance but decreasing species richness (Chace and Walsh 2006, Menon et al. 2012) as urban adapted species tend to utilize wide range of resources found in urban sites because of their generalist behavior (Menon and Rangaswamy 2016). Avian species both native depended upon native features and exotic that are able to exploit modified resources can be promoted by different range of environments and level of disturbances (White et al. 2005) and also diversity tends to rise in intermediate amount of urbanization (Blair 1996, Crooks et al. 2004, Tratalos et al. 2007, Gillings 2019) mainly due to presence of heterogeneous vegetative structure (Aronson et al. 2017).

Primary productivity is the most determining element for bird species richness and diversity (Ding et al. 2006, Haedo et al. 2017). Landscape features and habitat characteristics have profound control over bird community diversity and distribution (Skórka et al. 2016, Civantos et al. 2018). Many urban features affect bird communities such as their green spaces or parks and trees as these cover provide better resources options (Paker et al. 2014, Tryjanowski et al. 2017). In urban settings, public and private open spaces, primarily covered by vegetation, are termed as urban green spaces (Haq 2011) . With increasing urbanization, habitat is fragmented so green spaces and areas in cities are major factor for determining biodiversity (Goddard et al. 2010) and indicator for bird heterogeneity (Callaghan et al. 2018). Bird communities are also influenced by the forest patches sizes of urban sites (Kang et al. 2015), larger ones holding higher richness as well as the abundance of avian fauna. Trees density in urban forest patches are regarded to guide the bird abundance (Fontana et al. 2011, Menon and Rangaswamy 2016, Muhammad et al. 2018). Buildings or housing densities, building heights, built cover, electric cables and light lamp together with street dogs and cats also influence bird diversity in urban sites (Boren and Hurd 2005, MacGregor-Fors and Schondube 2011). Additionally, noise intensity is also striking factor that hampers the bird community in the urban setup (Rodrigues et al. 2018). Higher building cover results in decrease of bird richness (Latta et al. 2013, Leveau and Leveau 2016) while moderate to low housing densities are linked to increased species richness (Tratalos et al. 2007). Water bodies, mainly incorporation with green elements such as trees or agriculture land, are pivotal to increase species diversity (Melles et al. 2003, Menon and Rangaswamy 2016, Jasmani et al. 2017). Human view of birds is determined by the sector of respondents where urban pupils appreciate more diversity than density (Clergeau et al. 2001). Habitat degradation due to lack of awareness and low literacy rate among residents also hampers the avian diversity (Mehmood et al. 2018).

Seasonality is closely associated in determining the bird communities as diversity and richness vary in between seasons (Werema and Howell 2015, Tzortzakaki et al. 2017, Katuwal et al. 2018, Mehmood et al. 2018) and also exerts control over feeding guilds together with urbanization (Tryjanowski et al. 2015, Katuwal et al. 2018). However, species composition can also be relatively constant in between seasons (Leveau and Leveau 2016). Harsh weather and food abundance are consequences of climate (Collister and Wilson 2007), but climatic effects are also reliant upon dependent factors such as predation, competition (Wilson and Arcese 2006, Wilson et al. 2011). In context of climate change, although there are some evidence regarding shifting phenologies and distribution, a thorough research is required to understand mechanism and affirm it (Crick 2004, Chen et al. 2011, Knudsen et al. 2011).

1.2 Rationale of the study

There has been rapid increase in intensity of urbanization in Butwal Sub-Metropolitan City in recent years. Land use and land cover data shows increasing conversion of agricultural land into built up area (Neupane 2019). This land cover manipulation can adversely affect the avian fauna of the city.

Considering the study, it is one of the attempts to survey the avian diversity in Butwal Sub-Metropolitan City since there is no exact list of bird diversity specific to Butwal area. So, this work provides a new insight for evaluating avian diversity in the city and to assess the impact of urbanization on it.

1.3 Research objectives

Major objective of this research was to determine the avian community diversity in urban and sub-urban areas of the Butwal Sub-Metropolitan City. The specific objectives were:

- To explore the bird diversity in urban and suburban regions of Butwal Sub-Metropolitan City.
- To evaluate the effects of urbanization on avian diversity in Butwal Sub-Metropolitan City.

1.4 Limitations of the study

The research work was completed within a delimited time period and budget framework, so it had following limitations.

- Entire area of the Butwal Sub-Metropolitan City could not be surveyed and field works were carried out based on the survey design.
- Survey was conducted only during morning period.

2. LITERATURE REVIEW

2.1 Effects of urban gradient on avian diversity

Drastic urban expansion is a threat to biodiversity, which causes habitat loss, species extinction (Seto et al. 2012, Suri et al. 2017) and birds are no exception to this phenomenon. Many studies have used birds as indicator to measure the extent of urbanization and revealed that along urban-rural gradient the bird species richness and diversity gradually increases (Chace and Walsh 2006, Reis et al. 2012, Menon and Rangaswamy 2016), being peaked at intermediate level (Crooks et al. 2004, Blair and Johnson 2008, Gillings 2019). These responses of diversity and richness are obtained due to different factors and features made available along urban gradient. Although species richness declines, but urban conversion supports special birds that are able to exploit urban features increasing their abundance (Tratalos et al. 2007, MacGregor-Fors and Schondube 2011, Rodrigues et al. 2018) as habitat changes are bound to change bird community (Wang et al. 2014).

Human built infrastructures are the most prominent factor among which housing densities and buildings, despite being taken negatively (Marzluff et al. 2001, MacGregor-Fors and Schondube 2011, Reis et al. 2012, Rodrigues et al. 2018), tend to influence diversity not richness as sensitive species are replaced by generalist species (Tratalos et al. 2007, Fontana et al. 2011). As illustrated by MacGregor-Fors and Schondube (2011) and Menon and Rangaswamy (2016), urban infrastructures such as electric poles, cables and maximum building height are exploited by urban adapters. Although the human pressure causes decline in number of species (Lepczyk et al. 2008, MacGregor-Fors et al. 2009, MacGregor-Fors and Schondube 2011, Menon and Rangaswamy 2016, Rodrigues et al. 2018), the supplementary feeding behavior somehow compensate the avian communities (Crooks et al. 2004, Lepczyk et al. 2008, Galbraith et al. 2015). The human pressure is detrimental to species diversity stated by eco-system stress hypothesis (Rapport et al. 1985) is clearly demonstrated by declining bird species worldwide. The dominating guild in urban is debatable, but most depict omnivores (Chace and Walsh 2006, Menon and Rangaswamy 2016) while insectivores are also illustrated in some research (MacGregor-Fors 2008, Reis et al. 2012). The number of predators also cause decline in bird numbers (MacGregor-Fors et al. 2010, MacGregor-Fors and Schondube 2011), also aided by noise intensity and vehicular movements that hampers the avian community residing in urban landscapes (Menon and Rangaswamy 2016, Rodrigues et al. 2018). The collision with human made objects in urban areas also exert control on avian viability (Chace and Walsh 2006).

The intermediate-disturbance hypothesis (Connell 1978) stating moderate level of disturbance benefits species diversity is well supported by many authors in their findings (Blair 1996, Tratalos et al. 2007, Lepczyk et al. 2008, Filloy et al. 2019, Gillings 2019) while MacGregor-Fors and Schondube (2011) advocated contrary to this hypothesis demonstrating negative effects of urban intensity. However most research revealed that moderate density of urban development that consist of more open or green areas or settlement areas immediate to green spaces or a fragmented urban landscape supports more avian diversity and richness.

Vegetative cover is the most influential aspect to determine bird diversity and richness in urban landscape (White et al. 2005, Silva et al. 2016, Haedo et al. 2017, Oliveira Hagen et al. 2017, Filloy et al. 2019) as these cover provide foraging, nesting and shelter chances for wide range of species (Marzluff et al. 2001, Menon et al. 2015). Trees are the most prominent figure controlling the avian diversity (Pellissier et al. 2012, Rodrigues et al. 2018). Native and exotic cover also determines the abundance of birds as native species forage on native trees whereas on the contrary exotic species on exotic trees (Chace and Walsh 2006, Shwartz et al. 2008, Paker et al. 2014). Tress foliage and tree age are influential in promoting the bird richness as greater the foliage and older the tree, the extent of height is more and so provides more niches was also concluded by MacGregor-Fors (2008). However, the influence of herbs and shrubs to determine avian richness is somehow lesser than tress (Muhammad et al. 2018). Vegetative heterogeneity and complexity is pivotal to increase the bird diversity and richness as they contribute multiple niches (Crooks et al. 2004, MacGregor-Fors and Schondube 2011). Although urban development exerts negative impact on riparian birds, nevertheless, water bodies, along with vegetative components, are responsible for persistence of certain species and functional groups(Buckton and Ormerod 2002, Menon et al. 2015, Suri et al. 2017).

2.2 Effects of seasonality on avian diversity

In context of Nepal, Seasonality play crucial role in determining avian species distribution as one-third of birds are summer and winter migratory where winter migratory birds exceeds summer migratory (Grimmett et al. 2000, Inskipp et al. 2016). Birds' behaviors are driven due to resources availability in between seasons, like influencing their foraging and breeding habits (Cox et al. 2013, Mulwa et al. 2013, Tryjanowski et al. 2015). The lower seasonal variation in primary productivity in urban areas also contributes to the reduction of seasonal variation in bird communities as revealed by Leveau et al. (2018). Birds richness and diversity as found by many researchers was more in winter than in summer (Caula et al. 2008, Mehmood et al. 2018, Muhammad et al. 2018) which Katuwal et al. (2018), also illustrated in their study in Kathmandu, Nepal. Species richness and abundance are closely associated with climatic factors like temperature and rainfall, as they directly or indirectly influence avian community (Ferger et al. 2014).

3. MATERIALS AND METHODS

3.1 Study area

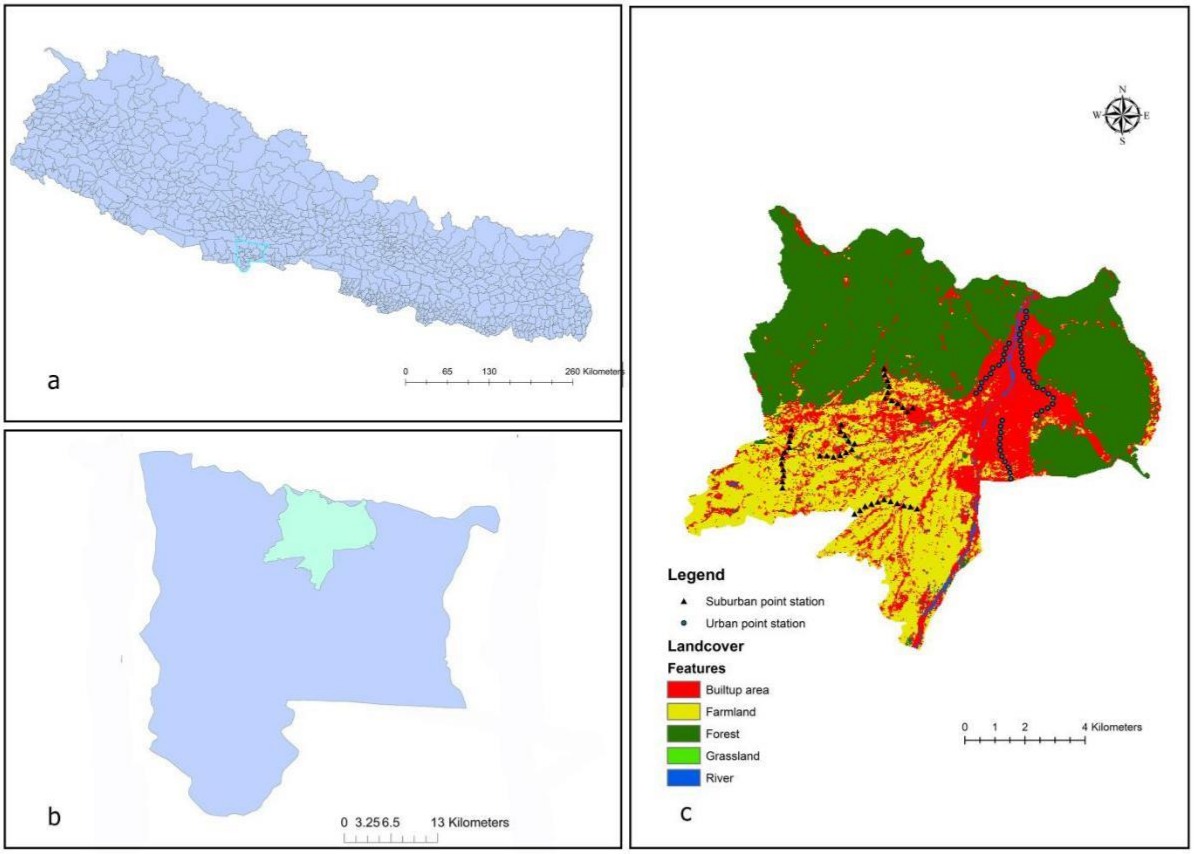

Figure 1.Study area map (a) Map of Nepal showing Rupandehi district. (b) Map of Rupandehi district showing Butwal Sub-Metropolitan City. (c) Land cover map with point stations of Butwal.

Butwal Sub-Metropolitan City also known as Batauli, lies in Rupandehi district in Lumbini Province. Geographically, it lies within the longitude of 83.36° E to 83.50°E and latitude of 27.61°N to 27.74°N (Fig. 1). It got an area of 101.61 square km. This city stands beside the bank of Tinau River, and at the northern edge of the Terai plain below the Siwalik Hills with mesmerizing view of plains and hills. It consists of 22 wards where 138742 populations reside out of which 68288 were males and 79454 were females according to 2011 AD census. Hindu, Buddhist, Muslim, Sikh, Christian, etc. religious people make it culturally vibrant. The main castes inhabiting are Brahmin, Chhetri, Newar, Gurung, Magar, Thakuri, Tharu, Thakali, etc.

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 up to 8 °C. Monsoon usually begins in June. The soil is also fertile for various crops.

3.2 Methods

3.2.1 Avian survey

Survey was conducted on February (1–8) and October (16–23), 2020, from 7 AM to 11 AM. Transects, each of 2 km length with point station at every 200 m (Filloy et al. 2019) were deployed representing the study area. Four such transects were deployed on both the urban and sub-urban sites which resulted a total of 88 point-count stations. The urban tracks run through major residential areas, fewer trees and green spaces and creeks while sub-urban tracks run through dispersed residential areas, farmlands and rivers (Fig 1c). Birds heard (call) and seen in the radius of 50 m from the count station were noted for 10 minutes. The birds were identified using binoculars and field guide book (Grimmett et al. 2016). The unknown birds were later identified using photographs taken during field work.

3.2.2 Habitat characteristics and environmental variables

Pickett et al. (2011) defined urban areas as the area with high population densities and higher impervious or built surfaces. Considering this, Butwal city was categorized into two levels of urbanization i.e. urban and suburban areas (excluding the forest). Survey areas with dispersed houses, more open spaces and farmlands was characterized as suburban and those with higher impervious or residential surfaces, few scattered trees and less open areas was characterized as urban sites. Similarly, urban and suburban sites were illustrated through lansat-8 image supervised classification of the city on the basis of landcover (Fig. 1c) combining band images (2,3,4).Further, demarcation was done on the basis of NDVI data, for which median value (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. The NDVI values for point stations were extracted for both seasons. Area with greater NDVI than the median value was regarded as the suburban area and that with lower NDVI was regarded as urban area. NDVI values of respective seasons were also extracted for point count stations. The average monthly temperature and average monthly precipitation for respective seasons were also extracted for point stations from WorlClim database (https://www.worldclim.org/bioclim). Human footprint index (Venter et al. 2018) was also extracted for each point stations and used as variable in the study. Both extraction and processing of images were done on ArcGIS 10.2.

3.2.3 Data analysis

Diversity indices were calculated for the avian diversity in both the urban and suburban areas. Indices with their formula are as follows:

$$\text{Shannon-Weiner Diversity Index (H)} = \sum[(pi)\times\ln(pi)]$$

where, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the naturallog and Σ is the sum of the calculations.

$$\text{Simpson' Index (D)} = 1/\sum pi^2$$

where, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N) and Σ is still the sum of the calculations.

$$\text{Evenness (E)} = H/H_{max}$$

where, H_{max} is maximum diversity possible.

Similarly, G-F index (Zhi-Gang and Li-Qiang 1999), procedure is to calculate diversity at genus (G index) and family (F index) level and then the ratio between them, was also calculated with following formulas:

$$D_{G\text{-}F} = 1\text{-}\ D_G/\ D_F$$

$$\text{For, } D_F = -\sum D_K = -\sum P_i \ln P_i$$

Where, K = particular family

P_i = number of species in genus i/ total number of species in the family k

$$\text{For, } D_G = -\sum D_G = -\sum P_j \ln P_j$$

Where, P_j = number of species in genus j/ total number of species in the class

The D_{G-F} index value ranges between 0 and 1. In the event that number of species in the class was single family; in other words, D_F=0, thus, $D_{G-F} = 1 - D_G / D_F = 0$.

To find the Coefficient of similarity, following formula was used in this study:

$$C = 2J/(a+b)$$

Where, C = Coefficient of similarity; a, b = number of species in two areas;

J = common species of a and b

Avian richness and abundance in urban and suburban areas were compared for the significance using Student's t-test. General Linear Model (GLM) was done to assess association of avian richness/abundance with environmental variables (NDVI, temperature and precipitation). Correlation was calculated between variables (NDVI and human foot print index) and species richness. Regression analysis was also done to establish relationship of species richness with NDVI and human footprint index for each season. These statistical analyses were done on R program (R Core Team 2017) using vegan package (Oksanen et al. 2019) and also PAST v3.14 (Hammer et al. 2001). Representative figures and tables were made using MS-Excel 2010. Birds were categorized according to their feeding guilds (Katuwal et al. 2018, Pandey et al. 2021).

4. RESULTS

4.1 Avian diversity in Butwal Sub-Metropolitan City

4.1.1 Avian species diversity and community structure

A total of 3,297 birds of 69 species were observed from 33 families under 14 orders. Among the 69 species, 58 were residents and 11 were migrants. Higher number of families (n=29) were recorded in winter than in post monsoon (n=26). Also, the species count was higher in winter (n=56) than in post monsoon (n=52). The species accumulation curve revealed a linear relationship with the possibility of finding more species with increasing sample effort (Fig. 2).

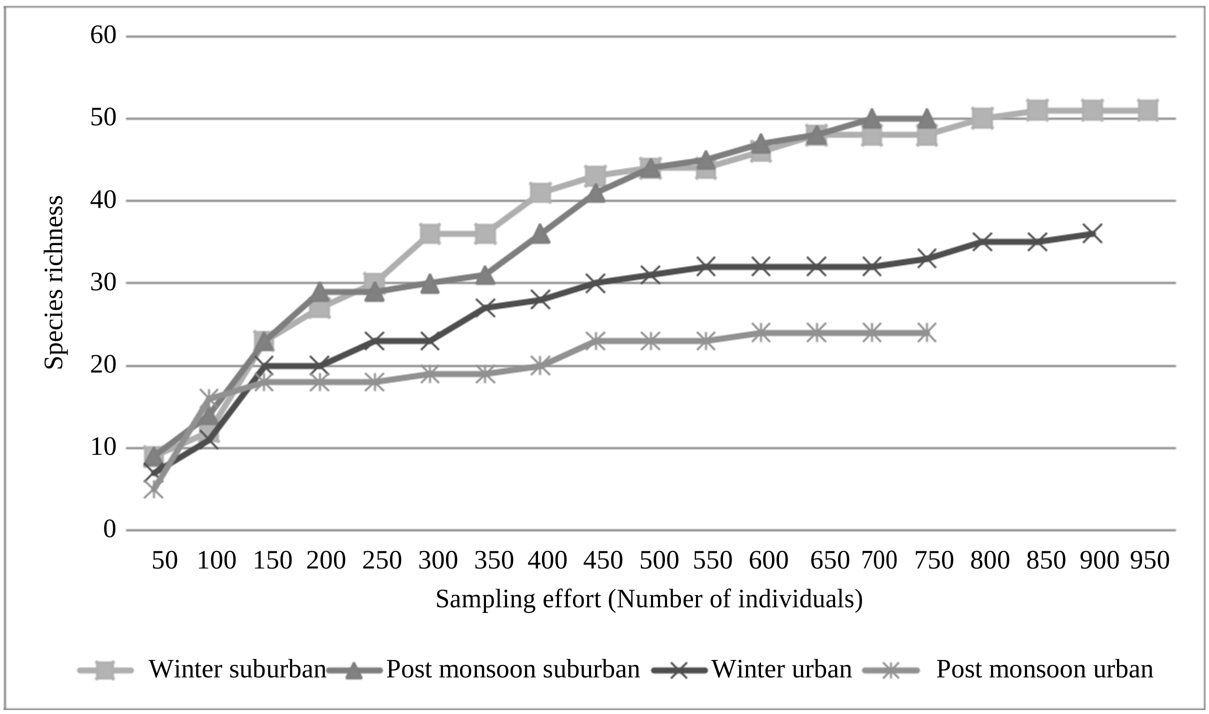

Figure 2. Species accumulation curve of birds recorded in Butwal Sub-Metropolitan City, Nepal

Order Passeriformes constituted the highest number of species (n= 38), where Muscicapidae was the most diverse family (n = 7) followed by the orders Pelecaniformes and Psittaciformes (Fig. 3). In winter, altogether 21 families and 36 species were recorded in urban areas while 25 families and 51 species were recorded from the sub-urban areas. In post monsoon, 17 families and 24 species were observed in the urban areas but 25 families and 49 species were noted from the sub-urban areas. On both occasions, sub urban habitats got higher number of families and species. House sparrow (*Passer domesticus*) was the most abundant species in both habitat types followed by house crow (*Corvus splendens*) and common pigeon (*Columba livia*) in urban areas. On the contrast, Red whiskered bulbul (*Pycnonotus jocosus*) was second to house sparrow in suburban habitats followed by common pigeon and house crow.

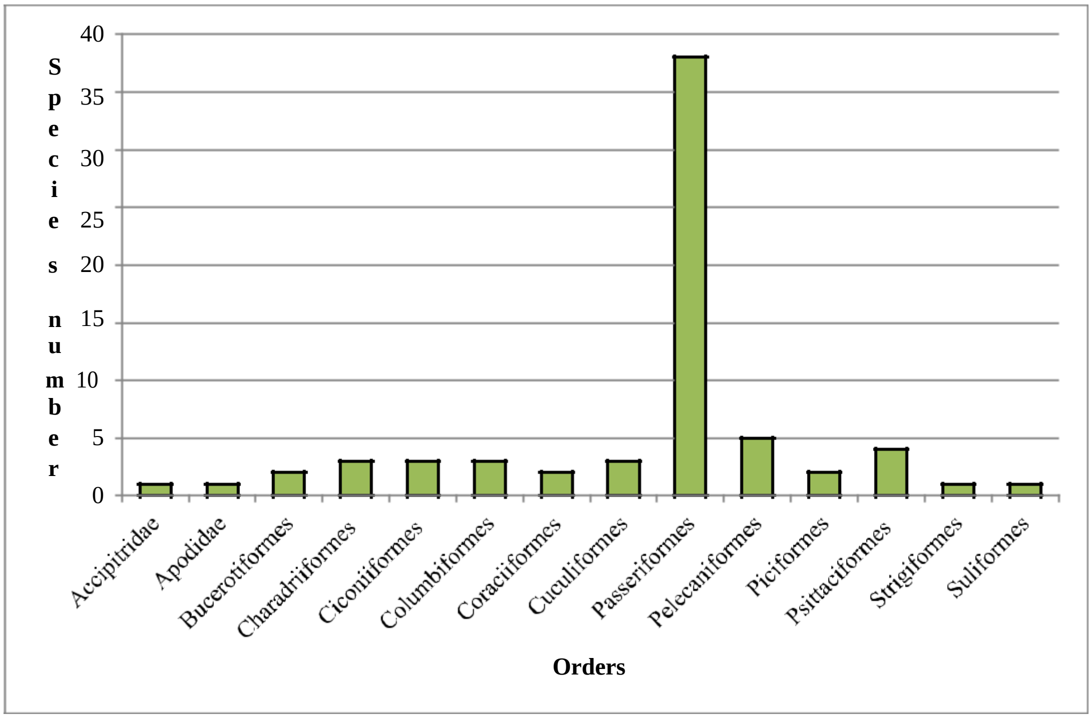

Figure 3. Order-wise species richness of birds in Butwal Sub-Metropolitan City

Asian openbill (*Anastomus oscitans*) and Lesser adjutant (*Leptoptilos javanicus*) were the vulnerable species, whereas, Alexandrine parakeet (*Psittacula eupatria*), Asian woolly-neck (*Ciconia episcopus*) and Red avadavat (*Amandava amandava*) were near threatened species recorded during the study.

Insectivores were the dominant feeding guild in both season followed by omnivores whereas, herbivores and nectarivores were least dominant (Fig 4). Similarly, insectivores were also the dominant guild in both urban and sub urban areas in each season (Fig 5 & 6).

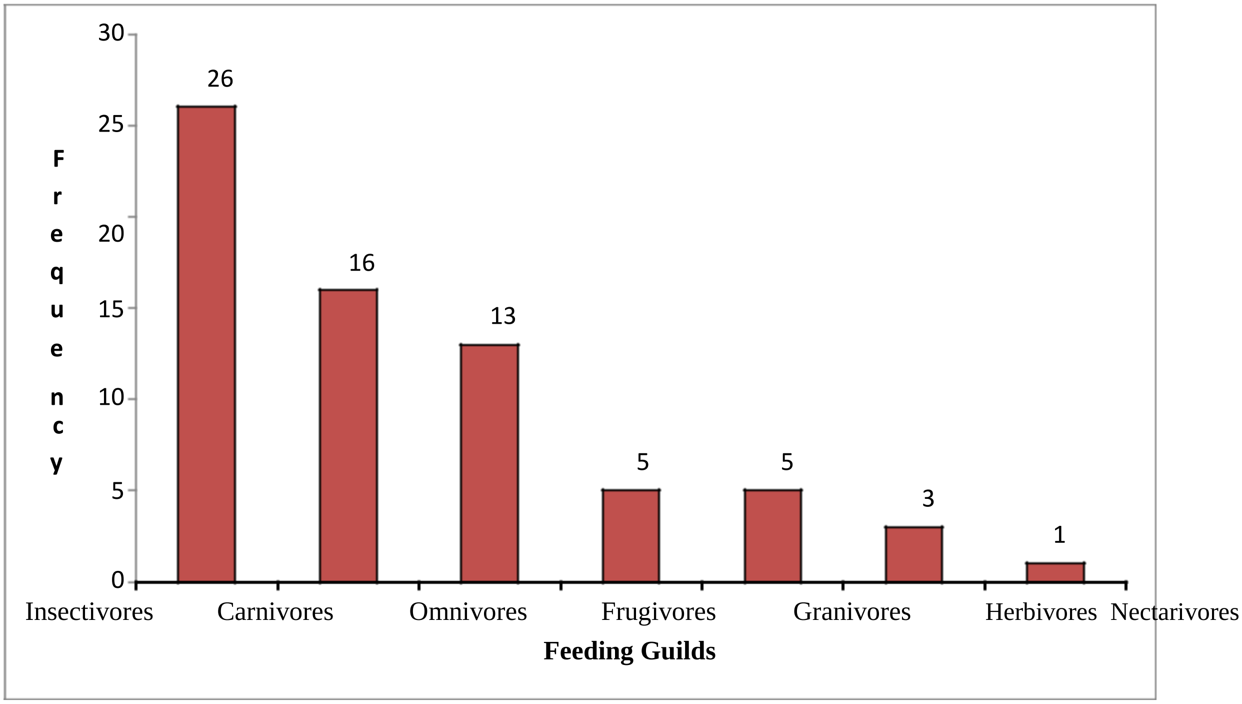

Figure 4. Feeding guild-wise richness of birds for both seasons

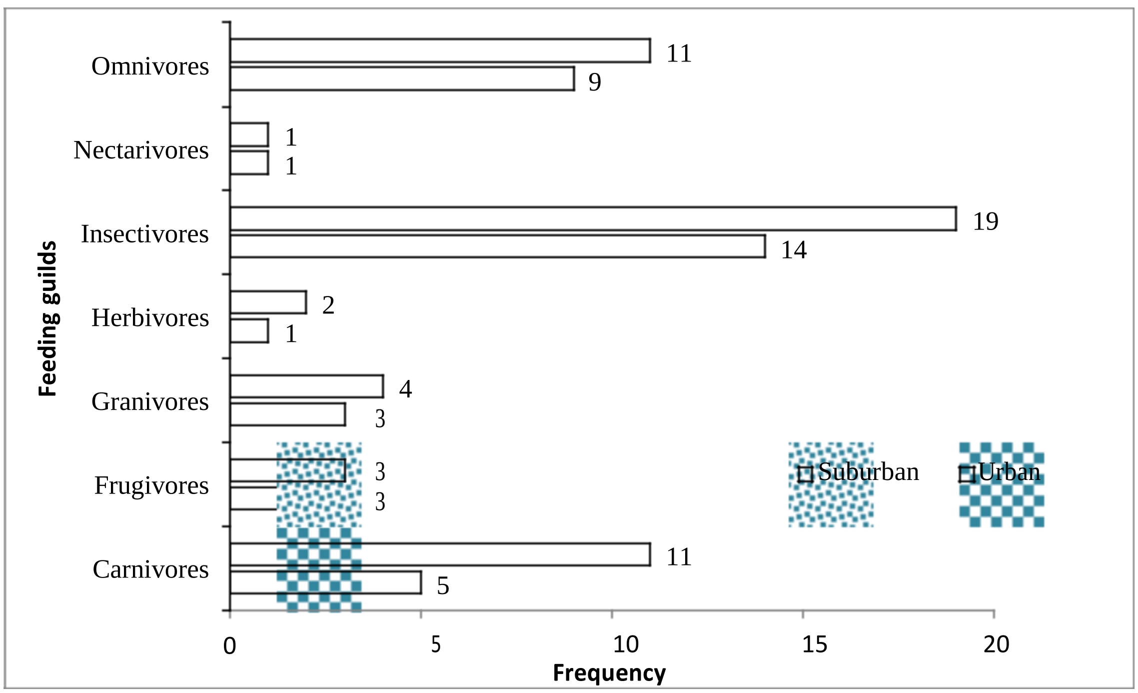

Figure 5. Feeding guild-wise richness of birds in the winter

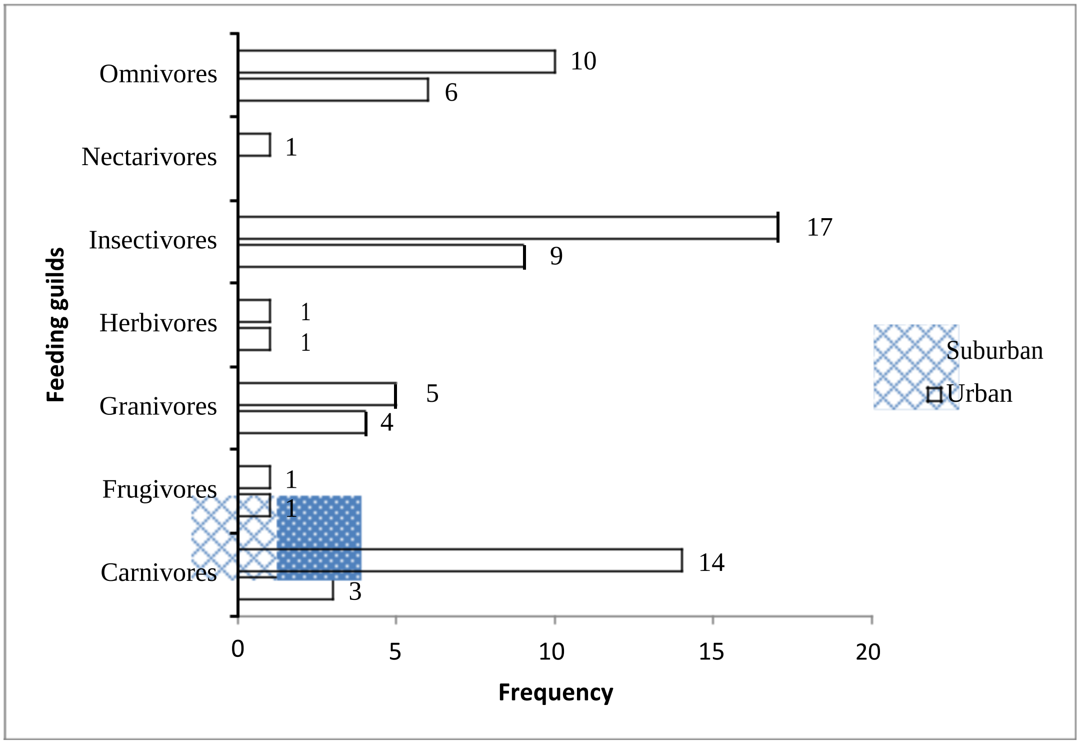

Figure 6. Feeding guild-wise richness of birds in the post-monsoon

Coefficient of similarity (C) of avian community between urban and suburban areas in winter and post monsoon was 0.71 and 0.57 respectively. While inter-season similarity coefficient of avian species was 0.72.

Significant difference was obtained between urban and suburban areas in species richness of winter ($t= 3.40$, $p < 0.05$) and post monsoon ($t= 5.12$, $p < 0.05$). In terms of inter season analysis between urban vs urban and suburban vs suburban, significant difference in species richness was recorded only in urban area ($t= 2.85$, $p < 0.05$) In case of species abundance, there was no significant variation ($p>0.05$) in intra- season but significant variation was noted for inter-season in suburban areas ($t= 2.04$, $p < 0.05$) only.

Diversity indices were higher in sub urban habitats respective of the seasons while, Simpson and Shannon indices were higher in winter than that of post-monsoon (Table 1).

Table 1. Diversity indices result between urban and sub-urban areas for both seasons**.**

	Winter		Post-monsoon	
Diversity Indices	Urban	Sub-urban	Urban	Sub-urban
Simpson's 1-D	0.6	0.71	0.57	0.68
Shannon's H	1.16	1.51	1.04	1.42
Evenness	0.74	0.77	0.81	0.79

4.1.2. Avian diversity at generic and family level

The G-F index was higher for suburban areas of respective seasons (Table 2).

Table 2. Comparison of G-F index in different study sites.

Season	Site	D_F index	D_G index	D_{G-F} index
Winter	Urban	4.44	1.42	0.68
	Suburban	6.95	1.92	0.72
Post monsoon	Urban	2.8	1.04	0.63
	Suburban	8.91	2.32	0.73

4.2 Effects of urbanization on avian diversity

4.2.1 Association between NDVI and avian richness

The correlation between NDVI and species richness was positive (r = 0.26 and 0.33) in suburban and urban in winter respectively. Similarly, the correlation between NDVI and species richness was positive (r = 0.0052 and 0.28) in suburban and urban in post monsoon respectively.

4.2.2 Association between Human Foot-Print data and avian richness

However, the correlation between human footprint index and species richness was negative (r = -0.0357, -0.0486 and -0.2307, -0.1441) for suburban and urban sites in winter and post monsoon respectively.

4.2.3 Determinants of avian richness along urbanization gradient

The GLM resulted species richness was significant in urban with precipitation during winter while in sub urban species richness was significant with temperature during winter and post monsoon. Only in urban, species richness witnessed significant variation with NDVI during winter (Table 3). Abundance was significant with temperature in winter but with both temperature and precipitation during post monsoon in suburban (Appendix 2). Similarly, regression analysis between NDVI with overall species richness for respective seasons was positively significant ($p < 0.05$). On the contrast, that of between species richness and human foot print index for both seasons was negatively significant ($p < 0.05$) (Fig 8).

Table 3. Summary of Generalized Linear Modeling (GLM) between Environmental variables and species richness for winter and post monsoon

Season	Site	Variables	Slope (a)	Intercept (b)	P value
Winter	Urban	NDVI	19.439	2.7484	**0.02425**
		Precipitation	-0.72549	9.3298	**0.018741**
		Temperature	2.181	-34.616	0.078976
	Sub-urban	NDVI	15.833	3.317	0.083178
		Precipitation	0.53846	3.7692	0.6783
		Temperature	-21.884	405.96	**0.0037225**
Post Monsoon	Urban	NDVI	8.5919	2.858	0.060929
		Precipitation	-0.20517	21.226	0.37241
		Temperature	1.0601	-23.705	0.12999
	Sub-urban	NDVI	0.26719	5.7046	0.97291
		Precipitation	-0.60274	55.065	0.15739
		Temperature	9	-241.51	**0.049295**

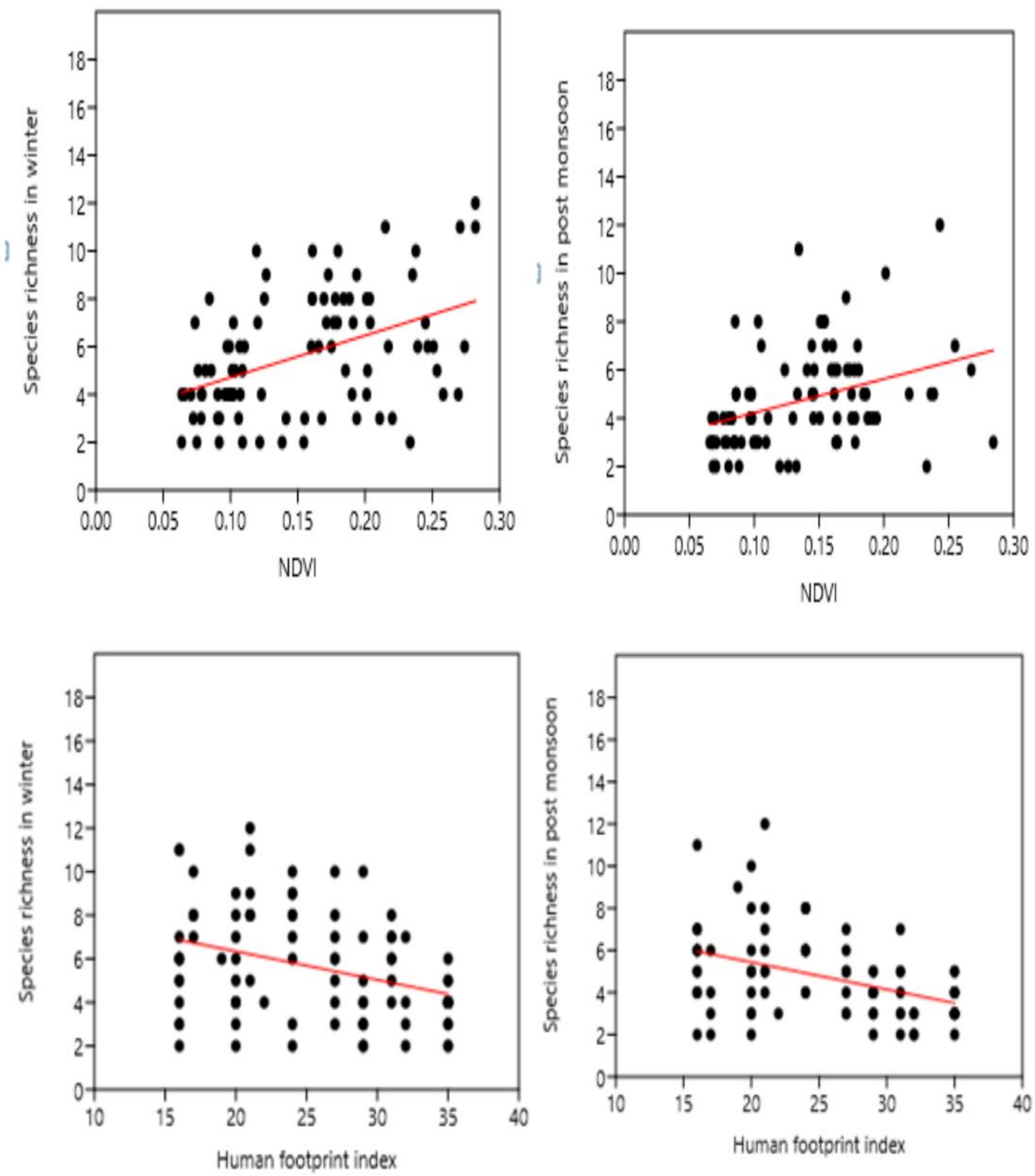

Figure 7. Relationship of species richness with NDVI and human footprint index for respective seasons

5. DISCUSSION

This research was done in order to explore the status of avian diversity in urban and suburban areas of Butwal Sub-Metropolitan City and know the effects of urbanization on avian diversity. Butwal has become a developmental hub in Lumbini Province, which drastic developmental changes can influence the avian diversity. This study done in two seasons at 88 point count stations seeks to determine the effects of urbanization.

5.1 Avian diversity and community structure

Out of 886 species described from Nepal, 69 species were observed i.e. 7.7 % of overall available species in Nepal. Passeriformes was the most dominant order, which was also reported in other studies (Ghosh 2016, Mukhopadhyay and Mazumdar 2019). Muscicapidae was the most diverse family, also illustrated in other findings (Panchani 2016, Lalruatkimi et al. 2019). House sparrow was the most abundant species followed by house crow and common pigeon, which is in contrast with the finding, common pigeon as abundant species, of Katuwal et al. (2018) in Kathmandu. Asian koel (*Eudynamys scolopaceus*) was the only summer visitor from 11 migrant species recorded in both seasons, and remaining 10 were winter visitors. Among migrant species, white wagtail (*Motacilla alba*) and grey wagtail (*Motacilla cinerea*) were the most common. The sightings of vulnerable species (Asian Openbill and Lesser adjutant) and near threatened species (Alexandrine parakeet, Asian woolly-neck and Red avadavat) makes the area important from conservational view point.

Diversity was higher in winter season (Katuwal et al. 2018, Mukhopadhyay and Mazumdar 2019) which is due to the abundant food supply mainly insects, winter fruiting trees in the area and more winter migrants (Mukhopadhyay and Mazumdar 2017, Katuwal et al. 2018).

Insectivores were most dominant feeding groups (Reis et al. 2012, Mukhopadhyay and Mazumdar 2017) which shows the abundance of arthropods in the area. Feeding guild wise higher diversity and richness was observed in suburban habitats than in urban habitats, the reason being wide availability of foraging resources for different feeding groups as a result habitat heterogeneity (Verma and Murmu 2015, Aronson et al. 2017) which is more profound in suburban areas.

The species accumulation curve demonstrated a linear relationship as sampling effort increased, showing higher chances of encountering new species.

5.2 Effects of urbanization on avian diversity

The findings followed the rural – urban gradient trend as illustrated by Chace and Walsh (2006) and Filloy et al. (2019). Significant variation was observed in species richness between urban and suburban while abundance was not significant, which may be due to more availability of some urban dwellers (MacGregor-Fors and Schondube 2011, Haedo et al. 2017) in case of urban habitat that make up for more diverse birds species available in sub urban habitats. The most abundant bird species were house sparrow, house crow and common pigeon which are known to be commensals with human (Jokimäki and Suhonen 1998). Insectivores were the most dominant guild while nectarivores were the least found guild, which matches the findings of Katuwal et al. (2018).

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).However, urban sites provide proper foraging and cover assets to some species, despite being altered from their original state (Melles et al. 2003). Species diversity and richness both decreases but abundance increases for urban exploiters as urban area expands is a common outcome also found in other studies (Reis et al. 2012, Rodrigues et al. 2018).This reduction may be due to lack of green spaces, fruiting trees and environmental pollution (Crooks et al. 2004). But this expansion also 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 least urban tolerant (Callaghan et al. 2019). The ability to feed on diverse food, nesting, roosting on urban built structures (building, poles & wires) and withstand anthropogenic pressure are the major causes of abundant presence of urban dwellers (MacGregor-Fors and Schondube 2011, Rodrigues et al. 2018). But, the negative influence of urbanization, that result in decrease species diversity and richness cannot be neglected. 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 Rangaswamy 2016, Filloy et al. 2019). Indeed anthropogenic pressure is second to none when it comes to decreasing richness and diversity (MacGregor-Fors and Schondube 2011, 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 noise were also detrimental to bird richness (Rodrigues et al. 2018, Filloy et al. 2019).

The presence of vegetative cover has always been associated with increasing diversity and richness in urban landscape which is taken as source of resources for avian species (Fontana et al. 2011, Haedo et al. 2017). The rise in number of species was also noted during this study in urban green spaces. Residential areas with trees around them recorded better richness of birds excluding the urban exploiters. This is supported by the positive significance of species richness with NDVI. This finding has also been demonstrated by other studies focusing the importance of vegetation (Crooks et al. 2004, White et al. 2005, Carbó-Ramírez and Zuria 2011, Silva et al. 2016). Tree foliage and tree age are also influential in promoting the bird richness as greater the foliage and older the tree, the extent of height is more and so provides more niches (MacGregor-Fors 2008, Zhou and Chu 2012). These vegetative covers provide the species with nesting, roosting, shelter and foraging, ultimately uplifting the species richness and diversity (Marzluff et al. 2001, Menon et al. 2015). Riverine patches also influence the bird richness in urban area as found by Menon and Rangaswamy (2016). In a nutshell, increasing green spaces with mix vegetation and residential vegetation leads to foster the avian diversity in urban areas (Smith et al. 2014).

This study stands true with the intermediate disturbance theory as found by other studies (Katuwal et al. 2018, Filloy et al. 2019, Gillings 2019). The avian diversity and richness was found to be more in the suburban areas. The presence of moderate number of houses and less human pressure surges the avian richness and diversity (Gillings 2019). The farmland landscape within suburban areas provides nesting, roosting or foraging resources for variety of avian species (Fuller et al. 2004) due to the heterogeneous habitat features comprising mixed vegetative cover and crops (Verma and Murmu 2015). On the contrary, intensive farming areas harbored only farmland birds, causing fall in species diversity (Herzon et al. 2008).However, riverine farmland or terrestrial and aquatic heterogeneity harbors more diverse bird species (Menon et al. 2015, Mukhopadhyay and Mazumdar 2019).

The most dominant feeding guild was noted to be insectivores, which was also observed in other studies (MacGregor-Fors 2008, Carbó-Ramírez and Zuria 2011, Katuwal et al. 2018). On the contrast, this finding is also opposite to some studies because generalist such as omnivorous species can exploit different resources (Clergeau et al. 1998, Chace and Walsh 2006, Silva et al. 2016), which is second to carnivores in this study. Urban warmer temperature probably supports large group of insectivores or arthropods which in turn allows specialist bird species to foster (Pena et al. 2017). But, the intensity of urbanization also decreases insect herbivory resulting lesser species in urban (Kozlov et al. 2017). The impacts of urbanization on feeding guild was also observed by Palacio et al. (2018). However, higher richness of observed feeding guilds and their diversity in suburban can be due to the more and complex vegetation structures which provide more foraging opportunities (Verma and Murmu 2015, Aronson et al. 2017, Katuwal et al. 2018).

Seasonality profoundly affects the avian communities by manipulating environmental variables which in turn brings changes in resources availability (Poulin et al. 1992, Tryjanowski et al. 2015). Species richness was higher in winter as 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 which are in contrast with this study. These seasonal fluctuation in species richness and abundance is associated with resources availability, climatic conditions and seasonal movement (Katuwal et al. 2018, Giri et al. 2020). The species richness and abundance negative significance with temperature during winter opposes the finding, temperature supports richness and abundance of species, of Howard et al. (2015) but at the same time is also supported by positive significance with temperature in post monsoon. Similarly, Classen et al. (2015) also found positive influence of temperature on species richness of bees. The species richness and abundance in tropics is known to constrained by moisture or precipitation, which is supported by the negative significance relationship that was observed in this study (Hawkins et al. 2003, Williams and Middleton 2008). Arthropods abundance influences the feeding guild diversity (Planillo et al. 2021). Although, the high availability of insectivores, omnivores and carnivores on both seasons depicts that the area is rich in invertebrate population, more richness was recorded in winter. Migrant insectivores aided to the higher number of insectivores population in winter depicting the seasonal fluctuation (Tryjanowski et al. 2015). The higher number of frugivores and herbivores in winter is due to the fruiting of trees that takes place in dry season (Borghesio and Laiolo 2004). Despite, the fact that climatic changes drive the bird assemblage, climate alone may not fully control these assemblages, additional factor like land cover can also influence the avian community (Reino et al. 2018).

6. CONCLUSION AND RECOMMENDATIONS

A total of 69 species of birds were recorded in Butwal Sub-Metropotitan City with Passeriformes as the most dominant order. There is a clear indication that intensity of urbanization and climatic factors affect the species diversity and richness. Species richness demonstrated gradual increase moving from urban areas to sub urban areas. The reasons for higher richness and diversity in suburban sites are habitat heterogeneity and moderate disturbances. For urban vicinity, green spaces are most phenomenal factor to positively influence species diversity. Vulnerable and Near Threatened species sightings make it more pivotal from conservation view point.

These findings demonstrate the need of green spaces in and around city in order to safeguard and foster the species diversity and richness while sketching out any developmental policies. The city policy makers need to make strategies and policies to increase, improve and restore green spaces together with plantation of trees in open spaces that can be crucial for uplifting species diversity.

Also, further research can be carried out in the forest around the city that may help to enlist more species and compare the diversity of the whole area.

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Appendix 1: Avian Checklist of Butwal Sub-Metropolitan City

English name	Scientific name	Order	Family	Status	Feeding guild	IUCN Status
Black Kite	*Milvus migrans*	Accipitriformes	Accipitridae	R	Carnivorous	LC
House Swift	*Apus affinis*	Apodiformes	Apodidae	R	Insectivorous	LC
Common Hoopoe	*Upupa epops*	Bucerotiformes	Upupidae	R	Insectivorous	LC
Indian Grey Hornbill	*Ocyceros birostris*	Bucerotiformes	Bucerotidae	R	Omnivorous	LC
Common Sandpiper	*Actitis hypoleucos*	Charadriiformes	Scolopacidae	M	Insectivorous	LC
Little Ringed Plover	*Charadrius dubius*	Charadriiformes	Charadridae	R	Carnivorous	LC
Red wattled Lapwing	*Vanellus indicus*	Charadriiformes	Charadridae	R	Carnivorous	LC
Asian Openbill	*Anastomus oscitans*	Ciconiiformes	Ciconiidae	R	Carnivorous	VU
Asian Woolly-neck	*Ciconia episcopus*	Ciconiiformes	Ciconiidae	R	Carnivorous	NT
Lesser Adjutant	*Leptoptilos javanicus*	Ciconiiformes	Ciconiidae	R	Carnivorous	VU
Common Pigeon	*Columba livia*	Columbiformes	Columbidae	R	Granivorous	LC
Spotted Dove	*Stigmatopelia chinensis*	Columbiformes	Columbidae	R	Granivorous	LC
Yellow footed pigeon	*Treron phoenicoptera*	Columbiformes	Columbidae	R	Frugivorous	LC
Green Bee eater	*Merops orientalis*	Coraciiformes	Meropidae	R	Insectivorous	LC
White throated Kingfisher	*Halcyon smyrnensis*	Coraciiformes	Alcedinidae	R	Carnivorous	LC
Asian Koel	*Eudynamys scolopaceus*	Cuculiformes	Cuculidae	M	Omnivorous	LC
Common Hawk Cuckoo	*Hierococcyx varius*	Cuculiformes	Cuculidae	R	Insectivorous	LC
Greater Coucal	*Centropus sinensis*	Cuculiformes	Cuculidae	R	Carnivorous	LC
Ashy Prinia	*Prinia socialis*	Passeriformes	Cisticolidae	R	Insectivorous	LC
Asian Pied Starling	*Gracupica contra*	Passeriformes	Sturnidae	R	Omnivorous	LC

Black Drongo	*Dicrurus macrocercus*	Passeriformes	Dicruridae	R	Insectivorous	LC
Black hooded Oriole	*Oriolus xanthornus*	Passeriformes	Oriolidae	R	Omnivorous	LC
Black Redstart	*Phoenicurus ochruros*	Passeriformes	Muscicapidae	M	Insectivorous	LC
Black-throated Thrush	*Turdus atrogularis*	Passeriformes	Turdidae	M	Omnivorous	LC
Brahminy Starling	*Sturnia pagodarum*	Passeriformes	Sturnidae	R	Omnivirous	LC
Brown Rock Chat	*Cercomela fusca*	Passeriformes	Muscicapidae	R	Insectivorous	LC
Brown Shrike	*Lanius cristatus*	Passeriformes	Laniidae	M	Insectivorous	LC
Common Myna	*Acridotheres tristis*	Passeriformes	Sturnidae	R	Omnivorous	LC
Common Stonechat	*Saxicola torquatus*	Passeriformes	Muscicapidae	M	Insectivorous	LC
Common Tailorbird	*Orthotomus sutorius*	Passeriformes	Cisticolidae	R	Insectivorous	LC
Greater Racket- tailed Drongo	*Dicrurus paradiseus*	Passeriformes	Dicruridae	R	Insectivorous	LC
Grey Wagtail	*Motacilla cinerea*	Passeriformes	Motacillidae	M	Insectivorous	LC
House Crow	*Corvus splendens*	Passeriformes	Corvidae	R	Omnivorous	LC
House Sparrow	*Passer domesticus*	Passeriformes	Passeridae	R	Granivorous	LC
Indian Jungle Crow	*Corvus culminatus*	Passeriformes	Corvidae	R	Carnivorous	LC
Jungle Babbler	*Turdoides striata*	Passeriformes	Leiothrichidae	R	Omnivorous	LC
Jungle Myna	*Acridotheres fuscus*	Passeriformes	Sturnidae	R	Omnivorous	LC
Longtailed Shrike	*Lanius schach*	Passeriformes	Laniidae	R	Carnivorous	LC
Oriental Magpie Robin	*Copsychus saularis*	Passeriformes	Muscicapidae	R	Insectivorous	LC
Paddyfield Pipit	*Anthus rufulus*	Passeriformes	Motacillidae	R	Insectivorous	LC
Pied Bushchat	*Saxicola caprata*	Passeriformes	Muscicapidae	R	Insectivorous	LC
Plain Prinia	*Prinia inornata*	Passeriformes	Cisticolidae	R	Insectivorous	LC
Purple Sunbird	*Cinnyris asiaticus*	Passeriformes	Nectariniidae	R	Nectarivorous	LC
Red Avadavat	*Amandava amandava*	Passeriformes	Estrildidae	R	Granivorous	NT
Red breasted Flycatcher	*Ficedula parva*	Passeriformes	Muscicapidae	M	Insectivorous	DD

Red vented Bulbul	*Pycnonotus cafer*	Passeriformes	Pycnonotidae	R	Omnivorous	LC
Red whiskered bulbul	*Pycnonotus jocosus*	Passeriformes	Pycnonotidae	R	Omnivorous	LC
Rufous Treepie	*Dendrocitta vagabunda*	Passeriformes	Corvidae	R	Frugivorous	LC
Scaly breasted Munia	*Lonchura punctulata*	Passeriformes	Estrildidae	R	Granivorous	LC
Scarlet Minivet	*Pericrocotus flammeus*	Passeriformes	Campephagidae	R	Insectivorous	LC
Spangled Drongo	*Dicrurus hottentottus*	Passeriformes	Dicruridae	R	Insectivorous	LC
Tickell's Leaf Warbler	*Phylloscopus affinis*	Passeriformes	Phylloscopidae	M	Insectivorous	LC
Verditer Flycatcher	*Eumyias thalassinus*	Passeriformes	Muscicapidae	M	Insectivorous	LC
White bellied Drongo	*Dicrurus caerulescens*	Passeriformes	Dicruridae	R	Insectivorous	LC
White browed Wagtail	*Motacilla maderaspatensis*	Passeriformes	Motacillidae	R	Insectivorous	LC
White Wagtail	*Motacilla alba*	Passeriformes	Motacillidae	M	Insectivorous	LC
Cattle Egret	*Bubulcus ibis*	Pelecaniformes	Ardeidae	R	Carnivorous	LC
Indian Pond Heron	*Ardeola grayii*	Pelecaniformes	Ardeidae	R	Carnivorous	LC
Intermediate egret	*Ardea intermedia*	Pelecaniformes	Ardeidae	R	Carnivorous	LC
Little Egret	*Egretta Egretta garzetta*	Pelecaniformes	Ardeidae	R	Carnivorous	LC
Red naped Ibis	*Pseudibis papillosa*	Pelecaniformes	Threskiornithidae	R	Omnivorous	LC
Brown headed Barbet	*Megalaima zeylanica*	Piciformes	Megalaimidae	R	Frugivorous	LC
Coppersmith Barbet	*Megalaima haemacephala*	Piciformes	Megalaimidae	R	Frugivorous	LC
Alexandrine Parakeet	*Psittacula eupatria*	Psittaciformes	Psittaculidae	R	Herviborous	NT
Plum headed Parakeet	*Psittacula cyanocephala*	Psittaciformes	Psittaculidae	R	Herbivorous	LC
Rose ringed Parakeet	*Psittacula krameri*	Psittaciformes	Psittaculidae	R	herbivorous	LC
Slaty headed Parakeet	*Psittacula himalayana*	Psittaciformes	Psittaculidae	R	Frugivorous	LC
Spotted Owlet	*Athene brama*	Strigiformes	Strigidae	R	Carnivorous	LC
Little Cormorant	*Microcarbo niger*	Suliformes	Phalacrocoracidae	R	Carnivorous	LC

Appendix 2: Summary of Generalized Linear Model (GLM) between Environmental variables and species abundance for winter and post monsoon

Season	Site	Variables	Slope(a)	Intercept(b)	P value
		Abundance			
Winter	Urban	NDVI	72.87	12.076	0.34408
		Precipitation	-2.4641	35.15	0.37401
		Temperature	10.666	-172.99	0.32503
	Sub-urban	NDVI	42.707	12.603	0.28718
		Precipitation	1.7487	12.308	0.75421
		Temperature	-92.693	1713.1	**0.0043732**
		Abundance			
Post Monsoon	Urban	NDVI	-11.583	18.597	0.77412
		Precipitation	0.15941	3.803	0.93535
		Temperature	1.3304	-17.121	0.82687
	Sub-urban	NDVI	11.694	14.581	0.73627
		Precipitation	-6.6849	563.52	**4.07E-05**
		Temperature	54.054	-1403.1	**0.0083053**

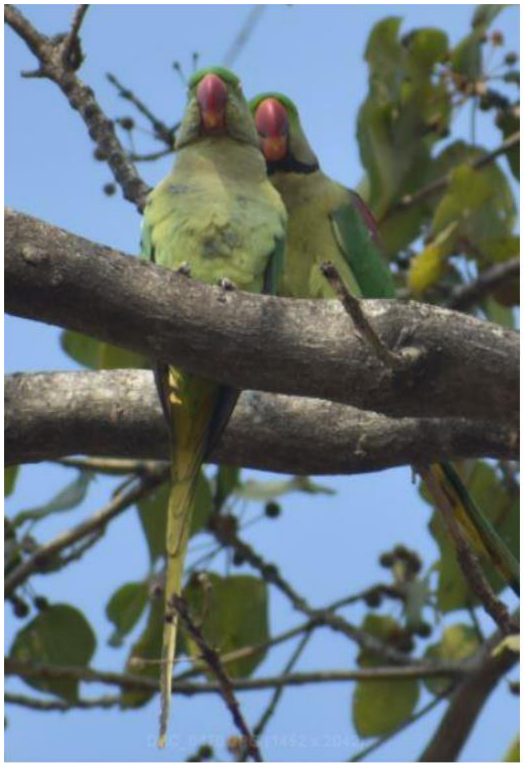
Appendix 3: Point station wise species richness and abundance

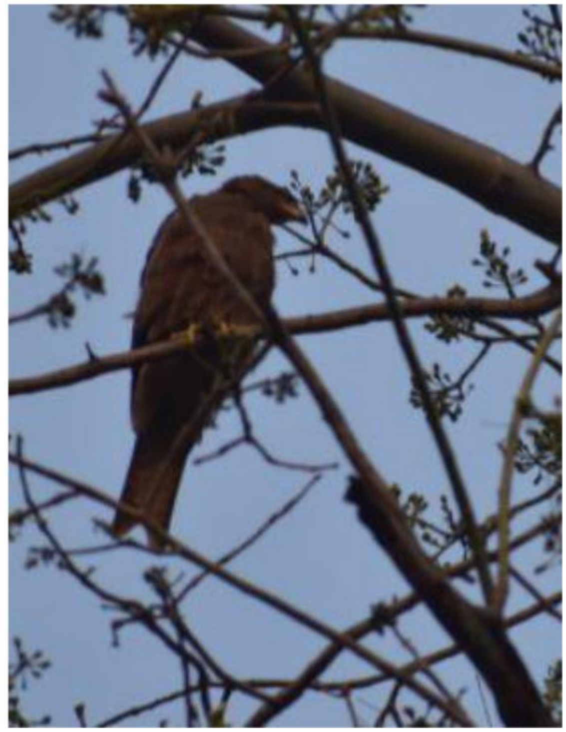
	Winter		Post monsoon	
Point station	Species richness	Species abundance	Species richness	Species abundance
1	9	33	8	35
2	8	28	6	30
3	8	41	5	36
4	9	23	8	17
5	8	21	12	45
6	5	16	7	14
7	8	30	6	13
8	10	48	4	18
9	8	12	6	26
10	7	20	3	36
11	8	26	2	5
12	12	34	4	18
13	11	38	5	14
14	9	20	5	32
15	4	11	10	21
16	4	6	5	10
17	7	14	6	19
18	4	15	8	16
19	2	2	4	5
20	2	3	8	13
21	3	12	4	9
22	7	10	6	12
23	3	13	3	10
24	8	36	3	7
25	6	16	5	8
26	10	36	6	7
27	8	13	6	12
28	6	16	8	22
29	9	33	4	20
30	5	11	3	5
31	3	13	6	6
32	4	15	3	6
33	6	18	3	9
34	6	23	9	13
35	6	21	5	19
36	6	20	6	10
37	5	17	7	15
38	7	37	11	31
39	11	44	7	23
40	6	8	6	11
41	2	3	7	12
42	11	35	5	9
43	3	17	4	21
44	3	27	4	9

45	5	38	3	10
46	5	13	2	7
47	2	4	3	17
48	3	4	4	18
49	4	11	4	12
50	3	11	3	11
51	2	7	3	7
52	2	10	4	7
53	4	11	3	3
54	4	7	7	12
55	6	18	4	22
56	4	16	4	29
57	4	16	5	44
58	4	17	4	20
59	2	3	4	19
60	4	15	4	22
61	7	31	5	18
62	5	13	4	36
63	3	14	3	11
64	5	12	4	20
65	4	21	2	14
66	3	15	2	5
67	6	20	6	38
68	10	30	5	12
69	7	37	5	35
70	7	27	2	3
71	8	21	5	10
72	6	10	3	14
73	5	17	3	25
74	2	13	2	8
75	3	12	3	14
76	7	29	2	6
77	4	12	3	9
78	5	15	2	11
79	7	22	5	15
80	4	12	4	17
81	10	114	7	33
82	8	39	5	16
83	6	16	5	28
84	6	28	3	47
85	3	19	5	5
86	4	19	3	15
87	4	17	4	22
88	4	33	3	17

Note: Point station (1-44) = Suburban , (45-88) = Urban

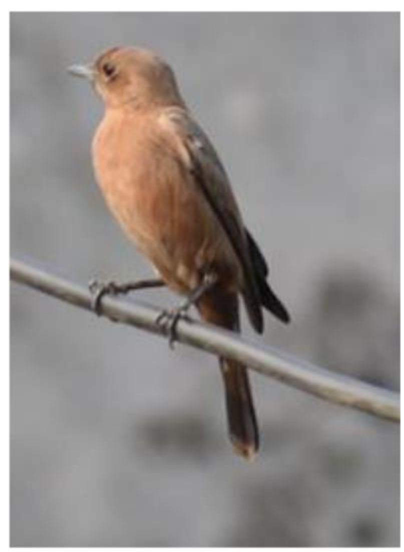
PHOTOGRAPHS





1. Alexandrine Parakeet

2. Black Kite



3.Verditer Flycatcher

4. Brown Rockchat

5. Black-throated thrush

6. Asian Openbill