1. INTRODUCTION

1.1. Background

In recent decades, there are increasing numbers of studies undergoing on altitudinal gradients for understanding the spatial variation in organismal diversity (He et al. 2019). Mountains act as powerful natural experimental systems because they occupy a large portion of earth's land surface, host high biodiversity and offer steep environmental gradients (Körner 2007). Previously, monotonic decrease in species richness with increasing elevation was once considered as a general pattern (Rahbek 1995). However, quantitative studies suggested that only a few early studies on tropical birds support it (Rahbek 1995,Mallet-Rodrigues et al. 2015). In many studies, the species richness exhibits hump-shaped curve with maximum richness occurring at mid-elevation (McCain 2004; Rickart 2001). In other cases, species richness peaked in the foothills and plateau at higher elevations (Herzog et al. 2005). So, actually there is no such a general pattern of elevational gradients in avian species richness.

Several factors like land area, geometric constraints, climate, food availability and productivity play important role in causing elevational diversity patterns (Colwell et al. 2004, Hu et al. 2017, Koh et al. 2006, McCain 2004, Price et al. 2014, Sanders and Rahbek 2012). For example, larger area should harbor more species because of higher habitat heterogeneity and lower extinction rates. The mid-domain effect, predicts that specie richness should tend to peak towards the center of a shared bounded domain due to geometric constraints (Colwell and Lees 2000). Some environmental factors also play vital role in generating patterns of species richness. Among these factors, climate influences the diversity in both directly and indirect ways. Climatic factors act as species filter by limiting species distribution on the basis of their physiological tolerances. On the other hand, species distribution can be indirectly influenced by gradients of some climate factors (such as precipitation, temperature), which affect photosynthetic activity and rates of biological processes in environment (Hurlbert and Haskell 2003, Wu et al. 2013, Paterson et al. 2016). Additionally, the complexity of energy and material transfer (i.e. productivity) can be reflected by species richness patterns, the enhanced vegetation index, which is quantified as the concentration of green leaf vegetation, could be a predictor of bird diversity patterns (Hawkins et al. 2005; Koh et al. 2006; Hawkins et al. 2007).

Nepal covers major portion of the total Himalayan ranges with an elevational range of 60m to 8848m above sea level (asl). This steep elevational change is the reason behind varied bioclimatic conditions (Grytnes and Vetaas 2002). This diverse climatic conditions and position at the border of Palearctic and Oriental realm favors a high biodiversity in Nepal (Mittermeier et al. 1999; Thompson 2009). A total of 887 bird species have been reported in Nepal (BCN and DNPWC 2016, Inskipp and Chaudhary 2016). Over 8% of the world's bird species have been recorded in Nepal. Out of 887 species of birds, around 550 are resident, 63 are summer migrants, 150 are winter migrants and 76 are vagrants (Inskipp et al. 2016). At present the nationally threatened species comprise 68 species (40%) as Critically Endangered, 38 (23%) as Endangered and 62 (37%) Vulnerable (Inskipp et al. 2016).

Annapurna Conservation Area (ACA), one of the largest protected areas in Nepal. It covers an area of 7,629 sq. km. and is home to over 100,000 residents of different cultural and linguistic groups. ACA provides a set of unique habitat and elevational gradients that favor great diversity of flora and fauna and is a treasure house of 1,226 species of flowering plants, 105 mammals, 518 birds, 40 reptiles and 23 amphibians. Several previous studies on bird diversity of Annapurna Conservation Area (ACA) have recorded 518 species of birds representing 14 Orders, 52 Families (Inskipp and Inskipp 2003). However, comprehensive studies of bird diversity patterns and factors underlying these patterns are still lacking. Thus, the present study explores the elevational species richness patterns of birds along the Mardi Himal trekking route and assess the role of driving factors underlying these patterns.

1.2 Rationale of the study

Diversity and species richness along elevation gradient in birds of Nepal are less explored and studies related to these are very insufficient (Paudel and Sipos 2014, Thiollay 1980). It is very necessary to study about diversity of those area, especially which face habitat destruction, habitat loss, receive maximum numbers of visitors, and other threats so as to aid in conservational activities of such area and to protect biodiversity. This study aims to understand the trends of species richness variation along different elevation bands of Mardi trekking route. Studying diversity pattern of the avian fauna not only helps to determine the species present in the area but later it will also assist in determining the factors affecting the distribution of birds in different altitudes. Understanding the state and distribution patterns of species is very essential in conservational work (Mittelbach et al. 2001). As Mardi trekking route is newly introduced trekking route, this study helps to explore avian fauna which can be one of the reasons for enhancing tourism. Birds of this study area are not studied yet and hence this study will fulfill this spatial gap and helps in providing a checklist of bird species in the study area which will assist as a basis for monitoring of birds' species.

1.3 Research Objectives

The major objective of this study is to explore the seasonal bird diversity along an elevation gradient in Mardi Himal trekking route. The specific objectives are –

- To explore the avian diversity in different elevation of the Mardi Himal trekking route.
- To understand seasonal variation in diversity of birds in the study area.
- To investigate the drivers of elevational and seasonal diversity patterns of birds in the study area.

1.4 Research Hypotheses

- Avian diversity differs along the elevation gradient.
- Avian diversity varies with season.

1.5 Limitations of the study

There were few limitations during the study. They are written below:

- Due to unavailability of the climatic data loggers, real time climatic data couldn't be obtained, all the climate data were retrieved from WorldClim (30 sec) database.
- Due to unavailability of latest satellite image of the study area, vegetation indices like normalized difference vegetation index (NDVI) was unable to calculate.

2. LITERATURE REVIEW

2.1 Species richness and elevational gradients

Previously, in biodiversity studies, elevational gradients were thought to be analogous to latitudinal gradients and believed that diversity should decrease monotonically with increasing elevation (Stevens, 1992; Rahbek, 1995). Traditionally, it was expected that there is inverse correlation between species richness and elevation as higher mountains are generally smaller in area, more isolated and with simpler vegetation structure (MacArthur, 1984). However, only few studies carried out on tropical birds (Rahbek, 1995), plant species along sub-tropical gradient in the Himalayas (Bhattarai and Vetaas, 2003), birds along trekking corridor of Sikkim Himalaya (Chettri et al. 2001) support the pattern.

Recent studies have revealed that hump-shaped pattern of species richness in relation to elevation gradient is more common than the inverse relationship (Rahbek, 1995; Brown, 2001; Lomolino, 2001). Studies carried out on small mammals along elevational gradient in Philippines (Heaney, 2001), Costa Rica (McCain, 2004) and China (Chen et al. 2017), and frogs along elevational gradients in the Hengduan Mountain at southern China (Fu et al. 2006) revealed hump-shaped pattern. In some cases, the richness curves seemed to peak in the foothills and plateau at high elevations (Herzog et al. 2005). So, there appears no such a general pattern of elevational gradients in species richness (Shuai et al. 2017). In bird diversity, generally four distinct patterns are followed: decreasing, low plateau, low plateau with a mid-elevation peak and unimodal with a mid-elevational peak (McCain, 2009).

Numerous factors such as land area, geometric constraints, climate, food availability and productivity play important role in causing elevational diversity patterns (Colwell et al., 2004; McCain, 2004; Koh et al., 2006; Nogues-Bravo et al., 2008; Sanders and Rahbek, 2012; Price et al., 2014; Hu et al., 2017). Area of elevational band can influence the species richness of band, i.e. larger area harbors more number of species (Rahbek 1997; McCain 2005; Romdal and Grytnes 2007; Williams et al. 2010). The mid-domain effect (MDE), describes the increasing overlap of species ranges towards the center of a shared bounded domain due to geometric constraints (Colwell and Hurtt 1994; Colwell et al. 2004; McCain 2004). Not only geometric factors, some environmental factors also seem to play important roles in generating patterns. Climate influence diversity directly and indirectly. Climate put restrictions on species' physiological tolerances and act as species filter (Currie 1991; Brown 2001). While climate factors (such as precipitation and temperature) indirectly influence species distribution by affecting photosynthesis and rates of biological processes in the environment (Currie 1991; O' Brien 1993; Hawkins et al. 2003). Therefore, climatic factors are considered as an important predictor of large scale patterns of biodiversity and their role in shaping species richness are supported by many studies (Chen et al. 2017, Fu et al. 2006; McCain 2007; Rowe 2009; Wu et al. 2013). Species richness patterns can reflect the complexity of energy and material transfer (i.e. productivity), the enhanced vegetation index which is quantified as the concentration of green leaf vegetation, could also be a predictor of bird diversity patterns (Hawkins and Soeller 2005; Koh et al. 2006; Hawkins 2007).

2.2 Species richness and seasonal variation

Several studies have analyzed species richness and seasonal variation. Seasonal changes in climate acts as a prominent characteristics of mountain ecosystem which can highly influence the bird species richness (Herzog et al. 2003; Blake 2000). Birds in mountain habitat are more sensitive to seasonal variation due to food and water availability and to temperature regulation requirements (Herzog et al 2003; Renner 2012). Cueto and deCasenave (2000) found highest bird diversity during spring and lowest during autumn season in the coastal woodland of the reserve 'EI Destino', Buenos Aires Province, Argentina. Basnet (2006) concluded that species richness was highest in winter and lowest in autumn, while doing research in Godawari Forest. There was a significant relation between the numbers of avian population with variation of season. Poudel (2005) reported higher number and diversity of birds in winter than in summer during their study at Kirtipur Municipality. Similarly, Malla (2006) recorded higher species richness of birds in winter and spring than other seasons of the year also recorded higher species richness along forest edges than in the interior of the forests. In the same way, Thakuri (2007) discussed the highest species richness in summer followed by autumn and spring season. Similarly, Rimal (2006) found the highest number of species in spring and least in July in Shivapuri National Park. Khanal (2008) recorded the higher diversity of birds in agricultural area than forest and grassland in winter season. Aryal (2013) reported that the species richness was found higher in spring than in the winter. In the same way, Katuwal (2013) discussed the high species richness of birds in post-monsoon (autumn) and least in pre-monsoon (spring) in Manaslu Conservation Area. Seasonal variation of rainfall and seasonal variation of food resources brings changes in species occurrence and abundance of birds (Gatson *et al*., 2000).A change in weather patterns have direct influence upon the several activities of birds and have direct impact upon the species richness of birds (Humphrey, 2004).

Katuwal et al. (2016) reported that species richness showed pronounced seasonal changes with higher species numbers during post- monsoon season. Hence, seasonal variation has a pronounced effect on species richness of birds.

3. MATERIALS AND METHODS

3.1. Location and Physiography

The Annapurna Conservation Area (ACA) is the largest protected area in Nepal, covering 7,629 sq. km. ACA is bounded to the north by the dry alpine desert of Dolpo and Tibet, to the west by Dhaulagiri Himal and the Kaligandaki Valley, to the east by Marshyangdi Valley, and to the south by the valleys and foothills surrounding Pokhara. The ACA consist of amazing topography like some of the world's highest mountains and the deepest river valley (i.e. Kaligandaki George) in the world (van Driem 2014).

Mardi Himal is the southernmost summit of Annapurna mountain range. It has its elevation of 5578m asl at its summit. Mardi Himal lies on the Macchapuchre Rural Municipality of Kaski district in central Nepal. Mardi Himal trek is a newly opened route which offers visitors with imaging view of Annapurna, Dhaulagiri, Macchapuchre and Manaslu range.

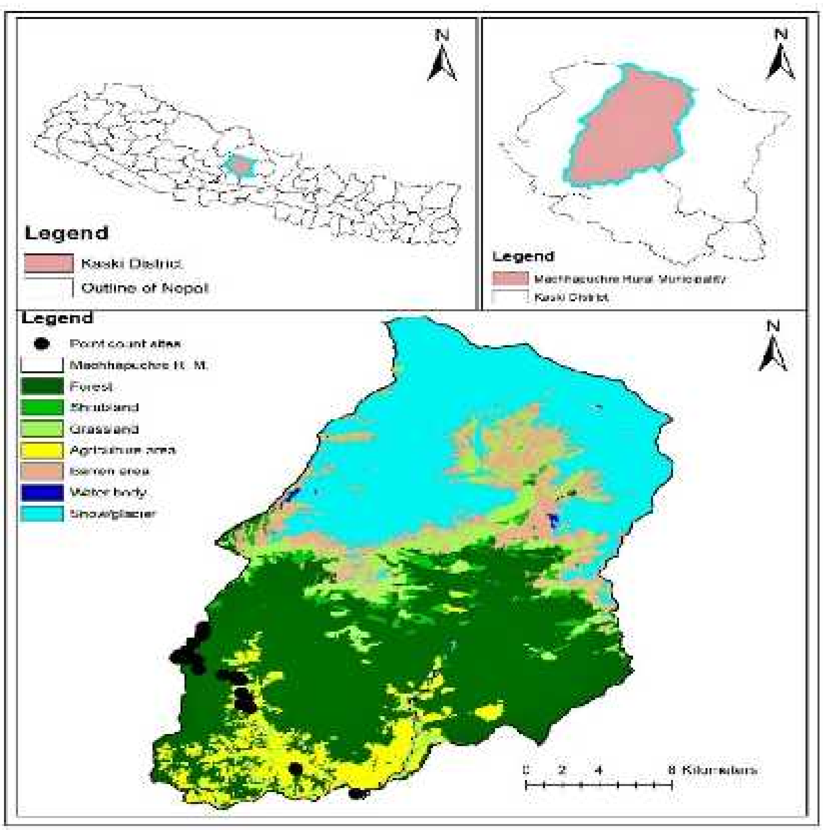

Figure 1. Map of study area.

3.2 Climate

The climate of the study area is extremely varied ranging from subtropical to upper temperate. It lies on southern aspect of Annapurna Mountain so receives comparatively more rainfall (ICIMOD 1994).

3.3 Vegetation

The extreme variation in altitude and landscape of Mardi Trekking route provide a diverse vegetation pattern. Mardi trekking route is characterized by the sub-tropical vegetation in the low to subalpine grasslands in the high hills. But, the climatic zone of study area ranges from sub-tropical to upper temperate. First two point count site are on the bank of Seti Gandaki and Idi khola respectively. These sites are characterized by presence of marshy grassland and agricultural field. Major tourist destination are Lwang, Lumre, Kalimati, Forest camp, Rest camp and Low camp and Kuibang. In Lumre, upper sub-tropical bioclimatic zone are found which are characterized by presence of vegetation like *Schima wallichii*, *Castanopsis indica*, *Alnus nepalensis*, *Holarrhena antidysenterica.* Alongside of Mardi trekking route, in Kalimati and Ghalel, vegetation found were Chandan (*Santalum* spp) (dominant), *Alnus nepalensis*, Ookhar (*Juglans regia)*, Aarupate (*Prunus* species), Nimaro (*Ficus auriculata*), Khurpani (*Prunus spp*). On the way to forest camp, there is dense forest of Sirlinge (*Osmanthus* spp), *Rhododendron arboreum*, *Juniperus squamat*, *Quercus semecarpifolia.*After forest camp (2600m asl), the trail leaves for Low Camp again in the jungle, but the trees soon start to get smaller. On the way to low camp, there is presence of vegetation like Sirlinge (*Osmanthus* spp), *Juniperus squamata*, *Rhododendron arboreum*, *Quercussemecarpifolia* etc.

3.4 Research Design

3.4.1 Research Plots

Two field surveys of birds from 1030 m to 3050 m asl were conducted in winter and summer season of 2019. The lowest elevational limit of survey was set by the confluence site of Seti Gandaki River and Mardi River (i.e. Seti Dovan) and the upper elevational limit was set at

Low Camp. During bird survey, data was collected from Seti Dovan to Low Camp (Seti Dovan- Khoramukh- Lumre- Pokhara Canoying- Lwang Ghalel- Kalimati- Tilichi kharka- Nasamru kharka- Siding Dovan kharka- Forest Camp- Rest Camp- Low Camp). The points were setup with about every 100m rise in elevation, which was recorded by Gramin GPS. Point count sites were chosen on the basis of diverse habitat and tourist spot, realizing the importance of diverse habitat and the impact of tourist on the assemblage of bird community.

3.4.2. Bird Survey Technique

<u>Point Count Method</u>

Point count method was used for counting the number of bird species (Bibby et al. 2000). Mostly in case of avian fauna, point count method are used for estimating population densities, defining population trends, assessing habitat preferences (Johnson 2000). Birds observed and heard within 50m radius were recorded from a fixed point in a center (Schulze et al. 2004). A digital range finder was used to estimate the 50m radius. The time period of observation for a point varied, based on the habitat where the point lies. In dense forest it was 20 minutes and in open area like agricultural field, it was 10 minutes. The birds were observed using Bushnell binoculars and photographs were taken using Nikon P900 camera. For the identification of birds, field book ‘Birds of Nepal’ (Grimmett et al. 2016) was used. The birds were observed between 30 minutes after dawn and 11:30 am and between 3:00 pm and 30 minutes before sunset. Bird surveys were not done during mid-day or during bad weather conditions.

Table 1. List of sampling sites in Mardi Himal trekking route where birds were observed and heard.

S.N.	Point Number	Places	Elevation (m asl)
	P1	Seti Dovan (28.2960°N, 83.9316°E)	1030
	P2	Edi Dovan Shivamandir, (28.3295°N, 83.8905°E)	1108
	P3	Tarebaraha Mandir, Lumre, (28.3518°N, 83.8793°E)	1193
	P4	Pokhara Cannoning, (28.3541°N, 83.8752°E)	1310
	P5	(28.3576°N, 83.8775°E)	1410
	P6	Ghalel, (28.3608°N, 83.8755°E)	1551
	P7	(28.3695°N, 83.8747°E)	1648
	P8	(28.37009°N, 83.8734°E)	1756
	P9	Kalimati Peak, (28.3718°N, 83.8723°E)	1862
	P10	Tilichi Kharka, (28.3728°N, 83.8661°E)	1950
	P11	Nasamru Kharka, (28.3763°N, 83.8540°E)	2084
	P12	Thado Kharda, (28.3825°N, 83.8533°E)	2175
	P13	(28.3832°N, 83.8499°E)	2263
	P14	Dovan Kharka, (28.3834°N, 83.8472°E)	2342
	P15	Forest Camp, (28.3835°N, 83.8433°E)	2449
	P16	(28.3857°N, 83.8447°E)	2515
	P17	Rest Camp, (28.3882°N, 83.8481°E)	2615
	P18	(28.3935°N, 83.8514°E)	2735
	P19	(28.3985°N, 83.8558°E)	2825
	P20	(28.4011°N, 83.8565°E)	2945
	P21	Low Camp, (28.4037°N, 83.8565°E)	3020

Different environmental variables whose influence affect the distribution of bird species were recorded at each sampling point. The variables are

Elevation: The elevation of particular sampling site was recorded using GPS in meters above sea level.

Slope: The inclination of each sampling site was recorded using Clinometer.

Habitat: Study area consist diverse habitat, lowest sampling site lies on the bank of Mardi river where riverine type of habitat is found, and highest sampling site lies on the Low Camp where almost tree line ends and shrubby alpine zone starts.

Agricultural field: It composed of land use for agriculture land or cultivation of different crops like paddy, millet, maize, barley, potato etc.

Meadows: It is generally composed of grassland without any other tall vegetation such as trees or shrubs.

Distance from settlement: It refers to estimated numerical description of how far the settlement is from the sampling point (Appendix V).

Distance from the water: it refers to numerical description of how far the water bodies like river, ponds, streams, were from the sampling point. In most of the cases, distance was measured with reference to the Mardi River, Modi River and Pau Khola (Appendix V).

Climatic Data:

Due to unavailability of the climatic data from on-field data loggers, all the climate data were extracted from WorldClim (https://www.worldclim.org/) (Fick and Hijmans 2017) database for the coordinates of the points to roughly describe climate conditions (mean monthly precipitation and mean monthly temperature) (Appendix IV).

3.4.3. Data Processing and Statistical Analysis

The collected data from the survey of field were at first entered in excel data sheet and then the data was analyzed by using the several statistical tools. The following statistical tools were used to analyze the data.

Shannon- Weiner Diversity (H):

The diversity of species was calculated by using Shannon-Weiner diversity index (Shannon and Weaver 1949).

Shannon Weiner diversity index is designated as H', which is calculated as:

$$H' = -\Sigma (Pi)*\ln (Pi)$$

Where,

$P_i = n_i / N$

N_i = Number of individuals of species i.

N = Total number of all individuals in the sample.

Ln = Logarithm of base e.

Simpson dominance index(C):

It measures diversity from 0 to 1 (a value close to 1 = dominance by one or few species, or less evenness and richness)

$$C = \sum_{i=1}^{s} (n / N)^2$$

Where, ni= number of individuals in each species,

N= total number of individuals,

S= total number of species

Shannon Evenness index (E):

To calculate whether species are distributed evenly across seasons and across landscapes elements, evenness index was determined by the following equation (Pieleu, 1966).

$E = H' / \log S$

Where,

H' = Shannon- Weiner's diversity index.

S = Total numbers of species in the sample.

All diversity indices were calculated using "Vegan" package in R-software.

Samples by species, sites, seasons and environmental variables were analyzed through multivariate analysis tool. Detrended correspondence analysis (DCA; Hill & Gauch, 1980) was performed to determine whether redundancy analysis (RDA), or canonical correspondence analysis (CCA) would be the most appropriate model to describe the association between species abundance, sites, seasons and environmental variables. The values of axis length and eigenvalues obtained from DCA suggest that the linear model associated with CCA was more applicable. Therefore, a direct multivariate ordination method (Ter Break, 1988a; Ter Break and Prentice 1988) based on a linear response of species to environmental gradients (Gauch, 1982; Ter Break 1986; Palmer, 1996) was applied by using vegan library in "R" (Oksanen et al., 2013). All ordination plots were drawn using Canoco v.5.01. Generalized Linear Model (GLM), Polynomial regression and Ordinary Least Square (OLS) regression were done using PAST v.3.14.

4. RESULTS

A total of 112 bird species were recorded belonging to 13 orders and 35 families in Mardi Himal trekking route. Globally, endangered species like Egyptian Vulture (*Neophron percnopterus*), near threatened species like River Lapwing (*Vanellus duvaucelli*), Himalayan Vulture (*Gyps himalayensis*) and endemic bird of Nepal- Spiny Babbler (*Turdoides nipalensis*) were recorded. The highest number of species (77) were represented by Order Passeriformes and lowest (1) by Order Anseriformes, Bucerotiformes, Psttaciformes and Stringiformes.

Table 2. List of Orders of bird species observed in the Mardi Himal trekking route.

S.N.	Order	Number of species
1	Passeriformes	77
2	Columbiformes	6
3	Piciformes	6
4	Pelecaniformes	5
5	Accipitriformes	4
6	Coraciiformes	3
7	Cuculiformes	3
8	Charadiriiformes	2
9	Galliformes	2
10	Anseriformes	1
11	Bucerotiformes	1
12	Psttaciformes	1
13	Strigiformes	1

In 42 point counts, a total of 673 individuals of birds belonging to 112 species were recorded. At the point level, resident species had greater species richness than migratory birds (Figure 2), 80 different types of resident birds and 32 different types of migratory birds were found. With respect to feeding guilds, highest number of Insectivorous species (75) were recorded followed by Frugivorous 38), Omnivorous (21) and lowest number of Carnivorous (18) (Figure 3). It was found that species number varied with seasons, 40 species were found only on summer season, 32 bird species were found only on winter season and 40 different species were common to both the seasons. .

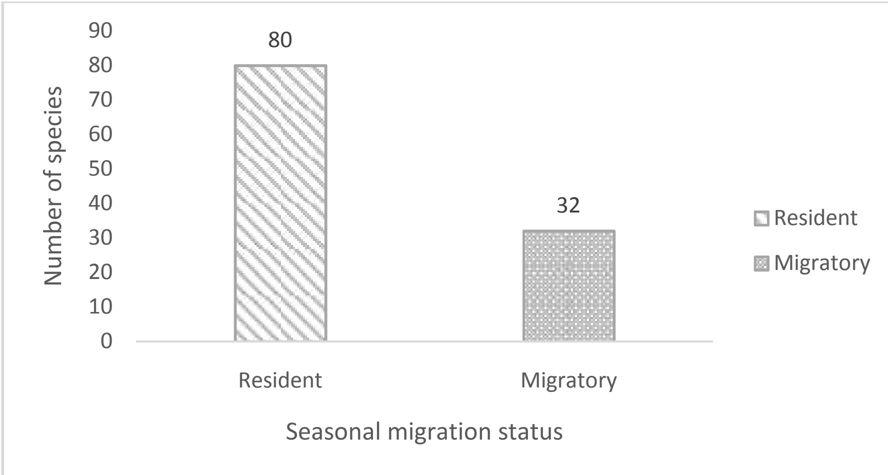

Figure 2. Species richness for different migration types

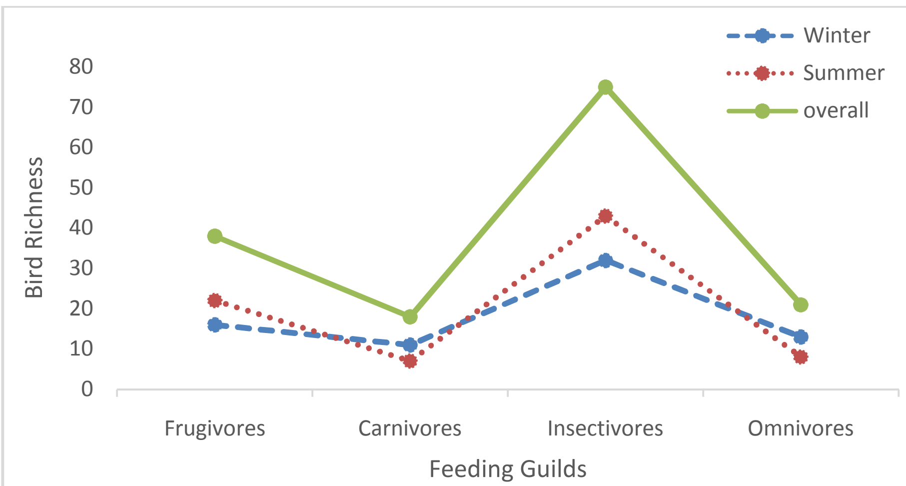

Figure 3. Species richness for different feeding guilds

Recorded 112 species were found during summer and winter field visit from different elevation ranging from Seti Dovan (1030 m asl) to low camp (3050 m asl). The highest species richness was recorded in point count 9 (p9). Diversity index from site-wise data revealed that highest diversity index was found in Point 9 (p9) followed by Point 3 (p3) and the lowest was found in Point 20 (p20).

Table 3. List of site-wise diversity indices.

Sites name, altitude (m asl)	Shannon-Weiner Index	Simpson Index	Evenness Index

p1, 1030	2.538	**0.913**	0.961
p2, 1108	2.531	0.907	0.934
p3, 1193	2.585	0.912	0.932
p4, 1310	2.464	0.899	0.934
p5, 1410	2.535	**0.913**	0.96
p6, 1551	2.336	0.891	0.94
p7, 1648	2.335	0.889	0.939
p8, 1756	2.218	0.863	0.892
p9, 1862	**2.661**	0.905	0.888
p10, 1950	2.444	0.898	0.926
p11, 2084	2.374	0.899	0.955
p12, 2175	2.05	0.835	0.855
p13, 2263	2.106	0.867	0.958
p14, 2342	2.107	0.855	0.915
p15, 2449	2.298	0.884	0.924
p16, 2515	2.002	0.837	0.911
p17, 2615	2.099	0.865	0.955
p18, 2735	1.893	0.842	**0.973**
p19, 2825	1.517	0.763	0.942
p20, 2945	1.379	0.702	0.856
p21, 3020	1.559	0.781	0.969

Seasonal changes in species richness

Only two field surveys (i.e. summer and winter) were carried out and higher species richness (i.e. 80) was found in summer and lower (i.e. 72) was found in winter. Results revealed that diversity indices (i.e. Shannon- Weiner, Simpson and Evenness) is higher for summer season than for the winter (Figure 4).

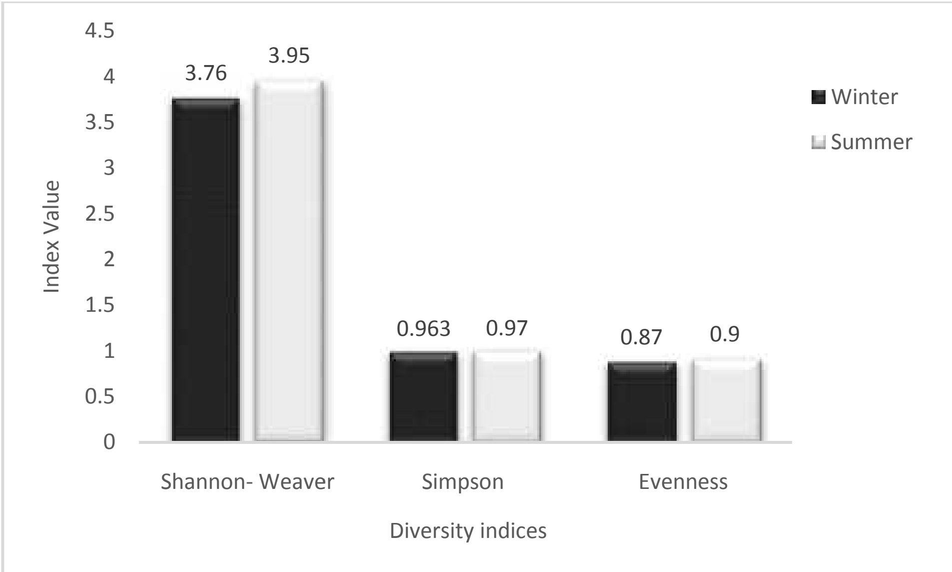

Figure 4. Values of different diversity indices in different seasons.

With respect to feeding guilds, in summer Insectivorous and Frugivorous species richness was higher compared to winter. But, in winter species richness of Carnivorous and Omnivorous species was higher compared to summer (Figure 3).

Avian diversity and environmental factors

Table 4. Generalized linear model (GLM) with normal distribution and identity link function test showing the effects of different environmental factors of different seasons on bird species richness in Mardi Himal trekking route. Values marked in bold are statistically significant at $P<0.05$.

	Slope (a)	Intercept (b)	P value
Summer			
Altitude	-0.0074	30.998	**0.0088**
Distance to nearest water source	-0.0042	22.564	**0.00769**
Distance to nearest settlement	-0.0074	18.8	0.1307
Precipitation (mean)	0.0415	0.094	**<0.001**
Temperature (mean)	1.7345	-18.478	**0.00787**

Winter			
Altitude	-0.00673	29.9	**0.028**
Distance to nearest water source	-0.003039	21	0.098
Distance to nearest settlement	-0.0031	17.417	0.564
Precipitation (mean)	-1.6763	41.096	**<0.001**
Temperature (Mean)	1.4872	2.175	**0.0098**

In summer, it was found that there was a significant difference in species richness of birds with increasing altitude, distance to nearest settlement, precipitation (mean) and temperature (mean).

In winter, it was found that there was a significant difference in species richness of birds with increasing altitude, precipitation (mean) and temperature (mean).

Elevation

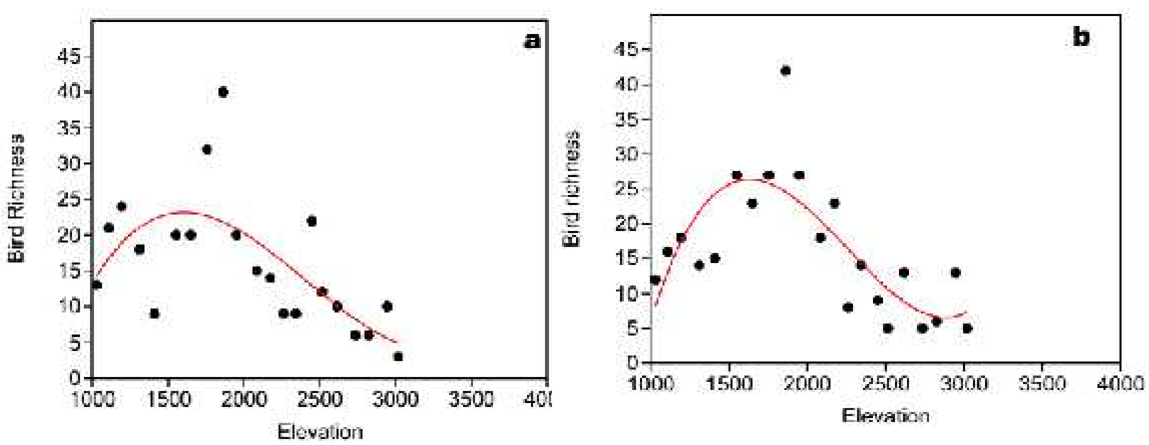

Figure 5. Relationship between bird species richness and elevation in different seasons.

aSummer season; **b** Winter season.

The polynomial regression (3rd order) of species richness patterns along elevational gradients demonstrated that the species richness followed hump-shaped patterns in both the seasons (summer, $r^2 = 0.448$, $p = 0.0154$; winter, $r^2 = 0.62$, $p = 0.0011$).

Temperature (mean)

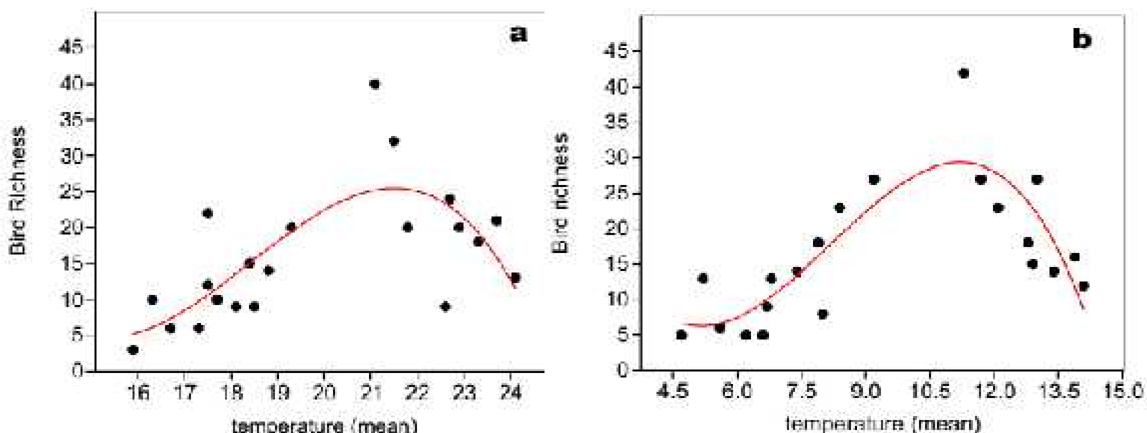

Figure 6. Relationship between bird species richness and temperature (mean) in(**a)** Summer season and (**b)** Winter seasonin Mardi Himal trekking route, Kaski.

The polynomial regression (3rd order) of species richness patterns along mean temperature demonstrated that the species richness is higher on moderate temperature, both high and low temperature do not favor larger number of species (summer, $r^2 = 0.525$, $p = 0.0045$; winter, $r^2 = 0.688$, $p < 0.001$).

Precipitation (mean)

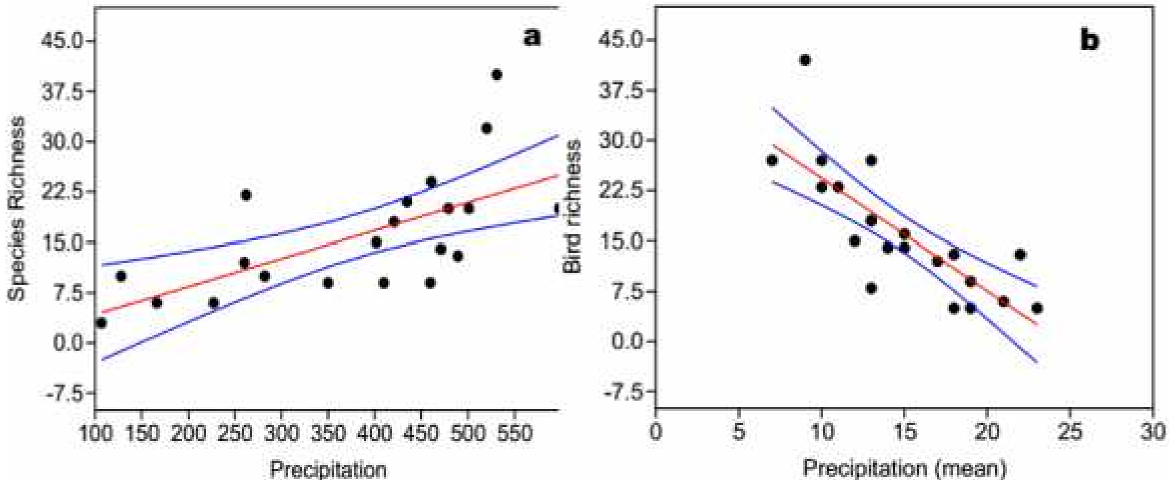

Figure 7. Relationship between bird species richness and precipitation (mean) in (**a**) Summer season and (**b**) Winter seasonin Mardi Himal trekking route, Kaski.

Ordinary Least Square (OLS) regression analysis at 95% bootstrapped confidence interval (N=1999) showed that mean precipitation is positively correlated with species richness in summer and is negatively correlated with species richness in winter season (summer, r = 0.65, $r^2 = 0.424$, p <0.001; winter, r = -0.79, $r^2 = 0.63$, p <0.001).

<u>Distance to nearest water source</u>

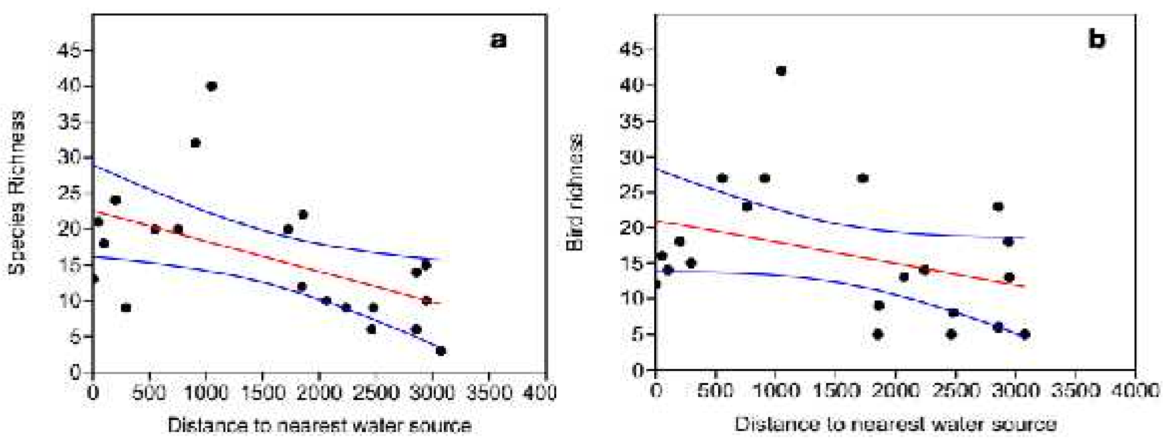

Figure 8. Relationship between bird species richness and distance to nearest water source in (**a**) Summer season and (**b**) Winter seasonin Mardi Himal trekking route, Kaski.

Ordinary Least Square (OLS) regression analysis at 95% bootstrapped confidence interval (N = 1999) showed that distance to nearest water source is significant only in summer season.

Distance to nearest water source is negatively correlated with species richness (summer, r = -0.53, r^2 =0.27, p=0.014; winter, r= -0.40, r^2 = 0.16, p =0.1).

<u>Distance to nearest settlement</u>

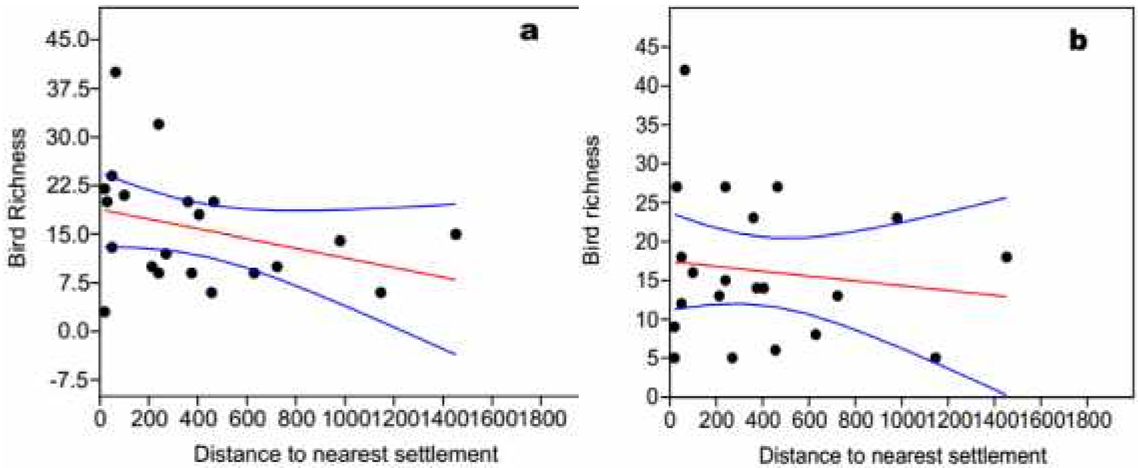

Figure 9. Relationship between bird species richness and distance to nearest settlement in (**a)** Summer season and (**b)** Winter seasonin Mardi Himal trekking route, Kaski.

Ordinary Least Square (OLS) regression analysis at 95% bootstrapped confidence interval (N=1999) showed that bird species richness has no significant relation to distance to nearest settlement (summer, r = -0.327, r^2 = 0.107, p = 0.1433; winter, r = -0.13, r^2 = 0.017, p =0.57).

<u>Habitat</u>

<u>Carnivorous bird species</u>

Species like Great Egret (*Casmerodius albus)*, Indian Pond Heron (*Ardeola grayii)*, Intermediate Egret (*Mesophoyx intermedia)* and Blue Eared Kingfisher (*Alcedo meninting)* show more associated with wetland habitat (Figure 10). Species like Goosander (*Mergus merganser)* shows association with water source adjacent to agricultural field. Species like Grey Treepie (*Dendrocitta formosae)*, Common Green Magpie (*Cissa chinensis*) and Himalayan Vulture (*Gyps himalayensis)* show more associated with forest habitat (Figure 10). Species like Himalayan Buzzard (*Buteo buteo*) shows more associated with pastureland and agricultural land near settlements. Species like Collared Owlet (*Glaucidium brodiei)* shows more associated with forest and pastureland habitat. Species like Common Kingfisher

(*Alcedo atthis)* and Little Egret(*Egretta garzetta*) show associated with wetland habitat and agricultural land near settlement (Figure 10).

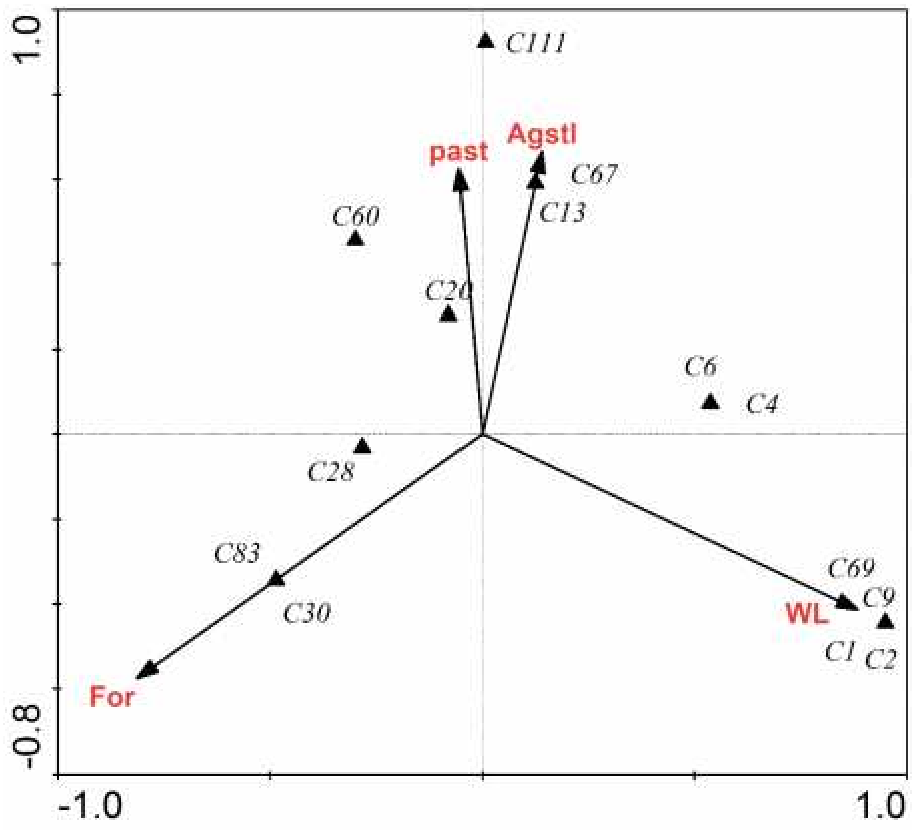

Figure 10. CCA ordination diagram (biplot) showing carnivorous bird species response to different types of habitat. Monte- Carlo permutation test of significance of all canonical axes. Traces =1.433, F= 1.837, P= 0.046 (with 499 permutations). First two axes are displayed. The first axis account for 46.6% and the second axis account for 33.4% of the variability (past=pastureland, for=forest, WL= wetland dependent habitat, Agstl= Agricultural land and settlement).

Frugivorous bird species

The frugivorous species were found closely associated with forest and pastureland than with others habitats (Figure 11). Species like Rufous Sibia (*Malacias capistratus)*, Speckled Wood Pigeon (*Columba hodgsonii)*, Black Francolin (*Francolinus francolinus)*, Blue Throated Barbet (*Megalaima asiatica)*, Wedge Tailed Green Pigeon (*Treron sphenurus)* and Spot Winged Grosbeak (*Mycerobas melanozanthos)* show close association with forest habitat (Figure 11). Species like Green Tailed Sunbird (*Aethopyga nipalensis)*, Mountain Bulbul(*Ixos mcclellandii)*, Mrs Gould Sunbird (*Aethopyga gouldiae)* show close association with pastureland adjacent to forest (Figure 11). Species like Oriental Turtle Dove (*Streptopelia orientalis)*, Russet Sparrow (*Passer rutilans)*, House Sparrow (*Passer domesticus)*, Great Barbet (*Megalaima virens)* and Common Pigeon (*Columba livia*)show close association with agricultural land near to settlement (Figure 11). Species like Spotted Dove (*Stigmatopelia chinensis)*, Slaty Headed Parakeet (*Psittacula himalayana)* and Golden Throated Barbet (*Megalaima franklinii)* show association with wetland/streams dependent habitat (Figure 11).

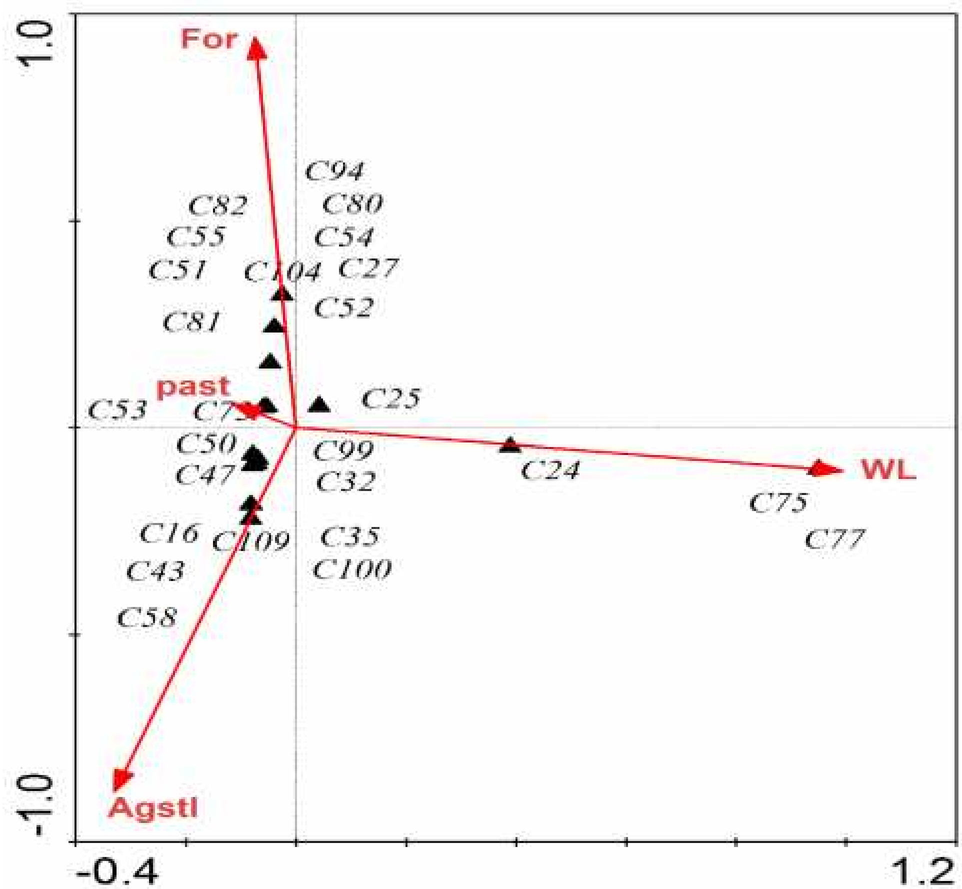

Figure 11. CCA ordination diagram (biplot) showing frugivorous bird species response to different types of habitat. Monte-carlo permutation test of significance of all canonical axes. Trace= 1.193, F=1.742, P=0.0340 (with 499 permutations). The first axis account for 48.5% and the second axis account for 40.3% of the variability.

Insectivorous bird species

Species like Lesser Coucal (*Centropus bengalensis)*, Great Tit (*Parus major)*, Striated Prinia (*Prinia crinigera)*, Paddy Field Pipit (*Anthus rufulus)*, Spiny Babbler (*Turdoides nipalensis)*, Common Stonechat(*Saxicola leucurus)* show close association with agricultural land near settlement (Figure 12). Species like River Lapwing (*Vanellus duvaucelii)*, Ashy Drongo, White Browed Wagtail, White Capped Redstart (*Chaimarronis leucocephalus)*, Red Wattled Lapwing, Cattle Egret show close association with wetland/ stream dependent habitat (Figure 12). Species like Black Lored Tit, Little Pied Flycatcher, Streaked Laughing Thrush, Black Throated Tit, Grey Winged Blackbird (*Turdus boulboul)*show close association with pastureland and species like Blue Whistling Thrush (*Mypphonus caeruleus)*, White Crested Laughing Thrush, Grey Head Woodpecker (*Dendropicos spodocephalus)*, Scarlet Minivet (*Perricrocotus flammeus)*, Ashy Throated Warbler, Grey Sided Bush Warbler (*Cettia brunnifrons)*, Himalayan Bluetail (*Tarsiger rufilatus)* show close association with forest (Figure 12).

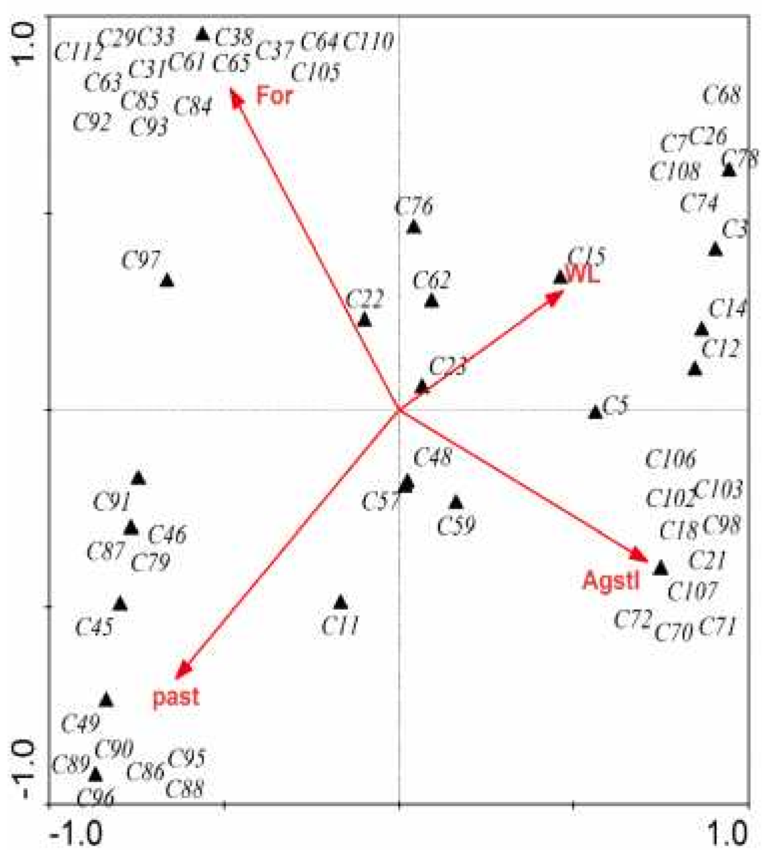

Figure 12. CCA ordination diagram (biplot) showing insectivorous bird species response to different types of habitat. Monte-Carlo permutation test of significance of all canonical axes. Trace= 1.760, F= 1.221, P= 0.0140 (with 499 permutations). The first axis account for 39.4% and the second axis account for 31.4% of the variability

Omnivorous bird species

The omnivorous species were found closely associated with forest habitat (Figure 13). Species like Oriental White Eye (*Zosterops palpebrosus)*, Green Backed Tit (*Parus monticulus)*, Black Kite (*Milvus migrans)*, Yellow Billed Blue Magpie (*Urocissa flavirostris)*, Red Billed Blue Magpie (*Urocissa erythrorhyncha)* and Large Billed Crow show close association with forest habitat (Figure 13). Species like Striated Bulbul (*Pycnonotus striatus)*, Kalij Pheasant (*Lophura leucomelanos)*, Alphine Chough (*Pyrrhocorax graculus)* show close association with pastureland (Figure 13). Species like Plumbeous Water Redstart (*Rhyacornis fuliginosa)* show close association with wetland/stream dependent habitat (Figure 13).

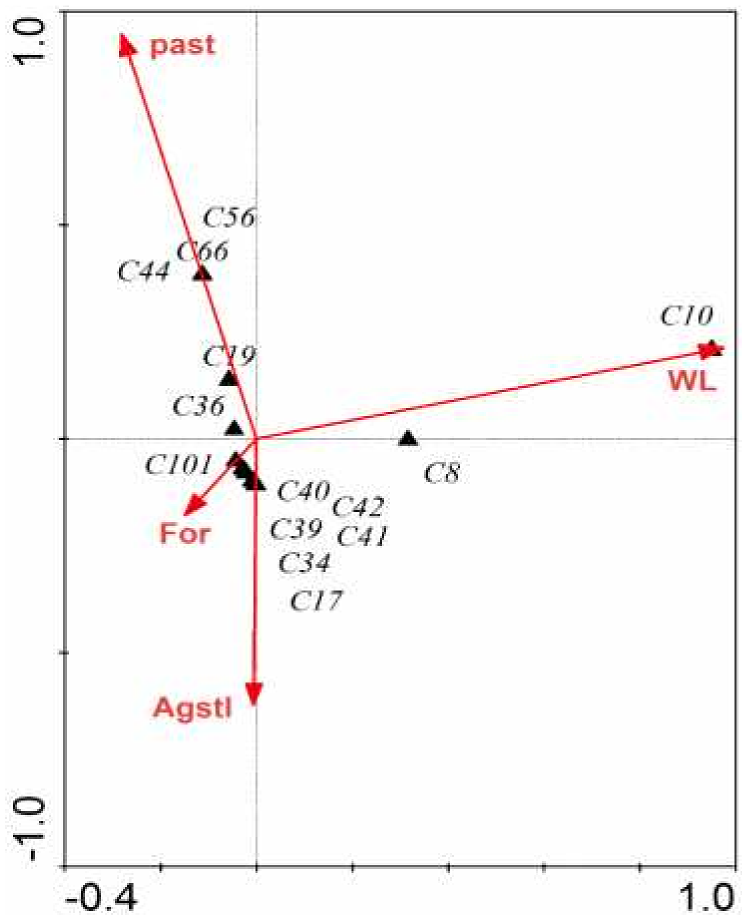

Figure 13. CCA ordination diagram (biplot) showing omnivorous bird species response to different types of habitat. Monte- Carlo permutation test of significance of all canonical axes. Traces =1.782, F= 2.326, P= 0.0020 (with 499 permutations). First two axes are displayed. The first axis account for 43.6% and the second axis account for 37.2% of the variability.

5. DISCUSSION

A total of 112 species of birds belonging to 13 Orders and 35 families were recorded during the study. Inskipp and Inskipp (2003) used Mackinnon's Species richness counting method, call counting method and limited use of point and line transects recorded 518 species of birds representing 14 orders and 52 families of the world in Annapurna Conservation Area (ACA).

5.1 Bird richness and elevation

Avian fauna showed a clear variation in species richness along elevational gradients having a peak in 1862m asl and decreasing onward with increasing elevation (Figure 5). This result seemed to be similar with previous studies for birds in Himalayas of Nepal (Thiollay 1980, McCain 2009, Paudel and Sipos 2014, Katuwal et al. 2016) exhibiting hump-shaped pattern. Ghimire (2015) in his research work also reported hump-shaped patterns of bird richness along an elevational gadients in Manang district. Not only bird species, studies carried out on small mammals along elevational gradient in Philippines (Heaney 2001), small mammals in Costa Rica (McCain 2004), frogs in Hengduan Mountain (Fu et al. 2006) and plant species (Rahbek 2005) revealed hump-shaped patterns along elevational gradients.

Point count (p9) site is a transition region of agricultural land and meadow of adjacent forest, which harbors high species richness due to edge effect. The meadows at this elevation were close to forest area, and hence bird richness might have been positively influenced by the forest via edge effect (Murcia 1995). Several studies revealed that edge effect caused peaks in diversity at ecotones, these ecotone zones are predicted to harbor more species due to overlapping range limits (Terborgh 1985, Lomolino 2001). Highest peak in diversity expected in dominant ecotones and minor peaks at minor ecotones (McCain and Grytnes 2001).

The decline in species richness of birds at an elevation of 1410m asl(Point count i.e.P5) might be due to high disturbance caused by construction of Saiti Hydropower Project (0.9 MV) and Upper Mardi Hydropower Project (7 MV). The distance from construction site to that vary site is less than 300m. Human disturbances like vehicles, construction etc. cause the negative impact on the avian species richness (Reijnen et al. 1995, Halfwerk 2011). The finding of numerous studies from around the globe have shown that specialist bird species are most susceptible to forest disturbances (Stouffer and Bierregaard 1995, Sekercioglu 2012, Arcilla et al. 2015, Pavlacky et al. 2015, Asefa 2017).

The lowest species richness of birds above 2500m asl might be due to less availability of food and harsh climatic condition. BCN and DNPWC (2011) stated that, the low species richness in meadow was due to overgrazing and less availability of food. On an extensive review of recreation effects on birds, Bennett and Zuelka (1999) concluded that the disturbances resulting from recreation activities like hiking, trekking, cycling, clearly has at least temporary effects on behavior and movements of birds. Another review work done by Boyle and Samson (1985) also found negative impacts on richness.

5.2 Seasonal variation

The bird community in any given habitat type is not static but changes seasonally (Avery and Riper III 1989), so there might be fluctuation in the number and species of birds with change in seasons. During the study, higher species richness was found in winter (i.e.340) and comparatively lower species richness in summer (i.e. 333). But, species number in winter (i.e.72) was less than that found in summer (i.e. 80). Higher species richness was due to occurrence of roosting site of bird species like Speckled Wood Pigeon (*Columba hodgsonii*) in point count site. And another reason might be due to assemblage of migratory birds in winter. Similar findings were made by (Basnet et al. 2005, Giri and Chalise 2008 and Abdar 2014). They found higher species richness in winter and explain the fact supporting that winter assures food availability and assemblages of many migratory birds in winter season due to favorable ecological and climatic condition.

A variation in diversity of birds was found between two seasons. Shannon weiner index shows summer season was more diverse (H= 3.95) than winter season. The Shannon weaver index for winter season was (H= 3.76). Having almost similar species richness with higher species number in summer is the reason for diverse assemblage of bird community during summer season. This variation might have been caused due to climatic and biotic factors which varied in different seasons. The temperature and climatic change according to seasons ultimately affect the distribution of birds (Shoo et al. 2005). The amount of energy available in a system (often measured as a primary productivity) is thought to be one of the major determinants of species diversity, especially the species richness (Bailey et al. 2004) which is generally lower during winter. Murgui (2007) studies the effects of seasonality on bird species and found that the bird richness was found higher during summer and spring than in the winter season due to the unfavourable climatic conditions, shortage of food and predation in winter season. Similar result was found having higher species richness recorded during summer in moist high-altitude grassland (Maphisa et al. 2016).

In this study, more species richness was found on moderate temperature condition in both seasons and also showed positive correlation with temperature. In winter, bird richness showed strong positive correlation with temperature. Similarly, precipitation was also found exhibiting strong negative correlation with bird richness during winter and moderate positive correlation during summer. Climate act as species filter by limiting species distribution on the basis of their physiological tolerances. On the other hand, species distribution can be indirectly influenced by gradients of some climate factors (such as precipitation, temperature), which affect photosynthetic activity and rates of biological processes in environment (Hurlbert and Haskell 2003, Wu et al. 2013, Peterson et al. 2016).

Results of this study showed that insectivore form is the most species-rich feeding guilds. Herzog et al. (2003), de Bonilla et al. (2012) and Katuwal et al. (2016) also found similar types of results, where they found more number of insectivorous birds.

Certain types of birds are confined to specific habitats such as agricultural fields, shrubs or forest. These ranges of habitat provide different kinds of food for various birds thus are distributes heterogeneously. Murcia (1995) in her review work found the more number of species around forest and cultivation lands.

In this study, species richness showed negative correlation with distance to nearest water source which means bird richness decreases with increase in distance to nearest water source. Li et al. (2013) concluded that species richness was hump shaped function of energy availability, but a linear function of water availability. He further concluded that water availability had strong effects on plant richness, and weaker effects on vertebrate richness.

Likewise, Currie (1991) found similar result, where the richness of vertebrates (birds, mammals, amphibians and reptiles) was more influenced by energy while tree species richness was more influenced by water availability.

Vertebrate richness, however, might not be direct repercussion of water availability. Contrary of that, influence of water on plants presumably affects vertebrate species richness staunchly since plants are the chief source of food and habitat and fulfill their dietary requirements and niche (Kissling et al. 2007).

6. CONCLUSIONS AND RECOMMENDATIONS

The avian diversity in different elevation of the Mardi Himal trekking route during two seasons (winter and summer) showed that there were altogether 112 species of birds belonging to 13 orders and 35 families. Species richness showed a peak at mid-elevation at 1800-1900 m asl, exhibiting hump-shaped patterns along Mardi Himal trekking route.

Species richness of birds did not vary significantly between two seasons but, there was a significant difference in diversity indices between the seasons.

Although the combined effects of different environmental factors such as elevation, gradients of climate (i.e. temperature and precipitation), distance to nearest water source, habitat and distance to nearest settlement play an important role in bird diversity and richness. This study showed that distance from nearest settlement is not that important compared to other factors in avian diversity in my study area.

Based upon this study, the study hasfew recommendations and as follows:

- High diversity of birds in the study area was found in short period of study time, so further research should be designed to cover more seasons within a year and in between years.
- As it is newly opened trekking trail in Annapurna Conservation Area, construction of infrastructure like hotels and trails should be monitored by concerned agencies in a way causing minimal destruction and disturbances to conserve biodiversity.

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8. APPENDICES

I. Abbreviations and Scientific name of species for CCA

S.N.	Common Name	Scientific Name	Bird Code
1	Great Egret	*Casmerodius albus*	C1
2	Indian Pond Heron	*Ardeola grayii*	C2
3	White browed Wagtail	*Motacilla maderaspatensis*	C3
4	Little Egret	*Egretta garzetta*	C4
5	Black Drongo	*Dicrurus macrocercus*	C5
6	Common Kingfisher	*Alcedo atthis*	C6
7	Red Wattled Lapwing	*Vanellus indicus*	C7
8	Spotted Forktail	*Enicurus maculatus*	C8
9	Blue Eared Kingfisher	*Alcedo meninting*	C9
10	Plumbeous Water Redstart	*Rhyacornis fuliginosa*	C10
11	Grey Bushchat	*Saxicola ferreus*	C11
12	Egyptian Vulture	*Neophron percnopterus*	C12
13	River Lapwing	*Vanellus duvaucelii*	C13
14	Ashy Drongo	*Dicrurus leucophaeus*	C14
15	Oriental Turtle Dove	*Streptopelia orientalis*	C15
16	House Crow	*Corvus splendens*	C16
17	Barn Swallow	*Hirundo rustica*	C17
18	Common Myna	*Acridotheres tristis*	C18
19	White Throated Kingfisher	*Halcyon smyrnensis*	C19
20	Lesser Coucal	*Centropus bengalensis*	C20
21	Blue Whistling Thrush	*Mypphonus caeruleus*	C21
22	Pied Bushchat	*Saxicola caprata*	C22
23	Long tailed Shrike	*Lanius schach*	C23
24	Spotted Dove	*Stigmatopelia chinensis*	C24
25	Red Vented Bulbul	*Pycnonotus cafer*	C25
26	White capped Redstart	*Chaimarronis leucocephalus*	C26
27	Black Bulbul	*Hypispetes leucocephalus*	C27

28	Grey Treepie	*Dendrocitta formosae*	C28
29	White Crested Laughing Thrust	*Garrulax leucolophus*	C29
30	Common Green Magpie	*Cissa chinensis*	C30
31	Grey Headed Woodpecker	*Dendropicos spodocephalus*	C31
32	Himalayan Bulbul	*Pycnonotus leucogenys*	C32
33	Upland Pipit	*Anthus sylvanus*	C33
34	Green Backed Tit	*Parus monticulus*	C34
35	House Sparrow	*Passer domesticus*	C35
36	Large Billed Crow	*Corvus macrorhynchos*	C36
37	Scarlet Minivet	*Perricrocotus flammeus*	C37
38	Wall creeper	*Tichodroma muraria*	C38
39	Black Kite	*Milvus migrans*	C39
40	Yellow Billed Blue Magpie	*Urocissa flavirostris*	C40
41	Red Billed Blue Magpie	*Urocissa erythrorhyncha*	C41
42	Rock Bunting	*Emberiza cia*	C42
43	Russet Sparrow	*Passer rutilans*	C43
44	Straited Bulbul	*Pycnonotus striatus*	C44
45	Black Throated Tit	*Aegithalos concinnus*	C45
46	Grey Winged Blackbird	*Turdus boulboul*	C46
47	Great Barbet	*Megalaima Virens*	C47
48	Eurasian Cuckoo	*Cuculus canorus*	C48
49	Black Lored Tit	*Parus xanthogenys*	C49
50	Mountain Bulbul	*Ixos mcclellandii*	C50
51	Speckled Wood Pigeon	*Columba hodgsonii*	C51
52	Rufous Sibia	*Malacias capistratus*	C52
53	Green Tailed Sunbird	*Aethopyga nipalensis*	C53
54	Black Francolin	*Francolinus francolinus*	C54
55	Blue Throated Barbet	*Megalaima asiatica*	C55
56	Kalij Pheasant	*Lophura leucomelanos*	C56
57	Verditer Flycatcher	*Eumyias thalassinus*	C57
58	Common Pigeon	*Columba livia*	C58
59	Red Billed Chough	*Pyrrhocorax pyrrhocorax*	C59
60	Collared Owlet	*Glaucidium brodiei*	C60
61	Variegated Laughing Thrush	*Garrulax variegatus*	C61
62	Darjeeling Woodpecker	*Dendrocopos darjellensis*	C62
63	Eurasian Crag Martin	*Ptyonoprogne rupestris*	C63
64	Ashy Throated Warbler	*Phylloscopus maculipennis*	C64
65	Grey Sided Bush Warbler	*Cettia brunnifrons*	C65
66	Alphine Chough	*Pyrrhocorax graculus*	C66
67	Goosander	*Mergus merganser*	C67
68	Cattle Egret	*Bubulcus ibis*	C68
69	Intermediate Egret	*Mesophoyx intermedia*	C69
70	Great Tit	*Parus major*	C70
71	Straited Prinia	*Prinia crinigera*	C71
72	Paddy Field Pipit	*Anthus rufulus*	C72

73	Barred Cuckoo Dove	*Macropygia unchall*	C73
74	Indian Cuckoo	*Cuculus micropterus*	C74
75	Golden Throated Barbet	*Megalaima franklinii*	C75
76	Rufous Billed Niltava	*Niltava sundara*	C76
77	Slaty Headed Parakeet	*Psittacula himalayana*	C77
78	Hoopoe	*Upupa epops*	C78
79	Straited Laughing Thrush	*Garrulax striatus*	C79
80	Black throated Sunbird	*Aethopyga saturata*	C80
81	Dark breasted Rosefinch	*Carpodacus nipalensis*	C81
82	Crested Bunting	*Melophus lathami*	C82
83	Himalayan Vulture	*Gyps himalayensis*	C83
84	Blue capped Rock Thrush	*Monticola cinclorhynchus*	C84
85	Scaly Thrush	*Zoothera dauma*	C85
86	Little Pied Flycatcher	*Ficedula westermanni*	C86
87	White browed Bush Robin	*Tarsiger indicus*	C87
88	Orange Headed Thrush	*Zoothera citrina*	C88
89	Grey Wagtail	*Motacilla cinerea*	C89
90	Streaked Laughing Thrush	*Garrulax squamatus*	C90
91	Hoary-throated Barwing	*Actinodura nipalensis*	C91
92	Black-winged Cuckoo Shrike	*Coracina melaschistos*	C92
93	Pale Blue Flycatcher	*Cyornis unicolor*	C93
94	Wedge Tailed Green Pigeon	*Treron sphenurus*	C94
95	Indian Blue Robin	*Luscinia brunnea*	C95
96	White Tailed Nuthatch	*Sitta himalayensis*	C96
97	White crested Laughing Thrush	*Garrulax leucolophus*	C97
98	Grey Hooded Warbler	*Phylloscopus xanthoschistos*	C98
99	Mrs Gould Sunbird	*Aethopyga gouldiae*	C99
100	Spot Winged Rosefinch	*Carpodacus rodopeplus*	C100
101	Oriental White Eye	*Zosterops palpebrosus*	C101
102	Aberrant Bush Warbler	*Cettia flavolivacea*	C102
103	Fulvous Breasted Woodpecker	*Dendrocopos macei*	C103
104	Spot Winged Grosbeak	*Mycerobas melanozanthos*	C104
105	Rufous Fronted Tit	*Aegithalos iouschistos*	C105
106	Spiny Babbler	*Turdoides nipalensis*	C106
107	Common Stonechat	*Saxicola leucurus*	C107
108	Grey Back shrike	*Lanius tephronotus*	C108
109	Common Rosefinch	*Carpodacus erythrinus*	C109
110	Hodgson's Redstart	*Phoenicurus hodgsoni*	C110
111	Himalayan Buzzard	*Buteo buteo*	C111
112	Himalayan Bluetail	*Tarsiger rufilatus*	C112

II. List of bird species with their orders and families

SN	Bird	Scientific Name	Order	Family
1	Himalayan Vulture	*Gyps himalayensis*	Accipitridae	Accipitrinae
2	Egyptian Vulture	*Neophron percnopterus*	Accipitriformes	Accipitridae
3	Black kite	*Milvus migrans*	Accipitriformes	Accipitridae
4	Himalayan Buzzard	*Buteo buteo*	Accipitriformes	Accipitridae
5	Goosander	*Mergus merganser*	Anseriformes	Anatidae
6	Hoopoe	*Upupa epops*	Bucerotiformes	Upupidae
7	Red Wattled Lapwing	*Vanellus indicus*	Charadriiformes	Charadriidae
8	River Lapwing	*Vanellus duvaucelii*	Charadriiformes	Charadriidae
9	Oriental Turtle Dove	*Streptopelia orientalis*	Columbiformes	Columbidae
10	Spotted dove	*Stigmatopelia chinensis*	Columbiformes	Columbidae
11	Speckled Wood Pigeon	*Columba hodgsonii*	Columbiformes	Columbidae
12	Common Pigeon	*Columba livia*	Columbiformes	Columbidae
13	Barred Cuckoo Dove	*Macropygia unchall*	Columbiformes	Columbidae
14	Wedge Tailed Green Pigeon	*Treron sphenurus*	Columbiformes	Columbidae
15	Common kingfisher	*Alcedo atthis*	Coraciiformes	Alcendinidae
16	Blue Eared Kingfisher	*Alcedo meninting*	Coraciiformes	Alcendinidae
17	White Throated Kingfisher	*Halcyon smyrnensis*	Coraciiformes	Alcendinidae
18	Lesser Coucal	*Centropus bengalensis*	Cuculiformes	Cuculidae

19	Eurasian Cuckoo	*Cuculus canorus*	Cuculiformes	Cuculidae
20	Indian Cuckoo	*Cuculus micropterus*	Cuculiformes	Cuculidae
21	Black Francolin	*Francolinus francolinus*	Galliformes	Phasianidae
22	Kalij Pheasant	*Lophura leucomelanos*	Galliformes	Phasianidae
23	White browed wagtail	*Motacilla maderaspatensis*	Passeriformes	Motacillidae
24	Black drongo	*Dicrurus macrocercus*	Passeriformes	Dicruridae
25	Spotted Forktail	*Enicurus maculatus*	Passeriformes	Muscicapidae
26	Plumbeous Water Redstart	*Rhyacornis fuliginosa*	Passeriformes	Muscicapidae
27	Grey Bushchat	*Saxicola ferreus*	Passeriformes	Muscicapidae
28	Ashy Drongo	*Dicrurus leucophaeus*	Passeriformes	Dicruridae
29	House Crow	*Corvus splendens*	Passeriformes	Corvidae
30	Barn Swallow	*Hirundo rustica*	Passeriformes	Hirundinidae
31	Common Myna	*Acridotheres tristis*	Passeriformes	Sturnidae
32	Blue Whistling Thrush	*Mypphonus caeruleus*	Passeriformes	Muscicapidae
33	Pied Bushchat	*Saxicola caprata*	Passeriformes	Muscicapidae
34	Long tailed shrike	*Lanius schach*	Passeriformes	Laniidae
35	Red Vented Bulbul	*Pycnonotus cafer*	Passeriformes	Pycnonotidae
36	White capped Redstart	*Chaimarronis leucocephalus*	Passeriformes	Muscicapidae
37	Black Bulbul	*Hypispetes leucocephalus*	Passeriformes	Pycnonotidae
38	Grey Treepie	*Dendrocitta formosae*	Passeriformes	Corvidae

39	White Crested Laughing Thrush	*Garrulax leucolophus*	Passeriformes	Leiotrichidae
40	Common Green Magpie	*Cissa chinensis*	Passeriformes	Corvidae
41	Himalayan Bulbul	*Pycnonotus leucogenys*	Passeriformes	Pycnonotidae
42	Upland pipit	*Anthus Sylvanus*	Passeriformes	Motacillidae
43	Green Backed Tit	*Parus monticulus*	Passeriformes	Paridae
44	House Sparrow	*Passer domesticus*	Passeriformes	Passeridae
45	Large Billed Crow	*Corvus macrorhynchos*	Passeriformes	Corvidae
46	Scarlet Minivet	*Perricrocotus flammeus*	Passeriformes	Campephagidae
47	Wall creeper	*Tichodroma muraria*	Passeriformes	Sittidae
48	Yellow Billed Blue Magpie	*Urocissa flavirostris*	Passeriformes	Corvidae
49	Red Billed Blue Magpie	*Urocissa erythrorhyncha*	Passeriformes	Corvidae
50	Rock Bunting	*Emberiza cia*	Passeriformes	Emberizidae
51	Russet Sparrow	*Passer rutilans*	Passeriformes	Passeridae
52	Straited Bulbul	*Pycnonotus striatus*	Passeriformes	Pycnonotidae
53	Black Throated Tit	*Aegithalos concinnus*	Passeriformes	Aegithalidae
54	Grey Winged Blackbird	*Turdus boulboul*	Passeriformes	Turdidae
55	Black Loved Tit	*Parus xanthogenys*	Passeriformes	Paridae
56	Mountain Bulbul	*Ixos mcclellandii*	Passeriformes	Pycnonotidae
57	Rufous Sibia	*Malacias capistratus*	Passeriformes	Leiotrichidae
58	Green Tailed Sunbird	*Aethopyga nipalensis*	Passeriformes	Nectariniidae

59	Verditer Flycatcher	*Eumyias thalassinus*	Passeriformes	Muscicapidae
60	Red Billed Chough	*Pyrrhocorax pyrrhocorax*	Passeriformes	Corvidae
61	Variegated Laughing Thrush	*Garrulax variegatus*	Passeriformes	Leiotrichidae
62	Eurasian Crag Martin	*Ptyonoprogne rupestris*	Passeriformes	Hirundinidae
63	Ashy Throated Warbler	*Phylloscopus maculipennis*	Passeriformes	phylloscopidae
64	Grey Sided Bush Warbler	*Cettia brunnifrons*	Passeriformes	Scotocercidae
65	Alphine Chough	*Pyrrhocorax graculus*	Passeriformes	Corvidae
66	Great Tit	*Parus major*	Passeriformes	Paridae
67	Straited Prinia	*Prinia crinigera*	Passeriformes	Cisticolidae
68	Paddy Field Pipit	*Anthus rufulus*	Passeriformes	Motacillidae
69	Rufous Billed Niltava	*Niltava sundara*	Passeriformes	Muscicapidae
70	Straited Laughing Thrush	*Garrulax striatus*	Passeriformes	Leiotrichidae
71	Black Throated Sunbird	*Aethopyga saturata*	Passeriformes	Nectariniidae
72	Dark Breasted Rosefinch	*Carpodacus nipalensis*	Passeriformes	Fringillidae
73	Crested Bunting	*Melophus lathami*	Passeriformes	Emberizidae
74	Blue Capped Rock Thrush	*Monticola cinclorhynchus*	Passeriformes	Muscicapidae
75	Scaly Thrush	*Zoothera dauma*	Passeriformes	Turdidae
76	Little Pied Flycatcher	*Ficedula westermanni*	Passeriformes	Muscicapidae
77	White Browed Bush Robin	*Tarsiger indicus*	Passeriformes	Muscicapidae

78	Orange Headed Thrush	*Zoothera citrina*	Passeriformes	Turdidae
79	Grey Wagtail	*Motacilla cinerea*	Passeriformes	Motacillidae
80	Streaked Laughing Thrush	*Garrulax squamatus*	Passeriformes	Leiotrichidae
81	Hoary Throated Barwing	*Actinodura nipalensis*	Passeriformes	Leiotrichidae
82	Black Winged Cuckoo Shrike	*Coracina melaschistos*	Passeriformes	Campephagidae
83	Pale Blue Flycatcher	*Cyornis unicolor*	Passeriformes	Muscicapidae
84	Indian Blue Robin	*Luscinia brunnea*	Passeriformes	Muscicapidae
85	White Tailed Nuthatch	*Sitta himalayensis*	Passeriformes	Sittidae
86	White crested Laughing Thrush	*Garrulax leucolophus*	Passeriformes	Leiotrichidae
87	Grey Hooded Warbler	*Phylloscopus xanthoschistos*	Passeriformes	phylloscopidae
88	Mrs Gould Sunbird	*Aethopyga gouldiae*	Passeriformes	Nectariniidae
89	Spot Winged Rosefinch	*Carpodacus rodopeplus*	Passeriformes	Fringillidae
90	Oriental White Eye	*Zosterops palpebrosus*	Passeriformes	Zosteropidae
91	Aberrant Bush Warbler	*Cettia flavolivacea*	Passeriformes	Scotocercidae
92	Spot Winged Grosbeak	*Mycerobas melanozanthos*	Passeriformes	Fringillidae
93	Rufous Fronted Tit	*Aegithalos iouschistos*	Passeriformes	Aegithalidae
94	Spiny Babbler	*Turdoides nipalensis*	Passeriformes	Leiotrichidae
95	Common Stonechat	*Saxicola leucurus*	Passeriformes	Muscicapidae
96	Grey Back shrike	*Lanius tephronotus*	Passeriformes	Laniidae

97	Common Rosefinch	*Carpodacus erythrinus*	Passeriformes	Fringillidae
98	Hodgson's Redstart	*Phoenicurus hodgsoni*	Passeriformes	Muscicapidae
99	Himalayan Bluetail	*Tarsiger rufilatus*	Passeriformes	Muscicapidae
100	Great Egret	*Casmerodius albus*	Pelecaniformes	Ardeidae
101	Indian Pond Heron	*Ardeola grayii*	Pelecaniformes	Ardeidae
102	Little Egret	*Egretta garzetta*	Pelecaniformes	Ardeidae
103	Cattle Egret	*Bubulcus ibis*	Pelecaniformes	Ardeidae
104	Intermediate Egret	*Mesophoyx intermedia*	Pelecaniformes	Ardeidae
105	Grey Headed Woodpecker	*Dendropicos spodocephalus*	Piciformes	Picidae
106	Great Barbet	*Megalaima Virens*	Piciformes	Megalaimidae
107	Blue Throated Basbet	*Megalaima asiatica*	Piciformes	Megalaimidae
108	Darjeeling Woodpecker	*Dendrocopos darjellensis*	Piciformes	Picidae
109	Golden Throated Barbet	*Megalaima franklinii*	Piciformes	Megalaimidae
110	Fulvous Breasted Woodpecker	*Dendrocopos macei*	Piciformes	Picidae
111	Slaty Headed Parakeet	*Psittacula himalayana*	Psittaciformes	Psittacidae
112	Collared Owlet	*Glaucidium brodiei*	Strigiformes	Strigidae

III. List of birds, their feeding guilds, season of occurrence and IUCN categories

SN	Bird	Feeding Guild	Season	IUCN
1	Great Egret	Carnivorous	Summer	LC
2	Indian Pond Heron	Carnivorous	Winter	LC
3	White browed wagtail	Insectivorous	Both	LC
4	Little Egret	Carnivorous	Both	LC
5	Black drongo	Insectivorous	Both	LC
6	Common kingfisher	Carnivorous	Winter	LC
7	Red Wattled Lapwing	Insectivorous	Winter	LC
8	Spotted Forktail	Omnivorous	Winter	LC
9	Blue Eared Kingfisher	Carnivorous	Winter	LC
10	Plumbeous Water Redstart	Omnivorous	Both	LC
11	Grey Bushchat	Insectivorous	Both	LC
12	Egyptian Vulture	Insectivorous	Both	**EN**
13	River Lapwing	Carnivorous	Winter	**NT**
14	Ashy Drongo	Insectivorous	Both	LC
15	Oriental Turtle Dove	Insectivorous	Both	LC
16	House Crow	Frugivorous	Both	LC
17	Barn Swallow	Omnivorous	Both	LC
18	Common Myna	Insectivorous	Both	LC
19	White Throated Kingfisher	Omnivorous	Both	LC
20	Lesser Coucal	Carnivorous	Both	LC
21	Blue Whistling Thrush	Insectivorous	Winter	LC
22	Pied Bushchat	Insectivorous	Both	LC
23	Long tailed shrike	Insectivorous	Both	LC
24	Spotted dove	Frugivorous	Both	LC
25	Red Vented Bulbul	Frugivorous	Both	LC
26	White capped Redstart	Insectivorous	Winter	LC
27	Black Bulbul	Frugivorous	Both	LC
28	Grey Treepie	Carnivorous	Both	LC
29	White Crested Laughing Thrush	Insectivorous	Winter	LC
30	Common Green Magpie	Carnivorous	Winter	LC
31	Grey Headed Woodpecker	Insectivorous	Both	LC
32	Himalayan Bulbul	Frugivorous	Both	LC
33	Upland pipit	Insectivorous	Winter	LC
34	Green Backed Tit	Omnivorous	Both	LC
35	House Sparrow	Frugivorous	Both	LC
36	Large Billed Crow	Omnivorous	Both	LC
37	Scarlet Minivet	Insectivorous	Winter	LC
38	Wall creeper	Insectivorous	Summer	LC
39	Black kite	Omnivorous	Winter	LC
40	Yellow Billed Blue Magpie	Omnivorous	Both	LC
41	Red Billed Blue Magpie	Omnivorous	Both	LC

42	Rock Bunting	Omnivorous	Winter	LC
43	Russet Sparrow	Frugivorous	Winter	LC
44	Straited Bulbul	Omnivorous	Winter	LC
45	Black Throated Tit	Insectivorous	Winter	LC
46	Grey Winged Blackbird	Insectivorous	Both	LC
47	Great Barbet	Frugivorous	Both	LC
48	Eurasian Cuckoo	Insectivorous	Both	LC
49	Black Loved Tit	Insectivorous	Both	LC
50	Mountain Bulbul	Frugivorous	Both	LC
51	Speckled Wood Pigeon	Frugivorous	Winter	LC
52	Rufous Sibia	Frugivorous	Both	LC
53	Green Tailed Sunbird	Frugivorous	Both	LC
54	Black Francolin	Frugivorous	Winter	LC
55	Blue Throated Basbet	Frugivorous	Winter	LC
56	Kalij Pheasant	Omnivorous	Winter	LC
57	Verditer Flycatcher	Insectivorous	Both	LC
58	Common Pigeon	Frugivorous	Both	LC
59	Red Billed Chough	Insectivorous	Both	LC
60	Collared Owlet	Carnivorous	Both	LC
61	Variegated Laughing Thrush	Insectivorous	Winter	LC
62	Darjeeling Woodpecker	Insectivorous	Both	LC
63	Eurasian Crag Martin	Insectivorous	Winter	LC
64	Ashy Throated Warbler	Insectivorous	Winter	LC
65	Grey Sided Bush Warbler	Insectivorous	Winter	LC
66	Alphine Chough	Omnivorous	Winter	LC
67	Goosander	Carnivorous	Winter	LC
68	Cattle Egret	Insectivorous	Summer	LC
69	Intermediate Egret	Carnivorous	Summer	LC
70	Great Tit	Insectivorous	Summer	LC
71	Straited Prinia	Insectivorous	Summer	LC
72	Paddy Field Pipit	Insectivorous	Both	LC
73	Barred Cuckoo Dove	Frugivorous	Summer	LC
74	Indian Cuckoo	Insectivorous	Summer	LC
75	Golden Throated Barbet	Frugivorous	Summer	LC
76	Rufous Billed Niltava	Insectivorous	Summer	LC
77	Slaty Headed Parakeet	Frugivorous	Summer	LC
78	Hoopoe	Insectivorous	Summer	LC
79	Straited Laughing Thrush	Insectivorous	Summer	LC
80	Black Throated Sunbird	Frugivorous	Summer	LC
81	Dark Breasted Rosefinch	Frugivorous	Summer	LC
82	Crested Bunting	Frugivorous	Summer	LC
83	Himalayan Vulture	Carnivorous	Summer	**NT**
84	Blue Capped Rock Thrush	Insectivorous	Summer	LC
85	Scaly Thrush	Insectivorous	Summer	LC
86	Little Pied Flycatcher	Insectivorous	Summer	LC

87	White Browed Bush Robin	Insectivorous	Summer	LC
88	Orange Headed Thrush	Insectivorous	Summer	LC
89	Grey Wagtail	Insectivorous	Summer	LC
90	Streaked Laughing Thrush	Insectivorous	Summer	LC
91	Hoary Throated Barwing	Insectivorous	Summer	LC
92	Black Winged Cuckoo Shrike	Insectivorous	Summer	LC
93	Pale Blue Flycatcher	Insectivorous	Summer	LC
94	Wedge Tailed Green Pigeon	Frugivorous	Summer	LC
95	Indian Blue Robin	Insectivorous	Summer	LC
96	White Tailed Nuthatch	Insectivorous	Summer	LC
97	White crested Laughing Thrush	Insectivorous	Summer	LC
98	Grey Hooded Warbler	Insectivorous	Summer	LC
99	Mrs Gould Sunbird	Frugivorous	Summer	LC
100	Spot Winged Rosefinch	Frugivorous	Summer	LC
101	Oriental White Eye	Omnivorous	Summer	LC
102	Aberrant Bush Warbler	Insectivorous	Summer	LC
103	Fulvous Breasted Woodpecker	Insectivorous	Summer	LC
104	Spot Winged Grosbeak	Frugivorous	Summer	LC
105	Rufous Fronted Tit	Insectivorous	Summer	LC
106	Spiny Babbler	Insectivorous	Summer	LC
107	Common Stonechat	Insectivorous	Winter	LC
108	Grey Back shrike	Insectivorous	Winter	LC
109	Common Rosefinch	Frugivorous	Both	LC
110	Hodgson's Redstart	Insectivorous	Winter	LC
111	Himalayan Buzzard	Carnivorous	Winter	LC
112	Himalayan Bluetail	Insectivorous	Winter	LC

IV. List of seasonal monthly mean precipitation and monthly mean temperature

	Winter	Winter	Summer	Summer
Point Name	Precipitation (ppm)	Temperature (°C)	Precipitation (ppm)	Temperature (mean),°C
p1	17	14.1	489	24.1
p2	15	13.9	435	23.7
p3	13	12.8	461	22.7
p4	14	13.4	421	23.3

p5	12	12.9	460	22.6
p6	13	13	479	22.9
p7	10	12.1	501	21.8
p8	10	11.7	520	21.5
p9	9	11.3	531	21.1
p10	7	9.2	598	19.3
p11	13	7.9	402	18.4
p12	11	8.4	471	18.8
p13	13	8	410	18.5
p14	15	7.4	350	18.1
p15	19	6.7	262	17.5
p16	18	6.6	260	17.5
p17	18	6.8	282	17.7
p18	19	6.2	227	17.3
p19	21	5.6	166	16.7
p20	22	5.2	128	16.3
p21	23	4.7	107	15.9

V. List of point count sites with their distance to nearest settlement and water source

Point Name	Distance to nearest source of water (m)	Distance to nearest settlement (m)
p1	0	50
p2	50	100
p3	200	50
p4	100	405
p5	294	240
p6	550	30
p7	759	360
p8	908	240
p9	1050	65
p10	1725	465
p11	2940	1452
p12	2856	980
p13	2475	630
p14	2241	375
p15	1856	20
p16	1848	270
p17	2066	723
p18	2461	1146
p19	2854	456
p20	2946	213
p21	3074	20

VI. List of Photoplates

Himalayan Vulture (*Gyps himalayensis*) Barred Cuckoo Dove (*Macropygia unchall*)

Egyptian Vulture (*Neophron percnopterus*)River Lapwing (*Vanellus duvaucelli*)

Landscape of Mardi Himal trekking route

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