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Bird diversity along an elevational gradient in Shivapuri Nagarjun National Park, Nepal

Nabina Kunwar[1], Naresh Pandey[1], K. Deepak Singh[1] and Bishnu Prasad Bhattarai[1,2*]

[1]Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
[2]Nepal Zoological Society, Kirtipur, Kathmandu, Nepal

**Email: bishnu.bhattarai@cdz.tu.edu.np*

Abstract

Shivapuri Nagarjun National Park (SNNP) plays an important role in global biodiversity conservation, but research based on avian diversity along elevation gradients has not been studied yet. Therefore, this study aims to explore avian diversity, its pattern, and environmental variables affecting bird species richness along elevation gradients. The point count method was carried out in the monsoon season (June and July) in 2019. Data for environmental variables including elevation, distance to settlement, distance to nearest water sources, temperature, and precipitation were assessed with respect to the feeding guild. A total of 130 species of bird belonging to 40 families and 12 orders were recorded including the Steppe eagle (endangered species) and Spiny Babbler (only endemic bird of Nepal), which indicate that SNNP supports avian diversity. Diversity indices showed diverse bird community assemblage such as the Shannon-Weiner diversity index (H'=2.65), Simpson diversity index (0.92), and evenness index E=0.94). Our study revealed insectivores were dominating among others and the order Passeriformes had the high species richness. Our observation revealed that the bird species richness was significantly greater at lower elevations than at mid and high elevations, showing a clear monotonic decline in species richness and diversity with increasing elevation. In the case of feeding guild (insectivores, omnivores, frugivores, and carnivores), most of the bird species showed a significant relationship with environmental variables (elevation, distance to settlement, distance to nearest water sources, temperature, and precipitation). It was concluded that not only environmental factors are responsible for affecting avian diversity but elevational gradients consisting of heterogeneous habitats can also play an important role in shaping avian diversity patterns.

Keywords: Diversity, elevation, environmental variable, feeding guild, monotonic

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Introduction

Bird diversity act as a strong bio-indicator signal (Bhatt and Joshi, 2011). They represent the health of ecosystem as they are sensitive to environmental change and status of biodiversity as a whole (Chettri, 2010; Pierson, Barton, Lane and Lindenmayer, 2015). Understanding the different species including bird diversity is an integral part of biodiversity conservation (Kremen, 1992). An extensive study on diversity of bird have been done in global label (Hawkins and Porter, 2001; McCain, 2009). The existence of an elevational gradient of species richness has long been recognized and been studying in ecology (Lomolino, 2001; Stevens, 1992). Bird species richness along the elevational gradient has been found to reveal four distinct patterns i.e. decreasing richness with increasing elevation, low-elevation plateaus, low-elevation plateaus with mid elevational peak and mid-elevational peaks (McCain, 2009). Among them,

the most common patterns seem to be either decreasing richness with increasing elevation or a hump-shaped pattern, in which diversity peaks at mid-elevations (McCain, 2009; Rahbek, 1995, 2005). Several factors like climate, productivity, mass effects, species-area relationships, Mid-Domain Effects, geomorphic constraints, evolutionary history, habitat structure and human-induced disturbances play an important role in avian elevational diversity pattern (Colwell, Rahbek and Gotelli, 2004). Species richness and the composition of birds often change rapidly with elevation (Blake and Loiselle, 2000; Williams, Shoo, Henriod and Pearson, 2010) which makes these gradients well suited for studying the responses of bird communities to different environmental factors (Korner, 2007; McCain, 2009).

The study of avian diversity, corresponding to their feeding guilds plays an important role in understanding the complexity of ecosystem structure and also provides information on different types of habitats (Azman *et al*., 2011). Knowledge of feeding guild is important for improving effectiveness in maintaining bird diversity (Li *et al*., 2019). Variation in vegetation structure affects the distribution of bird diversity and their feeding guilds (Pearman, 2002). Some birds, especially insectivores, are habitat specialists and are sedentary (Hu *et al*., 2018; Zhang, Kissling and He, 2013).

Understanding the relationship between species richness and different environmental factors is an integral part of avian conservation and protection (Mittelbach *et al*., 2001). The greatest number of bird diversity was recorded in slopes which consist of heterogeneous habitats and monotonic decline in species richness in the Central Himalayas (Basnet, Rokaya, Bhattarai and Münzbergová, 2016). Bird species richness in Eastern Himalaya gradient was high at mid-elevational range and was found significantly correlated with primary productivity and habitat suitability (Acharya, Sanders, Vijayan and Chettri, 2011). In Western Himalayas of Uttarakhand showed hump-shaped elevational richness and was significantly correlated with species richness and vegetation structure (Joshi and Bhatt, 2015). Climatic variables are also considered the main driver of bird diversity (McCain, 2009) and temperature shows a distinct pattern which gets decreases with increasing altitude, which directly affects the physiological tolerance of birds (Currie *et al*., 2004; Pan *et al*., 2016).

Out of 886 species of birds recorded from Nepal, Shivapuri Nagarjun National Park (SNNP) consists of 318 species of birds (BCN and DNPWC, 2018), which indicate SNNP as an Important Birds and Biodiversity Area (IBA) (Baral and Inskipp, 2005). Diversity and distribution of birds have been immensely studied in national parks, including SNNP. Though, SNNP is rich in avian diversity, but research based on elevational gradient has not been explored yet, therefore this study aimed to (i) explore avian diversity along the elevational gradients (ii) assess the elevational pattern of birds and bird response to different environmental variables affecting the richness pattern.

Materials and Methods

Study area

The study was conducted in SNNP from an initial point carried out at Sundarijal (27° 45' N and 85° 25' E) along with elevation gradient ranging from 1350 m to 2732 m (Peak). The SNNP was established in 2002 and is located in the country's mid-hills on the northern fringe of the Kathmandu valley and named after Shivapuri Peak of 2,732 m altitude. It covers an area of 159 km^2 (144 km^2 designated as Shivapuri forest and 15 km^2 as Nagarjun forest). The floral composition of the park has been categorized into four types viz. i) lower mixed hardwood forests ii) chirpine forests, iii) oak forests and iv) upper mixed hardwood forests. The major plant species found are *Schima wallichii, Castonopsis indica, Pinus roxburghii, Myrica esculenta, Pyrus pasia, Rhododendron arboreum, Juglans regia* and *Quercus* sp. (SNNP, 2010).

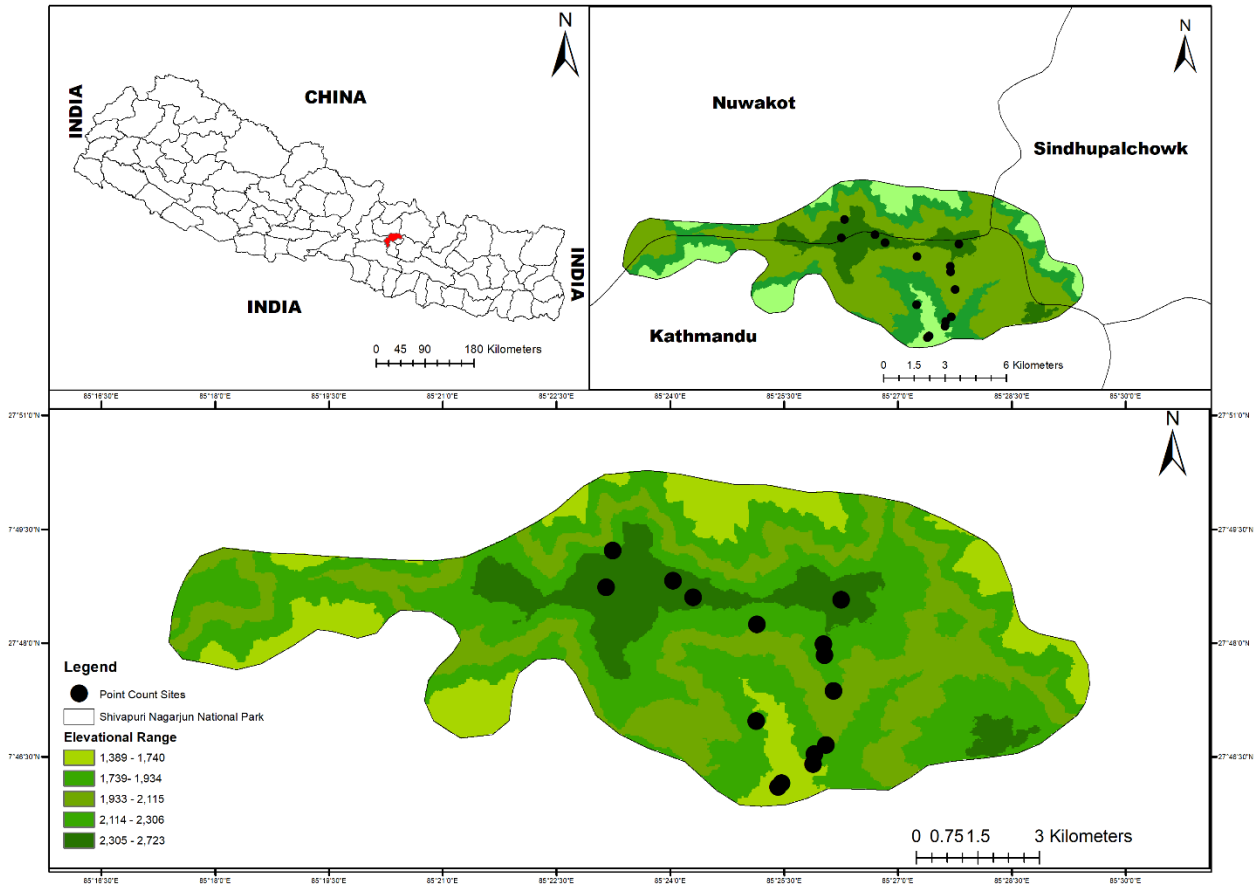

Figure 1. Map of the study area showing Shivapuri Nagarjun National Park showing point count sites.

Bird survey

Bird survey was carried out using point count method (Bibby, Burgess, Hill and Mustoe, 2000) which has been widely used for bird surveys. Observer records all birds detected (seen or heard) within a fixed point in a center (Petit, Petit, Saab and Martin, 1995; Ralph, Sauer and Droege, 1995). Bird count was conducted in the monsoon season from 15 June to 10 July 2019. A total of 15-point count locations were made in every 100 m altitudinal differences by using Garmin Etrex 10 GPS. The birds were observed for 10-20 min in each point count by using binoculars (10×50 wide angle) and photographs were taken using Nikon P1000 camera. Birds observed and heard within a 50 m radius were recorded from a fixed point. Incorporating a longer count period is advantageous in subtropical forests where many birds are cryptic and the vegetation structure birds may be hard to locate (Riley, 2003). Bird count was done from 6:30 a.m. to 11 a.m. in morning and 4 p.m. to 7 p.m. in evening under favorable condition. This time was the most efficient time for birders because most birds start foraging early in the morning after long sleep at night and in the evening before returning to their nests. For identification, nomenclature and systematic order of birds, field book Birds of Nepal (Grimmett, Inskipp, Inskipp and Baral, 2016) was used. Environmental variable like Distance to settlement (DTS) and Distance to the nearest water surface (DTW) was measured by using Google earth. The climate data of resolution 1km×1km on mean monthly precipitation and mean monthly temperature based on the coordinates of bird-count points were extracted from the World Clim database (https://www.worldclim.org/bioclim).

Data analysis

The data collected after the bird survey was interpreted and classified into four feeding guilds based on diet described in (Dangaura, Pandey, Chand and Bhusal, 2020; Katuwal *et al*., 2018) as insectivores (feeding predominantly on insects, larvae, worms, spiders), omnivores (feeding on both plants and animals), frugivores (feeding on fruits, berries, figs, drupes and nectars), and carnivores (feeding on fishes, amphibians, reptiles, birds and mammals). Birds were classified as residents, summer visitors, winter visitors and passage migrants based on (Grimmett *et al*., 2016). Shannon- Weiner (H) diversity index, Simpson diversity index and evenness index for the diversity of the birds were calculated by using PAST (V.3.04). Species response to elevation and environmental variations was established by Generalized Linear Model (GLM).

Results

Bird diversity

A total of 841 individuals of 130 bird species belonging to 40 families and 12 orders were recorded by point count method in the SNNP including Steppe Eagle (endangered species) and the only endemic bird of Nepal, Spiny Babbler (Annex I). Out of the 12 orders, order Passeriformes had the highest species richness (96) which alone occupied (73.84%) of total bird species, followed by Piciformes (7), Cuculiformes (7), whereas Pelacaniformes, Falconiformes and Galliformes had least bird species (1). Similarly, the highest number of bird species belong to family Muscicapidae (23) followed by Cuculidae (7), and Corvidae (7) (Figure 2). Guild structure analysis revealed that insectivore was the abundant guild (71) followed by omnivore (34), frugivore (16) and carnivore (9) (Figure 3). Resident species (106 species) had highest species richness followed by summer visitors (19 species), winter visitors (3 species) and passage migrants (2 species).

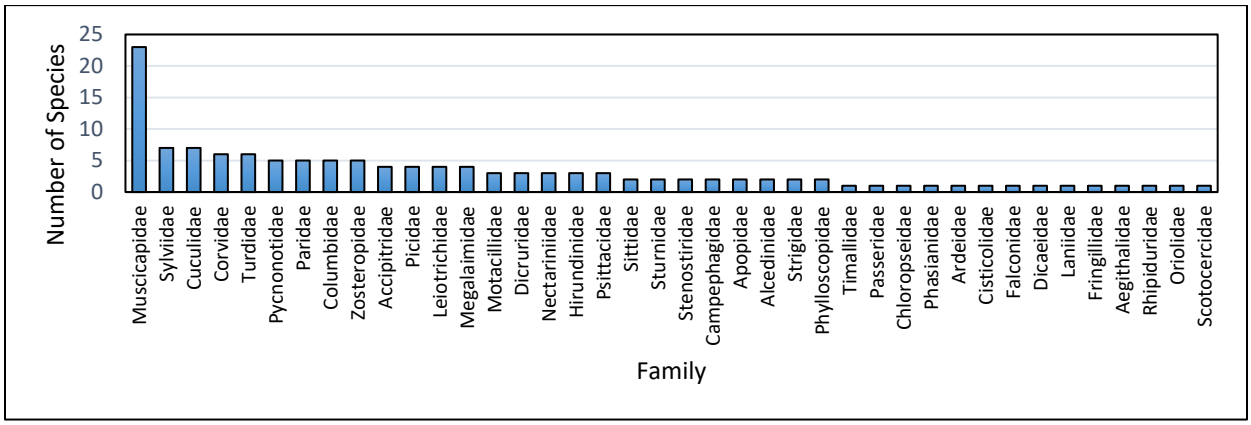

Figure 2. Number of bird species in different families observed in SNNP

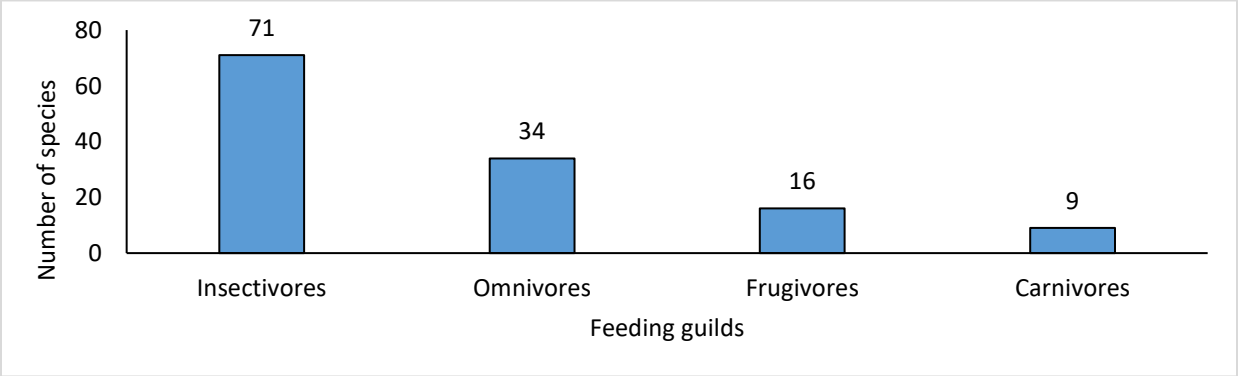

Figure 3. Species richness in different feeding guilds of birds observed in SNNP

Table 1. Bird species richness along elevational gradients

Site (Elevation)	Species richness	Shannon Wiener index (H')	Simpson Diversity Index
Sundarijal (Total)	130	2.65	0.92
S1 (1300m asl)	20	2.996	0.95
S2 (1400m asl)	25	3.219	0.96
S3 (1500m asl)	18	2.89	0.94
S4 (1600m asl)	16	2.773	0.94
S5 (1700m asl)	22	3.091	0.95
S6 (1800m asl)	12	2.485	0.92
S7 (1900m asl)	18	2.89	0.94
S8 (2000m asl)	12	2.485	0.92
S9 (2100m asl)	18	2.89	0.94
S10 (2200m asl)	19	2.944	0.95
S11 (2300m asl)	12	2.485	0.92
S12 (2400m asl)	10	2.303	0.90
S13 (2500m asl)	11	2.398	0.90
S14 (2600m asl)	9	2.197	0.89
S15 (2700m asl)	7	1.946	0.86

In case of distribution pattern, monotonically decrease in species richness with increasing elevation was observed (Figure 4). Bird species richness was significantly higher at 1400m asl and lower at 2700m asl. Various diversity indices were calculated and found Shannon-Weiner diversity index (H'=2.65) was observed in Sundarijal. Similarly, Simpson diversity index was (0.92) and evenness index was (E=0.94) indicating diverse bird assemblage. Site-wise diversity indices revealed that highest diversity was found in point count site 2 at 1400m asl.

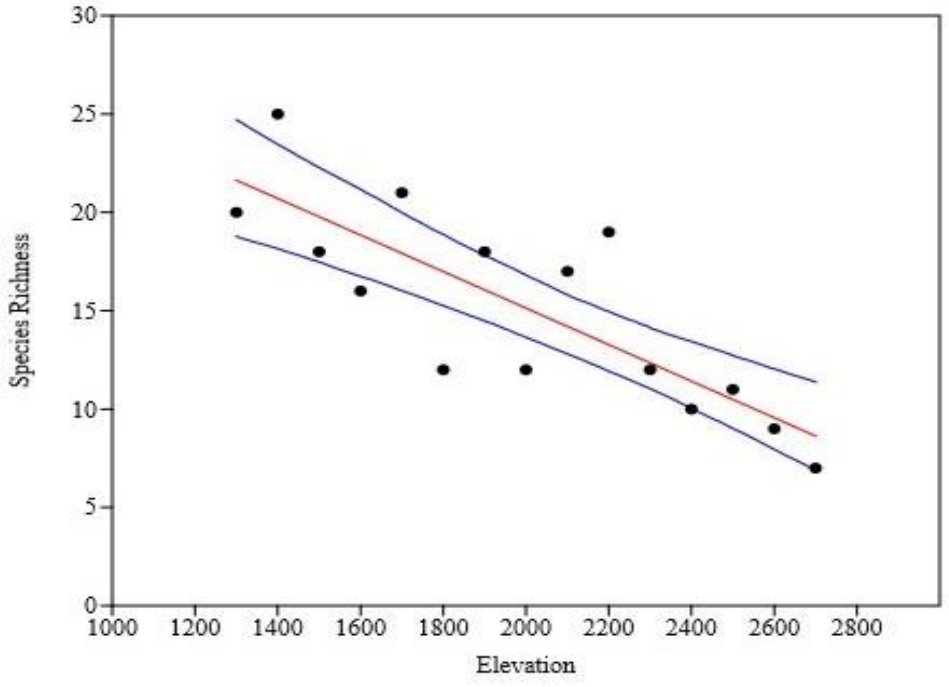

Figure 4. Distribution pattern of bird species richness along elevational gradient in SNNP.

Environmental factors affecting diversity

From the Generalized Linear Model (GLM), avian richness differed significantly with altitude, DTS, DTW, temperature and precipitation. For instance, insectivorous species richness showed significant relationship with altitude, DTS, temperature and precipitation. Similarly, omnivorous species richness showed significant relationship with altitude and temperature. Frugivorous species richness showed significant relationship with altitude, DTS, temperature and precipitation. In case of carnivorous species altitude, DTW, temperature and precipitation showed significant relationship.

Table 2. Generalized linear model (GLM) with normal distribution and identity link function test showing the effects of different environmental factors on avian richness pattern. Values marked in italics are statistically significant at $P < 0.05$.

Species	Variables	Slope	Intercept	P-value
Total species	Altitude	-0.00928	33.705	*0.005*
	DTS	-129.33	2832.7	*>0.001*
	DTW	-123.06	2325.7	*>0.001*
	Temperature	0.239	11.597	*>0.001*
	Precipitation	1.6176	173.05	*>0.001*
Insectivores	Altitude	-0.00225	11.3	*>0.041*
	DTS	-309.2	2978.2	*0.005*
	DTW	47.123	647.23	0.688
	Temperature	0.380	12.635	*>0.035*
	Precipitation	3.474	173.91	*>0.011*
Omnivores	Altitude	-0.002214	9.2952	*>0.006*
	DTS	-245.64	2071	0.127
	DTW	-107.3	1489.3	0.457
	Temperature	0.509	12.745	*>0.020*
	Precipitation	3.1714	182.1	0.092
Frugivores	Altitude	-0.003571	9.8762	*>0.001*
	DTS	-259.22	1584.1	*>0.023*
	DTW	-177.18	1452	0.085
	Temperature	0.5312	13.772	*>0.001*
	Precipitation	3.2579	188.63	*>0.014*
Carnivores	Altitude	-0.00125	3.2333	*>0.004*
	DTS	-438.54	1197.2	0.194
	DTW	-506.9	1339.4	*>0.048*
	Temperature	1.482	14.137	*>0.001*
	Precipitation	7.482	14.137	*>0.001*

Discussion

A diverse bird community was observed in SNNP during this study period. However, the number of bird species recorded in this study seemed low compared to the record of 318 species found in SNNP (BirdLife Nepal, 2018) which is the official checklist of birds that covers all sites of SNNP in all four seasons over a long period of time but our study was only limited in one trekking trail i.e., Sundarijal and only covers monsoon season. Insectivores were the most abundant species feeding guild in SNNP which is supported by many other studies on birds (Katuwal et *al*., 2016; Neupane, Khanal, Gyawali and Chalise, 2020; Pandey, Khanal, and Chalise, 2020). Bird Species belonging to Order Passeriformes were numerically most abundant in SNNP which is similar to study done by (Husein and Sultan, 2009) in mountainous landscape in Nansebo Forest of Southern Ethiopia as well as (Jha, 2020) in Nagarjun forest of SNNP revealed same result. Diversity indices were calculated and found that lower elevations have

diverse bird community compared to higher elevation. Diversity indices of whole study area showed diverse bird assemblage with decrease in species richness with increasing elevation in SNNP. A similar pattern was also observed in other studies (McCain, 2009; Neupane *et al*., 2020; Rahbek, 1995; Santhakumar, Arun, Sony, Murugesan and Ramesh, 2018). This is due to significant decrease in plant species richness with increase in elevation along sub-tropical gradient in the Himalayas which had provided different habitats for various avian species (Bhattarai, Vetaas and Grytnes, 2004). Decline in species richness was found to have been associated with decline in forest area at higher elevations due to declines in abundance and distribution of invertebrates, competition for life essence and changes in environmental conditions (Janes, 1994). Pan *et al*., (2016) revealed that the species richness of overall birds are positively correlated with forest habitat, productivity and habitat heterogeneity. According to the study done by (Fleishman, Austin and Weiss, 1998) in butterfly and (Fisher, 1996) in ant species also revealed monotonic decline in species richness as elevation increases, which directly (food) or indirectly (pollination) justifies the monotonic decline in avian species richness as elevation increases.

But a few studies revealed higher species richness at mid elevational range in compared to lower and higher elevations (Ding *et al*., 2019; Hu *et al*., 2018; Pandey *et al*., 2020). Similarly, the present study also recorded higher species richness at 1700m, 1900m and 2200m. This is due to the human settlement with agricultural field which provides very relevant source of food to many birds in the form of fruits, grains, insects, rodents, etc. that helps in increasing bird richness (Chettri, Deb, Sharma and Jackson, 2005). Agricultural land and human settlement area have played an important role as habitat, shelter and resources to species (Ferger, Schleuning, Hemp, Howell and Böhning-Gaese, 2014; Schaub *et al*., 2010). Due to less productive environment at higher altitudes cause a decline in abundance and distribution of invertebrate resources leads to lack of food items for birds and favors a very low number of species (Blake and Loiselle, 2000; Hu *et al*., 2018).

In case of environmental variables and their relationship with avian diversity, total species of birds showed significant relationship ($P < 0.05$) with all the environmental variables such as altitude, DTS, DTW, Temperature and Precipitation. It was found that most of the environmental variables of subtropical region along the elevation gradient show positive significant relationship with avian diversity (Chettri *et al*., 2005; Pandey *et al*., 2020). Specifically, (McCain, 2009) revealed the positive relationship between temperature and bird diversity, in shaping bird diversity along elevational gradients. Previous study showed that temperature is not the only climatic factor affecting bird diversity patterns (McCain, 2009; McCain and Grytnes, 2010) but precipitation also plays important role in shaping biodiversity in tropical ecosystems (Hawkins and Porter, 2001). Similarly, (Fraga, 1989) revealed that habitat having disturbed area like agricultural field may have the higher number of flowering plants, different fruiting plants under open conditions which attract frugivore bird. As well (Elphick, Taft and Lourenço, 2010; Laiolo, 2004) also revealed agricultural field, cultivation of rice, wheat and corn greatly attract granivore birds so they mostly prefer farm land consisting agricultural field due to easy access to food. But in case of feeding guilds (different feeding habitat), such as insectivore, omnivore, frugivore and carnivore shows variable relationships with their surrounding environment. For instance, insectivorous and frugivore birds had shown a significant relationship ($P < 0.05$) with most of the environmental variables except DTW. This is due to the fact that, during the study period, there was an adequate rainfall (monsoon period) which have made water availability more prominent around themselves then to depend upon major nearby water sources (Studds and Marra, 2011). In case of frugivore, they fed on fruits such as berries (blueberries, raspberries, mulberries, etc.) which are usually rich in water content (Pesotskaya, Chaplygina, Kratenko and Shupova, 2020).

Similarly, carnivorous bird species richness had also shown a significant relationship with most of the environmental variables except DTS which did not showed significant relationship with bird species. This might be due to lack of food availability around or near settlements as human either burry or throw the dead carcasses (domestic animals) far away from their settlements. According to (MacGregor-Fors, Morales-Pérez and Schondube, 2011) bird species richness values were approximately 30% lower in human settlements

than in shrub lands. As well (Samia, Nakagawa, Nomura, Rangel and Blumstein, 2015) revealed that human alters the prey distribution of carnivore bird species which reduced foraging efficiency of carnivore birds as well as they are less tolerant to human. But in case of omnivorous bird species, they had showed a positive relationship ($P < 0.05$) with only few of the environmental variables such as altitude, precipitation and Temperature. This is because omnivores have diverse kind of feeding habit like insects, crops, ripen fruits, nuts or grains according to available limited resources and conditions which allows them to have a broad range of choices and take advantage of more food sources for better survival (Abbas *et al*., 2019). The wide dietary range of omnivorous birds allows them to adapt easily to other food source, if their preferred food sources become scarce (Azman *et al*., 2011).

Conclusion

This study highlights the avian diversity along elevational gradients in SNNP which act as a IBAs. The assemblage of avian species richness in SNNP displayed decrease in species richness pattern with increasing elevational gradients. Elevational gradients not only supports species richness due to heterogenic habitats but also different species belonging to different feeding guild. Similarly, environmental variables like altitude, temperature, precipitation, DTS and DTW play an important role and showed significant relationship in avian richness and diversity patterns. However, during our study period, the study area was highly disturbed due to heavy construction (dam), settlements and frequent trekking activities which might affect the bird diversity. Thus, proper habitat conservation and integrated management should be implemented along the trekking trails and human settlement which plays vital role in sustaining avian diversity and their natural habitats for future generations.

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References

Abbas, S., E. Hussain , H. Abbas , S. Hussain, R. Tabassum , M.Z. Khan and M. Nabi 2019. Species diversity, feeding habits and conservation status of birds in Qurumbar National Park, Gilgit-Baltistan, Pakistan. *International Journal of Zoological Investigations, **5***(2): 108-117.

Acharya, B.K., N.J Sanders, L. Vijayan and B. Chettri 2011. Elevational gradients in bird diversity in the Eastern Himalaya: an evaluation of distribution patterns and their underlying mechanisms. *PLoS One,* **6**(12): e29097.

Adhikari, J.N., B.P. Bhattarai and T.B. Thapa 2019. Factors affecting diversity and distribution of threatened birds in Chitwan National Park, Nepal. *Journal of Threatened Taxa, **11***(5): 13511-13522.

Azman, N.M., N.S.A Latip, S.A.M. Sah, M.A.M.M. Akil, N.J. Shafie and N.L. Khairuddin 2011. Avian diversity and feeding guilds in a secondary forest, an oil palm plantation and a paddy field in Riparian areas of the Kerian River Basin, Perak, Malaysia. *Tropical Life Sciences Research, **22***(2): 45.

Baral, H. S., & Inskipp, C. (2005). Important Bird Areas in Nepal: key sites for conservation: Bird Conservation Nepal.

Basnet, T.B., M.B. Rokaya, B.P. Bhattarai and Z. Münzbergová 2016. Heterogeneous landscapes on steep slopes at low altitudes as hotspots of bird diversity in a Hilly Region of Nepal in the Central Himalayas. *PLoS One, **11***(3): e0150498.

BCN and DNPWC. 2018. Birds of Nepal: An official checklist. Bird Conservation Nepal and Department of National Parks and wildlife Conservation, Kathmandu, Nepal.

Bhatt, D. and K.K. Joshi 2011. Bird assemblages in natural and urbanized habitats along elevational gradient in Nainital district (western Himalaya) of Uttarakhand state, India. *Current Zoology, **57***(3): 318-329.

Bhattarai, K.R., O.R. Vetaas and J.A. Grytnes 2004. Fern species richness along a central Himalayan elevational gradient, Nepal. *Journal of biogeography, **31***(3): 389-400.

Bibby, C.J., N.D. Burgess, D.A Hill and S. Mustoe 2000. *Bird census techniques* (2nd edition ed.): Academic Press.

BirdLife Nepal 2018. Birds of Shivapuri. Retrieved from https://www.birdlifenepal.org/publication-detail/11

Blake, J.G. and B.A. Loiselle 2000. Diversity of birds along an elevational gradient in the Cordillera Central, Costa Rica. *The Auk*, ***117***(3): 663-686.

Chaudhari, U.K., G. Kafle and H.S. Baral 2009. Avifaunal diversity of khata corridor forest. *Journal of Wetlands Ecology*: 48-56.

Chettri, N. 2010. Cross-taxon congruence in a trekking corridor of Sikkim Himalayas: Surrogate analysis for conservation planning. *Journal for Nature Conservation,* ***18***(2): 75-88.

Chettri, N., D.C. Deb, E. Sharma and R. Jackson 2005. The relationship between bird communities and habitat. *Mountain Research and Development,* ***25***(3): 235-243.

Colwell, R.K., C. Rahbek and N.J. Gotelli 2004. The mid-domain effect and species richness patterns: what have we learned so far? *The American Naturalist,* ***163***(3): E1-E23.

Currie, D.J., G.G. Mittelbach, H.V. Cornell, R. Field, J.F. Guégan, B.A. Hawkins and J.R.G Turner 2004. Predictions and tests of climate-based hypotheses of broad-scale variation in taxonomic richness. *Ecology letters,* **7**(12): 1121-1134.

Dangaura, H.L., N. Pandey, D.B. Chand and K.P. Bhusal 2020. Avian richness of the Basanta Protected Forest, far-western lowland Nepal: Implication for conservation. *Nepalese Journal of Zoology*, ***4(***2): 68-84.

Ding, Z., J. Liang, Y. Hu, Z. Zhou, H. Sun, L. Liu and X. Si 2019. Different responses of avian feeding guilds to spatial and environmental factors across an elevation gradient in the central Himalaya. *Ecology and evolution,* ***9***(7): 4116-4128.

Elphick, C.S., O. Taft and P.M. Lourenço 2010. Management of rice fields for birds during the non-growing season. *Waterbirds*: 181-192.

Ferger, S.W., M. Schleuning, A. Hemp, K.M. Howell and K. Böhning-Gaese 2014. Food resources and vegetation structure mediate climatic effects on species richness of birds. *Global Ecology and Biogeography,* ***23***(5): 541-549.

Fisher, B.L. 1996. Ant diversity patterns along an elevational gradient in the Reserve Naturelle Integrale d'Andringitra, Madagascar. *Fieldiana Zoology*: 93-108.

Fleishman, E., G.T. Austin and A.D. Weiss 1998. An empirical test of Rapoport's rule: elevational gradients in montane butterfly communities. *Ecology,* ***79***(7): 2482-2493.

Fraga, R.M. 1989. Interactions between nectarivorous birds and the flowers of Aphelandra sinclairiana in Panama. *Journal of Tropical Ecology,* ***5***(1): 19-26.

Grimmett, R., C. Inskipp, T. Inskipp and H.S. Baral 2016. *Birds of Nepal*: Bloomsbury Publishing.

Hawkins, B.A. and E.E. Porter 2001. Area and the latitudinal diversity gradient for terrestrial birds. *Ecology letters,* ***4***(6): 595-601.

Hu, Y., Z. Ding, Z. Jiang, Q. Quan, K. Guo, L. Tian, and L. Gibson 2018. Birds in the Himalayas: What drives beta diversity patterns along an elevational gradient? *Ecology and evolution,* ***8***(23): 11704-11716.

Husein, Z.J. and M. Sultan 2019. Species Composition and Relative Abundance of Birds at Nansebo Forest, Southern Ethiopia.

Janes, S.W. 1994. Variation in the species composition and mean body size of an avian foliage-gleaning guild along an elevational gradient: correlation with arthropod body size. *Oecologia,* ***98***(3-4): 369-378.

Jha, P.K. 2020. Seasonal Diversity of Birds in Nagarjun Forest of Shivapuri Nagarjun National Park, Kathmandu, Nepal. *Tribhuvan University Journal,* ***35***(1): 33-43. doi:10.3126/tuj.v35i1.35832

Joshi, K. and D. Bhatt 2015. Avian species distribution along elevation at doon valley (foot hills of western Himalayas), Uttarakhand, and its association with vegetation structure. *Journal of Asia-Pacific Biodiversity,* ***8***(2): 158-167.

Katuwal, H.B., K. Basnet, B. Khanal, S. Devkota, S.K. Rai, J.P. Gajurel and M.P. Nobis 2016. Seasonal changes in bird species and feeding guilds along elevational gradients of the Central Himalayas, Nepal. *PLoS One,* ***11***(7): e0158362.

doi:10.1371/journal.pone.0158362

Katuwal, H.B., N.M.B. Pradhan, J.J. Thakuri, K.P. Bhusal, P.C. Aryal and I. Thapa 2018. Effect of urbanization and seasonality in bird communities of Kathmandu Valley, Nepal. *Proceedings of the Zoological Society*, ***71***(2): 103-113. doi:https://doi.org/10.1007/s12595-018-0265-z

Korner, C. 2007. The use of "altitude" in ecological research. Trends in Ecology and Evolution ***22***(11): 569-574.

Kremen, C. 1992. Assessing the indicator properties of species assemblages for natural areas monitoring. *Ecological Applications*, ***2***(2): 203-217.

Laiolo, P. 2004. Diversity and structure of the bird community overwintering in the Himalayan subalpine zone: is conservation compatible with tourism? *Biological Conservation*, ***115***(2): 251-262.

Li, N., Y. Sun, H. Chu, Y. Qi, L. Zhu, Ping, X….. and Z. Jiang 2019. Bird species diversity in Altai riparian landscapes: Wood cover plays a key role for avian abundance. *Ecology and evolution*, ***9***(17): 9634-9643.

Lomolino, M.V. 2001. Elevation gradients of species-density: historical and prospective views. *Global Ecology and Biogeography*, ***10***(1): 3-13.

MacGregor-Fors, I., L. Morales-Pérez and J.E. Schondube 2011. Does size really matter? Species–area relationships in human settlements. *Diversity and distributions*, ***17***(1): 112-121.

McCain, C.M. 2009. Global analysis of bird elevational diversity. *Global Ecology and Biogeography*, ***18***(3): 346-360.

McCain, C. M. and J.A. Grytnes 2010. Elevational gradients in species richness. *eLS*.

Mittelbach, G.G., C.F. Steiner, S.M. Scheiner, K.L. Gross, H.L. Reynolds, R.B Waide,., . . . L. Gough 2001. What is the observed relationship between species richness and productivity? *Ecology*, ***82***(9): 2381-2396.

Neupane, J., L. Khanal, B. Gyawali and M.K. Chalise 2020. Elevational pattern and seasonality of avian diversity in Kaligandaki River Basin, central Himalaya. *Journal of Threatened Taxa*, ***12***(14): 16927-16943.

Pan, X., Z. Ding, Y. Hu, J. Liang, Y. Wu, X. Si, …. . K. Jin 2016. Elevational pattern of bird species richness and its causes along a central Himalaya gradient, China. *PeerJ*, ***4****:* e2636.

Pandey, N., L. Khanal and M.K. Chalise 2020. Correlates of avifaunal diversity along the elevational gradient of Mardi Himal in Annapurna Conservation Area, Central Nepal. *Avian Research*, ***11***(1): 1-14.

Pearman, P.B. 2002. The scale of community structure: habitat variation and avian guilds in tropical forest understory. *Ecological monographs*, ***72***(1): 19-39.

Pesotskaya, V., A .Chaplygina, R. Kratenko, and T. Shupova 2020. Fruit and berry plants of forest belts as a factor of species diversity of ornithofauna during the breeding season and autumn migration period. *Biosystems Diversity*, ***28***(3): 290-297.

Petit, D.R., L.J. Petit, V.A. Saab and T.E. Martin 1995. Fixed-radius point counts in forests: factors influencing effectiveness and efficiency. *In: Ralph, C. John; Sauer, John R.; Droege, Sam, technical editors. 1995. Monitoring bird populations by point counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station: p. 49-56*, 149.

Pierson, J.C., P.S. Barton, P.W. Lane and D.B. Lindenmayer 2015. Can habitat surrogates predict the response of target species to landscape change? *Biological Conservation*, ***184***: 1-10.

Rahbek, C. 1995. The elevational gradient of species richness: a uniform pattern? *Ecography*: 200-205.

Rahbek, C. 2005. The role of spatial scale and the perception of large-scale species-richness patterns. *Ecology letters*, ***8***(2): 224-239.

Rahbek, C. and G.R. Graves 2001. Multiscale assessment of patterns of avian species richness. *Proceedings of the National Academy of Sciences*, ***98***(8): 4534-4539.

Ralph, C.J., J.R. Sauer and S. Droege 1995. Monitoring bird populations by point counts. *Gen. Tech. Rep. PSW-GTR-149. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station. 187 p*, 149.

Riley, J. 2003. Population sizes and the conservation status of endemic and restricted-range bird species on Karakelang, Talaud

Islands, Indonesia. *Bird Conservation International, **13***(1): 59-74.

Samia, D.S., S. Nakagawa, F. Nomura, T.F Rangel and D.T. Blumstein 2015. Increased tolerance humans among disturbed wildlife. *Nature communications, **6***(1): 1-8.

Santhakumar, B., P.R.Arun, R.K Sony, M. Murugesan and C. Ramesh, C 2018. The pattern of bird distribution along the elevation gradient of the Sutlej River basin, western Himalaya, India. *Journal of Threatened Taxa, **10***(13): 12715-12725.

Schaub, M.., N. Martinez, A. Tagmann-Ioset, N. Weisshaupt, M.L. Maurer, T.S. Reichlin,. . .. R. Arlettaz 2010. Patches of bare ground as a staple commodity for declining ground-foraging insectivorous farmland birds. *PLoS One, **5***(10): e13115.

SNNP, 2010. Shivapuri Nagarjun National Park, Brochure. Kathmandu: Shivapuri Nagarjun National Park, Panimuhan, Budhanilkantha, Kathmandu, Nepal.

Stevens, G.C. 1992. The elevational gradient in altitudinal range: an extension of Rapoport's latitudinal rule to altitude. *The American Naturalist, **140***(6): 893-911.

Studds, C.E. and P.P. Marra 2011. Rainfall-induced changes in food availability modify the spring departure programme of a migratory bird. *Proceedings of the Royal Society B: Biological Sciences, **278***(1723): 3437-3443.

Williams, S. E., Shoo, L. P., R. Henriod and R.G. Pearson 2010. Elevational gradients in species abundance, assemblage structure and energy use of rainforest birds in the Australian Wet Tropics bioregion. *Austral Ecology, **35***(6): 650-664.

Zhang, J., W.D. Kissling and F. He 2013. Local forest structure, climate and human disturbance determine regional distribution of boreal bird species richness in A lberta, C anada. *Journal of biogeography, **40***(6): 1131-1142.

Appendix 1. Check-list of bird with common name, scientific name, family, order, residential status and feeding guild.

Bird species	Scientific name	Family	Order	Sp account	Feeding guild
Asian koel	*Eudynamys scolopaceus*	Cuculidae	Cuculiformes	Resident	Omnivore
Ashy wood pigeon	*Columba pulchricollis*	Columbidae	Columbiformes	Resident	Frugivore
Asian barred owlet	*Glaucidium cuculoides*	Strigidae	Strigiformes	Resident	Carnivore
Ashy throated warbler	*Phylloscopus maculipennis*	Phylloscopidae	Passeriformes	Resident	Insectivore
Abberant bush warbler	*Cettia flavolivacea*	Scotocercidae	Passeriformes	Resident	Insectivore
Ashy drongo	*Dicrurus leucophaeus*	Dicruridae	Passeriformes	Summer visitor	Insectivore
Barn swallow	*Hirundo rustica*	Hirundinidae	Passeriformes	Summer visitor	Insectivore
Blue throated barbet	*Megalaima asiatica*	Megalaimidae	Piciformes	Resident	Frugivore
Blue whistling thrush	*Myophonus caeruleus*	Muscicapidae	Passeriformes	Resident	Omnivore
Black lored tit	*Parus xanthogenys*	Paridae	Passeriformes	Resident	Insectivore
Black bulbul	*Hypsipetes leucocephalus*	Pycnonotidae	Passeriformes	Resident	Omnivore
Black faced warbler	*Abroscopus schisticeps*	Sylviidae	Passeriformes	Resident	Omnivore
Black drongo	*Dicrurus macrocercus*	Dicruridae	Passeriformes	Resident	Insectivore
Bronze drongo	*Dicrurus aeneus*	Dicruridae	Passeriformes	Resident	Insectivore
Black kite	*Milvus migrans*	Accipitridae	Accipitriformes	Resident	Carnivore
Black throated tit	*Aegithalos concinnus*	Aegithalidae	Passeriformes	Resident	Insectivore
Blue rock thrush	*Monticola solitarius*	Muscicapidae	Passeriformes	Resident	Insectivore
Blue capped rock thrush	*Monticola cinclorhynchus*	Muscicapidae	Passeriformes	Summer visitor	Insectivore
Blue throated flycatcher	*Cyornis rubeculoides*	Muscicapidae	Passeriformes	Summer visitor	Insectivore
Black redstart	*Phoenicurus ochruros*	Muscicapidae	Passeriformes	Summer visitor	Insectivore
Black throated sunbird	*Aethopyga saturate*	Nectariniidae	Passeriformes	Resident	Frugivore
Blue capped redstart	*Phoenicurus caeruleocephala*	Muscicapidae	Passeriformes	Winter visitor	Insectivore
Bonellis eagle	*Aquila fasciata*	Accipitridae	Accipitriformes	Resident	Carnivore
Common stonechat	*Saxicola leucurus*	Muscicapidae	Passeriformes	Resident	Insectivore
Chestnut bellied nuthatch	*Sitta cinnamoventris*	Sittidae	Passeriformes	Resident	Insectivore
Chestnut-crowned warbler	*Seicercus castaniceps*	Sylviidae	Passeriformes	Resident	Insectivore
Common hawk cuckoo	*Hierococcyx varius*	Cuculidae	Cuculiformes	Resident	Insectivore
Chestnut headed tesia	*Tesia castaneocoronata*	Pycnonotidae	Passeriformes	Resident	Insectivore
Common kingfisher	*Alcedo atthis*	Alcedinidae	Coraciiformes	Resident	Carnivore
Crimson sunbird	*Aethopyga siparaja*	Nectariniidae	Passeriformes	Resident	Omnivore
Common myna	*Acridotheres tristis*	Sturnidae	Passeriformes	Resident	Omnivore

Cattle egret	*Bubulcus ibis*	Ardeidae	Pelecaniformes	Resident	Insectivore
Common tailor bird	*Orthotomus sutorius*	Cisticollidae	Passeriformes	Resident	Insectivore
Common kestrel	*Falco tinnunculus*	Falconidae	Falconiformes	Resident	Carnivore
Eurasian cuckoo	*Cuculus caronus*	Cuculidae	Cuculiformes	Summer visitor	Insectivore
Ferruginous flycatcher	*Muscicapa ferruginea*	Muscicapidae	Passeriformes	Passage migrants	Insectivore
Fire breasted flowerpecker	*Dicaeum ignipectus*	Dicaeidae	Passeriformes	Resident	Omnivore
Fulvous breasted woodpecker	*Dendrocops macei*	Picidae	Piciformes	Resident	Insectivore
Fired capped tit	*Cephalopyrus flammiceps*	Paridae	Passeriformes	Resident	Omnivore
Green tailed sunbird	*Aethopyga nipalensis*	Nectariniidae	Passeriformes	Resident	Omnivore
Grey treepie	*Dendrocitta formosae*	Corvidae	Passeriformes	Resident	Omnivore
Grey wagtail	*Motacilla cinerea*	Motacillidae	Passeriformes	Resident	Insectivore
Green backed tit	*Parus monticolus*	Paridae	Passeriformes	Resident	Omnivore
Grey headed canary flycatcher	*Culicicapa ceylonensis*	Stenostiridae	Passeriformes	Resident	Insectivore
Greater yellownape	*Picus flavinucha*	Picidae	Piciformes	Resident	Insectivore
Grey bush chat	*Saxicola ferrea*	Muscicapidae	Passeriformes	Resident	Insectivore
Grey winged blackbird	*Turdus boulboul*	Turdidae	Passeriformes	Resident	Omnivore
Golden spectacled warbler	*Seicercus burkii*	Sylviidae	Passeriformes	Resident	Insectivore
Grey throated babbler	*Stachyris nigriceps*	Sylviidae	Passeriformes	Resident	Omnivore
Grey hooded warbler	*Phylloscopus xanthoschistos*	Phylloscopidae	Passeriformes	Resident	Insectivore
Golden throated barbet	*Megalaima franklinii*	Megalaimidae	Piciformes	Resident	Frugivore
Rufous bellied woodpecker	*Dendrocopos hyperythrus*	Picidae	Piciformes	Resident	Omnivore
Great tit	*Parus major*	Paridae	Passeriformes	Resident	Insectivore
Great barbet	*Megalaima virens*	Megalaimidae	Piciformes	Resident	Frugivore
Grey bellied cuckoo	*Cacomantis passerinus*	Cuculidae	Cuculiformes	Summer visitor	Insectivore
House crow	*Corvus splendens*	Corvidae	Passeriformes	Resident	Omnivore
Himalayan bulbul	*Pycnonotus leucogenys*	Pycnonotidae	Passeriformes	Resident	Omnivore
House swift	*Apus nipalensis*	Apodidae	Apodiformes	Resident	Insectivore
Humes warbler	*Phylloscopus humei*	Phylloscopidae	Passeriformes	Resident	Insectivore
Himalayan swiftlet	*Aerodramus brevirostris*	Apodidae	Apodiformes	Summer visitor	Insectivore
House sparrow	*Passer domesticus*	Passeridae	Passeriformes	Resident	Frugivore
Indian blue robin	*Luscinia brunnea*	Muscicapidae	Passeriformes	Summer visitor	Insectivore
Indian cuckoo	*Cuculus micropterus*	Cuculidae	Cuculiformes	Summer visitor	Insectivore
Orange headed thrush	*Zoothera citrina*	Turdidae	Passeriformes	Summer visitor	Insectivore
Jungle myna	*Acridotheres fuscus*	Sturnidae	Passeriformes	Resident	Omnivore
Kalij pheasant	*Lophura leucomelanos*	Phasianidae	Galliformes	Resident	Omnivore

Large hawk cuckoo	*Hierococcyx sparverioides*	Cuculidae	Cuculiformes	Summer visitor	Insectivore
Little forktail	*Enicurus scouleri*	Muscicapidae	Passeriformes	Resident	Insectivore
Long tailed shrike	*Lanius schach*	Laniidae	Passeriformes	Resident	Insectivore
Large billed crow	*Corvus macrorhynchos*	Corvidae	Passeriformes	Resident	Omnivore
Large niltava	*Niltava grandis*	Muscicapidae	Passeriformes	Resident	Omnivore
Lesser yellownape	*Picus chlorolophus*	Picidae	Piciformes	Resident	Insectivore
Lesser cuckoo	*Cuculus poliocephalus*	Cuculidae	Cuculiformes	Summer visitor	Insectivore
Long tailed minivet	*Pericrocotus ethologus*	Campephagidae	Passeriformes	Resident	Insectivore
Liittle pied flycatcher	*Ficedula westermanni*	Muscicapidae	Passeriformes	Resident	Insectivore
Mountain hawk eagle	*Nisaetus nipalensis*	Accipitridae	Accipitriformes	Resident	Carnivore
Mountain bulbul	*Ixos mcclellandii*	Pycnonotidae	Passeriformes	Resident	Frugivore
Maroon oriole	*Oriolus traillii*	Oriolidae	Passeriformes	Resident	Omnivore
Nepal house martin	*Delichon nipalensis*	Hirundinidae	Passeriformes	Resident	Insectivore
Olive backed pipit	*Anthus hodgsoni*	Motacillidae	Passeriformes	Resident	Insectivore
Oriental magpie robin	*Copsychus saularis*	Muscicapidae	Passeriformes	Resident	Insectivore
Oriental turtle dove	*Streptopelia orientalis*	Columbidae	Columbiformes	Resident	Frugivore
Oriental white eye	*Zosterops palpebrosus*	Zosteropidae	Passeriformes	Resident	Omnivore
Orange billed leafbird	*Chloropsis hardwickii*	Chloropseidae	Passeriformes	Resident	Omnivore
Plumbeous water redstart	*Rhyacornis fuliginosus*	Muscicapidae	Passeriformes	Resident	Omnivore
Pied thrush	*Zoothera wardii*	Turdidae	Passeriformes	Summer visitor	Omnivore
Pied bushchat	*Saxicola caprata*	Muscicapidae	Passeriformes	Resident	Insectivore
Red billed blue magpie	*Urocissa erythrorhyncha*	Corvidae	Passeriformes	Resident	Omnivore
Red vented bulbul	*Pycnonotus cafer*	Pycnonotidae	Passeriformes	Resident	Frugivore
Rufous treepie	*Dendrocitta vagabunda*	Corvidae	Passeriformes	Resident	Omnivore
Rose ring parakett	*Psittacula krameri*	Psittacidae	Psittaciformes	Resident	Frugivore
Rufous vented yuhina	*Yuhina occipitalis*	Zosteropidae	Passeriformes	Resident	Omnivore
Rock pigeon	*Columba livia*	Columbidae	Columbiformes	Resident	Frugivore
Rosy pipit	*Anthus roseatus*	Motacillidae	Passeriformes	Winter visitor	Omnivore
Rufous sibia	*Malacias capistratus*	Leiothrichidae	Passeriformes	Resident	Frugivore
Red rumped swallow	*Cecropis daurica*	Hirundinidae	Passeriformes	Resident	Insectivore
Steppe eagle	*Aquila nipalensis*	Accipitridae	Accipitriformes	Winter visitor	Carnivore
Straited laughing thrush	*Garrulux striatus*	Leiothrichidae	Passeriformes	Resident	Insectivore
Streaked laughing thrush	*Garrulax squamatus*	Leiothrichidae	Passeriformes	Resident	Insectivore
Stripe throated yuhina	*Yuhina gularis*	Zosteropidae	Passeriformes	Resident	Insectivore
Spotted dove	*Streptopelia chinensis*	Columbidae	Columbiformes	Resident	Frugivore

Streak breasted scimitar babbler	*Pamotorhinus ruficollis*	Timaliidae	Passeriformes	Resident	Omnivore
Slaty headed parakeet	*Psittacula himalayana*	Psittacidae	Psittaciformes	Resident	Frugivore
Slaty backed forktail	*Enicurus schistaceus*	Muscicapidae	Passeriformes	Resident	Insectivore
Small niltava	*Niltava macgrigoriae*	Muscicapidae	Passeriformes	Summer visitor	Insectivore
Straited bulbul	*Pycnonotus striatus*	Pycnonotidae	Passeriformes	Resident	Omnivore
Spiny babbler	*Turdoides nipalensis*	Leiothrichidae	Passeriformes	Resident	Insectivore
Scarlet minivet	*Perricrocotus flammeus*	Campephagidae	Passeriformes	Resident	Insectivore
Spotted owlet	*Athene brama*	Strigidae	Strigiformes	Resident	Carnivore
Snowy browed flycatcher	*Ficedula hyperythra*	Muscicapidae	Passeriformes	Resident	Insectivore
Spotted forktail	*Enicurus maculatus*	Muscicapidae	Passeriformes	Resident	Insectivore
Tickells thrush	*Turdus unicolor*	Turdidae	Passeriformes	Summer visitor	Insectivore
Tickells leaf warbler	*Phylloscopus affiins*	Phylloscopidae	Passeriformes	Passage migrants	Insectivore
Verditer flycatcher	*Eumyias thalassinus*	Muscicapidae	Passeriformes	Summer visitor	Insectivore
Wedge tailed green pigeon	*Treron sphenura*	Columbidae	Columbiformes	Resident	Frugivore
White throated fantail	*Rhipidura albicollis*	Rhipiduridae	Passeriformes	Resident	Insectivore
White throated laughing thrush	*Garrulux albogularis*	Leiothrichidae	Passeriformes	Resident	Insectivore
Whiskered yuhina	*Yuhina flavicollis*	Zosteropidae	Passeriformes	Resident	Insectivore
White tailed robin	*Myiomela leucura*	Muscicapidae	Passeriformes	Summer visitor	Insectivore
White tailed nuthatch	*Sitta himalayensis*	Sittidae	Passeriformes	Resident	Insectivore
Nepal fulvrtta	*Alcippe nipalensis*	Sylviidae	Passeriformes	Resident	Insectivore
White capped redstart	*Chaimarrornis leucocephalus*	Muscicapidae	Passeriformes	Resident	Insectivore
White collared blackbird	*Turdus albocintus*	Turdidae	Passeriformes	Resident	Omnivore
White browed fulvetta	*Fulvetta vinipectus*	Timaliidae	Passeriformes	Resident	Insectivore
White crested laughing thrush	*Garrulux leucolophus*	Leiothrichidae	Passeriformes	Resident	Insectivore
White throated kingfisher	*Halcyon smyrnensis*	Alcedinidae	Coraciiformes	Resident	Carnivore
Yellow breasted green finch	*Carduelis spinoides*	Fringillidae	Passeriformes	Resident	Frugivore
Yellow billed blue magpie	*Urocissa flavirostris*	Corvidae	Passeriformes	Resident	Omnivore
Yellow browed tit	*Sylviparus modestus*	Paridae	Passeriformes	Resident	Omnivore
Yellow bellied fantail	*Chelidorhynx hypoxantha*	Corvidae	Passeriformes	Summer visitor	Insectivore