PATTERNS OF AVIAN DIVERSITY IN DIFFERENT LAND-USE AND FOREST PATCH SIZE OF KUMAON HIMALAYAS, UTTARAKHAND

A THESIS
Submitted by

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Under the guidance of

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DECLARATION

I hereby declare that the work conducted under the thesis titled "**Patterns of avian diversity in different land-use and forest patch size of Kumaon Himalayas, Uttarakhand**", is a record of original research work, done by me and subsequently submitted for the award of the degree of doctor of Philosophy in Wildlife Science to Saurashtra University, Rajkot. This research work has been carried out under the guidance and supervision of Dr. Gopi, G.V., Scientist-E, Wildlife Institute of India. The work has not formed the basis for the award of any other degree, diploma or any other qualification. I also declare that the thesis embodies my own work, analysis, observation and understanding and the particulars given in it are true to the best of my knowledge.

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Mr. Sumit Kumar Arya has put more than six semesters of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

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I certify that the research work was appreciated by all who were present, and the comments made by the faculty and researchers have been appropriately included in the thesis.

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Dedicated to my

Parents

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Executive summary

The Himalayas are well known for containing major river basins, regulating regional climate, and harboring rich biodiversity, diverse and hetrogeneous ecosystems. The region harbours around 10,000 plant species, 300 mammalian species, and over 1000 bird species. The Himalayas are home to ten percent of the world's birds and 330 Important Bird Areas. However, over the last few decades, there has been a rapid increase in the human population, which has resulted in a shift in land use patterns. The expansion of agriculture, pasture land, degradation of forests also increases with the increasing human population. This shift in land use leads to a potential decline in biodiversity and negatively impacts the region's forest birds. Birds are also one of the best indicators of the environment and its habitat quality; hence it is crucial to monitor the birds in the different land use or habitats for assessing the habitat quality.

The present study was conducted in the Pithoragarh districts of the Kumaon Himalayas in Uttarakhand. The point count method was performed in matrices of agriculture land and forests of the lower Pithoragarh district to assess bird diversity patterns in different land use, habitat types, and disturbance regimes. A multiscale landscape heterogeneity approach was performed for determining the impact of forest patch size and vegetation structure on bird diversity. For assessment of the seasonal changes in the bird diversity pattern, a village ecosystem was monitored in the landscape. Trail walks and vehicle survey was conducted in the whole district for collecting the geographic locations of various

pheasants and vultures in the district for their possible distribution in the landscape.

A total of 216 species belonging to 54 families were recorded from the landscape, including some opportunistic sightings. 6 species belong to Threatened and 5 to Near Threatened categories in the IUCN Red List. Seven species are strictly protected under the Schedule-I of Indian Wildlife (Protection) Act, 1972. 52 species were recorded as forest specialist bird species, while nearly 44% are Himalayan endemic. A total of 37 species that are common in both categories as forest specialists and Himalayan endemic have high conservation values. These species are relatively under a high threat to extinction due to land use patterns and climate change. A total of 37 species were recorded for the first time from the Pithoragarh district which were not listed in the available previous literature.

During the point counts, 3573 individuals of 157 species belonging to 45 families and 110 genera were recorded. A maximum number of species were recorded from the Temperate mixed forests followed by Oak forest and Agriculture lands. The highest per-point bird diversity and richness were recorded from the 2000 – 2500 m elevation bands. Among different land-uses, maximum bird diversity was found in the agriculture lands and least in shrub lands in the landscape. Within different habitats, the highest bird diversity was found in agricultural land followed by Deodar forests, Temperate mixed, Oak, and least in Chir pine forests.

It was found that the Sal forest was the most disturbed habitat in the landscape. Maximum tree cutting and lopping were recorded from these forests, however Deodar forest was the least disturbed forest in the landscape. Most of the Deodar forests are sacred groves in the study area, and tree cutting and tree lopping are strictly prohibited in these forests. It was also observed that low tree cutting and moderate lopping supporting the highest bird diversity and richness, whether bird diversity is slightly low in the cattle presence sampling plots.

Multiscale landscape heterogeneity modeling revealed that a combination of the variables such as Shannon diversity index, Forest area, Shrub and grasslands area, patch density of shrub and grasslands, shape of shrub and grasslands, elevation, habitation, slope, and waterbodies variables is the best-fitted model for the bird diversity. Elevation and forest area are the best predictors of bird diversity within the model, with 99.9% confidence interval. It was found that landscape diversity, elevation, and waterbodies are positively correlated with bird diversity. However, forest area, shrub and grasslands area, shrub and grasslands shape and patch density, habitation, and slope negatively correlated with the bird diversity.

Bird study during different seasons recorded the maximum number of species during the spring season, followed by winter, summer, and monsoon. However, the monsoon season was the second most species-abundant season after the spring season. Similarly, per point diversity indices revealed that the spring season supports the maximum bird diversity in all the habitats except Sal forest. Sal forest was most diverse in terms of birds during the monsoon season.

Assessment of distribution of various pheasants and vultures in the landscape, revealed that the climatic variables play an essential role in the distribution of pheasants and Himalayan vultures in the landscape, followed by land-use and topographic variables. Pheasants continue to face many threats such as habitat destruction, hunting pressure, and shifting habitats towards the high elevation areas due to global warming. Effective conservation and management strategies are required to protect the habitat of these conservation significant species.

The thesis is organized into five chapters; with chapter 1 dealing with the General Introduction, Chapter 2 describes the Study Area. Chapter 3 deals with the bird diversity pattern in different land-use and disturbance regimes of the lower Pithoragarh district. Chapter 4 deals with the effects of forest patch size, vegetation structure, and seasons on bird diversity. Chapter 5 deals with the distribution of rare and threatened species in the Pithoragarh district.

CHAPTER 1

General Introduction

The Himalaya is one of the world's most biodiverse regions (Olson & Dinnerstein 1998; Myers et al. 2000; Brooks et al. 2006), having extreme variation in eco-climatic conditions coupled with diverse topographic and landscape features manifested in habitat diversity. It exhibits close affinities with adjacent biogeographic regions and represents the high level of endemism among flora and fauna (Nayar 1996; Pandit et al. 2000; Telwala et al. 2013). It harbours over 10000 plant species, 300 mammals, and nearly 1000 bird species (Pandit & Kumar 2013; Rana & Rawat 2017). With roughly 330 Important Bird Area sites, the Himalayan region is home to nearly 10% of the world's bird species (Elsen et al. 2016; Pandit et al. 2014). However, over the past few decades, due to rapid population growth and intensive anthropogenic activities such as the expansion of agriculture, human settlement, and linear infrastructure, there has been an unprecedented change in land use which raises the concern over the loss of habitats (Pandit et al. 2007, Rana & Samant 2010; Chitale et al. 2014). The loss of habitats and climate change is likely to result in the decline of many species (Bharali & Khan 2011; Bagchi et al. 2013; Xu et al. 2019), thereby making it pertinent for long term monitoring of the biodiversity of the Himalayan ecosystem for their better management and conservation.

Due to their easy detection and good indicators for studying environmental impact, birds are often used for monitoring biodiversity in many terrestrial and wetland ecosystems (Holmes et al. 1986; Gregory et al. 2003). Their distribution necessitates a specific habitat that changes with the seasons, which is susceptible to disturbance and destruction, leading to extinction. (Chauhan et al. 2008). The Indian subcontinent is home to 1,263 different bird species (Praveen et al. 2016), and around 75% (940) species of them are found in the

Indian Himalayan region (Mandal et al. 2018). More than 56% of the Indian birds and around 75% of Indian Himalayan Region (IHR) birds (710 species) has been recorded from the state of Uttarakhand (Mohan & Sondhi 2017), representing the rich diversity of birds in the state. The vast altitudinal range and climatic conditions support various habitat types for avian species in the state.

Review of Literature

From the pioneering work in the eighties, various studies have been conducted in the IHR. However, most of them were in the eastern Himalayas (Chettri et al. 2001; Laiolo 2003; Birand & Panwar 2004; Chaudhary 2006; Acharya et al. 2010; Acharya 2011; Mazumdar et al. 2011; Besnet & Badola 2012; Price et al. 2014) compared to the western Himalayas at (Ramesh et al. 2005; Thakur et al. 2008; Price et al. 2011; Singh & Price 2015). In the Uttarakhand state, Garhwal region (western region) is more explored in terms of birds (Green 1986; Singh 2000; Sathyakumar 2004; Kumar et al. 2006; Mohan & Kumar 2010; Naithani & Bhatt 2012; Kukreti & Bhatt 2014; Dixit et al. 2016) than the Kumaon region (eastern region) (Ahmed 2010; Bhatt & Joshi 2011; Palita et al. 2011; Joshi et al. 2012; Shahabuddin et al. 2017; Menon et al. 2019). In Kumaon Himalayas, most bird-related studies have been carried out in the Nainital and Almora districts. Pithoragarh district has remained the least studied (Tak & Sati 1994; Tak 1995; Sultana & Khan 2000; Sultana 2002; Raza 2005).

Birds in different land use and disturbance regimes

Alteration and conversion of natural habitats due to anthropogenic activities are among the greatest threats to biodiversity (Newbold et al. 2013). Substantial evidence emphasizes the significance of human land-use changes as a driver of extinction and species declines (Scharlemann et al. 2004). Agricultural expansion and urbanization throughout the world and its impact on biodiversity have received much attention from scientists in recent years (Sengupta et al. 2014, Elsen et al. 2016). It is one of the dominant drivers of forest loss (Curtis et al. 2017) and has led to dramatic species losses across the tropics (Kremen et al. 2002).

Birds can play an essential role in demonstrating the effects of change in landscape (Derleth et al. 1989; Bonfim et al. 2021) because of their highly mobile and visible ability exceptionally responsive to landscape-level alterations (Balent & Courtiade 1992). It is poorly known how the change in land-use patterns affects the biodiversity in the Himalayas, despite widespread deforestation and agricultural intensification (Elsen et al. 2016). However, according to certain recent studies, agricultural land may support a high amount of biodiversity. (Swift 2004; Karp et al. 2012; Srinivasan et al. 2019). For instance, low-intensity agricultural fields have more avifaunal species than primary forests during winters, according to a study in the western Himalayas (Elsen et al. 2017). In contrast, summers are equal in agricultural lands and primary forests. (Elsen et al. 2018).

An ecosystem can be restructured of its communities through a variety of means due to human activities. However, the influence can differ in different ecosystems (Brash, 1987). As rural populations rely on forests for livelihood and sustenance, human-induced disturbances such as firewood extraction, grazing, logging, and extraction of non-timber forest products (NTFP) may be the most pervasive strain on forests in the developing nations (Harris and Muhammad 2003; Shahbuddin and Kumar 2007). It causes subtle to significant landscape change (Chettri et al. 2005). Several studies are done worldwide based on the impact of human disturbance on bird community (Blumstein et al. 2005; Price 2008; Yuan et al. 2014, DuBay et al. 2017; Vallino et al. 2019). In the Indian sub-continent, on the response of birds to human distance (Burger 1991), human interference and nesting behavior of birds (Datta and Pal 1993; Kale et al. 2018), avifauna in disturbed forest habitats (Beehlar et al. 1986; Kumar & Shahbuddin 2005; Shahbuddin & Kumar 2006, 2007; Mehta & Kulkarni 2012; Verma & Murmu 2015) are the major studies. IHR is relatively understudied in terms of birds in different disturbance regimes. However, few significant studies in the IHR are on pheasants (Bhattacharya 2009; Jolly & Pandit 2011) and other bird communities (Jolly 2017; Menon et al. 2019; Bhattacharya et al. 2019).

Birds in different forest patch size

Habitat fragmentation divides continuous forests into smaller pieces of forests of a natural system through natural fire (Pickett & Thompson 1978) windfall (Foster & Reiners 1986). But the extension and intensification of human land use is the most important and large-scale level source of forest fragmentation. (Andren 1994; Taubert et al. 2018; Bełcik et al. 2020). This expansion and intensification also lead to divides the large forest habitat into small forest patches. In terms of bird diversity, these forest patches haven’t gotten much attention (Watt 1991; Pearson 1993; Mansor et al. 2018; Mola et al. 2021). However, the studies at the multiscale level in these landscape heterogeneity are more significant (Hill & Hamer 2004; Kuczynski 2010). These forest patches and landscape heterogeneity in bird diversity are not much explored, and few studies observed the effects of avian diversity in these matrices of forest and agricultural lands (Morelli 2013, Lee & Martin 2017; Maseko et al. 2020).

Seasonal influence on bird diversity

Birds are sensitive to the seasonal fluctuation in climate due to the availability of resources for food, water, and temperature regulation requirements in the mountain ecosystem (Herzog et al. 2003; Blake & Loiselle 2000; Shoo et al. 2005). In the Himalayan ecosystems, seasonal changes in climate are an additional prominent characteristic that can influence the temporal dynamics of bird species richness and composition (Dixit et al. 2016; Elsen et al. 2016). Various factors such as climate, elevation gradients, species-area relationship, productivity, mid domain effects, evolutionary history, geomorphic constraints, habitat character, and anthropogenic disturbances can affect the diversity and richness (Mccain et al. 2009; Acharya et al. 2011; Katuwal et al. 2016). Habitat structure is also an essential factor influencing the avian community (Chettri et al. 2005; Srinivasan, 2021).

Distribution and Habitat suitability modeling

Rare species seem to be at greater risk of extinction because of their lower abundances, restricted geographical ranges, and high susceptibility to environmental changes (Pimm et al. 1995 Broennimann et al. 2005; Lomba et al. 2010). Hence, the species distribution models (Guisan & Zimmermann 2000; Guisan & Thuiller 2005) play an essential role in finding suitable habitats for a species. These distribution models are increasingly used to inform monitoring programs and thus conservation policies. MaxEnt (Maximum Entropy) is a widely used model for determining and predicting habitat distribution (Moreno et al. 2011, Thapa et al. 2018). It estimates a set of functions relating to habitat appropriateness and environmental factors using the maximum entropy principle on presence-only data to approximate the species' niche and probable global dispersion. (Phillips et al. 2006;

Warren & Seifert 2011). In IHR Dunn et al. (2015), Singh et al. (2020), Rai et al. (2020) and Chettri et al. (2021) used MaxEnt for assessing the suitable areas of pheasant species.

Objectives

1- To determine the bird species diversity and richness in different land use and disturbance regimes of lower parts of Pithoragarh district.

2- To determine the effects of forest patch size, vegetation structure, and seasons on bird diversity.

3- To prepare the species distribution and abundance model for rare and threatened species.

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CHAPTER 2

Study Area

The study was conducted in the Indian part of the Kailash Sacred Landscape (KSL-India), forming 96% of the Pithoragarh district and 4% of the Bageshwar district. Pithoragarh is the easternmost district in the Himalayan state of Uttarakhand covers near 7100 sq. Km area and elevation range from 350 m to 7000 m above sea level (Fig 2.1). Its located between 29º 20'-30º 55'N Latitude and 79º 50'- 81º 0'E Longitude. The Kali river separates the district's eastern boundary from Nepal, and in the North, it touches the international boundary with the Tibet Autonomous Region (China). The Northwestern and western border of the district touches the boundary with Chamoli and Bageshwar districts, respectively. A small portion of Kapkot tehsil in the Bageshwar district also falls under the KSL-India, towards the South-west and South sides Pithoragarh district shares the boundary with Almora and Champawat district respectively. Pithoragarh district is rich in biodiversity, but due to anthropogenic pressures and climate change its facing various environmental challenges, including fragmentation of natural habitats and degradation.

Flora

The major forest types range from moist subtropical broadleaf to sub-tropical needle-leaved, temperate oak and mixed forests, subalpine conifers and mixed forests, high altitude birch forests, alpine meadows, and grasslands are present in the landscape.

In the lower altitude (< 800 m), moist tropical and dry deciduous forest of *Shorea robusta* mixed with *Syzygium cumini*, *Aegle marmelos, Haldina cordifolia*, *Ficus* *religiosa*, *F. benghalensis*, *F. auriculata*, *F. virens*, *Acacia catechu*, *Bombax cieba*, *Butea monosperma*, *Toona ciliata*, *Albizia lebbeck*, and *Terminalia alata* etc. trees are found. With increasing the altitude, the vegetation type also changes. Higher up between elevation range from 1000 to 3000 m of above sea level, mixed dominant types of *Rhododendron arboreum, Quercus leucotrichopora, Lyonia ovalifolia*, *Myrica esculenta* etc tree species along with understory plants such as *Viburnum cotinifolium*, *Symplocos paniculata*, *Lonicera quinquelocularis*, *Neolitsea umbrosa*, *Cornus macrophylla*, etc. are also seen mixed up. The gymnosperms, first to make an appearance is *Pinus roxburghii*. These mixed forests are followed by *Quercus floribanda*, *Q. semecarpifolia*, *Q. glauca*, *Acer sp.*, *Prunus puddum* forest with species of *Euonymus, Ilex excels*, *Aesculus indica* and *Carpinus viminea* tree species. At certain places, pure stands of *Pinus roxburghii*, *Cedrus deodara*, *Taxus wallichiana*, *Abies pindrow* make it a sight to behold. On dry slopes, *Pyrus pashia*, *Prinsepia utilis, Berberis lycium,* and *B. chitria* are dominant.

Further higher up the elevation, *Betula utilis* forms the tree limit with *Rhododendron campanulatum* in this part of Himalaya. Above altitude, shrubby or herbaceous plants like species of *Hippophae, Juniperus*, *Saussurea*, *Primula*, *Corydalis*, *Pleurospermum*, *Rheum*, *Rhododendron anthopogon*, *Meconopsis aculeata*, etc. make the vegetational cover.

Fauna

Different forest types provide different habitats which support varieties of animals. Among the mammals, species such as Snow leopard (*Panthera uncia*), Himalayan tahr (*Hemitragus jemlahicus*), Himalayan musk deer (*Moschus leucogaster*), Himalayan serow (*Capricornis thar*), Himalayan Blue sheep (*Pseudois nayaur*), Himalayan goral

(*Naemorhedus goral*), etc. are found in the Pithoragarh district and are endemic to Himalaya. Species such as Royal Bengal tiger (*Panthera tigris tigris*), Common leopard (*Panthera pardus*), Sambar deer (*Rusa unicolor*), The Indian muntjac (*Muntiacus muntjak*), Indian Wild Pig (*Sus Scrofa*) etc. are also recorded from the study area. Among birds, species such as Tibetan snowcock (*Tetraogallus tibetanus*), Satyr tragopan (*Tragopan satyra*), Himalayan monal (*Lophophorus impejanus*), Snow partridge (*Lerwa lerwa*), Hill partridge (*Arborophila torqueola*), Cheer Pheasant (*Catreus wallichii*), Kalij Pheasant (*Lophura leucomelanos*), Black Francolin (*Francolinus francolinus*) pheasants, Bearded vulture (*Gypaetus barbatus*), Himalayan vulture (*Gyps himalayensis*) Egyptian vulture (*Neophron percnopterus*), White-throated tit (*Aegithalos niveogularis*), Wallcreeper (*Tichodroma muraria*), Grey-hooded warbler (*Phylloscopus xanthoschistos*), Himalayan Bulbul (*Pycnonotus leucogenys*) etc. found in the landscape.

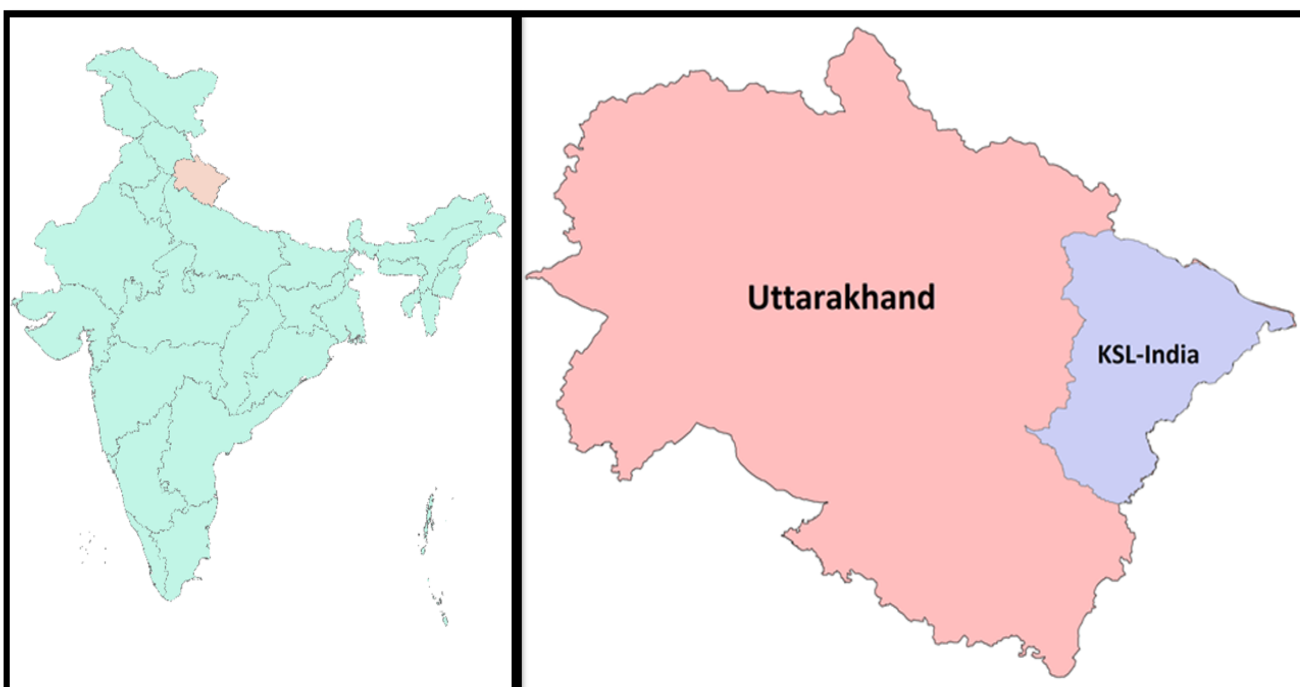

Figure 2.1: Study Area Location

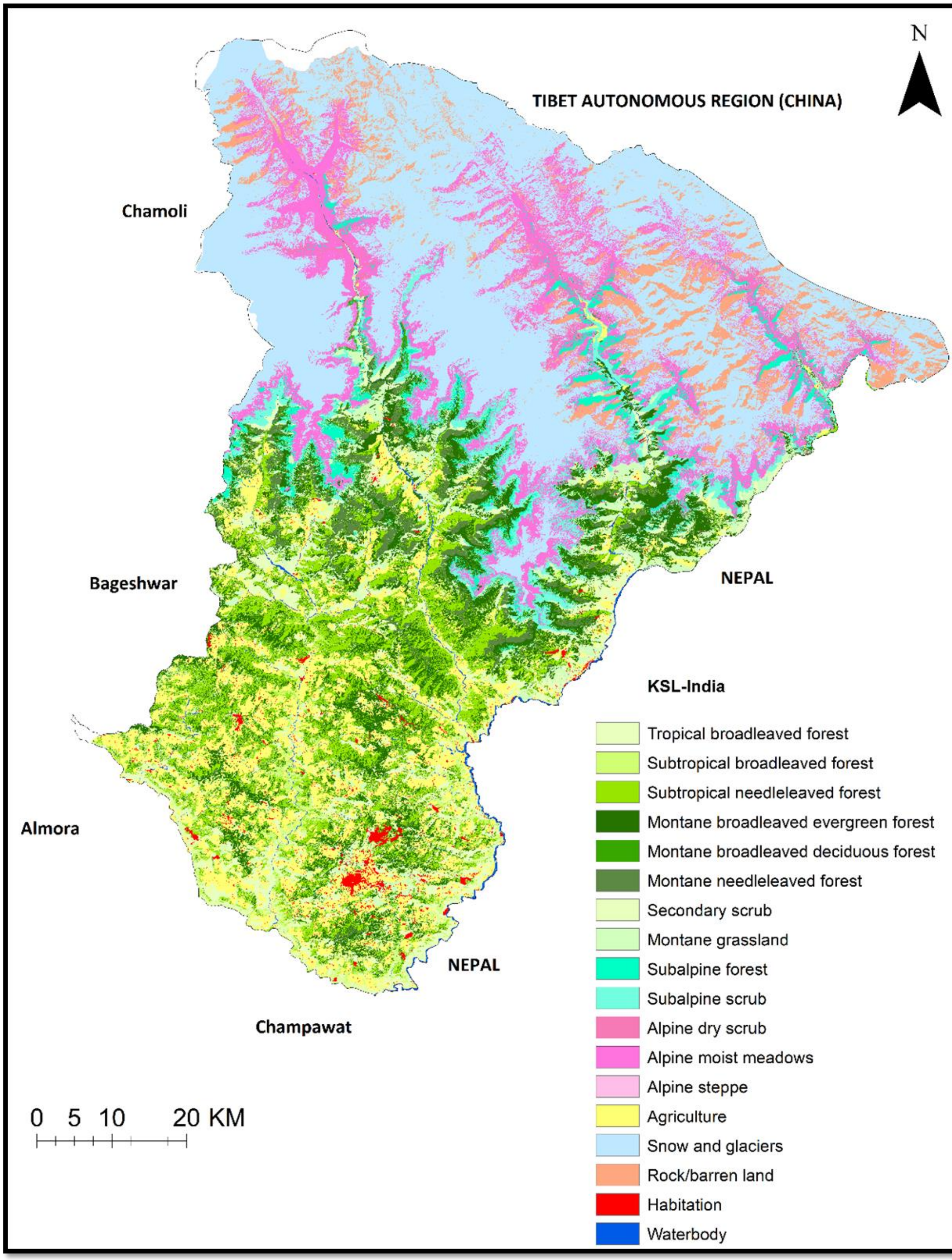

Figure 2.2: Study Area – Kailash Sacred Landscape – India (Pithoragarh district)

CHAPTER 3

Objective 1. To determine the bird species diversity and richness in different land use and disturbance regimes of lower parts of Pithoragarh district.

Study Area

The survey was conducted in the lower parts of the Pithoragarh district. A total of 27 sampling sites were selected in the three watersheds (Godigadh, Ramganga purvi and Jhulaghat), mainly covering lower reaches of the Pithoragarh district (500–2500 m a.s.l.) (Fig. 3.1). The lower reaches of the landscape are primarily drained by the Saryu, Ramganga, and Kali rivers. This region is dominated by the matrices of Agriculture lands (45%), Forests (30), grasslands and shrublands (20%), and Human habitation and water bodies (5%). The vegetation in this area is dominated mainly by sub-tropical mixed (*Emblica officinalis*, *Toona cilata*, *Macaranga pustulata*, *Erythrina suberosa*), Sal (*Shorea robusta*) forest, Chir pine (*Pinus roxburghii*) forest, Banj Oak (*Quercus leucotrichophora* and *Myrica esculenta*) forest, and Temperate mixed forests (*Q. floribunda*, *Q. lanuginosa*, and *Rhododendron arboreum* etc.).

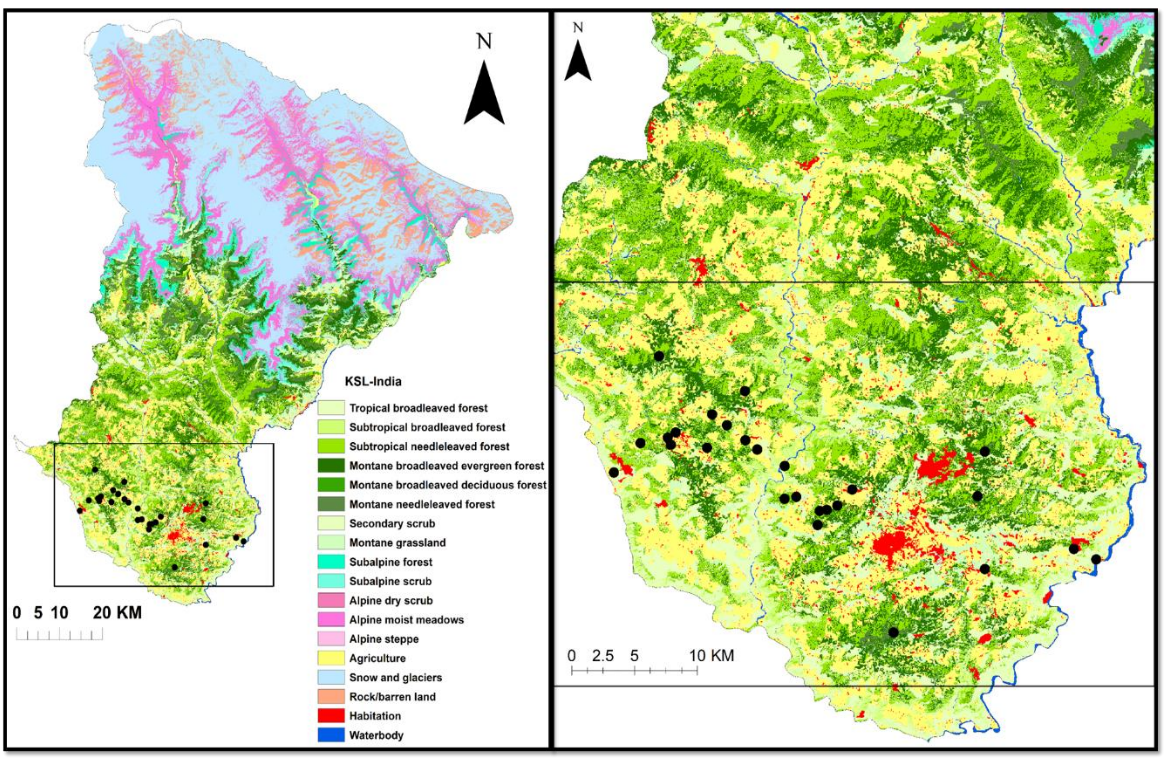

Figure 3.1: Study Area – Sampling sites in Lower parts of Pithoragarh district

Figure 3.2: Different habitat types in lower Pithoragarh district

Methods

Sampling design

Three watersheds such as Godigadh, Ramganga purvi, and Jhulaghat, which cover most of the lower reaches of the KSL-India, were selected to cover the lower parts of the district. A total of 27 sampling sites were chosen from west to east between the 500m to 2500m of elevation range.

Data collection

The survey was conducted during the winter, spring, and post-monsoon seasons between October 2013 to June 2017. The fixed-width point count (25m radius) method was used (Bibby et al. 2000). We maintained the distance between 150 to 200m within each point count to avoid double counting. All species seen/heard within 15 minutes were recorded (Menon et al. 2019). Birds were observed with the aid of 8 × 42 Bushnell binoculars and identified using Grimmett et al. (1998, 2011). Various habitat parameters such as canopy cover, grass cover, shrub cover, and litter cover were recorded in percentage (%) from each sampling plot based on the percent area covered of the sampling plot. Topographic parameters such as slope and aspect were also recorded.

Migration status to the species was assigned based on the field observations and Grimmett et al. (2011). Species frequently seen throughout the year were designated as residents, if seen during March to July as summer visitors, and October and February as winter visitors. For unconfirmed migration status, we followed Grimmet et al. (2011).

We assigned the forest specialist to the species based on the combination of field observations and habitat description in field guide Ali & Ripley (1987) and Grimmett et al. (2011).

Tree cutting, tree lopping, and cattle presence data were collected in each bird sampling plot for habitat disturbance. The tree cutting was divided into three broad classes based on the number of tree cuts found in a sampling plot, such as Low= 0-2 cuttings, Moderate=3-4 cuttings, High= >4 cuttings. For tree lopping, data was collected based on the percent of tree branches lopped in a sampling plot and further divided as Low= <20%, Moderate= 20%- 50%, High= <50% of tree lopping.

A total of 700 point counts were conducted in the 27 different sampling sites in the landscape (Table 3.1). Of these points, 77% were laid in the forest land, 11% in agricultural land, 7% in riverine, and 5% in shrublands. Sampling points within different habitats are in table 3.2.

Table 3.1. Total point counts in different sampling sites along with elevation ranges and major vegetation types.

SN.	Sampling sites	Latitude (N)	Longitude (E)	Altitude Range (m)	Major vegetation	Point counts
1	Lali	29.6558	80.0281	1600 - 1800	Oak, chir pine	62
2	Hanera	29.6508	80.0308	1650 - 1950	Deodar	18
3	Rawal gaon	29.6595	80.0346	1400 - 1600	Deodar, oak, chir pine	27
4	Kuntola	29.6310	79.9840	550 - 850	Sal, riverine, shrubland	31
5	Simalkot	29.6489	80.0600	1500 - 1700	Oak, temperate mixed, shrubland	20
6	Patal-bhuvaneshwar	29.6889	80.0913	1400 - 1700	Oak, temperate mixed	22
7	Pali	29.6543	80.0920	1000 - 1400	Chir pine, sub-tropical mixed	49
8	Boyal	29.6480	80.1018	750 - 1050	Sal, sub-tropical mixed, riverine	39
9	Jhulaghat	29.5724	80.3812	500 - 800	Sal, sub-tropical mixed, shrubland	41
10	Munakot	29.5652	80.2897	1350 - 1500	Oak, temperate mixed	35
11	Majirkanda	29.5797	80.3628	1000 - 1500	Chir pine, temperate mixed	27
12	Jajurauli	29.6149	80.1343	650 - 1050	Chir pine, sub-tropical mixed	32
13	Bans	29.6052	80.1535	1000 - 1700	Oak, sal, chir pine	30
14	Nakot	26.6091	80.1772	1600 - 1800	Oak	26

15	Gurura	29.6204	80.1801	1600 - 1900	Oak, chir pine	34
16	Jagtar	29.6059	80.1594	1900 - 2150	Oak, temperate mixed	18
17	Sintoli	29.6090	80.1681	1650 - 1800	Oak	15
18	Thalkedar	29.5193	80.2236	2000 - 2500	Temperate mixed	23
19	Dhwaj	29.6485	80.2914	1700 - 2500	Oak, temperate mixed	18
20	Pabhe	29.5982	80.1468	1900 - 2000	Deodar, oak	15
21	Khati	29.6136	80.1254	1200 - 1300	Chir pine	14
22	Aonlaghat	29.6363	80.1245	800 - 500	Sal, riverine, shrubland	31
23	Lamkeshwar	29.7111	80.0211	1900 - 2400	Oak, temperate mixed	20
24	Hanera laggha	29.6519	80.0057	1400 - 1600	Chir pine	8
25	Futsil	29.6724	80.0645	1400 - 1700	Chir pine	13
26	Chitgal	29.6671	80.0777	1400 - 1600	Chir pine	15
27	Sorlekh	29.6163	80.2834	1900 - 2100	Deodar, oak, temperate mixed	17
Total						**700**

Table 3.2. Sampling points within different habitats of the study area.

S.N	Habitats	Point counts
1	Agriculture land	79
2	Oak forest	156
3	Chir pine forest	121
4	Temperate mixed forest	120
5	Sub tropical mixed forest	66
6	Sal forest	45
7	Riverine	45
8	Shrub land	36
9	Deodar forest	32
Total		**700**

Data analysis

We used Past 3x software (Hammer et al. 2001) for diversity indices of Birds. Shannon diversity (H) and Margalef's richness (R) and Evenness values (MacArthur & MacArthur, 1961; Magurran, 2004) were used to compute Bird Species Diversity (BSD) and Bird Species Richness (BSR) and evenness at each point. One-way ANOVA test with Tukey post hoc test was performed to determine the significant differences of BSD and BSR between different land-use categories and habitats. Vegan package for R was used to calculate ANOVA, and Tukey post hoc test (Oksanen et al. 2019).

Formulas

- Shannon Diversity : $H = -\Sigma Pi\ (\log Pi)$.
- Margalef Richness : $R = (S-1)/\log(n)$.
- Evenness : $E = H/\mathrm{Log}\ (S)$.

Where H = Shannon Diversity, Pi = proportion of a species individuals and the total number individuals of species in a sample.

R = Margalef Richness, S = Total number of species, n = Total number of Individuals in a sample.

Results

A total of 3573 individuals of 157 species belonging to 45 families and 110 genera were recorded during the point counts. Among them, 39 species are forest specialists and exclusively recorded from the forests. The maximum number of species were recorded from the Temperate mixed forest (81) followed by Oak forest (79), Agriculture land (69), sub-tropical mixed forest (62), Chir pine forest (48), Riverine (41), Sal forest (36), shrubland (29) and least in Deodar forest (27).

Bird diversity indices in different elevation ranges

Within different elevation ranges of the landscape as the species diversity per point, we have recorded the highest BSD (.92 ± .06) and BSR (1.19 ± .07) from the 2001 - 2500 m asl. elevation range followed by 1501 – 2000 and least in the 500 – 1000 m asl. elevation range (Figure 3.3).

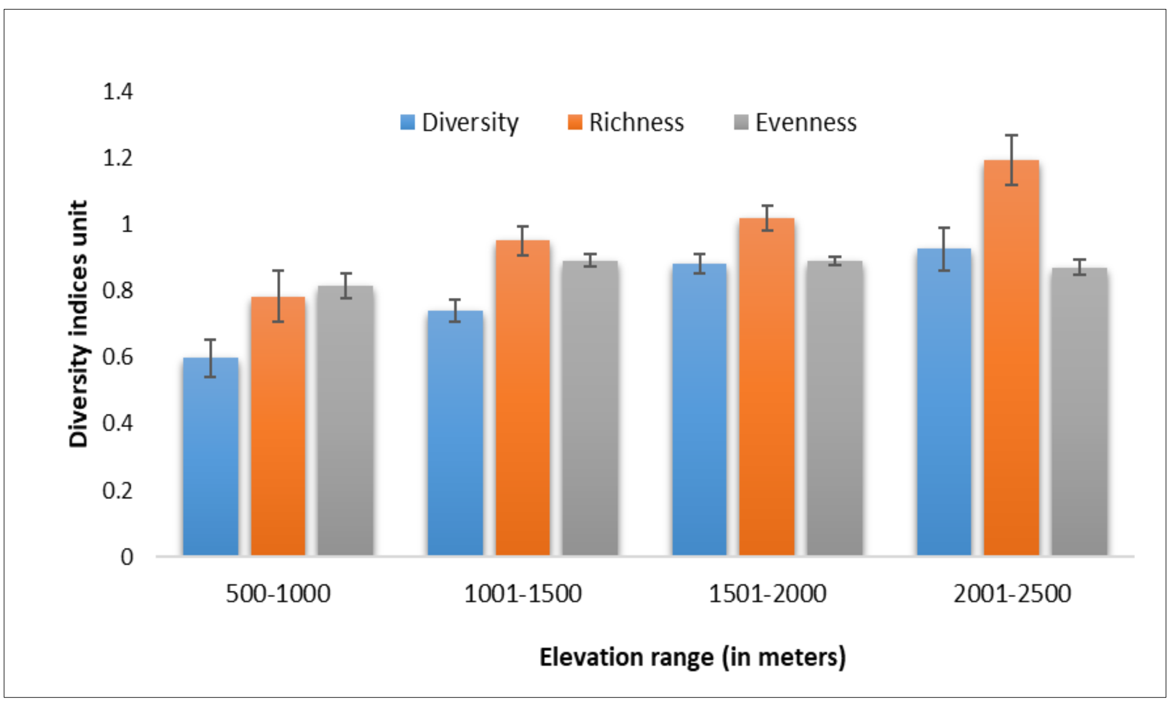

Figure 3.3: Bird diversity across different elevation ranges

Bird diversity indices in different land-use categories

Amongst different land use categories, maximum bird species diversity (BSD) (1.16 ± .05) and bird species richness (BSR) (1.4 ± .07) were recorded from agricultural land followed by forest (BSD .78 ±. 02, BSR 1.02 ± .03) and riverine (BSD .66 ± .09, BSR .91 ± .14) where shrubland has least BSD (.55 ± .11) and BSR (.85 ± .15). ANOVA test reveals a significant difference between forest, agricultural land, and riverine land use categories in species diversity and richness. BSD in agriculture land and forest are highly significantly different with p = 6.5*10-5 (P<0.001), where BSR is significantly different with p=.0021 (P<0.01). BSD between agriculture and riverine land use categories are significantly different with p= .002 (P<0.01), and BSR is significantly different with p= .045 (P<0.05) (Figure 3.4).

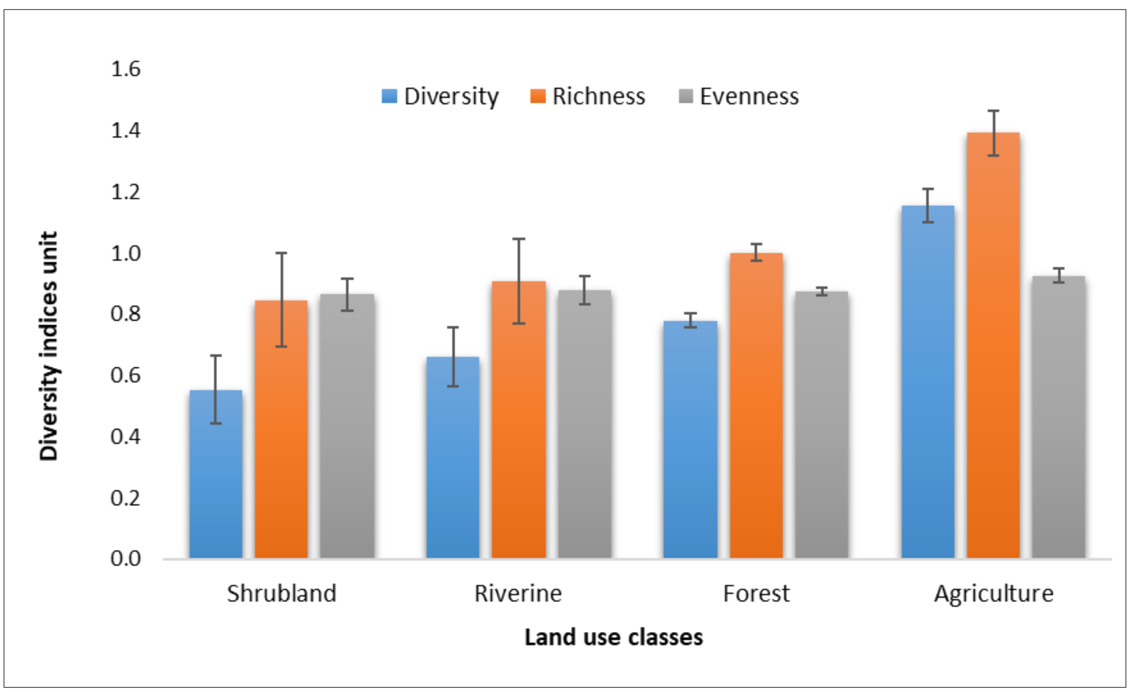

Figure 3.4: Bird diversity in different land use categories

Bird diversity indices in different habitats

Among different habitats, agricultural land is the richest and most diverse in terms of avifauna. Maximum BSD (1.16 ± .05) was recorded from agriculture land followed by Deodar forest (BSD 1.07 ± .09), Temperate mixed (BSD .99 ± .05) and Oak forest (BSD .97 ± .04) and least in Chir pine forest (BSD .46 ± .04). Agricultural land also has highest BSR (1.4 ± .07) followed by Temperate mixed forest (BSR 1.31 ± .06), Oak forest (BSR 1.2 ± .04) and least is in Chir pine forest (BSR .66 ± .05) (Figure 3.5). ANOVA test founds out that there is a significant difference among the habitats with p = 2*10-16 (P<.001). Further Post hoc test reveals that agriculture land is significantly different with Chir pine forest and Sal forest whether Deodar forest is significantly different from Chir pine and Sal forests. Oak forest is significantly different from Chir pine and Sal forests, and Chir pine forest is significantly different from sub-tropical mixed and temperate mixed forests. Sal forest is significantly different from the sub-tropical mixed forest and temperate mixed forest in BSD and BSR with a p-value < 0.001. In contrast, the Deodar forest and Oak forest are significantly different from riverine habitats. Shrubland is significantly different from Chir pine and Sal forest in BSD with a p-value < .05.

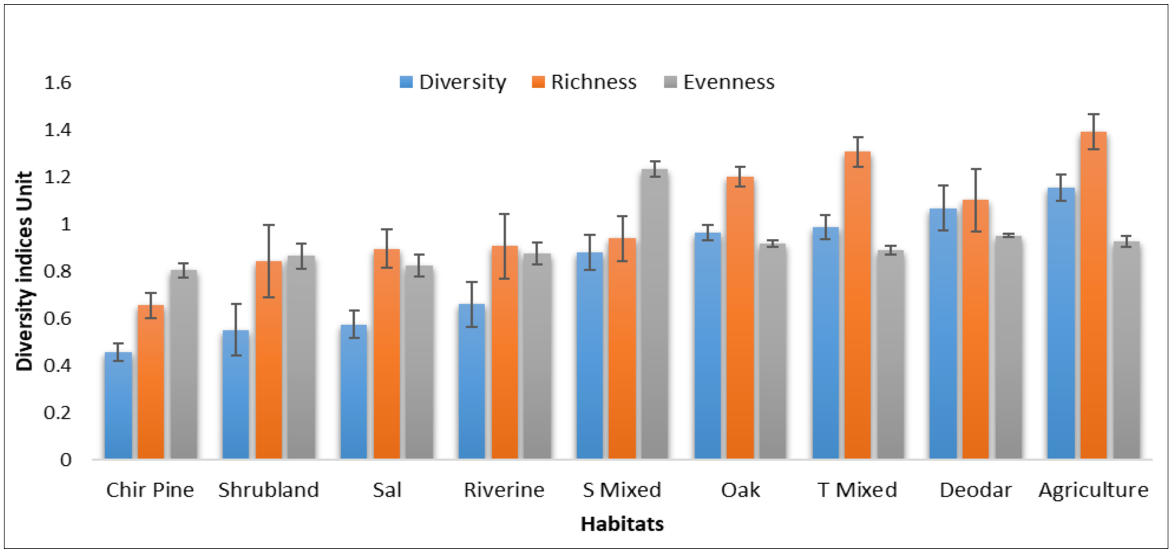

Figure 3.5: Bird diversity in different Habitats

Bird diversity in different habitat parameters

Overall bird diversity in different canopy cover classes

Within different canopy cover classes in the landscape, Maximum BSD (.79 ± .03) and BSR (1.04 ± .04) wa s recorded from the moderate category followed by High (BSD .78 ± .04, BSR 1.04 ± .5) and least in Low canopy cover class (BSD .72 ± .05, BSR .92 ± .06) (Figure 3.6).

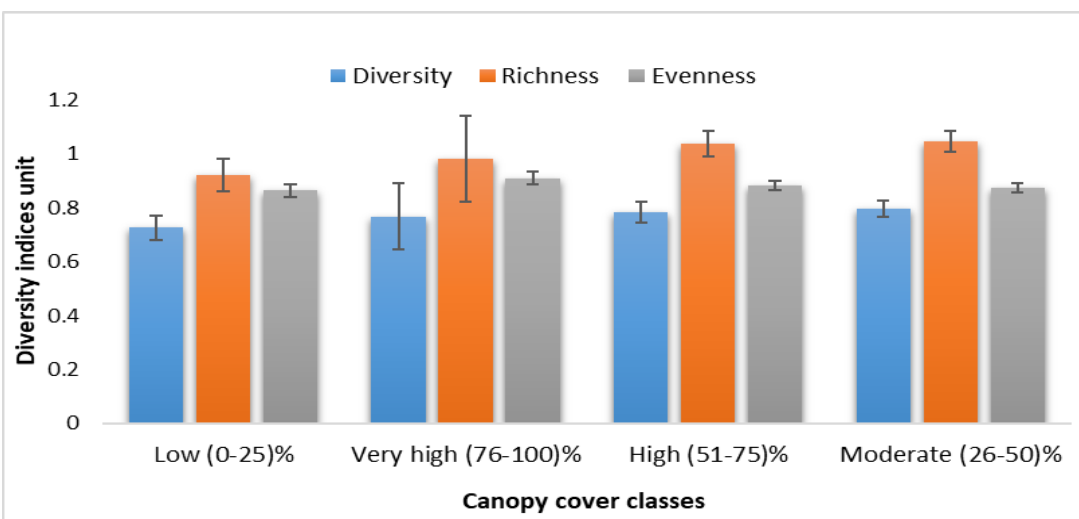

Figure 3.6: Bird diversity in different canopy cover classes

Bird diversity in canopy cover classes of different land use

Diversity indices within different canopy cover classes of different land-use categories reveal that agriculture land has maximum BSD (1.12 ± .16) and BSR (1.45 ± .26) in high canopy cover (31-45%) category followed by medium (16-30%) and low (0-15%) canopy cover category. In forest habitat maximum BSD (.81 ± .03) and BSR (1.01 ± .03) was recorded in medium (31-60%) canopy cover class followed by High (61-90%) and Low (0-30%). Similarly, shrubland has highest BSD (1.2 ± .3) and BSR (1.5 ± .8) in High (11-20%) canopy cover class followed by medium (5-10%) and low (0-5%). The riverine habitat has the highest BSD (.86 ± .14) and BSR (1.23 ± .27) in medium (16-30%) canopy cover class followed by high and low classes (Figure 3.7).

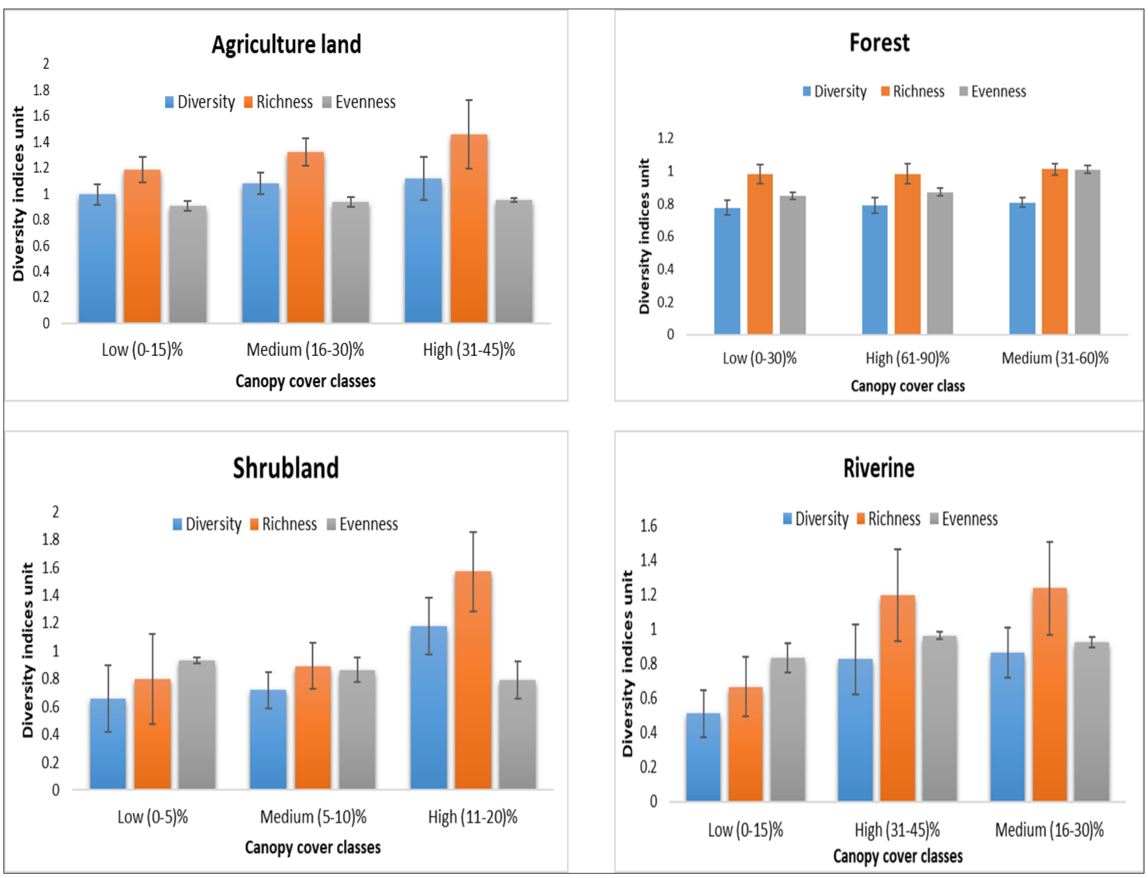

Figure 3.7: Bird diversity in different canopy cover classes of different land-use categories

Bird diversity in canopy cover classes of different forest habitats

Within different forest habitats of the landscape, Deodar forest has maximum BSD (1.26 ± .09) and BSR (1.68 ± .2) in the medium (21-40%) canopy cover class followed by high (41-60%) and least in low (0-20%). Similarly, temperate mixed forest has highest BSD (.94 ± .06) and BSR (1.23 ± .07) in medium (30-60%) canopy cover class followed by low (0-30%) and high (61-90%). Oak and Chir pine forest has maximum BSD (1.12 ± .09 and .51 ± .07) and BSR (1.37 ± .11 and .71 ± .12) in low (0-30%) canopy cover class. Sub-tropical mixed forest has highest BSD (1.07 ± .17) and BSR (1.3 ± .18) in high (41-60%) canopy cover class followed by Medium (21-40%) and least in low (0-20%) canopy cover class. Whether in Sal forest maximum BSD (.47 ± .11) was found in medium (25-50%) canopy cover class and BSR (.68 ± .11) was highest in high (51-75%) canopy cover class (Figure 3.8).

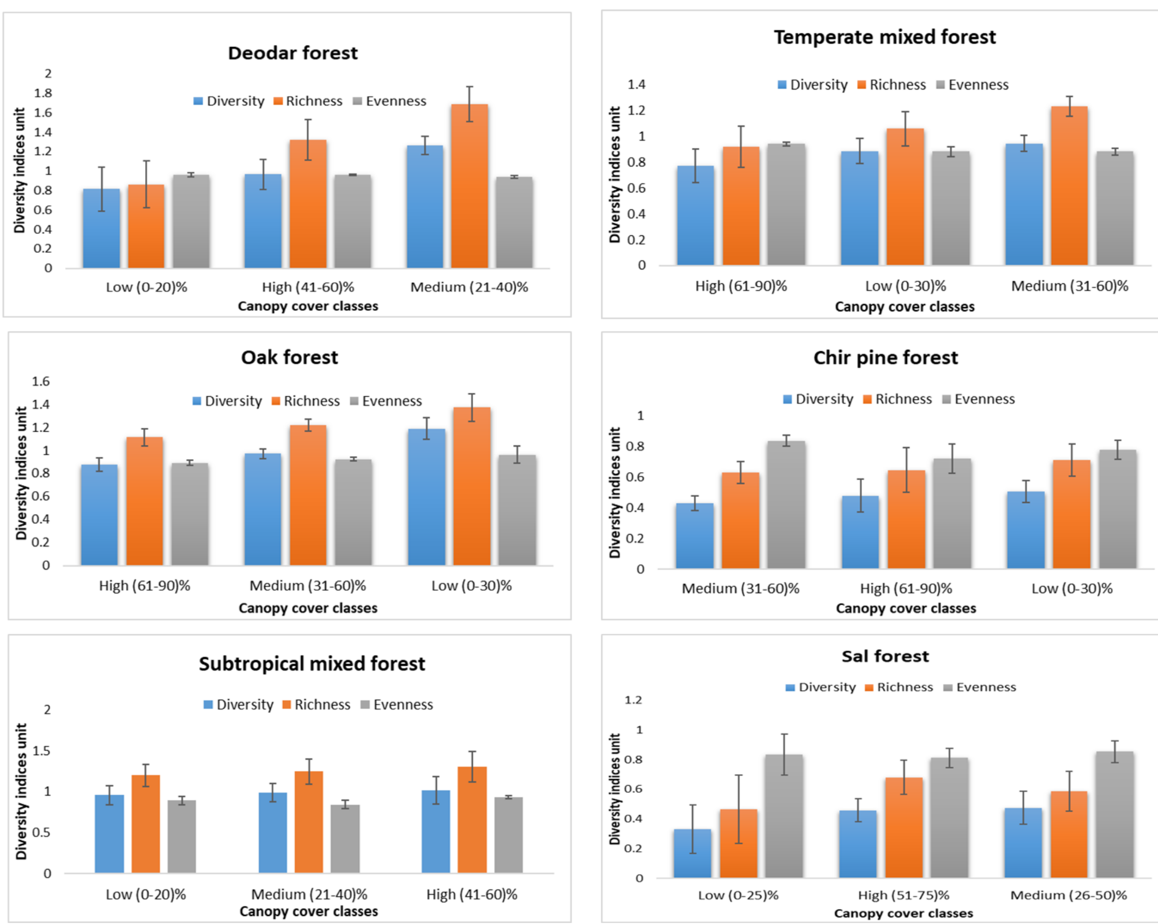

Figure 3.8: Bird diversity in different canopy cover classes of different habitats

Overall bird diversity in different shrub cover and grass cover classes

Diversity indices within different grass cover classes revealed that low grass cover (0-30%) supports highest BSD (.84 ± .02) and BSR (1.06 ± .03) followed by medium (31-60%) and high (61-90%) grass cover. Whether medium shrub cover class (31-60%) supports highest BSD (.89 ± .03) and BSR (1.1 ± .04) followed by low (0-30%) and high (61-90%) grass cover class (Figure 3.9).

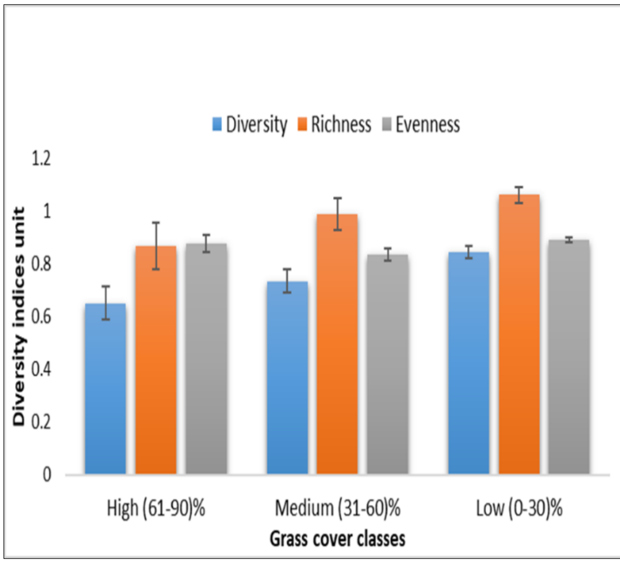

Figure 3.9.A: Bird diversity in different grass cover classes

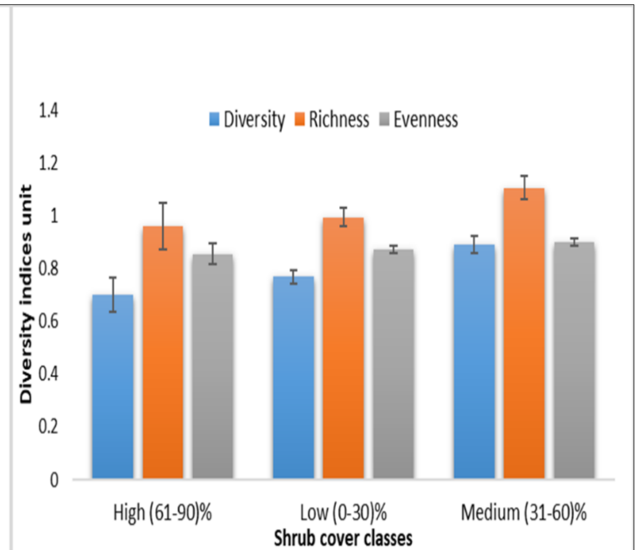

Figure 3.9.B: Bird diversity in different shrub cover classes

Bird diversity indices in different litter cover classes

Highest BSD (.82 ± .02) and BSR (1.06 ± .03) was recorded from low litter cover class (0-20%). Very high litter cover class (61-80%) is the second highest in BSR (.99 ± .14) but least in BSD (.72 ± .1) (Figure 3.10).

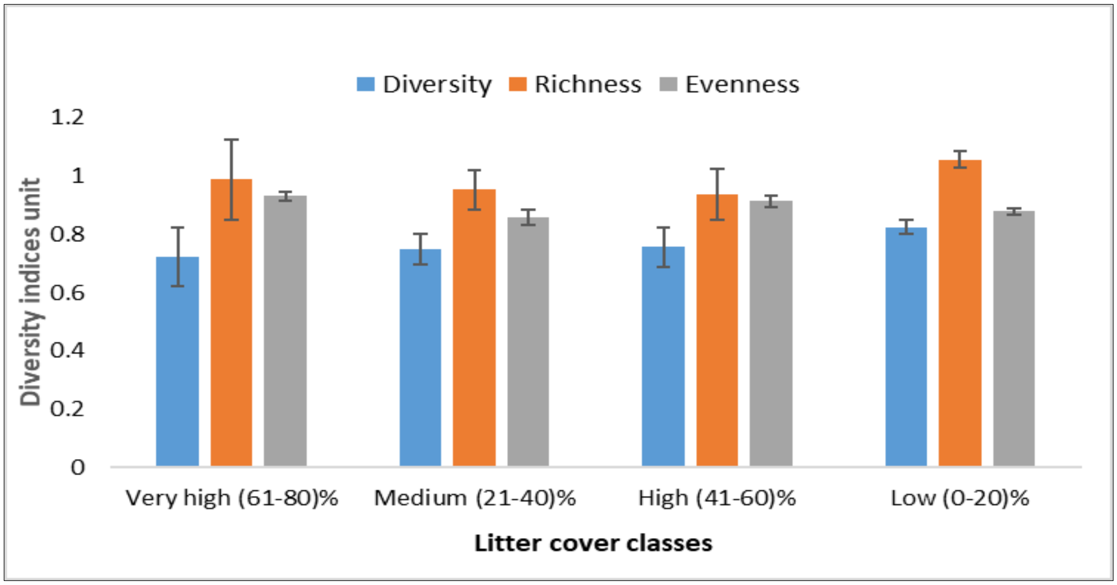

Figure 3.10: Bird diversity in different litter cover classes

Bird diversity indices in different slope categories and aspects

The highest BSD (.89 ± .05) and BSR (1.13 ± .07) was recorded in the slope between 0°-25° followed by 26°-60° and least in 76°-90°. Within different aspects, maximum BSD (.91 ± .06) and BSR (1.23 ± .08) was recorded from the west (W) aspect whether least BSD (.69 ± .05) and BSR (.90 ± .07) was found in the southwest (SW) aspect (Figure 3.11).

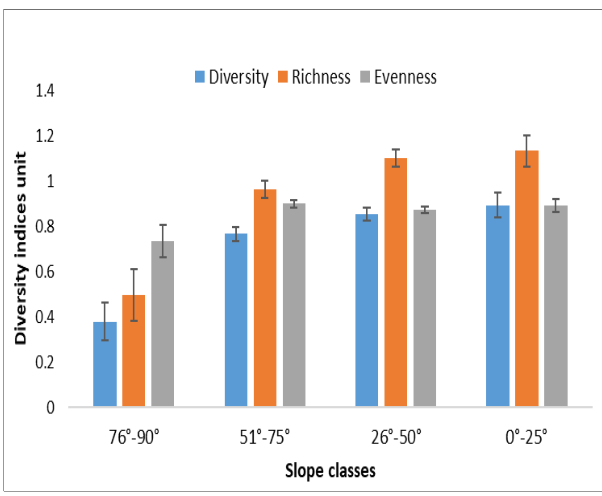

Figure 3.11.A: Bird diversity in different slope classes

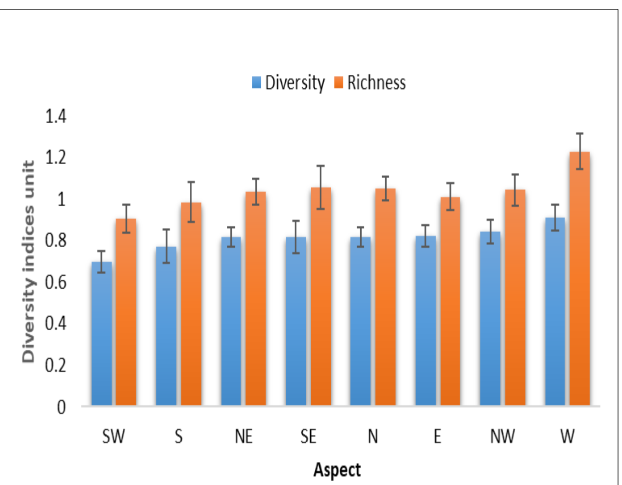

Figure 3.11.B: Bird diversity in different aspects

Abbreviations: Aspect- E= East, W= West, N= North, NE= Northeast, NW= Northwest, S= South, SE= Southeast, SW= Southwest.

Habitat disturbance

Overall disturbance

Overall in 76% of sampling plots were found to be low in tree cutting, 5% of plots with high tree cutting, and 19% with moderate cutting. Within 45% of plots, tree lopping was recorded, of which 9% with high lopping and 36% with moderate lopping whether evidence of cattle presence was found within 48% of sampling plots (Figure 3.12).

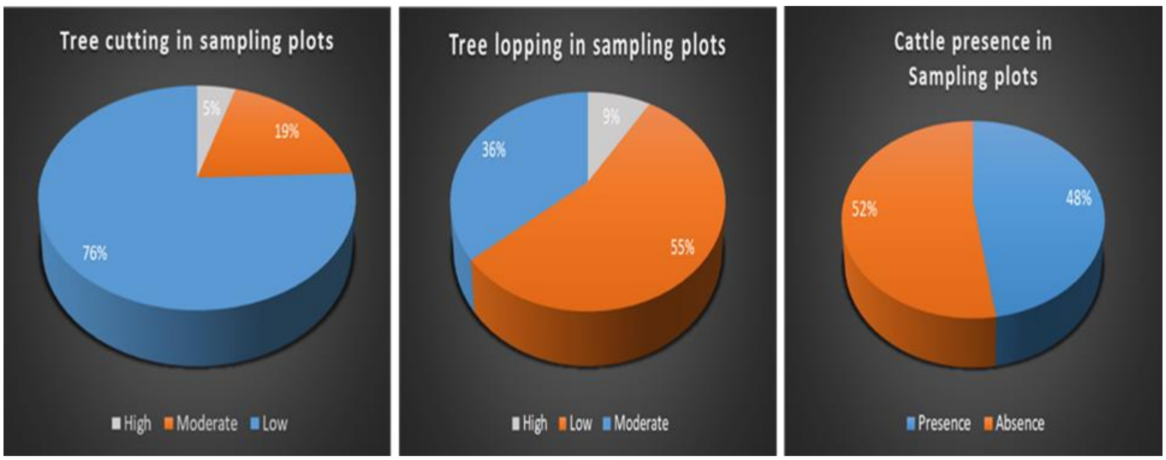

Figure 3.12: Tree cutting, tree lopping and presence of cattle in different sampling

Disturbance within different habitats

Among all the habitats, Deodar forest was the least disturbed habitat in tree cutting (6% moderate) and tree lopping (9% moderate), whether highest disturbed in terms of cattle presence with 72% of sampling plots found to be the presence of cattle. Chir pine forest has also highly disturbed with the cattle presence as within 63% of plots, evidence of cattle presence was found whether in 7% plots high tree cutting and 16% plots moderate tree cutting found. Oak forest was also found slightly disturbed with 24% of moderate tree cutting, and 49% of moderate and 5% of high tree lopping, wherein 37% of plots presence of cattle was found (Figure 8.2). Sal forest was the most disturbed habitat in the landscape; within 18% of sampling plots, high tree cutting was recorded, and 38%

moderate cutting. Tree lopping was also highest recorded in the Sal forest, with 42% of plots having high tree lopping and 35% moderate. Near 24% moderate and 8% low tree cutting was recorded from the sub-tropical mixed forest. However, tree lopping was also high in this habitat with 50% and 18% of moderate and high tree lopping, respectively. However in 38% of sampling plots, cattle presence was found in sub-tropical forest. The temperate mixed forest was also slightly disturbed with 21% moderate and 5% high tree lopping, 13% and 2% of plots moderate and high tree lopping was recorded respectively. Within near 20% of sampling plots, cattle presences were recorded in the temperate mixed forest. Within riverine and shrubland habitats, in 31% and 42% of plots, respectively were found the presence of cattle, and due to the less tree cover, we did not record the tree cutting and lopping in these habitats (Figure 3.13: A, B).

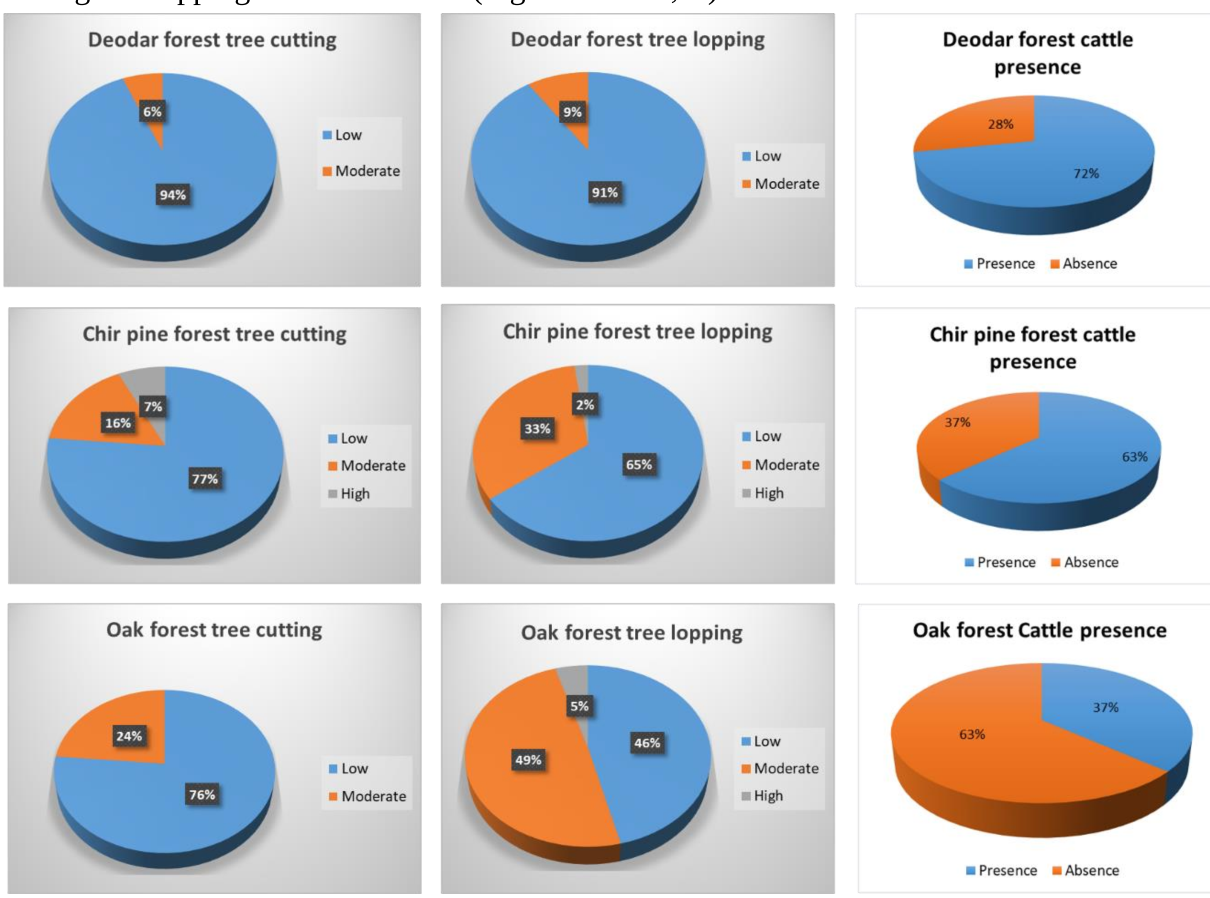

Figure 3.13.A: Tree cutting, tree lopping and presence of cattle within different habitats

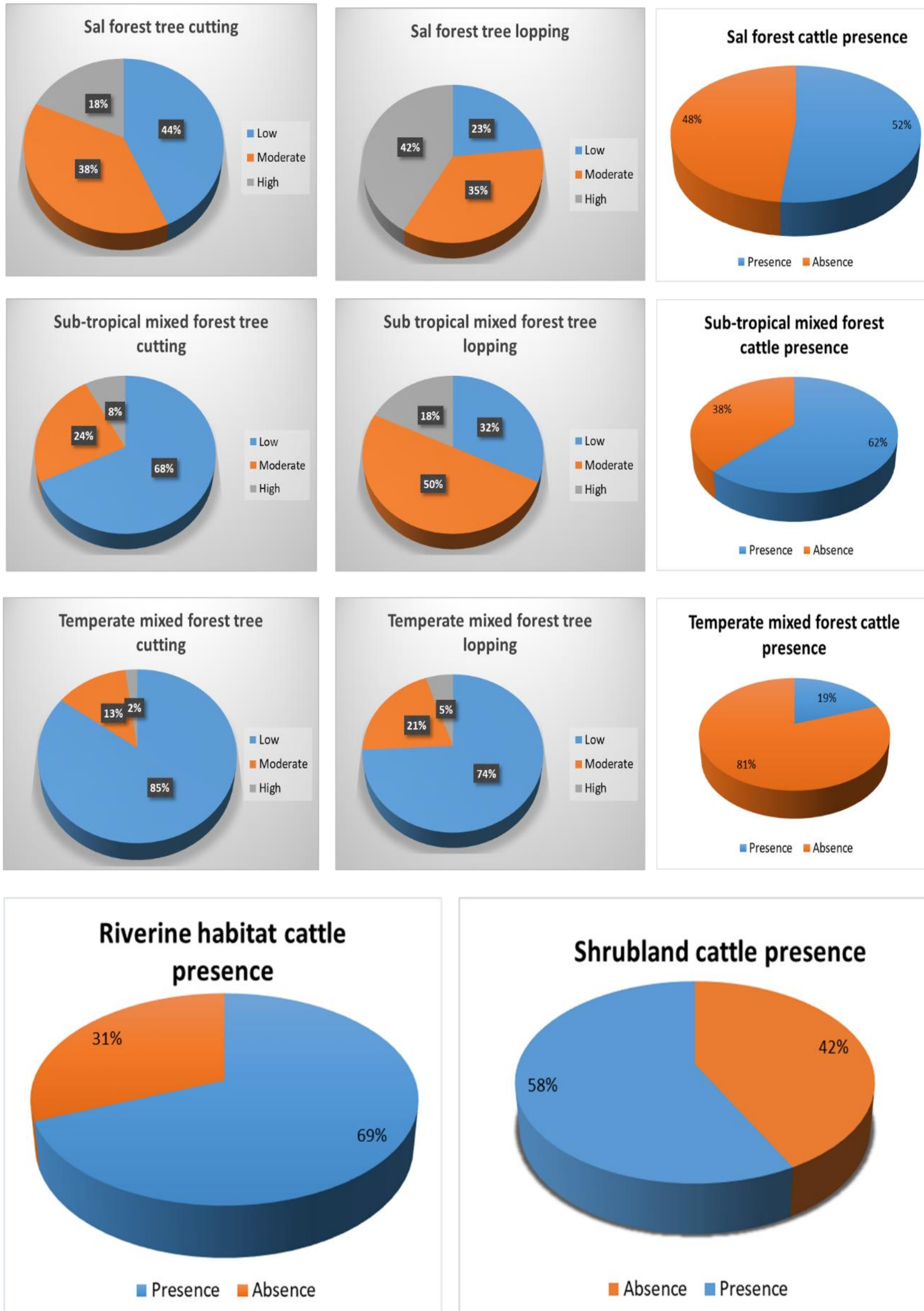

Figure 3.13.B: Tree cutting, tree lopping and presence of cattle within different habitats

Bird diversity within different disturbance regimes

Bird diversity in overall disturbance regimes

In the forest habitats, analysis in different tree cutting classes reveal that the low tree cutting class supports the highest BSD (.81 ± .02) and BSR (1.04 ± .03) followed by moderate and high tree cutting classes. The highest BSD (.81 ± .03) and BSR (1.05 ± .04) were recorded from a moderately lopped class followed by low and high tree lopping classes within different lopping classes. The presence of cattle is not much impacting on BSD and BSR in the landscape. BSD (.78 ± 03) is slightly higher in cattle absence plots the BSD (.77 ± 03) in cattle presence plots. Similarly, in BSR (1.01 ± .04) is somewhat highest in cattle absence plots. (Figure 3.14).

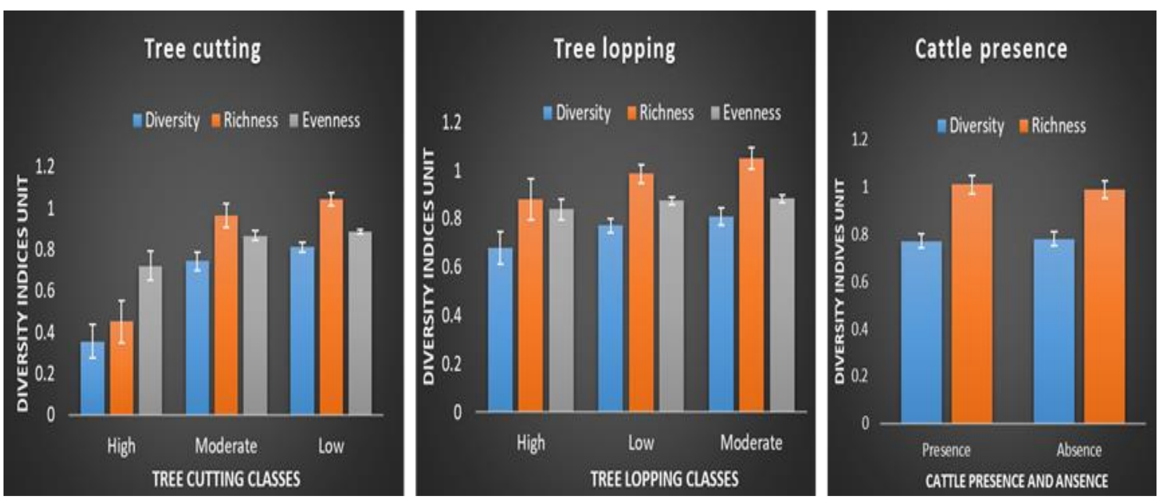

Figure 3.14: Bird diversity in different disturbance regimes

Bird diversity in different disturbance regimes of different habitats

In the Deodar forest, maximum BSD (1.18) and BSR (1.15) were found in the low tree cutting class. Highest BSD (1.12) and BSR (1.47) was found in the low tree lopping category and the presence of cattle does not much affect the diversity indices as BSD (1.07) and BSR (1.4) was slightly higher in cattle presence plots compared to BSD (1.05) and BSR (1.37) in cattle absence plots. In Chir pine forest, low tree cutting supports the highest BSD (.51) and BSR (.72) followed by moderate and high tree cutting classes, whether moderate tree lopping supports high BSD (.5) and BSR (.7). In the Chir pine forest, BSD (.53) and BSR (.74) are higher in the cattle presence plots than the cattle absence plots. In the Oak forest, moderate cutting and lopping support high BSD (1.12 and 1.08) and BSR (1.4 and 1.36), BSD and BSR are slightly higher in cattle presence plots (Figure 10.1). Similarly, moderate tree cutting and lopping classes in Sal forest have the maximum BSD (.5 and .52), whether BSR (.64) was the highest in the low tree lopping class. BSD and BSR were higher in the cattle presence plots than the absence plots in the Sal forest. Sub-tropical mixed forest supports highest BSD (1.1) BSR (1.4) in low tree cutting class whether BSD (1.08) was highest in moderate tree lopping class and BSR (1.37) was highest in low tree lopping class, here cattle absence plots have high BSD and BSR then the cattle presence plots. In temperate mixed moderate tree cutting and tree lopping class found the be highest in BSD and BSR. The riverine habitat presence of cattle supports slightly higher BSD and BSR than cattle absence plots, wherein shrubland habitat BSD (1.06) and BSR (1.3) were higher in the cattle absence plots. (Figure 3.15.A, B).

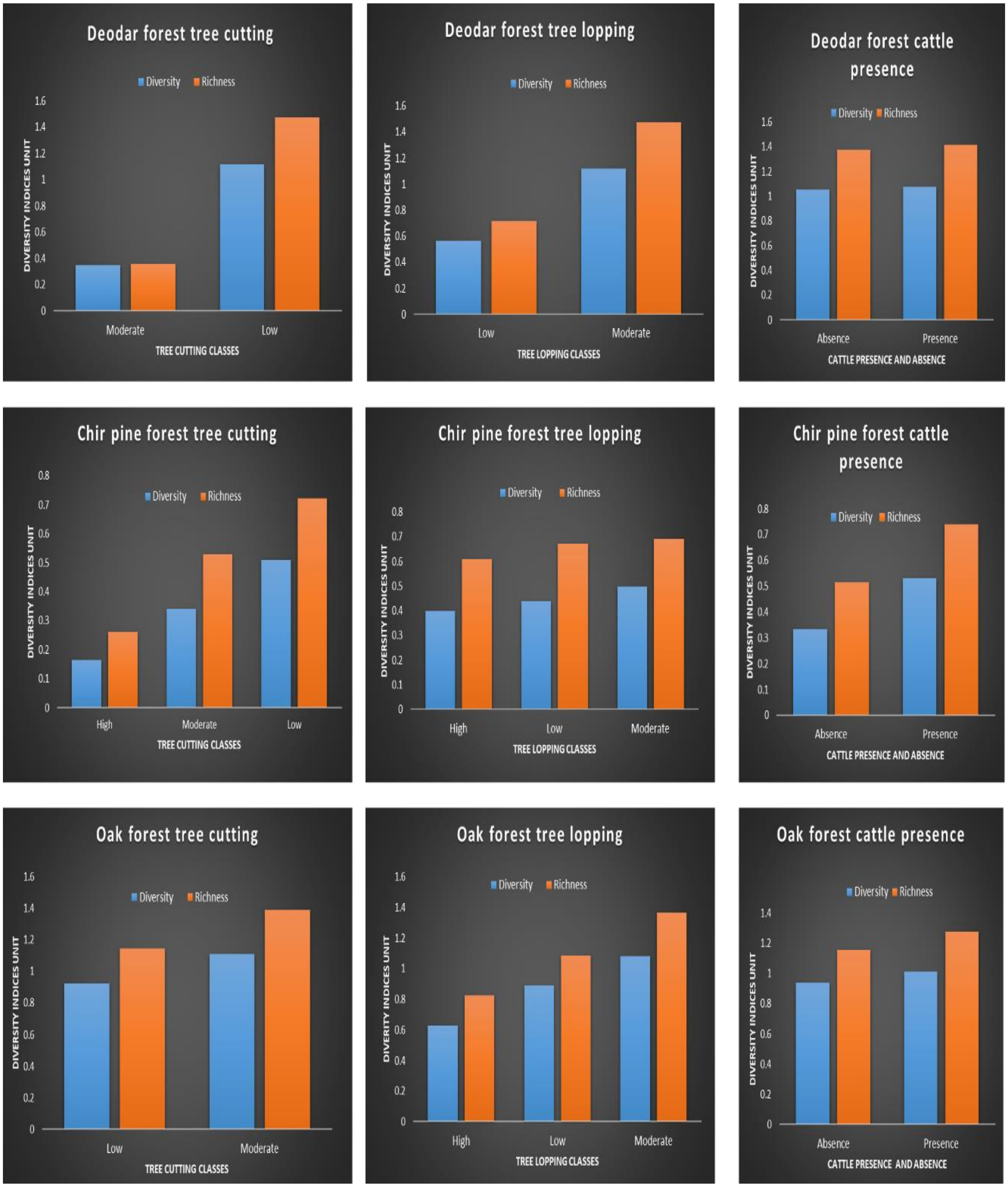

Figure 3.15.A: Bird diversity within different disturbance regimes of different habitats

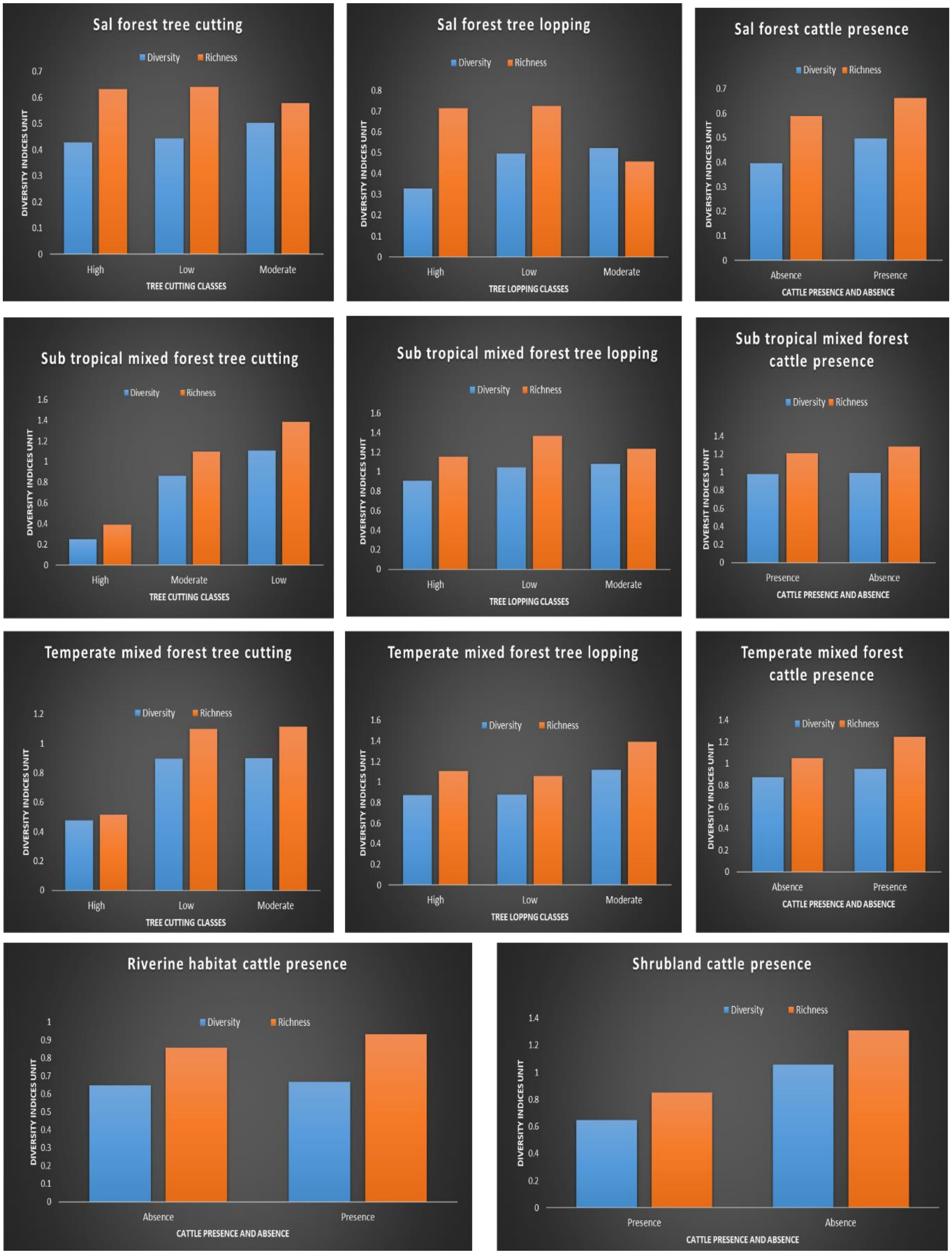

Figure 3.15.B: Bird diversity within different disturbance regimes of different habitats

Species encounter rate within different habitats

The encounter rate of species was calculated within each habitat as individuals recorded per hour. Overall bird encounter rate (ER) was recorded as 20.4 individuals/hour. Among the different habitats highest bird encounter rate (ER 27.7) was found in the agriculture land, followed by temperate mixed forest (ER 27.03), Oak forest (ER 25.26), sub-tropical mixed forest (ER 22.15). The least encounter rate was recorded in the Chir pine forest (ER 11.07) and riverine habitat (11.78). Grey-hooded warbler was the highest recorded species in the landscape with 1.36 ind/hr of encounter rate followed by Himalayan bulbul (ER 1.32), Slaty-headed parakeet (ER .83), Black-throated tit (ER .78). White-throated kingfisher, Pied bushchat, White-browed fantail, etc. were encountered least. Within the Agriculture habitats, Common myna was encountered the most (ER 3.14), followed by House sparrow (ER 2.53), Himalayan bulbul (ER 1.87), Plum-headed parakeet (ER 1.52). In the Deodar forest, species such as Himalayan bulbul (ER 2.5), Grey treepie (ER 2), Oriental turtle dove (ER 1.75), and Grey bushchat (ER 1.63) were encountered the most. In Oak and temperate mixed forest, Grey-hooded warbler was recorded the most with ER 2.46 and ER 2.27 followed by Black-throated tit (ER 1.97, ER 1.43), respectively. White-throated laughingthrush (ER 1.43) is also the second-highest encounter species in temperate mixed forest, Slaty-headed parakeet was the third-highest encountered (ER 1.33) in Oak forest. In the Chir pine forest, Slaty-headed parakeet (ER .96) was recorded highest, followed by Long-tailed minivet and Grey-hooded warbler with the same quantity (ER .83) and Himalayan bulbul (ER .73). In the Riverine habitat, White-capped redstart (ER .8), Grey treepie (ER .8), Plumbeous redstart (ER .71), and Great tit (ER .53) were the highest encountered. In the sub-tropical mixed forests and shrublands, Himalayan bulbul (ER 1.66 and ER 2.89 respectively) was the most recorded species. Slaty-headed parakeet (ER 1.48) was the second-highest encountered species in the sub-tropical mixed forest, followed by Plum-headed parakeet (ER 1.29) and Great tit (ER 1.23). Grey bushchat (ER 1.33) was second highest in shrubland followed by Plum-headed parakeet (ER .78) and Jungle babbler (ER .56). Within the Sal forest Grey-hooded warbler (ER 1.87) was the highest recorded species, followed by Great tit (ER 1.33), Oriental white-eye (ER .98) and so on. (Table 3.3)

Table 3.3. Bird species encounter rates (individuals/hour) within different habitats during point counts.

Species	Agriculture	Deodar	Oak	Chir pine	Riverine	S. mixed	Sal	Shrub-land	T. mixed	Overall ER
Ashy bulbul	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.01
Ashy drongo	0.25	0.50	0.05	0.00	0.09	0.18	0.18	0.00	0.03	0.10
Asian barred owl	0.20	0.00	0.03	0.00	0.00	0.12	0.00	0.00	0.13	0.06
Asian emerald dove*	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.07	0.02
Asian Koel	0.05	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.01
Bar tailed treecreeper	0.00	1.00	0.62	0.43	0.00	0.12	0.53	0.00	0.37	0.37
Barn swallow	0.15	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.10	0.04
Bearded vulture	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.01
Black bulbul	0.15	0.50	0.67	0.40	0.00	0.98	0.18	0.00	0.63	0.47
Black chinned babbler	0.10	0.00	0.33	0.07	0.00	0.06	0.36	0.44	0.00	0.15
Black eagle*	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.13	0.03
Black faced warbler*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.03
Black francolin	0.10	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.02
Black headed jay	0.05	0.00	0.13	0.07	0.00	0.00	0.00	0.00	0.67	0.16
Black lored tit	0.15	0.00	0.23	0.17	0.00	0.00	0.00	0.00	0.10	0.11
Black throated thrush	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01
Black throated tit*	0.00	0.50	1.97	0.30	0.00	0.25	0.00	0.00	1.43	0.78
Blue capped redstart	0.00	0.00	0.08	0.20	0.00	0.00	0.00	0.00	0.03	0.06
Blue capped rockthrush*	0.00	0.25	0.05	0.13	0.09	0.06	0.09	0.00	0.00	0.06
Blue fronted redstart	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.07	0.02
Blue throated barbet	0.20	0.00	0.03	0.03	0.09	0.25	0.00	0.00	0.03	0.07
Blue trhoated flycatcher*	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01

Blue whistling thrush	0.15	0.50	0.51	0.53	0.44	0.12	0.27	0.11	0.07	0.32
Blue winged minla	0.05	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.07	0.03
Blyth's leaf warbler*	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Brown dipper	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.01
Brown fronted woodpecker	0.10	0.25	0.10	0.50	0.09	0.12	0.53	0.33	0.07	0.21
Buff barred warbler*	0.00	0.00	0.08	0.00	0.00	0.00	0.27	0.00	0.60	0.14
Chestnut bellied nuthatch	0.00	1.25	0.56	0.13	0.27	0.12	0.00	0.00	0.70	0.35
Chestnut bellied rockthrush	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Chestnut crowned laughingthrush	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.40	0.08
Chestnut headed bee-eater	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Chestnut tailed minla	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.01
Chestnut tailed starling	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.02
Chukar partridge	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.22	0.00	0.02
Common hoopoe	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Common kingfisher	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.01
Common myna	3.14	0.00	0.18	0.00	0.00	0.80	0.00	0.00	0.27	0.51
Common rosefinch	0.71	0.00	0.54	0.00	0.00	0.68	0.00	0.00	0.00	0.26
Common sandpiper	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.01
Common stonechat	0.25	0.00	0.00	0.07	0.00	0.00	0.00	0.33	0.00	0.06
Common tailorbird	0.00	0.00	0.00	0.00	0.00	0.12	0.09	0.22	0.00	0.03
Common wood pigeon*	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.02
Crested bunting	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Crested kingfisher	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.02
Crested serpent eagle	0.00	0.00	0.00	0.03	0.00	0.12	0.00	0.00	0.00	0.02
Crimson sunbird	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.01
Crow billed drongo*	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Dark breasted rosefinch	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Dark sided flycatcher	0.10	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.07	0.03
Egyptian vulture	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.01
Eurasian collared dove	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.01
Eurasian jay*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.07
Fire breasted flowerpecker	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.13	0.03
Fire tailed sunbird*	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.47	0.09
Great barbet	0.46	0.50	0.38	0.03	0.18	0.49	0.27	0.00	0.20	0.27
Great tit	0.46	0.25	0.28	0.53	0.53	1.23	1.33	0.22	0.13	0.49

Greater yellownape*	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.20	0.07
Green backed tit	0.05	0.88	0.56	0.07	0.00	0.00	0.18	0.00	0.33	0.25
Green tailed sunbird*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.05
Grey breasted prinia	0.15	0.00	0.00	0.00	0.18	0.12	0.00	0.00	0.00	0.04
Grey bushchat	0.91	1.63	0.36	0.26	0.44	0.92	0.44	1.33	0.43	0.59
Grey capped pygmy woodpecker	0.00	0.00	0.00	0.00	0.00	0.06	0.18	0.00	0.00	0.02
Grey headed canary flycatcher	0.05	0.63	0.21	0.00	0.00	0.06	0.27	0.00	0.13	0.13
Grey headed woodpecker	0.00	0.25	0.18	0.36	0.18	0.12	0.27	0.11	0.13	0.18
Grey hooded warbler	0.20	1.50	2.46	0.83	0.44	0.43	1.87	0.00	2.27	1.36
Grey sided bush warbler	0.00	0.00	0.00	0.03	0.00	0.12	0.00	0.00	0.00	0.02
Grey treepie	0.25	2.00	0.90	0.17	0.80	0.49	0.27	0.00	0.57	0.56
Grey wagtail	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.01
Grey winged blackbird	0.15	0.00	0.18	0.03	0.00	0.00	0.00	0.00	0.00	0.06
Hill partridge*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.03
Hill pigeon	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.09
Himalayan bulbul	1.87	2.50	1.21	0.73	0.44	1.66	0.80	2.89	1.27	1.32
Himalayan vulture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.03	0.01
Himalayan woodpecker*	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.43	0.09
House sparrow	2.53	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.30
Hume's leaf warbler	0.05	0.00	0.79	0.10	0.00	0.37	0.00	0.22	0.37	0.31
Indian paradise flycatcher	0.15	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.02
Jungle babbler	0.76	0.00	0.38	0.20	0.44	0.68	0.00	0.56	0.30	0.38
Kalij pheasant*	0.00	0.00	0.03	0.00	0.00	0.18	0.09	0.00	0.80	0.17
Large billed crow	0.35	0.50	0.28	0.40	0.00	0.00	0.36	0.00	0.27	0.26
Large cuckooshrike	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.01
Large hawk cuckoo*	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.01
Large woodshrike*	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.01
Lemon rumped warbler*	0.00	0.25	0.49	0.00	0.18	0.00	0.62	0.00	0.67	0.29
Lesser yellownape	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.27	0.05
Long billed thrush*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01
Long tailed minivet*	0.00	0.50	0.00	0.83	0.00	0.43	0.18	0.00	0.40	0.29
Long tailed shrike	0.25	0.00	0.00	0.07	0.09	0.00	0.00	0.00	0.00	0.05
Maroon oriole*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.02
Mistle thrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.01
Mountain bulbul*	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Mountain hawk eagle*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01

Orange bellied leafbird	0.05	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.02
Oriental magpie robin	0.10	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.02
Oriental turtle dove	1.01	1.75	0.49	0.30	0.09	0.92	0.18	0.44	0.37	0.54
Oriental white eye	0.71	0.38	0.36	0.07	0.27	1.05	0.98	0.33	0.20	0.42
Paddyfield pipit	0.20	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.05
Pied bushchat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.01
Pink browed rosefinch*	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.23	0.05
Plum headed parakeet	1.52	0.00	0.00	0.10	0.44	1.29	0.00	0.78	0.13	0.40
Plumbeous redstart	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.05
Purple sunbird	0.05	0.00	0.00	0.00	0.00	0.06	0.00	0.22	0.00	0.02
Red billed blue magpie	1.06	0.63	0.38	0.36	0.09	0.74	0.00	0.11	0.43	0.45
Red rumped swallow	0.10	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.03
Red vented bulbul	1.22	0.00	0.64	0.03	0.00	1.11	0.09	0.44	0.00	0.42
Rock bunting	0.10	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.03
Rosy pipit	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.03
Rufous bellied niltava*	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.07	0.09
Rufous breasted accentor	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.27	0.08
Rufous chinned laughingthrush*	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Rufous gorgeted flycatcher	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.37	0.10
Rufous sibia	0.10	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.47	0.14
Rufous treepie	0.05	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.02
Rufous woodpecker	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Russet sparrow	1.27	0.00	0.10	0.07	0.00	0.55	0.36	0.11	0.23	0.30
Rusty cheeked scimitar babbler	0.61	0.00	0.41	0.00	0.00	0.25	0.00	0.33	0.47	0.28
Rusty tailed flycatcther	0.05	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Scaly bellied woodpecker*	0.00	0.00	0.23	0.13	0.00	0.00	0.00	0.00	0.23	0.11
Scaly breasted munia	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.03
Scarlet minivet*	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.01
Shikra	0.05	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Slaty backed forktail	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.01
Slaty blue flycatcher	0.00	0.00	0.03	0.07	0.00	0.00	0.00	0.00	0.00	0.02
Slaty headed parakeet	0.71	0.00	1.33	0.96	0.00	1.48	0.36	0.11	0.70	0.83
Small niltava	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.07	0.02
Snow pigeon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.02
Spangled drongo	0.41	0.00	0.00	0.00	0.18	0.12	0.00	0.00	0.00	0.07
Speckled piculet*	0.00	0.00	0.10	0.03	0.00	0.12	0.00	0.00	0.13	0.06

Spot winged starling	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.02
Spotted dove	0.20	0.38	0.18	0.03	0.00	0.12	0.00	0.00	0.27	0.14
Spotted forktail	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.01
Streak breasted scimitar babbler*	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Streaked laughingthrush	0.81	0.00	0.18	0.17	0.00	0.55	0.00	0.11	0.10	0.23
Striated laughingthrush*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.06
Striated prinia	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.22	0.07	0.03
Stripe throated yuhina*	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.20	0.10
Tickell's leaf warbler	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.40	0.09
Ultramarine flycatcher	0.10	0.25	0.26	0.00	0.00	0.00	0.00	0.00	0.13	0.10
Variable wheatear	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Verditer flycatcher	0.25	0.25	0.21	0.20	0.36	0.18	0.09	0.11	0.27	0.22
Wedge tailed green pigeon*	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Whiskered yuhina	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.33	0.09
Whistlier's warbler*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.01
White breasted waterhen	0.05	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.01
White browed fantail*	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01
White browed wagtail	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.01
White capped redstart	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.05
White crested laughingthrush	0.96	0.00	1.18	0.17	0.36	0.00	0.00	0.00	1.27	0.64
White rumped munia	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
White throated Fantail	0.10	0.63	0.13	0.00	0.00	0.18	0.18	0.00	0.20	0.13
White throated kingfisher	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.01
White throated laughingthrush*	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.00	1.43	0.51
White wagtail	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.01
Yellow bellied fantail*	0.00	0.00	0.13	0.00	0.00	0.06	0.00	0.00	0.20	0.07
Yellow breasted greenfich	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.02
Yellow crowned woodpecker	0.05	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.02
Overall species ER in Habitats	**27.70**	**20.38**	**25.26**	**11.07**	**10.76**	**22.15**	**12.9**	**11.8**	**27.03**	**20.42**

Abbrevation: * = Forest specialist, S. mixed = Sub-tropical mixed, T. mixed = Temperate mixed, ER = Encounter rate.

Discussion

Our study highlights avifaunal diversity and abundance status in forest and agriculture land matrices of the KSL-India, Pithoragarh district. The species diversity shows the complexity of the ecosystem that exists in such areas despite considerable human interference. In the Himalayas, with increasing elevation, the species richness also increases until a certain elevation (Acharya et al. 2011; Paudel and Sipos, 2014; Joshi and Bhatt, 2015). Our results also support that with increasing elevation range, bird richness is also increases. Maximum species richness and diversity in the 2000-2500 m asl. elevation range were recorded. However, species richness may begin to decrease by going beyond this elevation range due to extreme weather conditions (Dixit et al 2016). Similarly, the maximum species were recorded in the temperate mixed forest in the 2000 - 2500 m elevation range that supports high species richness.

Within different land use patterns in the landscape, diversity and richness were found maximum in agriculture lands. In the Himalayas, traditional agriculture is typically diverse, with a variety of fodder, ornamental and sacred plants in the croplands using organic farming practices (Bisht et al. 2006). We recorded a variety of fodder or ornamental trees such as *Ficus racemosa, Ficus palmata, Ficus religiosa, Celtis australis, Grewia optiva*, *Celtis australis, Pyrus passia*, and so from the agricultural lands. Various birds use branches of these trees for perching and foraging purposes. Previous studies have discussed the premise that if agricultural lands are managed organically and maintained with diverse shade trees, they can harbor a significant amount of wild biodiversity with unique community assemblages of plants and animals (Harvey et al. 2006; Sharma & Vetaas, 2015; Mellink et al. 2017). Also, the study by Elsen et al. (2016)

in the Himalayan region found the agricultural land supporting higher bird diversity than the forests during winters. In shrublands due to low abundance of trees, BSD and BSR was found least. A significant difference in BSD and BSR among the forest and agriculture land-use, and riverine and agriculture land use categories were recorded.

Diversity indices in the different habitats of the landscape reveal that agriculture land has the highest BSD and BSR, and the reason has been discussed earlier. Within the forest habitats, the Deodar forest was the most species diverse habitat. Most of these forests are the sacred grooves in the study area, so human disturbance was significantly less in this habitat. Most of these Deodar trees are mature and tall, and shrub cover was also recorded high in these forests, supporting different perch heights to the various passerine birds for foraging and nesting. BSR was highest found in the temperate mixed forest after the agriculture land, whether in BSD, temperate mixed forest and Oak forest were third and fourth highest respectively. The canopy cover in both of these forests found between medium to high with wide branching, and the ground surface was mostly covered with leaf litter or shrubs that support a variety of passerine and ground-dwelling birds for foraging and nesting.

James (1971) suggested that the canopy and tree cover are essential variables affecting bird diversity. Diversity indices within different canopy cover classes reveal that the low canopy cover (0-25%) represents the least BSD and BSR. Similarly, Chettri et al. (2001) and Devis et al. (2012) found that the low tree canopy cover supports low avian diversity. We found moderate canopy cover class (25-50%) was the richest and most diverse as in the moderately open canopy, chances of bird detections are high. However, the difference in BSD and BSR is not much in moderate (25-50%), high (51-75%), and Very high (76-100%) classes.

Analysis among different land-use canopy cover classes reveals, in agriculture lands, the highest canopy cover class was 30-45%, and it's the richest and most diverse class in terms of avifauna in the agriculture lands. These lands represent open canopy, and diverse shade of trees provides good perching heights to various avifauna species (preferred forest edges and human habitation) for foraging their food. The detection of these birds is also high due to the openness of the habitat. In the overall forest cover, the highest BSD and BSR were recorded from in the medium class (31-60%). In moderate open forests, bird detection is high compared to the dense canopy in the forest (Slater 1994). Deodar, temperate mixed, and Sal forest's medium canopy cover support the highest BSD in different forest habitats. As Deodar and temperate mixed forests are primarily mature forests in the landscape with the least disturbance and moderately open forests support the good detection of birds (Chettri et al. 2001). High shrub cover was found in the medium canopy cover class in the Sal forest and supports a high avifaunal diversity of shrub dependent and tree dependent species. In the Oak and Chir pine forests, the highest BSD and BSR were found in the low canopy cover class as most of these forests were present at the edges of agriculture lands in the study area. These edges are low in canopy cover compared to the interior, but these edges support high BSD and BSR because of the ecotone effect of the two ecosystems. The highest canopy cover class in the shrublands was 11-20%, and sub-tropical mixed forests were 40-60%. This is the most bird species-rich and diverse class among these habitats, as with increasing tree canopy, bird diversity also increases (Cubley et al. 2020).

In different grass cover classes, low grass cover supports high BSD and BSR, as grassland is less species-rich than the woodlands (Ernst et al. 2020). Low grass cover can also represent high tree cover and shrub cover in the study area that supports high avian diversity. However, grass cover was also recorded high in Chir pine forests and shrubland habitat, but both support low avian diversity. Medium shrub cover supports the high BSD and BSR as in this class, it was found that high to medium tree cover that keeps the high BSD.

The slope class 0°-25° found to be the most species-rich class as this slope class was covered by most of the agricultural lands in the landscape that support high avian diversity and richness. In the high slope class (76°-90°), most shrublands and low tree cover were found, supporting low BSD and BSR in the landscape.

Disturbance factors within different habitats, our results demonstrate that Sal forest was highly disturbed habitat among all the habitats in the landscape, as more than 55% tree cutting and 70% tree lopping plots were recorded within the habitat. These forests are located near human settlements, with high timber, fuelwood, and fodder value, so the tree cutting and lopping pressure are also high. The sub-tropical mixed forests also face high anthropogenic pressure as near 30% of tree cutting, and near 60% tree lopping was found within the habitat. Oak forest is also facing the pressure of tree lopping and cattle grazing or browsing. Deodar forest was the least disturbed forest from the anthropogenic pressure among all habitats as most of these forests are sacred grooves in the landscape, and tree cutting and lopping are restricted in these forests. But we found the highest cattle presence in this habitat as high grass cover and shrub cover provide good fodder to cattle. High cattle presence was also found in Chir pine forest, and riverine habitat as grass cover high in the Chir pine forest provides fodder. Most cattle used to drink water in nearby rivers in the landscape; hence cattle presence is high in the riverine habitat.

Concerning avifaunal diversity within various disturbance regimes, we found high BSD and BSR in the low tree cutting class. The low tree cutting plots also reflect the high tree density, affirming the high avifauna diversity and richness (Chettri et al. 2001; Acharya et al. 2011). The moderate tree lopping class supports the high bird diversity in the landscape as moderate tree lopping also slightly opened the canopy, increasing the visibility and bird detection chances. Whether the presence of cattle slightly affects the bird diversity compared to cattle absence plots, as livestock negatively affects the abundance and ground-dwelling birds (Martin & McIntyre 2007).

All the low tree cutting class habitats support high avian diversity within the different habitats except the Sal forest, where moderate tree cutting supports the high avian diversity. Most of the moderate tree cutting plots in the Sal habitat were found at the junction of Sal forest and agricultural lands, where bird diversity was recorded high due to the ecotone (edge effects). Within the tree lopping classes, moderate tree lopping supporting the high bird diversity and richness; similarly, Bheeler et al. (1987) and Chettri et al. (2005) have reported that moderately disturbed forest supporting the high BSD. However, in the Deodar forest, low tree lopping supports high BSD as tree lopping was recorded within only three sampling plots, so there may be an error due to the low sample size. The presence of cattle in different habitats is not much affected in BSD and BSR except Shrubland. In the Shrubland habitat presence of livestock is negatively affecting the BSD and BSR. Most ground-dwelling and shrub-dependent were recorded from the shrubland, and cattle generally disturb their habitat, which directly impacts avian diversity in the habitat.

In the landscape, the Grey-hooded warbler had the highest encounter rate. The species was found in all the habitats except the Shrublands. This species also had the highest encounter rate in the Temperate mixed, Oak, and Sal forest. Similarly, Sultana and Hussain (2012) and Shahabuddin et al. (2017) found the high density of the species in the nearby district's forest habitats. Himalayan bulbul was the second-highest recorded species in the landscape and documented from all the habitats. As our study area is located within the matrices of the forests and agricultural lands that form more forest edges, this species prefers forest edges, agricultural lands, and shrublands (Shahabuddin et al. 2017). Hence, the species was recorded from all the habitats, and the overall encounter rate was high. Common myna was encountered the highest within the agricultural lands, as the species prefers the cultivation lands, and the high abundance was mainly recorded as roosting on trees in the agriculture field during the evening hours of sampling. In the Chir pine forests, Slaty-headed parakeet was recorded with the maximum encounter rate. This species prefers the upper canopy of tall trees and close to agricultural lands, and most of them were recorded at the edges of Chir pine forest and agricultural land. Grey treepie, White-capped redstart, and Plumbeous redstart were the highest encountered species in the riverine habitat. Most of the riverine habitats support mixed vegetation in the study area. However, the disturbance is also high in the habitat, and the Grey treepie also preferred mixed vegetation type and the surroundings of human habitation (Jan et al. 2011).

A total of 39 forest specialist species were recorded during the point counts and exclusively recorded from the forest habitat. Species such as Asian-emeraled dove, Black eagle, Balck-faced warbler, Blue-throated flycatcher, Blyth's leaf warbler, Crow-billed drongo, Eurasian jay, Fire-tailed sunbird, Hill partridge, Himalayan woodpecker, Long-billed thrush, Maroon oriole, Mountain bulbul, Maountain hawk-eagle, Pink-browed rosefinch, Rufous-bellied niltava, Rufous-chinned laughingthrush, Streak-breasted scimitar babbler, Striated laughingthrush, Stripe-throated yuhina, Wedge-tailed green pigeon, Whistler's warbler and White-throated laughingthrush were exclusively recorded from the interior of Oak and temperate mixed forest. These species have high conservation significance values as increasing anthropogenic pressure may lead to habitat degradation.

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CHAPTER 4

Objective 2. To determine the effects of forest patch size, vegetation structure, and seasons on bird diversity.

This objective is devided into two parts for this study:

1- To determine the effects of forest patch size and vegetation structure on avian diversity and
2- To determine the seasonal influence on bird diversity.

Effects of forest patch size, vegetation structure

Study Area

As discussed in chapter 3.

Methods

Multi-scale landscape heterogeneity and modelling approach was used to determine the effects of forest patch size and vegetation structure on avian diversity.

Data collection

As discussed in chapter 3.

Birds

Bird diversity was calculated per point using the Past 3X software, and Shannon Diversity (H) value was used to compute the diversity.

Formula

$$\text{Shannon Diversity: } H = - \Sigma Pi (\log Pi).$$

Where H = Shannon Diversity, Pi = proportion of a species individuals and the total number individuals of species in a sample.

Landscape, environmental, and ecological parameters selection

Land-use data was obtained from Landsat 8 using earth explorer and freely available IRS LISS III and IRS LISS IV data from the Bhuvan website. Total 18 land use classes were categorized into six major categories: cultivated land, Forests, Grasslands, Waterbodies, Habitation, and Snow. The digital elevation model (DEM) was employed with a spatial resolution of 30 metres. We examine the geographic scale at which the bird diversity responds to the environmental and landscape variables. We performed multiscale modeling based on four topographic, one anthropogenic, and 22 landscape configurational variables by using moving windows analysis. Each variable was independently tested using circular windows with radii on 27 scales (50m to 1000m at 50m of an interval, 1000m to 1400m at 100m of an interval, 1450m, 1500m, and 2000m).

Using focal statistic sampling in Arc map 10.3 (ESRI 2015), moving window analysis (Ducci et al. 2015; Sarkar et al. 2018) was applied for the above-selected scales on different continuous environmental variables such as elevation, slope, aspect, human habitation, and waterbodies. Total 64 landscape configuration, landscape composition, topographic and Human pressure variables were selected, of which 56 landscape and class level matrices were derived using FRAGSTAT 4.2 (McGarigal et al. 2012), considering the scales mentioned above. Removing highly inter-correlated variables in multivariate analysis is worthy for avoiding multicollinearity (Sánchez et al. 2013; Vergara et al. 2016). Hence, the pairwise Pearson's correlations among the variables was conducted for eliminating the highly correlated variables. The variable pair that have Pearson's correlation coefficient $\geq$0.75 were eliminated. Six landscape-level matrices (viz. Area_AM = Patch area_Area-weighted Mean Distribution, ED = Edge density, Para_AM

= Perimeter Area Ratio_Area-weighted Mean, SHDI = Shannon Diversity Index, SHEI = Shannon Diversity Evenness, and TE = Total Edge) and seven class level matrices (AI = Aggregation Index, AREA_AM= Patch area_Area-weighted Mean Distribution, ED = Edge density, LSI = Landscape Shape Index, PD = Patch Density, PARA_AM = Perimeter Area Ratio_Area-weighted Mean, SHAPE_AM = Shape Index Distribution_ Area-weighted Mean) were prepared. The moving window works by moving a circular window with a fixed radius over the map one pixel at a time. It calculated the required indices within the window and delivered the computed value to the window's central pixel. The resultant continuous surface reflects the context of each land cover pixel in the neighboring areas (Riitters et al. 2002). A two-kilometer radius of inner buffer was used at the administrative KSL-India boundary to avoid the edge effect (as the spatial scale data availability is limited beyond the international boundary) to assess the effects of habitats on avian diversity.

Statistical analysis

Univariate scaling with logistic regression was performed (Elliot et al. 2014; Krishnamurthy et al. 2016, Sarkar et al. 2018) for all the 27 scales of each variable to find the appropriate scale at which bird diversity and function of habitat variables within the landscape has the most robust linear relationship. All univariate modelling was carried out by using a general linear model (GLM) with the Poisson distribution. By keeping all of the assumptions of this modelling technique in mind (Hosmer et al. 2013), the glm function (with logit link) in R v4.0.2 (R Core Team 2020) was used. The most acceptable univariate model to find the best supported scale for each variable was determined using the Akaike information criterion (AIC) for model selection (Aho et al. 2014; Akaike

1998). The spatial scale with the lowest AIC rating was chosen as the best appropriate variable scale for each variable. The MuMIn package (Barton & Barton 2015) of R v.4.0.2 was used for this analysis (R Core Team, 2020).

To test all possible combinations of our 27 variables, we utilised GLM using the Poisson distribution. Model averaging based on AIC values were used to create parameter estimates for a final model. The models with the lowest AIC values were chosen as the best models for predicting avian diversity.

Table 4.1. Ecological and environmental variables consider for correlating bird species diversity with habitat structure.

	Category	**Variable name**	**Scale**	**Variable Code**
Landscape configuration	Landscape variables	Aggregation Index	2000	AI_L
		Patch Area_Area-weighted Mean	**1000**	**Area_AM_L**
		Contiguity Index_Area-weighted Mean	2000	Contig_AM_L
		Edge Density	**2000**	**ED_L**
		Gyration_Area-weighted Mean	1100	Gyrate_AM_L
		Largest Patch Index	850	LPI_L
		Number of Patches	2000	NP_L
		Perimeter Area Ratio_Area-weighted Mean	**350**	**Para_AM_L**
		Patch Density	2000	PD_L
		Patch Richness Density	1100	PRD_L
		Shape Index_Area-weighted Mean	**350**	**Shape_AM_L**
		Shannon's_Diversity_Index	**2000**	**SHDI_L**
		Shannon's_Evenness_Index	**250**	**SHEI_L**
		Total Edge	**2000**	**TE_L**
	Class variables	Aggregation Index Agriculture	100	AI_C_A
		Patch Area_Area-weighted Mean Agriculture	**100**	**area_am_C_A**
		Class Area Agriculture	200	ca_C_A
		Contiguity Index_Area-weighted Mean Agriculture	100	Contig_AM_A
		Edge Density Agriculture	**2000**	**ed_C_A**
		Gyration_Area-weighted Mean Agriculture	50	Gyrate_am_C_A
		Landscape Shape Index Agriculture	**100**	**lsi_C_A**
		Largest Patch Index Agriculture	250	lpi_C_A
		Number of Patches Agriculture	50	NP_C_A

		Patch Density Agriculture	**50**	**pd_C_A**
		Percentage of landscape Agriculture	200	pland_C_A
		Perimeter Area Ratio_Area-weighted Mean Agriculture	**200**	**para_am_C_A**
		Shape Index_Area-weighted Mean Agriculture	**2000**	**Shape_am_C_A**
		Total Edge Agriculture	200	te_C_A
		Aggeregation Index Forest	100	Ai_C_F
		Patch Area_Area-weighted Mean Forest	**200**	**area_am_C_F**
		Class Area Forest	150	ca_C_F
		Contiguity Index_Area-weighted Mean Forest	50	contig_am_C_F
		Edge Density Forest	300	ed_C_F
		Gyration_Area-weighted Mean Forest	200	gyrate_am_C_F
		Landscape Shape Index Forest	**100**	**lsi_C_F**
		Largest Patch Index Forest	150	lpi_C_F
		Number of Patches Forest	50	np_C_F
		Patch Density Forest	**50**	**pd_C_F**
		Percentage of landscape Forest	150	pland_C_F
		Perimeter Area Ratio_Area-weighted Mean Forest	50	prara_AM_C_F
		Shape Index_Area-weighted Mean Forest	**300**	**shape_am_C_F**
		Total Edge Forest	300	te_C_F
		Aggregation Index Scrub and Grassland	**250**	**ai_C_S**
		Patch Area_Area-weighted Mean Scrub and Grassland	**400**	**area_am_C_S**
		Class Area Scrub and Grassland	350	ca_C_S
		Contiguity Index_Area-weighted Mean Scrub and Grassland	250	contig_am_C_S
		Edge Density Scrub and Grassland	350	ed_C_S
		Gyration_Area-weighted Mean Scrub and Grassland	300	gyrate_am_C_S
		Landscape Shape Index Scrub and Grassland	250	lsi_C_S
		Largest Patch Index Scrub and Grassland	400	lpi_C_S
		Number of Patches Scrub and Grassland	550	np_C_S
		Patch Density Scrub and Grassland	**550**	**pd_C_S**
		Percentage of landscape Scrub and Grassland	350	pland_C_S
		Perimeter Area Ratio_Area-weighted Mean Scrub and Grassland	**350**	**para_am_C_S**
		Shape Index_Area-weighted Mean Scrub and Grassland	**250**	**Shape_am_C_S**
		Total Edge Scrub and Grassland	350	te_C_S
Landscape Composition		Agriculture	350	Agriculture
		Forest	150	Forest
		Scrub and Grassland	350	Scrub and Grassland

Topographic variables	**Aspect**	**450**	**Aspect**
	Elevation	**900**	**Elevation**
	Slope	**600**	**Slope**
	Waterbodies	**1400**	**Waterbodies**
Human pressure	**Habitation**	**1200**	**Habitation**

Abbreviation: Variables in bold are not highly inter-related with Pearson's correlation coefficient ≥0.75).

Results

During the study, bird diversity data was collected from 700 point counts of 27 villages. Multiscale analysis revealed that the intensity and nature of reported connections between bird diversity and all measured environmental and ecological variables are strongly reliant on the focal scale generated by the variable.

Scales performance

Landscape matrices – The relation between Landscape-level matrices with the bird diversity reveals that the SHDI_L has the highest degree of support at the most significant focal landscape scale 2000 m with a p-value less than 0.001. This indicates the strong correlation between SHDI_L and bird diversity. Similarly, SHEI_L at the spatial scale of 250 m was more significant with a p-value less than 0.01.

Landscape matrices class level – Analysis between Agriculture class matrices, area_am_C_A, ed_C_A, lsi_C_A, pd_C_A, and Shape_am_C_A are found to be most significant at the scale of 100, 2000, 100, 50, and 2000 m with p-value less than 0.001. These all variables are strongly positively correlated with bird diversity. Analysis between the forest class matrices reveals area_am_C_F 200, lsi_C_F are most significant at 200 and 100, respectively p-value less than 0.001. It represents the strong correlation between these matrices and bird diversity. Similarly, in the Grassland and scrubland matrices such as ai_C_S, area_am_C_S, pd_C_S, and Shape_am_C_S are most significant at 250, 400, 550, and 250 m of scales respectively with less than 0.001 of p-value and are strongly correlated with the bird diversity, whether para_am_C_S is most significant at 350 m of scale with p-value less than 0.1 and the correlation with bird diversity.

Environmental variables and habitation – Environmental variables such as Elevation, Slope, and Waterbodies are highly supported at the 900, 600, and 1400 m of scale with p-value less than 0.001 and strongly correlate to bird diversity. Habitation is most significant at 1200 m of spatial scale with a p-value less than 0.01 and strongly correlated with bird diversity.

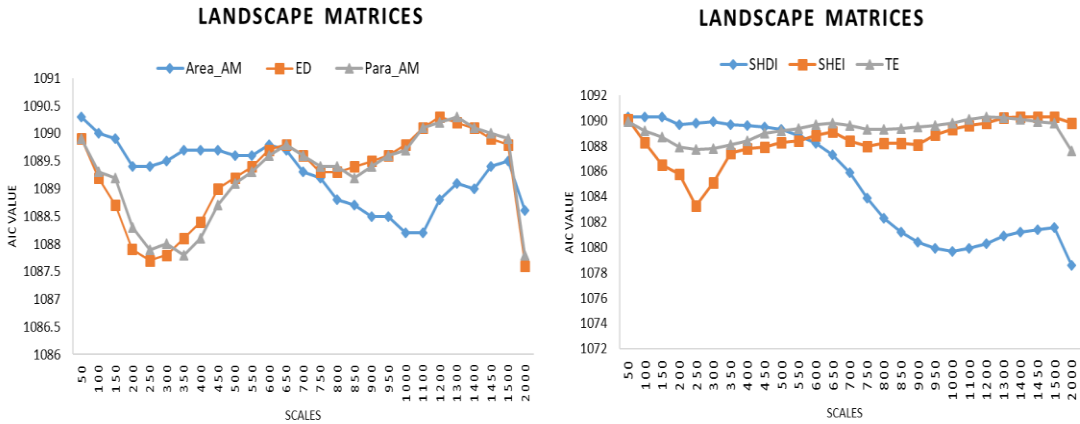

Figure 4.1: Multiscale performance of landscape variables at different scales as bird diversity indicator

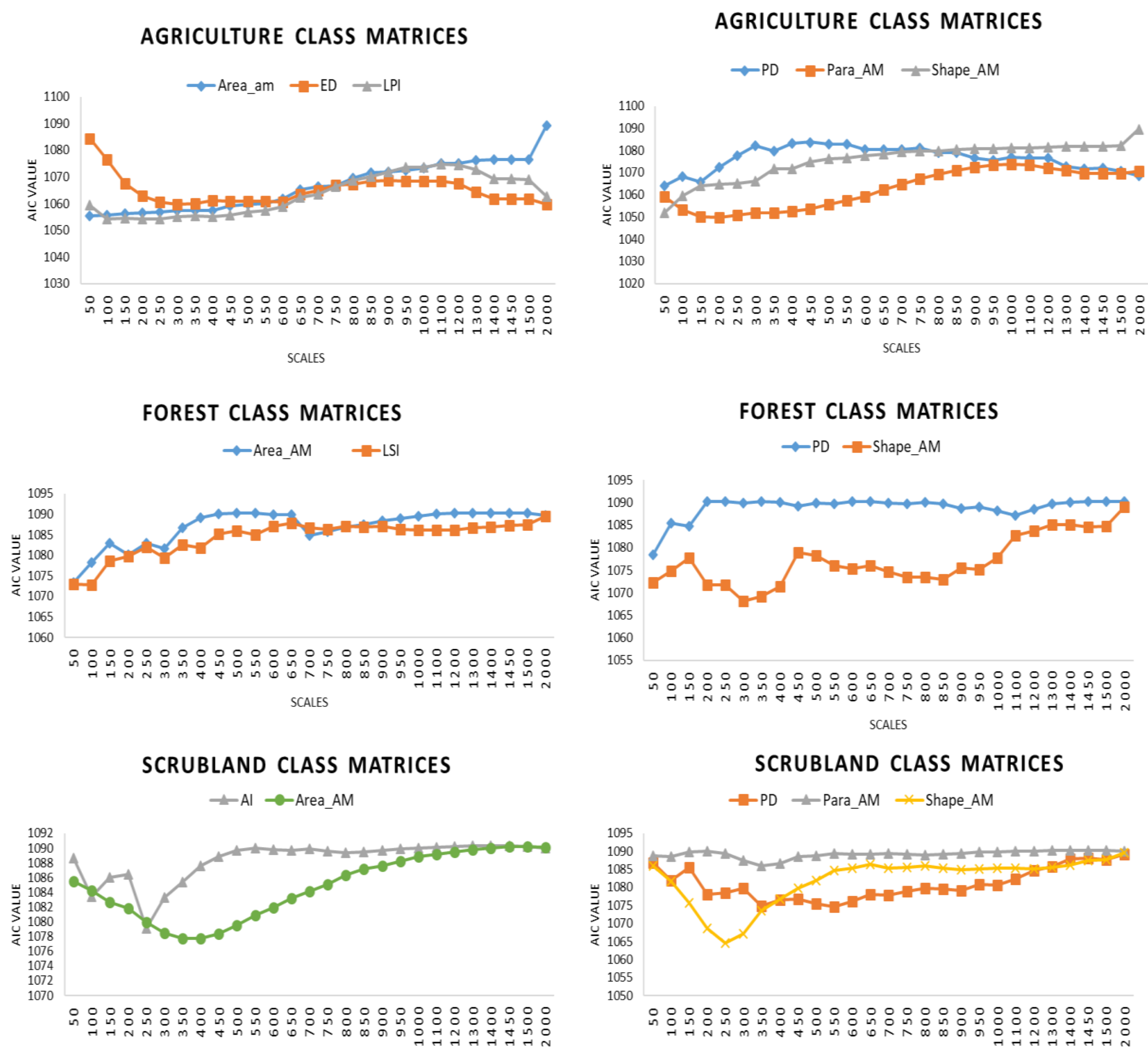

Figure 4.2: Class variables at different spatial scales as indicator of bird diversity

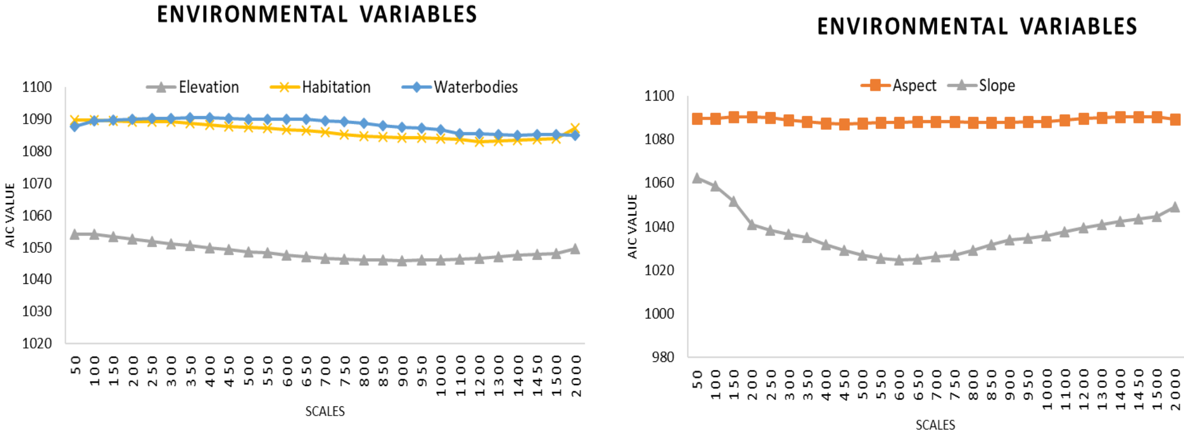

Figure 4.3: Environmental variables at different spatial scales as indicator of bird diversity

Bird diversity spatial distribution

The GLMs was performed with the combinations of different independent variables and bird diversity (Table. 2). Altogether 65 different models were tested for the best suitable model. The best model was evaluated employing AICc values retained nine variables. The best predictor variables of the bird diversity were found to be Elevation and area_am_C_F with 99.9% of the confidence interval. Variables such as SHDI_L, area_am_C_S, and Waterbodies were significant at the 99% of confidence interval. Elevation contributed the most, followed by area_am_C_F, Waterbodies, area_am_C_S, SHDI_L, Slope, pd_C_S, Habitation, and Shape_am_C_S (Table. 4.2).

Table 4.2. Models, AICc, and AIC model weights for all candidate models with non-zero AIC weights. The variable acronyms correspond to those give in Table 4.1. Delta—difference in AICc between the model on that line and the model with the lowest AICc; wi—AIC weight of the model.

Model	AICc	Delta	Weight
SHDI_L+area_am_C_F+area_am_C_S+pd_C_S+Shape_am_C_S+Elevation+Habitation+Slope+Waterbodies	959.30	0.000	0.342
SHDI_L+area_am_C_F+area_am_C_S+pd_C_S+Shape_am_C_S+Elevation+Slope+Waterbodies,	960.09	1.107	0.197
SHDI_L+area_am_C_F+area_am_C_S+pd_C_S+Elevation+Slope+Waterbodies	961.19	2.145	0.117

SHDI_L+area_am_C_F+area_am_C_S+Elevation+Habitation+Slope+Waterbodies	962.71	3.661	0.055
area_am_C_F+area_am_C_S+Shape_am_C_S+Elevation+Slope+Waterbodies	962.77	3.668	0.055
SHDI_L+area_am_C_F+area_am_C_S+pd_C_S+Elevation+Waterbodies	962.86	3.765	0.052
SHDI_L+area_am_C_F+area_am_C_S+Elevation+Slope+Waterbodies	962.98	3.878	0.049
Area_AM_L+SHDI_L+TE_L+area_am_C_A++area_am_C_F+area_am_C_S+pd_C_S+Elevation+Habitation+Slope+Waterbodies	964.43	5.494	0.022
SHDI_L+area_am_C_F+area_am_C_S+area_am_C_A+Elevation+Slope+Waterbodies	964.54	5.638	0.020
SHDI_L+area_am_C_F+area_am_C_S+area_am_C_A+Elevation+Habitation+Slope+Waterbodies,	964.63	5.657	0.020
SHDI_L+area_am_C_F+area_am_C_S+Elevation+Waterbodies	965.09	5.949	0.017
SHDI_L+area_am_C_F+area_am_C_S+Habitation+Elevation+Waterbodies	965.35	6.250	0.015
SHDI_L+area_am_C_F+area_am_C_S+area_am_C_A+Elevation+Waterbodies	966.32	7.218	0.009
SHDI_L+area_am_C_F+area_am_C_A+area_am_C_S+Habitation+Elevation+Waterbodies	967.01	7.969	0.006
area_am_C_F+area_am_C_S+area_am_C_A+Elevation+Slope+Waterbodies	967.27	8.176	0.006
area_am_C_F+area_am_C_S+Habitation+Elevation+Slope+Waterbodies	967.34	8.244	0.006
area_am_C_F+area_am_C_S+Elevation+Waterbodies	969.42	10.237	0.002
area_am_C_F+area_am_C_S+pd_C_S+area_am_C_A+Elevation+Waterbodies	969.59	10.490	0.002
area_am_C_F+lsi_C_F+pd_C_F+area_am_C_S+pd_C_S+Shape_am_C_S+Aspect+Elevation+Habitation+Slope+Waterbodies	969.61	10.836	0.002
area_am_C_A+area_am_C_F+Elevation+Slope+Waterbodies	970.81	11.669	0.001
SHDI_L+area_am_C_A+area_am_C_F+Elevation+Slope+Waterbodies	970.87	11.769	0.001
area_am_C_F+area_am_C_S+area_am_C_A+Elevation+Waterbodies	971.04	11.899	0.001
area_am_C_F+area_am_C_S+Habitation+Elevation+Waterbodies	971.41	12.266	0.001
SHDI_L+area_am_C_F+Habitation+Elevation+Waterbodies+Slope	971.7	12.605	0.001
SHDI_L+area_am_C_F+area_am_C_S+Habitation+Elevation+Slope	972.8	13.704	0.000
area_am_C_F+Habitation+Elevation+Slope+Waterbodies	972.94	13.792	0.000
area_am_C_F+area_am_C_A+area_am_C_S+Habitation+Elevation+Waterbodies	972.97	13.868	0.000
area_am_C_F+Elevation+Slope+Waterbodies,	973.11	13.920	0.000
area_am_C_F+area_am_C_S+Habitation+Elevation+Slope	974.58	15.432	0.000
area_am_C_F+area_am_C_S+Elevation+Slope	974.64	15.458	0.000
area_am_C_F+area_am_C_S+area_am_C_A+Elevation+Slope	976.34	17.195	0.000
SHDI_L+area_am_C_F+area_am_C_A+Elevation+Waterbodies	976.88	17.738	0.000
SHDI_L+pd_C_S+Elevation+Habitation+Slope+Waterbodies+area_am_C_A	977.02	17.974	0.000
area_am_C_F+area_am_C_S+Elevation,	977.87	18.650	0.000
SHDI_L+area_am_C_F+area_am_C_S+Elevation	978.29	19.101	0.000
area_am_C_F+pd_C_S+area_am_C_A+Elevation+Waterbodies	978.47	19.325	0.000
area_am_C_F+Habitation+Elevation+Slope	978.74	19.551	0.000
SHDI_L+area_am_C_F+Habitation+Elevation+Slope	979.01	19.865	0.000
area_am_C_F+area_am_C_S+area_am_C_A+Elevation	979.31	20.124	0.000
SHDI_L+area_am_C_A+Elevation+Slope+Waterbodies	979.54	20.391	0.000
area_am_C_F+area_am_C_A+Elevation+Slope	980.06	20.874	0.000
SHDI_L+area_am_C_S+area_am_C_A+Elevation+Slope+Waterbodies	981.34	22.237	0.000

Area_AM_L+ED_L+SHDI_L+SHEI_L+TE_L+area_am_C_A+ed_C_A+lsi_C_A+pd_C_A+para_am_C_A+Shape_am_C_A+area_am_C_F+lsi_C_F+pd_C_F+Shape_am_C_F+ai_C_S+area_am_C_S+pd_C_S+para_am_C_S+Shape_am_C_S+Aspect+Elevation+Habitation+Slope+waterbodiesWaterbodies	982.25	24.426	0.000
SHDI_L+area_am_C_F+Habitation+Elevation+Waterbodies	983.57	25.192	0.000
area_am_C_S+area_am_C_A+Elevation+Slope+Waterbodies	984.4	25.256	0.000
area_am_C_F+Elevation+Waterbodies,	984.96	25.736	0.000
area_am_C_F+SHDI_L+Elevation+Waterbodies	986.37	27.186	0.000
area_am_C_A+Elevation+Slope	987.73	28.508	0.000
area_am_C_S+area_am_C_A+Elevation+Slope	989.72	30.539	0.000
SHDI_L+pd_C_S+Elevation+Habitation+Slope+Waterbodies	1001.1	41.998	0.000
area_am_C_A+Habitation+Slope	1010.3	51.034	0.000
SHDI_L+Habitation+Elevation+Slope+Waterbodies	1010.5	51.359	0.000
area_am_C_S+SHDI_L+Habitation+Slope,	1023.9	64.691	0.000
Slope	1024.6	65.357	0.000
SHDI_L+Elevation+Waterbodies+Habitation	1044.3	85.143	0.000
Elevation+Waterbodies	1045.1	85.892	0.000
SHDI_L+Elevation+Waterbodies	1045.7	86.443	0.000
Elevation	1045.8	86.566	0.000
area_am_C_F+area_am_C_S+area_am_C_A,	1049	89.795	0.000
area_am_C_S+area_am_C_F	1049.2	89.916	0.000
lsi_C_A	1058.8	99.544	0.000
area_am_C_F	1073.6	114.339	0.000
area_am_C_S	1077.7	118.424	0.000
SHDI_L	1078.6	119.344	0.000
Waterbodies	1084.7	125.419	0.000

Table 4.3. Covariates of the best GLM model.

Variables	Estimate	Std.Error	t value	Pr(>|t|)	varImp
(Intercept)	-0.069524	0.3711944	-0.187	0.85148	
SHDI_L	0.552209	0.2012171	2.744	0.00622**	2.744345
area_am_C_F	-0.0386789	0.0060057	-6.44	2.23E-10 ***	6.44033
area_am_C_S	-0.0106653	0.0037711	-2.828	0.00482**	2.828165
pd_C_S	-0.0043855	0.0023982	-1.829	0.06788	1.828668
Shape_am_C_S	-0.0707084	0.0408905	-1.729	0.08422	1.729212
Elevation	0.0006489	0.0001003	6.472	1.18E-10***	6.472415
Habitation	-0.8589101	0.4852118	-1.77	0.07714	1.770176
Slope	-0.0100524	0.0052961	-1.898	0.0581	1.898092
Waterbodies	10.3439953	3.2024172	3.23	0.0013**	3.230059

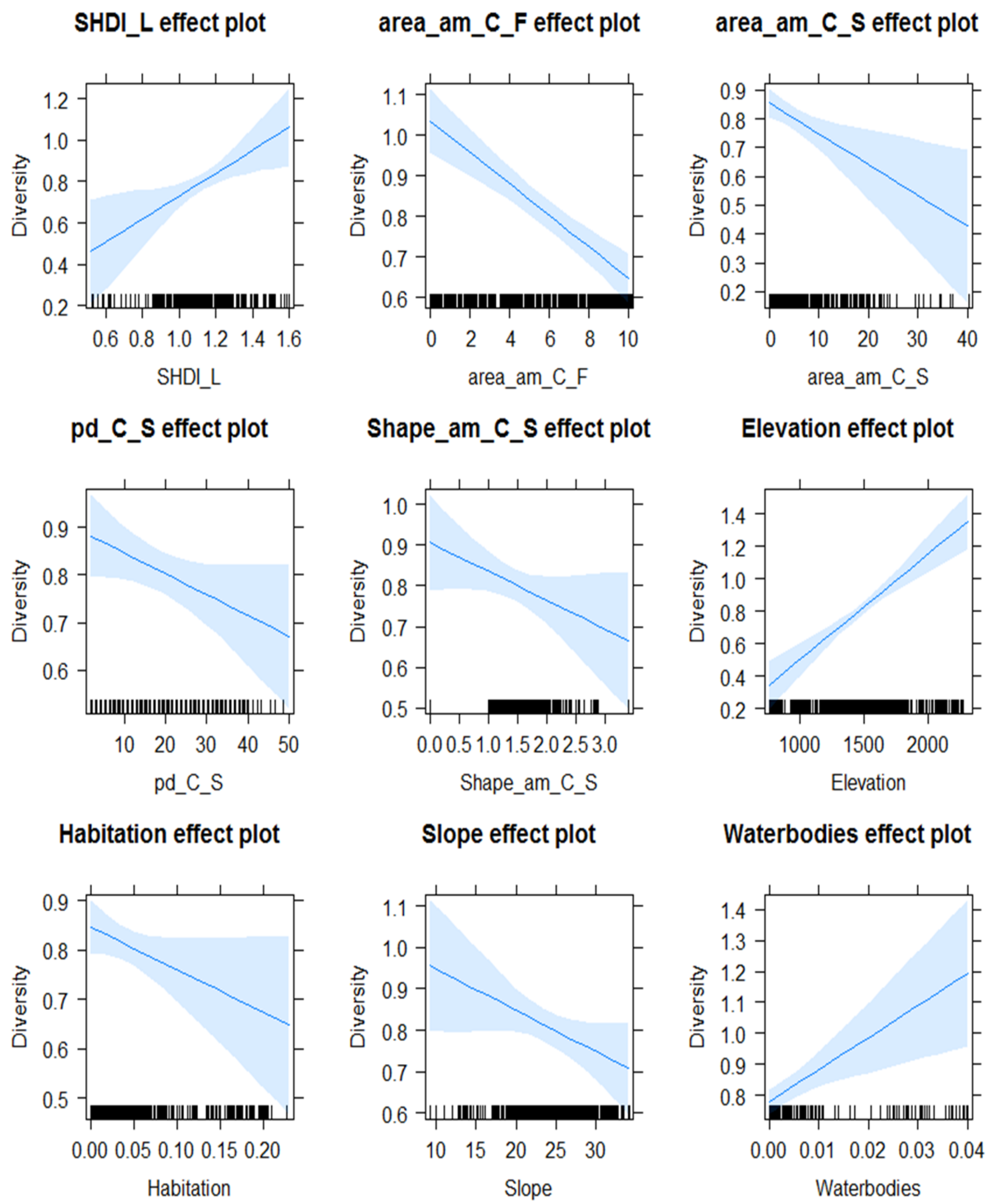

Figure 4.4: Relationship between bird diversity and variables of best suited model

Discussion

The widespread availability of digital maps has increased the ability to apply biodiversity models to large areas in recent years, allowing changes in landscapes to be linked to anticipated changes in patterns of species variety and richness (Griffiths & Lee, 2000; Coops et al. 2009). Because of their multiscale potential, remote sensing technologies are useful for bridging the gap between intensive ecological research and landscape management (Estes et al. 2010). The use of satellite image-derived variables to predict bird diversity in agricultural land and forest matrices was investigated in the mountain ecosystem.

Various studies have been developed to quantify biodiversity, focusing on using environmental data derived from existing maps (Guisan & Zimmermann, 2000; McCain, 2005; Morellie, 2013). For example, landscape heterogeneity matrices were used in Spain's forest and agricultural land matrices by Pino et al. (2000), which revealed the strong association between species diversity and landscape diversity. However, the quality and quantity of the input data determine the accuracy of the association. It's also important to keep in mind that habitat scale varies with species and more extensive home ranges (Cornell & Lawton, 1992). As a result, determining the optimal spatial scale for the environmental data acquired is critical in order to improve biodiversity prediction. The multi-scaling approach used in this study demonstrated that the scale of habitat variables examined had a significant impact on the sensitivity of bird diversity habitat connections. In addition, we found that the landscape fragmentation variables had strong and consistent associations. with the uniformly positive association SHDI_L and agricultural class variables such as Area, Edge density, Patch density, and shape.

Similarly, Pino et al. (2000) found that the avifaunal diversity also increases with increasing the landscape diversity. Agro-ecosystems can harbor a substantial amount of natural biodiversity with unique community assemblages of plants and animals if managed organically and maintained with diverse shade trees (Mayfield et al. 2005; Harvey et al. 2006; Sharma and Vetaas 2015).In the Kumaon Himalayan region of Uttarakhand, Traditional agro-ecosystems are very diverse with ancillary practices of animal husbandry and grazing lands representing complex and interlinked production systems (Bisht et al. 2006). Elsen et al. (2016) have also reported the highest diversity in the Agricultural land during the winters in the western Himalaya.

Bird diversity is relatively low in the grasslands in Himalayan region (Rawat 1998; Joshi and Bhatt 2011; Ghimri et 2021). Similarly, it is found, grasslands and scrublands habitat variables have a negative correlation with avian diversity. These habitats are significantly less in tree numbers and are mainly used as pasture lands for the cattle in the study area. Trees help terrestrial birds provide different perch heights, hide from predators and nesting locations, and cattle grazing is a disturbance factor for the ground-dwelling and other grassland and scrubland birds in the landscape. So the variables such as aggregation index, area_am, patch density and, the shape of scrub and grasslands are negatively correlated with the bird diversity. Although, these habitats also have high conservation values as they support many threatened, habitats specialists and conservation significant species (Rawat 1998; Ghimri et. 2021).

Among the environmental parameters, we found the bird diversity strongly correlates with the elevation in the study area. For example, Acharya et al. (2011), Acharya and Vijayan (2017), Santhakumar et al. (2018), Bushra et al. (2020) reported species richness, or diversity is increases along with the elevation near about 2000m above sea level in the Himalayan region. However, afterward, it starts to decline due to the harsh climatic conditions. Similarly, the results of this study also support previous studies as study area of present study falls between 500 to 2500m of elevation, and bird diversity is also significantly increasing.

There is a significantly negative correlation found between avian diversity slope intensity. The tree cover is low in most of the steep slope mountain hills in the study area. These areas are mainly covered with Barren grassland or scrublands and Cirpine forest, which is supporting low avifaunal diversity.

Waterbodies were found to have a significant positive correlation with bird diversity. Most of the streams and riverine habitats in the study area have mixed forests and agricultural lands adjoining them. These habitats support high avifaunal diversity in the study area (Joshi and Bhatt 2015; Elsen et al. 2018).

Increasing human habitation leads to degrading the forest habitat, which directly impacts bird diversity negatively. Our study also found that Human habitation or settlement has a significantly negative correlation with bird diversity. Similarly, studies in the western Himalaya (Bhattacharyya 2019; Menon et al. 2019; Shahabuddin et al. 2021) have reported the negative impact of anthropogenic pressure on avian diversity.

Only around half of the variation in species density or abundance is explained by most habitat models (Morrison et al. 2008). For example, Wasserman et al. (2012) empirically tested a suite of habitat models for various species. They discovered that most of the variance in species abundances could not be explained by hundreds of habitat variables at various spatial scales. As a result, even if a model shows strong links between species occurrence and habitat gradients, it will typically fail to explain the majority of variation. The present study demonstrates the combination of habitat variables such as SHDI_L, area_am_C_F, area_am_C_S, pd_C_S, Shape_am_C_S, and environmental variables like Elevation, Waterbodies, Slope, and Habitation are the best predictors of bird diversity. Among them, variables such as SHDI_L, Elevation, Waterbodies are strongly positively correlated with the avian diversity. And scrubland variables, Slope and habitation, have a negative correlation with bird diversity.

In conclusion, this study demonstrates the link between field-measured bird diversity and satellite remote sensing image-derived factors in the human-dominated landscape in a mountain ecosystem. It is observed that the landscape diversity or heterogeneity supports a high bird diversity and is a good predictor of bird diversity. Forests, agriculture, and grasslands or scrublands habitats are also good predictors of bird diversity. Grasslands and scrublands represent low in avian diversity due to low tree cover and cattle pressure, as these ecosystems support some habitat specialists and conservation significant species. These ecosystems require conservation attention and better management.

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Seasonal influence on bird diversity

Study Area

A village ecosystem lying in the mid-elevation range was selected to monitor birds in different seasons. Bans – Maitoli village is located near 25 km north-west of district headquarters between 29.61342 to 29.60747 N latitude and 80.1391 to 80.1493 E longitude. There are 427 families distributed in 9 hamlets with a total population of 1350. Bans-Maitoli covers approximately 5 Sq. km of the area with an elevation range of 800 – 1800 m a.s.l. and forms a part of Gokarneshwar gad micro-watershed in the Bin block Pithoragarh District (Fig.4.5). This village represents a heterogeneous landscape in the form of Forest-Grassland and Agriculture interface. There are three types of forests in the village landscape such as Sub-tropical broadleaf forests dominated by Sal (Shorea robusta), Montane broadleaf forest by Banj oak (*Quercus leucotrichophora*), and Conifer forest by Chir Pine (*Pinus roxburghii*), covering the different areas in different elevational bands (Table 4.4).

Table 4.4. Birds monitoring and vegetation plots in different habitat types of Bans-Maitoli village along with altitudinal range and area.

Habitat	**Area (ha)**	**Altitudinal range (m)**	**Vegetation plots**	**Birds monitoring plots**	**Total point counts**
Oak Forest	86	1380-1800	4	12	144
Chir Pine Forest	68.5	1330-1590	2	5	60
Sal Forest	16	940-1150	3	8	96
Agricultural field	170	850-1650	-	9	108
Total			**9**	**32**	**432**

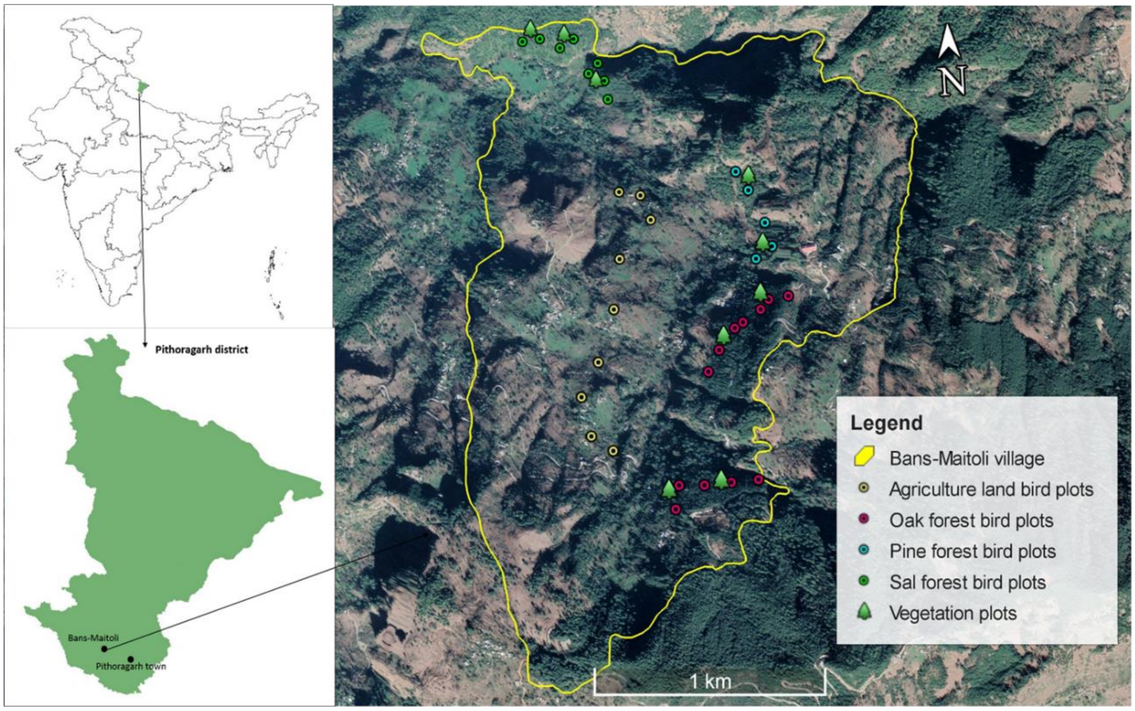

Figure 4.5: Location of the sampling site (Bans-Maitoli village), Birds monitoring, and vegetation plots in different habitats.

Methods

Data collection

Bird survey

The survey was done between January 2014–April 2016 during the morning (07h00-11h00) and evening sessions (15h30-18h30) when birds are known to be more active (Trnka et al. 2006). We selected 34 points with a minimum of 200 m distance in the different habitat types of the study area. Fixed width point counts of 25 m radius (Bibby et al. 2000) were performed for the bird survey. 12, 5, 8, and 9 points in Oak, Chir Pine, Sal, and Agriculture fields, respectively were monitored. Due to terrain constraints (steep and inaccessible) in the Chir Pine forest, five plots in this forest type were laid. Four seasons viz. Winter (December to January), Spring (Mid-February to Mid-April), Summer (May to Mid-June), and Monsoon (July to Mid-August) were monitored, and two replicates of each season were conducted in different habitat types. A total of 408 point counts were performed, of which 144 were in Oak forests, 60 in Chir Pine forests, 96 in Sal forests, and 108 in the village's agricultural land during different seasons. Birds were observed with aid of 8×42 Bushnell binocular for 15 minutes at a point and species identified with field guide help (Grimmett et al. 2011).

Vegetation survey

A vegetation plot of 20m*20m quadrat within each forest type was laid with a minimum distance of 500 m. All the tree species were counted, and their girth at the breast height (GBH) was measured (Rana et al. 2011). Altogether, 9 vegetation plots were laid, 4 in Oak, 3 in Sal, and 2 in Chir Pine forest. Within each 20m*20m plot, 2 quadrats of 5m*5m were laid for the shrub abundance and richness, and all the shrubs, seedling, and sapling were counted within the plot. Trees less than 20 cm in GBH were counted as saplings (Rai et al. 2012).

Data analysis

Past 3x software (Hammer et al. 2001) for diversity indices of birds was used. Shannon diversity (H) and Margalef's richness (R) values (MacArthur & MacArthur, 1961; Magurran, 2004) were used to compute Bird Species Diversity (BSD) and Bird Species Richness (BSR) at each point. The relative abundance index was calculated in percentage by dividing the total observations to the particular species observation. Species accumulation curve was calculated to determine the adequate sampling points required to reach species saturation or asymptote. Two-way ANOVA test with Tukey post hoc test was performed to determine the significant differences of BSD and BSR between different habitats and seasons. Vegan package for R was used to calculate species accumulation curve, ANOVA, and Tukey post hoc test (Oksanen et al. 2019).

The formula for Shannon Diversity $H = -\Sigma Pi (\log Pi)$. (where H is Shannon Diversity, Pi is the proportion of a species and the total number of species in a sample.)

Formula for Margalef richness $R = (S-1)/\log(n)$. (where S is the total number of species and n is the total number of individuals in a sample.)

In the vegetation analysis, the density of trees and shrubs was calculated as the number of individuals per hectare using the formula $D = (Ni/A) \times 10000$. (where Ni is the number of individuals in a plot and A is the plot area.)

The global range to each species was assigned by following the website Birds of the world (2021) and Migration status based on the field observations and description in the field guide (Grimmett et al. 2011).

Results

Vegetation structure

Overall tree density in the forest habitat is 703 trees per hectare area with an average GBH of 77.6 cm and 21,000 individuals per hectare is the shrub density. Within different forest habitats, maximum tree density was found in Oak forest (950 trees/hectare) with an average GBH of 71.8 cm, followed by Chir Pine forest (675 trees/hectare) with 75.89 cm of mean GBH. The least tree density was in Sal forest, 391 trees/hectare, but average GBH was the highest (86.46 cm) compared to other forest habitats. Maximum tree richness was found in the Oak forest, trees such as Chir Pine (*Pinus roxburghii*), Kafal (*Myrica* *esculenta*), and Rhododendron (*Rhododendron arborium*) were recorded within the forest habitat. In contrast, Sal forest was mixed with the few Chir Pine trees, and in Chir Pine forest, no other tree species were recorded.

On the other hand, shrub density was highest in Sal forest (28200 individuals/hectare). The number of seedlings and saplings of Sal trees was higher than the other habitats. However, the infestation of weed *Ageratina adenophora* was also higher in the Sal forest. Oak forest was the second-highest in shrub density (21400 individuals/hectare) but ranked highest in species richness. Species such as *Pyracantha sp.* and *Symplocos sp.* are abundant in Oak forest, sapling and seedlings of *Pyrus pashia*, *Rhododendron arborium*, *Myrica esculenta*, *Quqercus leucotrichophora* and *Q. glauca* were recorded from the Oak forest.

Overall bird status

A total of 2335 individuals of 95 species belonging to 32 families were recorded from 408 point counts in the study area. In contrast, the species accumulation curve shows the asymptote near around 300 point counts (Figure 4.6). Among the recorded species, 48 are Himalayan endemic. 4 species are endemic to the western and central Himalayas. 11 species are restricted to Himalaya of South Asia (Afganistan, Pakistan east to Mayanmar), and 33 species are restricted to Himalaya and occurring from India to Indo china and/or South-eastern China (Birds of the world 2021). Based on the forest dependency, 16 Oak forest specialist species (exclusively recorded from the Oak forests) were recorded. A total of 30 altitudinal or long-range migratory species were recorded. Among the migration status, we recorded 14 species as summer visitors, 15 winter visitors, and one species (Greenish leaf Warbler) as a passage visitor. Among the winter visitor species, 2 species (Black-throated Accentor, Black-throated Thrush) are long-range migratory (Non-resident in the Indian sub-continent), and the rest 13 species are altitudinal migrants. The schedule status of the Indian Wildlife Protection Act 1972 revealed that 57 species are under IV and are protected under Indian laws. (Table. 4.2).

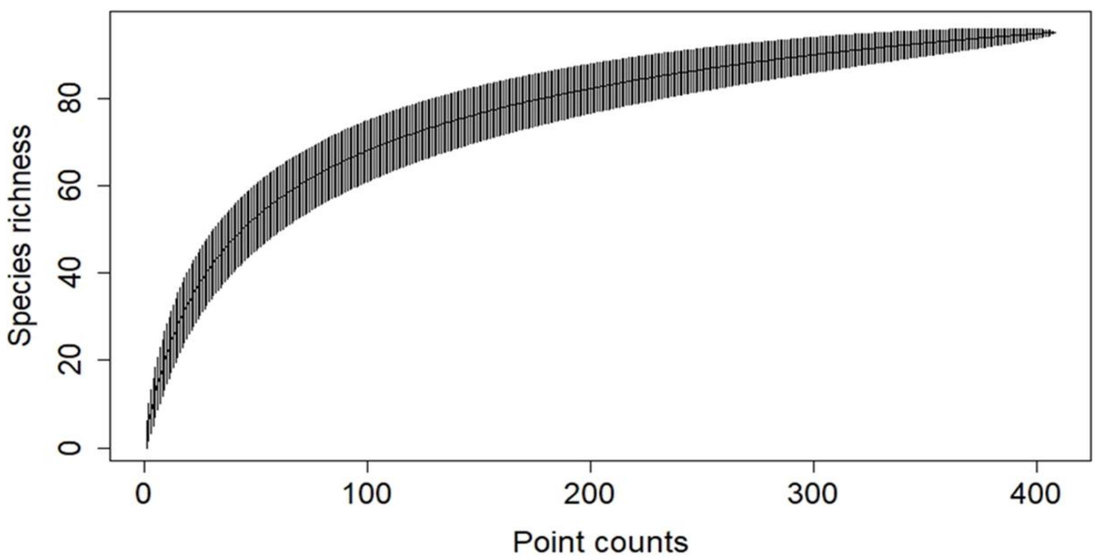

Figure 4.6: Species area curve for bird richness in the village landscape

Birds in different habitats

Within different habitats in all the seasons, maximum number of species and their individuals were recorded from the agro-ecosystem such as 67 species and 1109 individuals, followed by Oak forest (65 species and 743 individuals), Sal forest (47, 353), and Pine forest (35, 130) (Figure 4.7.A).

Within different habitats in all the seasons, the maximum number of species and their individuals were recorded from the agro-ecosystem; 67 species and 1109 individuals, followed by Oak forest (65 species and 743 individuals), Sal forest (47, 353), and Pine forest (35, 130) (Fig. 4.7.B).

Overall point diversity within different habitats reveals that agricultural land has the highest BSD (1.33 ± 0.03) and BSR (1.6 ± .04) among all the habitats followed by Oak forest (BSD .93 ± .03, BSR 1.2 ± .04) and least in the Chir Pine forest (BSD .49 ± .05, BSR .8±.09). ANOVA test finds out that there is a highly significant difference in the BSD (F3, 404= 67.66, P=2*10-16) and BSR (F3, 404= 29.3, P=2*10-16) in different habitats. Further, Tukey post hoc test showed that agricultural land was significantly different from the Oak, Chir pine and Sal forests in BSD and BSR with p-value <0.001. Oak forest was also found to be significantly different in BSD and BSR from Chir pine with p-value <.0001, and from Sal forest in BSD with p-value <0.05. Sal forest was also found significantly different from the Chir pine forest in BSD and BSR with p-value <.001.

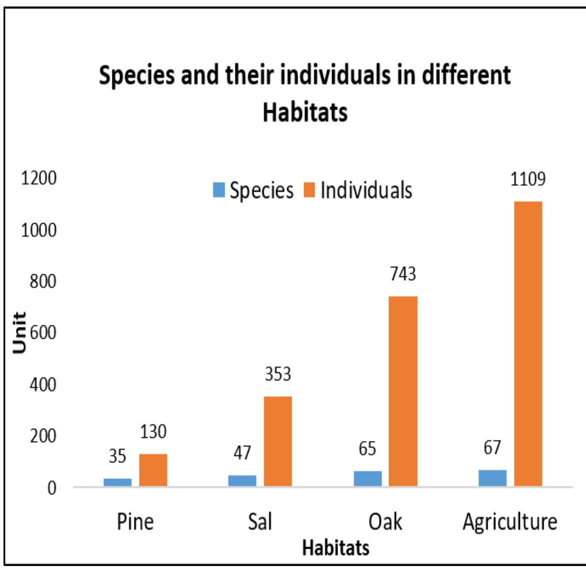

Figure 4.7.A: Species and their individuals recorded from different habitats of the village ecosystem.

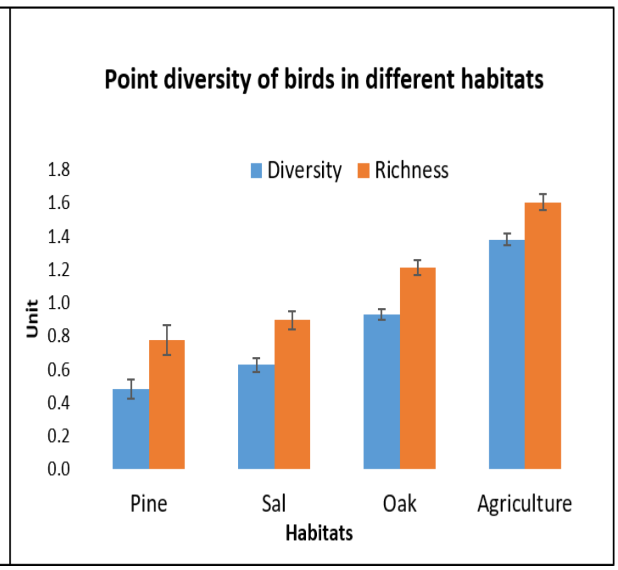

Figure 4.7.B: Point diversity of birds within different habitats. Significant differences in BSD ($F_{3, 404}$= 67.66, P=2*10^{-16}) and BSR ($F_{3, 404}$= 29.3, P=2*10^{-16}) was found during different habitats.

Birds during different seasons

Among different seasons, a maximum number of species were recorded during spring (70) and winter season (62), followed by summer (60) and monsoon season (57). In contrast, species abundance was highest during spring (694 individuals), followed by monsoon (628 individuals), summer (524 individuals), and least in the winter season (489 individuals) (Figure 4.8.A).

Diversity indices per point reveal that among the different seasons in the village ecosystem maximum BSD 1.08 ± .05 and BSR 1.39 ± .06 was recorded during Spring season followed by Monsoon (BSD .94 ± .04, BSR 1.19 ± .05), and Summer season BSD (.87 ± .04) is slightly higher than Winter (BSD .86 ± .05) whereas BSR in Winter (1.15 ± 06) is higher than Summer (BSR 1.13 ± .06). ANOVA test showed the significant difference in BSD (F3, 404 = 4.92, P=.002) and BSR (F3, 404 = 3.86, P=.009) among different seasons. Tukey post hoc test revealed the significant differences in BSD (P = 0.004) and BSR (P = 0.03) between Winter-Spring seasons, and BSD (P = 0.007) and BSR (P = 0.03) between Summer-Spring seasons (Fig. 4.8.B).

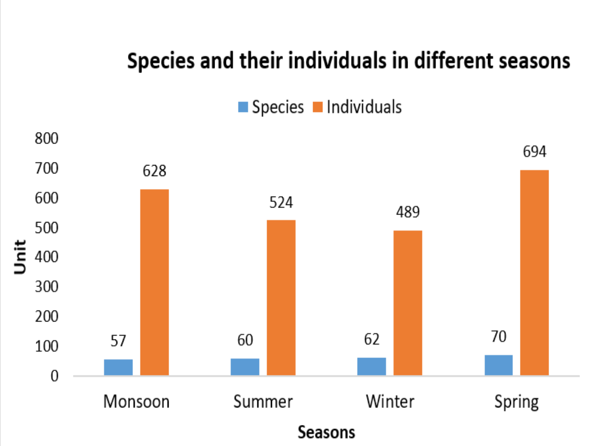

Figure 4.8.A: Bird species and their individuals recorded in different seasons.

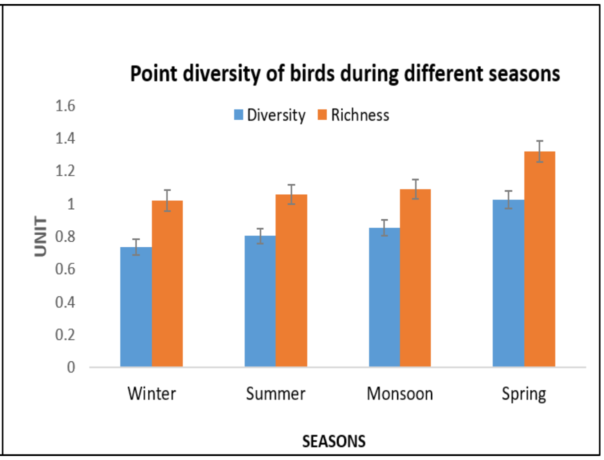

Figure 4.8.B: Point diversity of birds during different seasons. Significant differences in BSD ($F_{3, 404}$ = 4.92, P=.002) and BSR ($F_{3, 404}$ = 3.86, P=.009) was found during differences seasons.

Birds in different habitats during different seasons

During different seasons in different habitats, the maximum number of species were recorded from Agriculture land, of which summer (43 species) and spring (40 species) seasons are more species-rich than winter (34 species) and monsoon (33 species) seasons. We found Oak and Sal forests have the maximum number of species during the spring season (40, 29), followed by Monsoon (39, 27) and least in summer (36, 22) and winter (37, 22). Whereas, Pine forest had the least species numbers were throughout the seasons, with the highest in monsoon (18) followed by spring (15) and winter (15), and summer season (13).

Diversity indices per point in different habitats during different seasons found that the agricultural land had the maximum BSD (1.55 ± 0.06) and BSR (1.83 ± .09) during the Spring season followed by Winter (BSD 1.29 ± .06, BSR 1.56± .08), and least in Summer season (BSD 1.23 ± .05, BSR 1.42 ± .07). A significant difference was found among the seasons in BSD (F3, 104= 6.58, P=.0004) and BSR (F3, 104= 4.93, P=.003). Tukey Post hoc test revealed Spring season was significantly higher in BSD than Monsoon (P=.003), Summer (P=.0007) and winter seasons (P=.01). Whereas BSR in the spring season was significantly higher from Monsoon (P=0.01), and Summer (P=0.002) seasons.

Similarly, in Oak forest maximum BSD (1.08 ± .07) and BSR (1.4± .08) was recorded during Spring seasons followed by Summer (BSD .94± .05, BSR 1.24 ± .07), Monsoon (BSD .9 ± .07, BSR 1.12 ± .09) and least during Winter (BSD .8 ± .07, BSR 1.04 ± .09). ANOVA test reveals the significant difference in BSD (F3, 140= 3.5, P=0.02) and BSR (F3, 140= 3.11, P=0.028). Significantly difference found between Winter and Spring seasons in BSD (P=.008) and BSR (P=.02).

In Sal forest, maximum BSD (.91 ± .08) was recorded during Monsoon season followed by Spring (BSD .82 ± .1) and Winter (BSD .78 ± .07) whether BSR (1.19 ± .11) was highest in Winter Season followed by Monsoon (BSR 1.16 ± .11) and Spring seasons (BSR 1.12 ± .13). Least BSD (.61± .08) and BSR (.9 ± .12) were recorded during Summer season. ANOVA test finds no significant difference in BSD (F3, 92 = 2.065, P=.11) and BSR (F3, 92 = 1.205, P=.31) among different seasons in the Sal forest.

Pine forest has the maximum BSD (.66 ± .12) and BSR (.98 ± .18) during Spring season followed by Monsoon (BSD .5 ± .08, BSR .85 ± .15), Summer (BSD .45 ± .12, BSR .72 ± .2) and least in Winter (BSD .36 ± .11, BSR .64 ± .18). There were no significant differences found in BSD (F3, 56 = 1.27, P=.29) and BSR (F3, 56 = .73, P=.54) during different seasons in the Chir pine forest (Fig. 4.9).

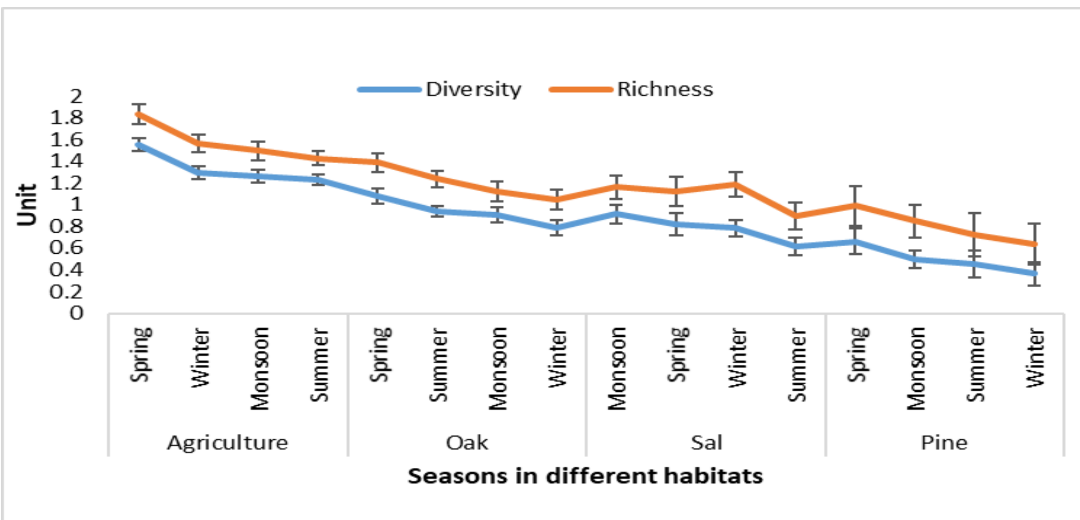

Figure 4.9: Average point BSD and BSR in different habitats during different seasons. Pine forest ($F_{3, 56}$ = 1.27, P=.29) and BSR ($F_{3, 56}$ = .73, P=.54) (no significance difference). Sal forest ($F_{3, 92}$ = 2.065, P=.11) and BSR ($F_{3, 92}$ = 1.205, P=.31) (no significance difference). Oak forest BSD ($F_{3, 140}$= 3.5, P=0.02) and BSR ($F_{3, 140}$= 3.11, P=0.028) (significance difference). Agriculture filed: BSD $F_{3, 104}$= 6.58, P<.001 and BSR $F_{3, 104}$= 4.93, P<.01

Species and their abundance in different habitats during different seasons

The slaty-headed parakeet was dominant in the agriculture land during the monsoon and spring season, whether Plum-headed parakeet was most recorded during the summer season. Grey-hooded leaf warbler and Black-throated tit were the most dominant species in the Oak forest, especially during monsoon, winters, and summers. Whether during spring, Himalayan bulbul and Hume's leaf warbler abundance also increases in the Oak forest. In Sal forest, Grey-hooded leaf warbler and Himalayan bulbul were highest in numbers in all four seasons. The pine forest was the least bird species rich and abundant forest than other habitat type in the village ecosystem. However, Grey-hooded leaf warbler was the dominant species in this habitat in all the seasons. During monsoon, White-crested laughingthrush was recorded highest during summer and winters. Hume's leaf warbler was also found high in the Chir pine forest.

Table 4.5. Most abundant species during different seasons in different habitats.

	Agriculture		Oak		Sal		Pine	
Seasons	**Species**	**A**	**Species**	**A**	**Species**	**A**	**Species**	**A**
Monsoon	Slaty-headed parakeet	49	Grey-hooded Leaf Warbler	17	Grey-hooded Leaf Warbler	19	White-crested Laughingthrush	4
	Black bulbul	23	Black bulbul	15	Himalayan Bulbul	16	Grey-hooded Leaf Warbler	3
	Common myna	21	Black-throated tit	14	Black-chinned babbler	10	Bar-tailed treecreeper	3
Winter	Common Myna	25	Black-throated tit	21	Grey-hooded Leaf Warbler	10	Grey-hooded Leaf Warbler	6
	Himalayan Bulbul	19	Grey-hooded Leaf Warbler	14	Himalayan Bulbul	7	Hume's Leaf Warbler	3
	Grey-hooded Leaf Warbler	13	Yellow-breasted Greenfinch	12	Grey bushchat	6	Blue whishlingthrush	2
Spring	Himalayan Bulbul	56	Grey-hooded Leaf Warbler	31	Grey-hooded Leaf Warbler	15	Grey-hooded Leaf Warbler	9
	Slaty-headed Parakeet	52	Himalayan Bulbul	15	Himalayan Bulbul	11	Himalayan Bulbul	5
	Common Myna	20	Hume's Leaf Warbler	13	Cinereous Tit	8	Grey bushchat	5
Summer	Plum-headed Parakeet	40	Grey-hooded Leaf Warbler	21	Grey-hooded Leaf Warbler	13	Grey-hooded Leaf Warbler	5
	Himalayan Bulbul	31	Black-throated tit	17	Himalayan Bulbul	11	Grey bushchat	4
	Common Myna	22	Himalayan Bulbul	16	Hume's Leaf Warbler	6	Hume's Leaf Warbler	4

Abbreviations: A= abundance

Abundant bird families and species

Among the 32 recorded avifaunal families from the study area, Muscicapidae was the most species-rich family with 19 species. Blue Whistling thrush (2.74%) and Grey Bush chat (2.40%) were the most abundant species. Picidae was the second richest family (7 species), of which species such as Brown-fronted Woodpecker (1.03%) and Grey-headed Woodpecker (0.9%) were the most abundant. Phylloscopidae family was the most abundant (16.52%) and third species-rich (6 species) family of which Grey-hooded Leaf Warbler (8.95%), Hume's Leaf Warbler (4.15%), and Lemon-rumped Warbler (2.18%) were the most abundant species. Pycnonotidae family was the second-largest family (14.44%), and Himalayan Bulbul (9.76%), Black Bulbul (2.91%), and Red-vented Bulbul (2.53%) were the most abundant species in the family (Table 4.2).

Table 4.6. Birds recorded during point counts from Bans-Maitoli village with status of restricted range, migration protection, habitat of occurrence and relative abundance index.

Family/Scientific name	**English name**	**GR**	**IWPA schedule**	**MS**	**Habitat**	**RAI (%)**
Columbidae						**2.7**
Columba rupestris	Hill pigeon		IV	R	O	0.51
Streptopelia orientalis	Oriental Turtle Dove		IV	R	A, O, S, P	1.33
Streptopelia chinensis	Spotted Dove		IV	R	A, O, P	0.64
Streptopelia decaocto	Eurasian Collared Dove		IV	R	S	0.04
Treron sphenurus	Wedge-tailed Green Pigeon	H3	IV	R	O	0.17
Upupidae						**0.09**
Upupa epops	Common Hoopoe			SV/LM	A	0.09
Campephagidae						1.16
Pericrocotus ethologus	Long-tailed Minivet	H3	IV	R	A, O, S, P	1.16
Certhiidae						**1.11**
Certhia himalayana	Bar-tailed Treecreeper			R	O, S, P	1.11
Cisticolidae						**0.81**
Prinia hodgsonii	Grey-breasted Prinia			R	A, S	0.77
Prinia crinigera	Striated Prinia	H3		R	P	0.04
Corvidae						**5.87**

Garrulus lanceolatus	Black-headed Jay	H1	IV	R	A, O, S, P	0.47
Dendrocitta formosa	Grey Treepie		IV	R	A, O, S, P	2.87
Corvus macrorhynchos	Large-billed Crow			R	A, S, P	0.39
Urocissa erythrorhyncha	Red-billed Blue Magpie	H3	IV	R	A, O, S, P	1.84
Urocissa flavirostris	Yellow-billed Blue Magpie	H2	IV	R	O	0.30
Dicaeidae						**0.09**
Dicaeum ignipectus	Fire-breasted Flowerpecker	H3	IV	R	O	0.09
Dicruridae						**1.07**
Dicrurus leucophaeus	Ashy Drongo		IV	SV/LM	A, O, S, P	0.77
Dicrurus hottentottus	Hair-crested Drongo		IV	R	A	0.30
Emberizidae						**0.26**
Melophus lathami	Crested Bunting		IV	WV/LM	A	0.26
Fringillidae						**1.76**
Erythrina erythrina	Common Rosefinch		IV	WV/LM	A, O	0.39
Procarduelis nipalensis	Dark-breasted Rosefinch	H3	IV	WV/LM	A	0.09
Carpodacus rodochroa	Pink-browed Rosefinch	H2		WV/LM	O	0.17
Chloris spinoides	Yellow-breasted Greenfinch	H2	IV	WV/LM	A, O, S	1.11
Leiothrichidae						**6.38**
Trudoides striata	Jungle Babbler		IV	R	A, O	1.41
Heterophasia capistrata	Rufous Sibia	H2		R	A, O, P	1.20
Trochalopteron lineatum	Streaked Laughingthrush	H2	IV	R	A, O	0.26
Garrulax leucolophus	White-crested Laughingthrush	H3	IV	R	A, O, S, P	2.61
Garrulax albogulris	White-throated Laughingthrush	H3	IV	R	O	0.90
Monarchidae						**0.04**
Terpsiphone paradisi	Indian Paradise-Flycatcher			SV/LM	A	0.04
Motacillidae						**0.34**
Anthus roseatus	Rosy Pipit	H3	IV	WV/LM	A	0.21
Motacilla maderaspatensis	White-browed Wagtail			R	A	0.13
Muscicapidae						**9.04**

Myphonus caeruleus	Blue Whistling Thrush	H3		R	A, O, S, P	2.74
Monticola cinclorhynchus	Blue-capped Rock Thrush			SV/LM	O, S, P	0.21
Monticola rufiventris	Chestnut-bellied Rock Thrush	H3		R	A, P	0.09
Adelura coeruleocephala	Blue-capped Redstart			R	P	0.04
Adelura frontalis	Blue-fronted Redstart	H3		WV/LM	A, O, S	0.47
Enicurusschistaceus	Slaty-backed Forktail	H3		R	A	0.04
Saxicola maurus	Siberian Stonechat			SV/LM	A	0.09
Saxicola ferreus	Grey Bushchat	H3		R	A, O, S, P	2.40
Saxicola caprata	Pied Bushchat			SV/LM	S	0.09
Tarsiger rufilatus	Himalayan Bush Robin	H3		R	A, O, S	0.26
Copsychus saularis	Oriental Magpie Robin			R	A	0.13
Niltava macgrigoriea	Small Niltava	H3		R	A	0.09
Niltava sundara	Rufous-bellied Niltava	H3		R	O	0.04
Culicicapa ceylonensis	Grey-headed Canary-Flycatcher		IV	SV/LM	A, O, S	0.43
Muscicapa sibirica	Dark-sided Flycatcher		IV	SV/LM	O	0.09
Ficedula strophiata	Rufous-gorgeted Flycatcher	H3	IV	R	O, S	0.51
Ficedula ruficauda	Rusty-tailed Flycatcher		IV	SV/LM	O	0.09
Ficedula superciliaris	Ultramarine Flycatcher		IV	SV/LM	A, S, P	0.39
Eumiyas thalassinus	Verditer Flycatcher		IV	SV/LM	A, O, S, P	0.86
Nectariniidae						**0.69**
Aethopyga saturata	Black-throated Sunbird	H3	IV	R	O	0.13
Aethopyga siparaja	Crimson Sunbird		IV	SV/LM	S	0.04
Aethopyga nipalensis	Green-tailed Sunbird	H3	IV	R	A, O	0.34
Cinnyris asiaticus	Purple Sunbird		IV	SV/LM	A	0.17
Paridae						**7.97**
Parus xanthogenys	Black-lored Tit	H2	IV	R	A, O, S, P	0.69
Aegithalos concinnus	Black-throated Tit	H3	IV	R	A, O, P	2.91
Parus cinereus	Cinereous Tit		IV	R	A, O, S, P	2.66
Parus monticolus	Green-backed Tit	H3	IV	R	A, O, S, P	1.71
Passeridae						**2.48**
Passer domesticus	House Sparrow			R	A	1.71
Passer cinnamomeus	Russet Sparrow			R	A	0.77

Phylloscopidae						**16.52**
Phylloscopus pulcher	Buff-barred warbler	H3		WV/LM	O	0.64
Phylloscopus trochiloides	Greenish Leaf Warbler			PV/LM	A	0.30
Phylloscopus xanthoschistos	Grey-hooded Leaf Warbler	H2		R	A, O, S, P	8.95
Phylloscopus humei	Hume's Leaf Warbler			SV/LM	A, O, S, P	4.15
Phylloscopus chloronotus	Lemon-rumped Warbler	H2		WV/LM	A, O, S	2.18
Phylloscopus affinis	Tickell's Leaf Warbler			WV/LM	A, O	0.30
Prunellidae						**0.21**
Prunella atrogularis	Black-throated Accentor			WV	A	0.21
Pycnonotidae						**15.25**
Hypsipetes leucocephalus	Black Bulbul	H3	IV	R	A, O, S, P	2.91
Pycnonotus leucogenys	Himalayan Bulbul	H2	IV	R	A, O, S, P	9.76
Ixos mcclellandii	Mountain Bulbul	H3	IV	R	O	0.04
Pycnonotus cafer	Red-vented Bulbul		IV	R	A, O, S	2.53
Rhipiduridae						**1.24**
Rhipidura albicollis	White-throated Fantail			R	A, O, S	1.24
Scotocercidae						**0.17**
Cettia brunnifrons	Grey-sided Bush Warbler	H3		WV/LM	A	0.17
Sittidae						**1.88**
Sitta cinnmoventris	Chestnut-bellied Nuthatch	H3		R	A, O, S, P	1.80
Tichodroma muraria	Wallcreeper			WV/LM	P	0.09
Stenostiridae						**0.13**
Chelidorhynx hypoxantha	Yellow-bellied Fairy-fantail	H3		WV/LM	A, O, S	0.13
Sturnidae						**3.77**
Acridotheres tristis	Common Myna		IV	R	A	3.77
Timaliidae						**2.27**
Cyanoderma pyrrhops	Black-chinned Babbler	H1	IV	R	A, O, S	1.93
Erythrogenys erythrogenys	Rusty-cheeked Scimitar Babbler	H2	IV	R	A, O	0.34
Turdidae						**0.9**
Turdus atrogularis	Black-throated Thrush		IV	WV	A, O, S	0.17
Turdus boulboul	Grey-winged Blackbird	H3		R	A, O, S, P	0.73

Zosteropidae						**1.28**
Zosterops palpebrosus	Oriental White-eye		IV	R	A, O, S	1.20
Yuhina gularis	Stripe-throated Yuhina	H3		R	O	0.09
Megalaimidae						**2.91**
Psilopogon asiaticus	Blue-throated Barbet	H3	IV	R	A, O, S, P	1.07
Psilopogon virens	Great Barbet	H3	IV	R	A, O, S, P	1.84
Picidae						**3.51**
Dendrocopos auriceps	Brown-fronted Woodpecker	H1	IV	R	A, O, S, P	1.03
Chrysophlegma flavinucha	Greater Yellow-naped Woodpecker		IV	R	O	0.30
Dendrocopos canicapillus	Grey-capped Pygmy Woodpecker		IV	R	S	0.47
Picus canus	Grey-headed Woodpecker		IV	R	O, S, P	0.90
Picus chlorolophus	Lesser Yellow-naped Woodpecker		IV	R	O	0.30
Picus sqamatus	Scaly-bellied Woodpecker	H1	IV	R	O, S	0.47
Picumnu sinnominatus	Speckled Piculet		IV	R	O	0.04
Psittaculidae						**8.01**
Psittacula cyanocephala	Plum-headed Parakeet		IV	R	A, O, S	2.40
Psittacula hamlayana	Slaty-headed Parakeet	H2	IV	R	A, O, S	5.61
Strigidae						**0.09**
Glaucidium cuculoides	Asian Barred Owlet	H3	IV	R	A, P	0.09

Abbreviations. GR = Global Range; **H1**=Restricted to Western and Central Himalaya (Afghanistan, Pakistan, India and Nepal), **H2**=Restricted to Himalaya of South Asia (Afghanistan, Pakistan eastward to Myanmar), **H3**= Restricted to Himalaya and occurring from India to Indo china and/or South-eastern China. **IWPA** = Indian Wildlife Protection Act (1972) Schedule. **MS=** Migration status; **R**= Resident, **LM**= Local/Altitudinal migratory, **SV**= Summer visitor, **WV**= Winter visitor, **PV**= Passage visitor. **Habitat**; **A**= Agriculture field, **O**= Oak forest, **S**= Sal forest, **P**= Pine forest. **RAI%=** Relative abundance index in percent.

Discussion

Among the recorded 95 species in point counts, nearly 50% were Himalayan endemic species, more than 30% were migratory species such as passage visitors, summer visitors, and winter visitors. Moreover, 60% of the species recorded have been accorded conservation priority in India under schedule IV of the Wildlife Protection Act 1972. It represents the vital role of the village ecosystem in providing suitable habitats to these conservation significant species.

Among the recorded Himalayan endemic and forest specialist species, 10 species such as Yellow-billed Blue Magpie, Pink-browed Rosefinch, Wedge-tailed Green Pigeon, Fire-breasted Flowerpecker, White-throated Laughingthrush, Rufous-bellied Niltava, Black-throated Sunbird, Buff-barred warbler, Mountain Bulbul, and Stripe-throated Yuhina were found in both categories. However, change in the land-use patterns and forest degradation in the Himalaya makes these range-restricted and forest specialist species more vulnerable to extinction, and hence with high conservation significance value.

Naturalists have widely reported seasonal migration in the Himalaya over the past few decades (Grimmett et al. 1998, Kery et al. 2000). It occurs due to fluctuations in food productivity and climatic conditions (Blake & Loiselle, 1991; Norris & Marra, 2007; Acharya et al. 2010). Our study area that is located at the mid-elevation range, which is at the junction of the low and high elevation ranges of the Himalaya supports 30 migratory species. This corroborates previous observations by ornithologists/naturalists that food and suitable habitat availability during seasonal change plays a major role in the diversity of species encountered (Vazquez & Givnish, 1998; Naithani & Bhatt, 2010).

Avifaunal richness and abundance was found highest in the agricultural land. Typically, in the Himalayas, traditional agriculture is diverse, with a variety of fodder, ornamental and sacred plants in the croplands using organic farming practices (Bisht et al. 2006). We recorded a variety of fodder trees like *Ficus racemosa*, *Ficus palmata*, *Grewia optiva*, *Celtis* australis, *Pyrus passia*, and so from the agricultural land of the village. Various birds use branches of these trees for perching and foraging purposes. Previous studies have discussed the premise that if agricultural lands are managed organically and maintained with diverse shade trees, they can harbour a significant amount of wild biodiversity with unique community assemblages of plants and animals (Harvey et al. 2006; Sharma & Vetaas, 2015; Mellink et al. 2017). This highlights the importance of agricultural land in the elevation band in terms of species enrichment.

Oak forest was the second-highest in the BSD and BSR, as the forest supports high richness and density of trees and shrubs, which provides shelter and suitable habitat to different forest-dwelling bird species. On the other hand, the Chir Pine forest was least in terms of bird diversity; a probable reason could be the similarity of this habitat to a monoculture, as the variety of tree species was negligible in this forest. Another possible cause is that the density and diversity of shrubs were also the lowest in this habitat. The previous study has recorded that avifaunal diversity depends on habitat variety with different species of trees and shrubs (Laiolo et al. 2004).

Highest number of species were rcorded during the Spring season, as most of the Himalayan birds start breeding (Elsen et al. 2018; Shahabuddin et al. 2021), become more vocally active during this season, thereby increasing their detection rates also. Another factor could be that spring is a transition season between winter and summer, and the mid-elevation areas are the juncture of crossovers from lower to higher altitudes and vice-versa in the landscape. Similarly, we found BSD and BSR were highest during spring seasons in all the habitat types except Sal forest.

In Sal forest, maximum BSD was recorded in the Monsoon season. Despite the tree density being significantly lower than other forest types, the shrub density increases during the monsoon, which supports high bird diversity (Acharya et al. 2011). In contrast, BSR was highest during the Winter season as sal forest type is present in lower elevation areas, and during winters, birds residing at high altitudes migrate to these areas (Naithani & Bhatt, 2010).

The insectivorous feeding guild is the richest and most abundant feeding guild in the Himalaya (Acharya et al. 2010; Joshi & Bhatt, 2011; Katuwal et al. 2016). This study also recorded Muscicapidae (19 species), Picidae (7 species), Phylloscopidae (6 species) families that are most species-rich which predominantly depend on insects for food. Grey-hooded Warbler and Hume's Leaf Warbler was the most encountered species from the most abundant family Phylloscopidae. Studies done by Ghosh et al. (2011) and Shahabuddin et al. (2017) reported Grey-hooded Warbler and Hume's Leaf Warbler as the most abundant species in the Phylloscopidae family from the Himalayan foothills and nearby districts (Almora and Nainital), respectively.

Nesting or roosting sites of a species represent the population persistence of that species in the landscape (Arya et al. 2021). Similarly, an active nesting site of Bearded Vulture and Common Kestrel was observed on a cliff near the Chir pine forest, and a roosting site of Himalaya vulture and Egyptian Vulture on a hilltop during winters. It represents that this village ecosystem is providing suitable habitats to these globally threatened species and top predatory species.

Conclusion

The present study records the seasonal pattern of avian diversity over two years in a mid altitudinal range village ecosystem. The region supports many conservation significant species, Himalayan endemics and forest specialists. Most of the species recorded are more susceptible to land-use change and forest degradation. BSD and BSR positively correlate with habitat diversity, indicating that a more diverse habitat supports higher abundance values. Anthropogenic pressure in the Sal forest is much higher than in other forests and requires conservation and better management attention. Spring season (Breeding season) was observed as the most species-rich and diverse amongst all seasons. Winter was the second most species-rich season but least in species abundance, whereas monsoon was high in species abundance but least in species richness.

Studies on the seasonal pattern of avian diversity in different habitats are significantly lower in the Indian Himalayan Region. This study aims to provide a basic understanding of how avifaunal diversity pattern changes across seasons in different habitat types in a mid-altitudinal region which serves as a juncture for crossover.

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Photo plate 1. Some summer migratory birds recorded from the Bans-Maitoli Village ecosystem**. A.** Ashy Drongo, **B.** Common Hoopoe, **C.** Pied Bushchat, **D.** Indian Paradise-Flycatcher, **E.** Blue-capped Rock Thrush, **F.** Siberian Stonechat

Photo plate 2. Some winter migratory birds recorded from the Bans-Maitoli Village ecosystem**. A.** Pink-browed Rosefinch, **B.** Dark-breasted Rosefinch, **C.** Yellow-breasted Greenfinch, **D.** Crested Bunting, **E.** Blue-fronted Redstart, **F.** Wallcreeper

CHAPTER 5

Objective 3. To prepare the species distribution and abundance model for rare and threatened species.

Two important conservation dependent groups of birds, such as pheasants and vultures, were selected as they area rare and threatened birds in the landscape. The pheasant group of birds in the Himalayas has a high endemicity (Sathyakumar et al. 2010), and the vultures are the most threatened group of birds (Ogada et al. 2016).

Study Area

The entire Pithoragarh district for assessing the possible distribution of the pheasants and raptor species was selected. The study area has clearly been described in Chapter 2.

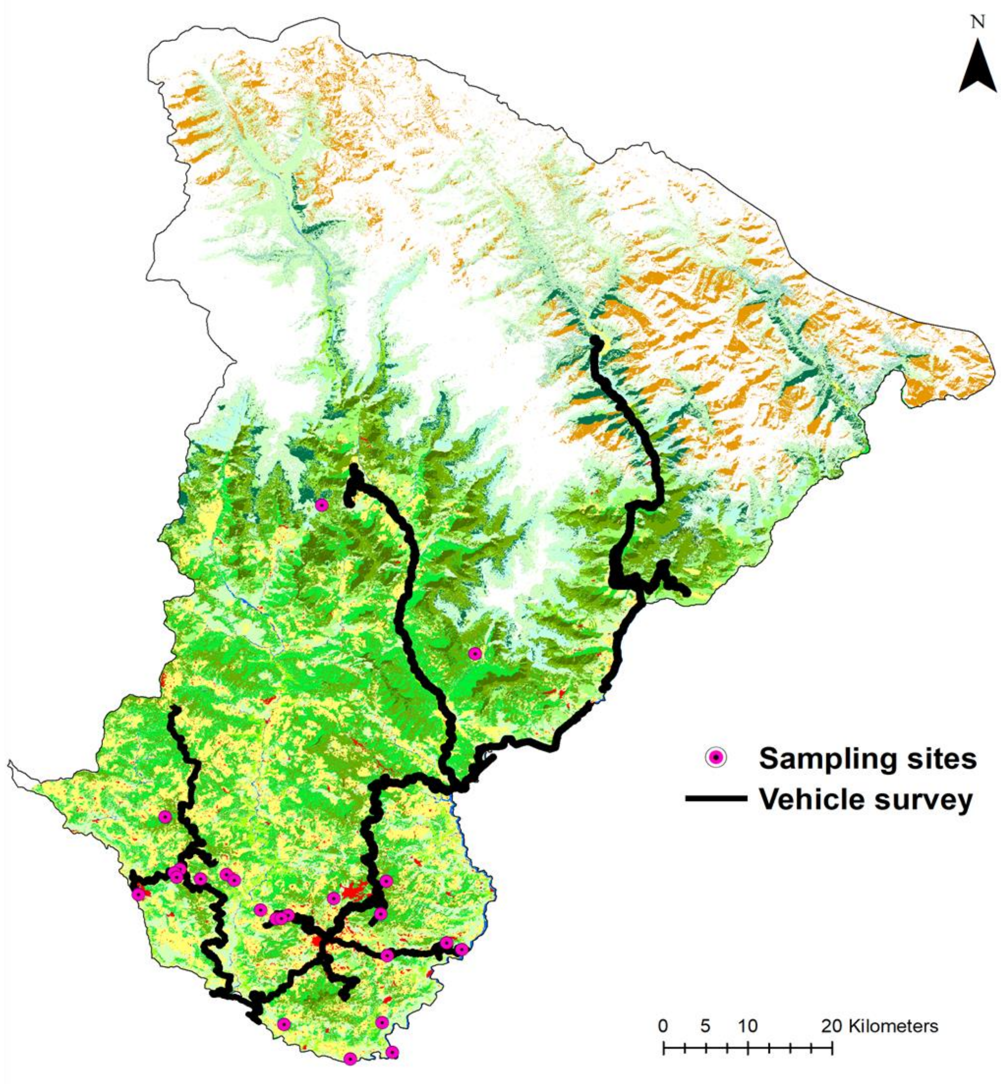

Figure 5.1: Sampling sites and vehicle survey in the study area.

Methods

Pheasant survey

The survey was conducted during spring (February to April), summer (May and June), and winter (October to December) seasons in the landscape through trail walks (Bibby et al. 1998, 2000) in different habitats of the landscape. Altogether 72 trail walks of 466 km (each trail length between 2 km to 14 km) passing through agricultural land, grasslands, scrublands, and forests were conducted between 400 and 4000 m above sea level. Encountered species along with their Individuals and geographic location were recorded. The survey was conducted between 0600 to 1700 h with the help of two observers. Bushnell's (8×42) binocular was used for observations and species identified using the handbook (Grimmett et al. 2011).

Vulture survey

The survey was conducted through trail walks and vehicle surveys. Trail walks were conducted during the spring, summer, and winter seasons. Total 57 trails of 320 km (each between 3-8 km) were walked, passing through different forests (Subtropical mixed, Sal, Chir pine, Oak and Temperate mixed), agriculture and grassland habitats of various localities between the elevation of 600-2500 m asl. 1,162 kilometers was the total area surveyed by road transects with two-wheeler at the constant speed of 25-30 km/hr during summer and winter (May 2017, October-December 2017) (Figure 5.1). The survey was conducted between 0800 to 1700 h with the help of two observers (field assistants). Geographical location, habitat type, and locality at species nesting, roosting, and perching sites were recorded. These locations were used in predicting the habitat suitability of species in the landscape.

Environmental parameters

For the current distribution of the RET species, 37 different environmental parameters, viz. climatic parameters (19 climatic variables, assessed from www.worldclim.org), topographic parameters (two variables), land use parameters (16 variables), and Human pressure (two variables) were used. Further, each variable was prepared in 100m*100m of climate raster resolution based on climate raster resolution, which was the coarsest of map layers using ArcGis 10.3 (ESRI 2015). Files were modified to have the same extent, snapped to the same base raster, and converted into .asc files to perform the Maxent. The highly correlated environmental variables were removed (Pearson's correlation coefficient ≥0.75) to avoid multicollinearity by computing pairwise Pearson's correlations among the variables (Vergara et al. 2016) (Table 5.1).

Maxent model construction

To develop a model for the species' habitat appropriateness, mxent software 3.4.3 (Phillips, 2006) was used. MaxEnt is a machine learning and artificial intelligence (AI) application that aids in developing plausible global distribution models based on species occurrence records and factors that may be used in prediction maps (Elith et al. 2011). The habitat distribution of species recorded more than 15 times from the different locations was used for prediction.

To predict the species' existing distribution, We used the recommended default Maxent settings: maximum number of iterations (500), convergence threshold (0.00001), regularization multiplier (1), and logistic output with 0 to 1 ranging suitability values was used (Philips & Dudik 2008). The regularisation of multiplier point fixed at 1 with fixed 10000 background points for the model. For cross-validation, performed 20 sets of replicates for species locations more than 30, and 50 sets of replicates for less than 30 locations of a species to assess the robustness of the species distribution model. The set of location records was partitioned as 20% testing data and 80% training data during each replicate. The Jackknife analysis of the regularized gain with training data was used to examine the importance of variables during the modeling process.

The AUC (Area Under Curve) value to test the model's accuracy was used, which falls between 0 and 1. AUC value of 1 denotes an accurate model based on the threshold level for the model performance.

Table 5.1. Environmental parameters used in assessing the species habitat suitability model.

S. N.	Parameters	Variables
1	Climatic	Bio 1 (Annual Mean Temperature)
2		**BIO 2 (Mean Diurnal Range (Mean of monthly (max temp - min temp)))**
3		BIO 3 (Isothermality (BIO2/BIO7) (×100))
4		BIO 4 (Temperature Seasonality (standard deviation ×100))
5		BIO 5 (Max Temperature of Warmest Month)
6		BIO 6 (Min Temperature of Coldest Month)
7		**BIO 7 (Temperature Annual Range (BIO5-BIO6))**
8		BIO 8 (Mean Temperature of Wettest Quarter)
9		BIO 9 (Mean Temperature of Driest Quarter)
10		BIO 10 (Mean Temperature of Warmest Quarter)
11		BIO 11 (Mean Temperature of Coldest Quarter)
12		**BIO 12 (Annual Precipitation)**
13		BIO 13 (Precipitation of Wettest Month)
14		**BIO 14 (Precipitation of Driest Month)**
15		BIO 15 (Precipitation Seasonality (Coefficient of Variation))
16		BIO 16 (Precipitation of Wettest Quarter)
17		BIO 17 (Precipitation of Driest Quarter)
18		BIO 18 (Precipitation of Warmest Quarter)
19		**BIO 19 (Precipitation of Coldest Quarter)**
20	Human pressure	**HFI (Human Footprint Index)**
21		**Habitation**
22	Topographic	**Elevation**
23		**Slope**
24	Land use	**Agriculture**
25		**Barrenland**
26		Forest
27		**Grassland**
28		**Montane_broadleaved_deciduous_forest**
29		**Montane_broadleaved_evergreen_forest**
30		**Montane_needleleaved_forest**
31		**Scrubland**
32		Snow
33		**Sub_alpine_forest**

34		**Subtropical_broadleaf_forest**
35		**Subtropical_needleleaved_forest**
36		**Tropical_broadleaf_forest**
37		**Waterbodies**

Results

The study exclusively focused on 2 RET species i.e. pheasants and vulture species in the landscape. We prepared the habitat suitability model of six pheasant species (*Francolinus francolinus*, *Alectoris chukar*, *Lophura leucomelanos*, *Arborophila torqueola*, *Lophophorus impejanus* and *Purasia macrolopha*), and one vulture species (*Gyps himalayensis*) was prepared based on the recorded geographic locations in the landscape.

Pheasants habitat suitability

The present habitat suitability modeling using Maxent indicates the Himalayan pheasants' potential habitats extend from the subtropical forests to the snow-capped mountains. Our model performed well and revealed the probability distribution's strong predictive result. The regularisation multiplier of 0.1 was opted because it is ideal for model sensitivity and area under the curve (AUC) compared to other multipliers. Species such as *Francolinus francolinus* (AUC 0.971), *Alectoris chukar* (AUC 0.971), *Lophura leucomelanos* (AUC 0.985), *Arborophila torqueola* (AUC 0.994), *Lophophorus impejanus* (AUC 0.993) and *Purasia macrolopha* (AUC 0.987) showed strong predictive results of the probability distribution (Figure 5.2). The environmental parameter as the predictor, climatic variables for the species, 82.2% was the maximum contributor to the model for the *Purasia macrolopha* followed by 79.6% (*Lophophorus impejanus*), 55.5% (*Arborophila torqueola*), 41.9% (*Lophura leucomelanos*) and least was 32.6% (*Alectoris chukar*). The *Alectoris chukar* model demonstrated, 19.2% as the highest percentage of human pressure followed by the 7.1% (*Lophophorus impejanus*), 6% (*Lophura leucomelanos*) and 3.7% (*Purasia macrolopha*), whether the least was of *Arborophila torqueola* (0.9%). Similarly, the topographic variables suggested the maximum effort to the model for the *Francolinus francolinus* (37.8%) followed by *Lophura leucomelanos* (20.2%), *Alectoris chukar* (10%) and the least was *Arborophila torqueola* (2.2%) and *Purasia macrolopha* (9.2%). The landuse variables contributed to the model for *Arborophila torqueola* (41.3%) followed by *Alectoris chukar* (38%), *Lophura leucomelanos* (31.7%), *Francolinus francolinus* (20.6%) and least was *Lophophorus impejanus* (3.5%) and *Purasia macrolopha* (4.7%). Within the different variables of the environmental parameters, the maximum contribution of the variable of the model for *Francolinus francolinus* was BIO 12 (24.8%) followed by Elevation (24.1%), Slope (13.7) and Subtropical_needleleaved_forests (10.3%). For *Alectoris chukar* the highest contribution of the variable was BIO 12 and Grassland with 22.4% followed by HFI (18.3%), Elevation (7.1%), Subtropical_needleleaved_forest (5.7%) and BIO 2 (5.5%). The *Lophura leucomelanos* was the highest contributed by the variable Montane_broadleaved_evergreen_forest with 20.6%, followed by BIO 12 (16.2%), Elevation (16%) and BIO 7 (14.2%). The BIO 7 with 42.6% was the highest contributed variable for the model of *Arborophila torqueola* followed by Montane_broadleaved_evergreen_forest (26.4%), BIO 2 (7.9) and Grassland (7.5%). Similarly, for the *Lophophorus impejanus* was maximum contributed by the variables BIO 19 (42.5%) followed by BIO 2 (13.3%) and BIO 12 (12.1%). For *Purasia macrolopha*, BIO 2 (45.7%) was the maximum contributed variable followed by BIO 12 (14.8%) and BIO 19 (9.6%) (Table 5.2).

Other than these pheasant species, *Catreus wallichii*, and *Tragopan satyra* was also encountered, however these species were recorded less then 6 locations during the survey.

Table 5.2. Environmental parameters contribution to the model of the pheasants in the Landscape.(**Abberevations**: PC= Percent contribution; PI= Permutation importance).

		Black Francolin *Francolinus francolinus*		***Chukar Partridge*** *Alectoris chukar*		**Kalij Pheasant** *Lophura leucomelanos*		***Hill Partridge*** *Arborophila torqueola*		***Himalayan Monal*** *Lophophorus impejanus*		***Koklass Pheasant*** *Purasia macrolopha*	
Variables		**PC**	**PI**	**PC**	**PI**	**PC**	**PI**	**PC**	**PI**	**PC**	**PI**	**PC**	**PI**
Climatic variables	BIO 2	1.6	1.9	5.5	1.8	1.1	3.9	7.9	0.8	13.3	46.4	45.7	52.1
	BIO 7	8.5	3.8	1.5	0.4	14.2	1.6	42.6	78.7	10.1	0.7	9.4	0.3
	BIO 12	24.8	7.9	22.4	12.5	16.2	3.8	1.3	0.5	12.1	1.2	14.8	17.8
	BIO 14	1.4	4.1	1.5	2.7	1.6	1.1	0.7	0.2	1.6	4	2.7	5.1
	BIO 19	2.8	9.7	1.7	2.8	8.8	33.7	3	0.5	42.5	37.6	9.6	1.8
	Sub total	**39.1**	**27.4**	**32.6**	**20.2**	**41.9**	**44.1**	**55.5**	**80.7**	**79.6**	**89.9**	**82.2**	**77.1**
Human pressure	HFI	1.8	0.9	18.3	5.8	5.7	0.7	0.9	0.1	7.1	3.9	3.7	2.9
	Habitation	0.8	0.3	0.9	0.2	0.5	0.1	0	0	0	0	0	0
	Sub total	**2.6**	**1.2**	**19.2**	**6**	**6.2**	**0.8**	**0.9**	**0.1**	**7.1**	**3.9**	**3.7**	**2.9**
Topographic variables	Elevation	24.1	40.3	7.1	17.1	16	33.8	0.8	0.3	9.3	3.3	4	7.1
	Slope	13.7	14.9	2.9	2.1	4.2	2.3	1.4	0.9	0.5	0.3	5.2	4.6
	Sub total	**37.8**	**55.2**	**10**	**19.2**	**20.2**	**36.1**	**2.2**	**1.2**	**9.8**	**3.6**	**9.2**	**11.7**
Landuse variables	Agriculture	2.3	0.8	2	0.4	2.3	6.7	1.5	5.9	0.1	0.1	0.5	2
	Barrenland	0	0	0.1	0	0	0.1	0.1	0	0	0	0	0
	Grassland	2.3	3.5	22.4	12.5	2.5	6.3	7.5	5.7	2.1	1.2	0.4	1.9
	Montane_broadleaved_deciduous_forest	0.1	0	0.2	0	0	0	0.4	0	0.2	0.1	1.4	0.4
	Montane_broadleaved_evergreen_forest	1.2	0.8	1.7	17.8	20.6	2.2	26.4	3.1	0.1	0.5	0.4	0.1
	Montane_needleleaved_forest	0.6	1.4	1.6	0.1	0.4	0	2.3	0	0.4	0.3	0.1	0.5
	Scrubland	2	3.9	2.5	1.8	1.9	1.5	0.8	1.2	0.3	0.1	0.1	0.1
	Sub_alpine_forest	0.1	0	0.6	0	0	0	0.6	0	0.1	0	1.1	0.1
	Subtropical_broadleaf_forest	0.7	0.1	0.7	0.2	1	0.5	0	0	0	0	0.1	0
	Subtropical_needleleaved_forest	10.3	5.6	5.7	22.5	2.6	1.2	1.7	1.9	0.1	0.4	0.6	3.2
	Tropical_broadleaved_forest	0.4	0.1	0.4	0.1	0.3	0	0	0	0.1	0.5	0	0
	Waterbodies	0.6	0.1	0.1	0	0.1	0.6	0	0	0	0	0	0.1
	Sub total	**20.6**	**16.3**	**38**	**55.4**	**31.7**	**19.1**	**41.3**	**17.8**	**3.5**	**3.2**	**4.7**	**8.4**

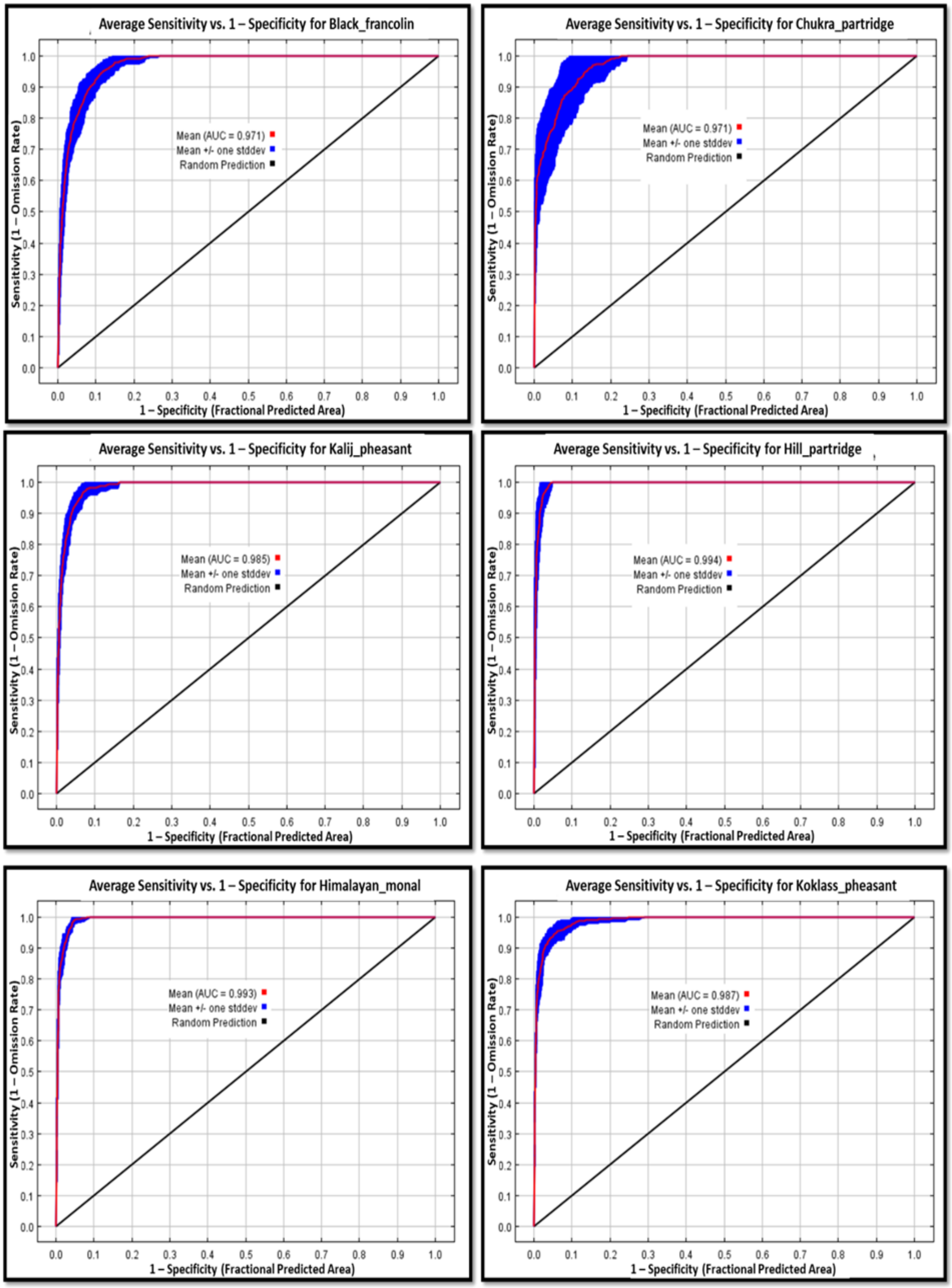

Figure 5.2: ROC curve and AUC value for MaxEnt model.

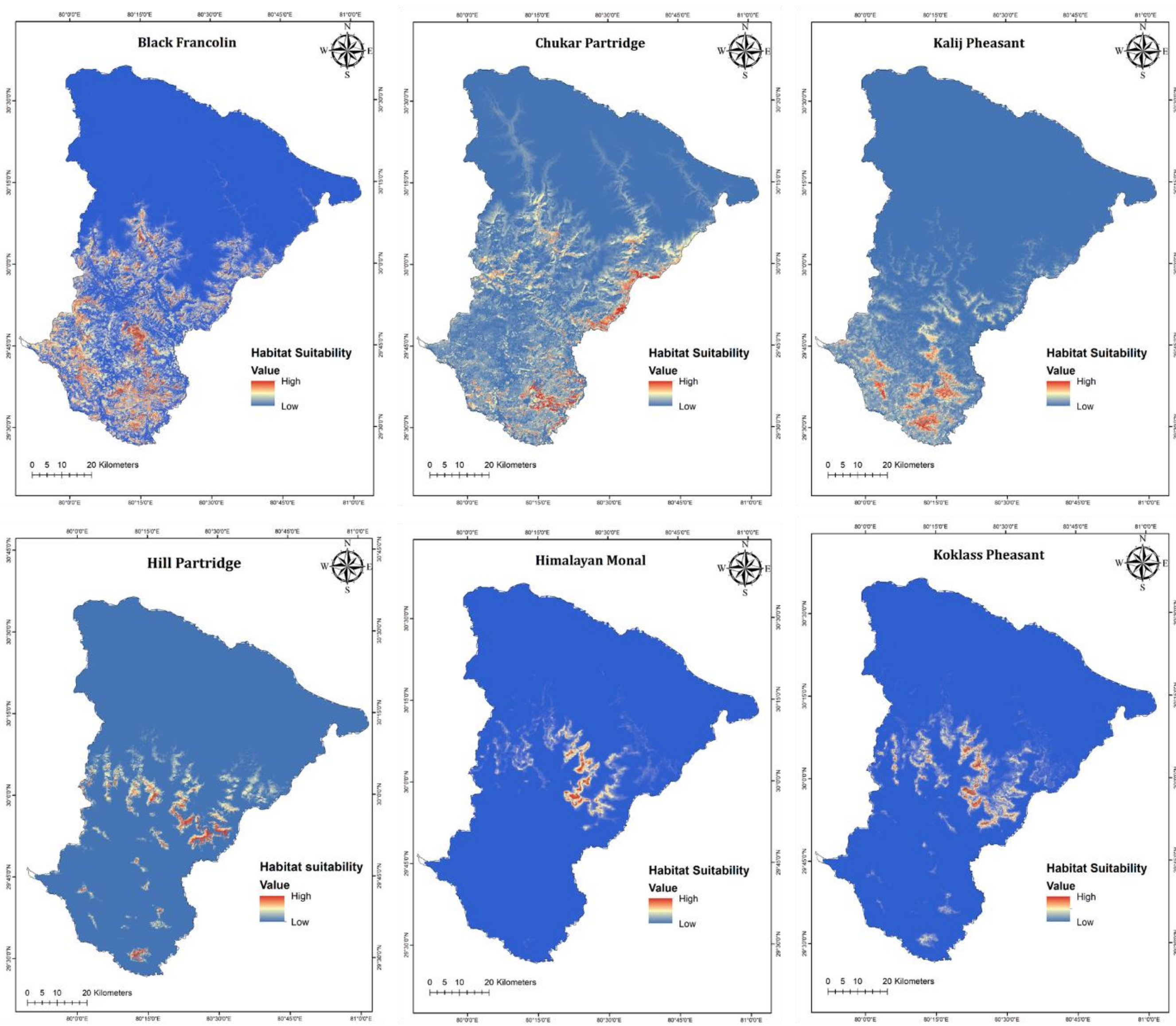

Figure 5.3: Habitat suitability of pheasant species in the landscape

Vulture habitat suitability

Habitat suitability maps were prepared based on the nesting, roosting, and perching sites of vultures. Based on the criteria, The model was run for *Gyps himalayensis*, as it was the only species recorded among vultures that was recorded from 15 different locations as nesting, roosting, perching or carcass feeding. The model performed well with an AUC value of 0.981, representing strong predictive results of the probability distribution of the species. Within the environmental parameters, climatic variables contributed the most with 49.7% in the habitat suitability followed by land use variables (21.8%), topographic variables (16.3%), and least Human pressure with 12.3%. Among the climatic variables, BIO 12 (24.1%) variable contributed the most, followed by BIO 19 (9.7%) and BIO 7 (7.4%) whether the HFI contributed the most with 10.3% within the Human pressure variables. Elevation had the highest contribution with 8.7% among the topographic variables, and in landuse variables Subtropical_needleleaved_forest contributed the maximum with 9.2% followed by Scrubland (4%) and Agriculture (2.5%).

Table 5.3: Environmental parameters contribution to the model of the Himalayan vulture in the landscape.

	Variable	**Percent contribution**	**Permutation importance**
Climatic variables	BIO2	7	2.5
	BIO7	7.4	11.1
	BIO 12	24.1	1.9
	BIO14	1.5	1.7
	BIO 19	9.7	39.5
	Subtotal	**49.7**	**56.7**
Human pressure	HFI	10.3	1.8
	Habitation	2	1.3
	Subtotal	**12.3**	**3.1**
Topographic variables	Elevation	8.6	16.8
	Slope	7.7	5.1
	Subtotal	**16.3**	**21.9**
Landuse variables	Agriculture	2.5	3.6
	Barrenland	0.2	0
	Grassland	1.8	8.9

	Montane_needleleaved_forest	0.8	0.1
	Montane_broadleaved_evergreen_forest	1.9	2.8
	Montane_broadleaved_deciduous_forest	0	0
	Scrubland	4	2.1
	Sub_alpine_forest	0.2	0
	Subtropical_broadleaf_forest	0.6	0.1
	Subtropical_needleleaved_forest	9.2	0.5
	Tropical_broadleaf_forest	0.4	0.1
	Waterbodies	0.2	0
	Subtotal	**21.8**	**18.2**

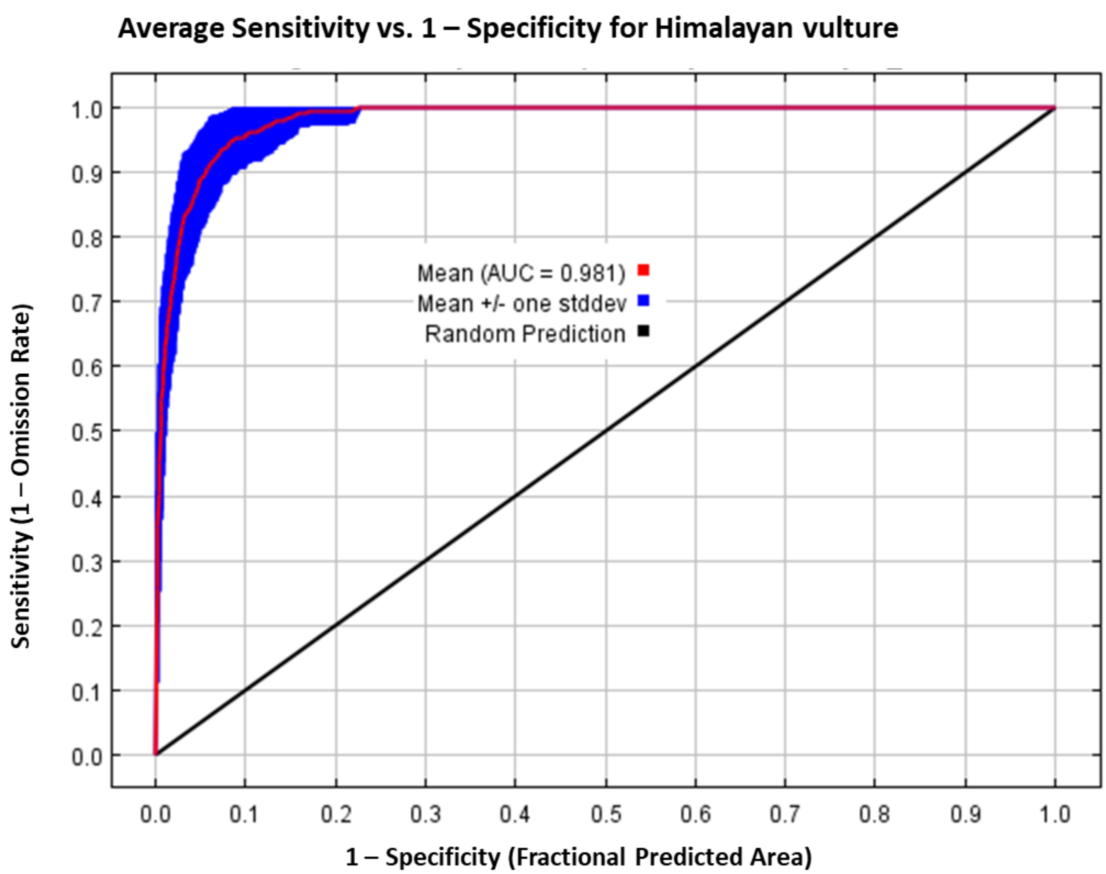

Figure 5.4: ROC curve and AUC value for MaxEnt model

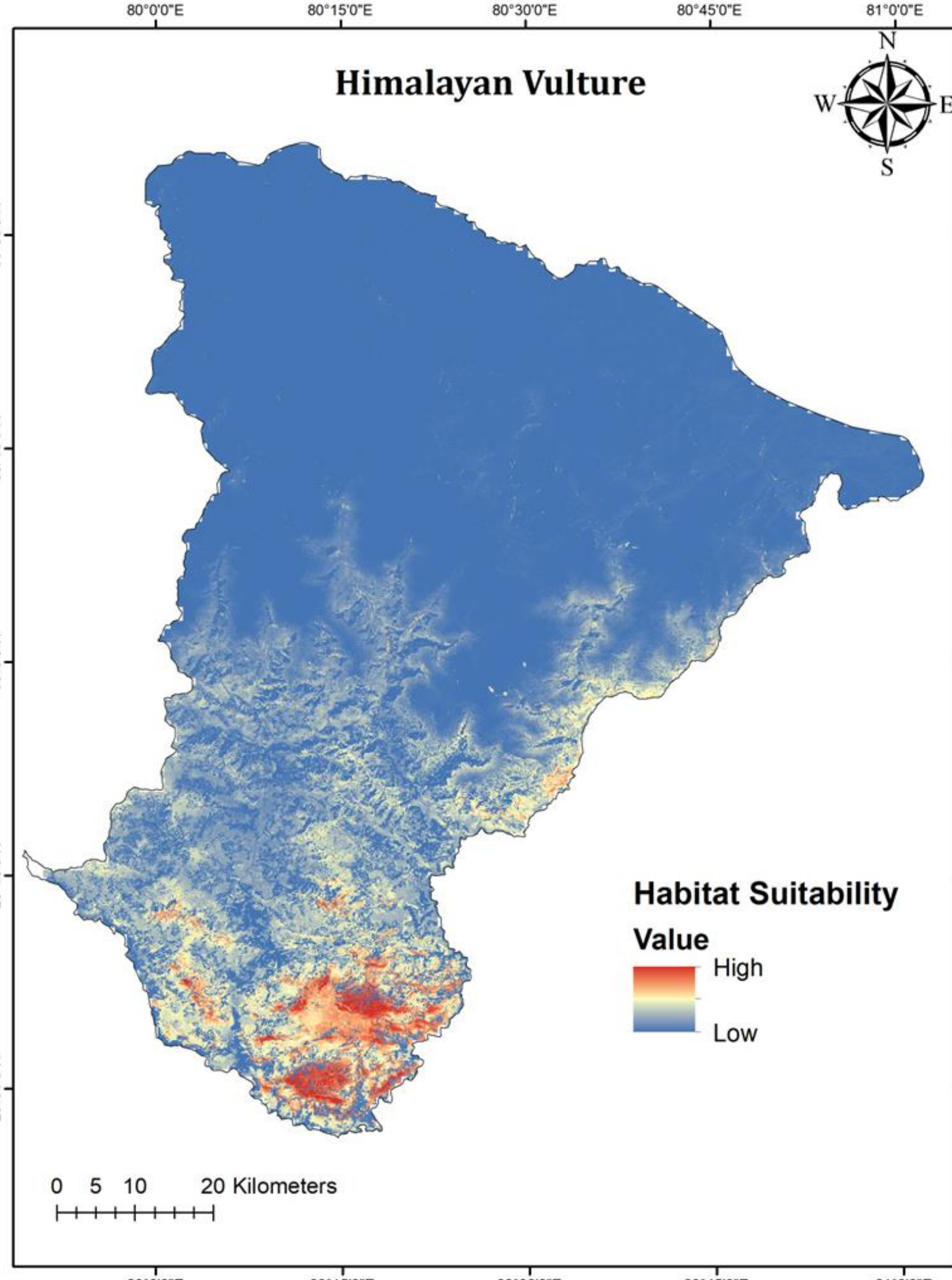

Figure 5.5: Prediction of Habitat suitability of Himalayan vulture in the landscape

Discussion

Most of the pheasant species are endemic to the Himalayas (Jayapal 2008). Increasing anthropogenic activities, climate change, habitat loss, hunting, and poaching are significant reasons for their declining population (Ramesh et al. 1999; Kaul 2004; Chettri et al. 2021). The species distribution models are critical tools for conserving and managing these rare and poorly documented species (Ashoori et al. 2018). In the Himalaya, it is difficult to cover all the areas due to its topography as the terrains is mostly rugged, harsh climatic conditions, and hence by using Maxent models, we can predict the probable distribution of the species based on its habitat suitability.

Results indicate that the climatic variables are playing an essential role in the distribution of these pheasants in the landscape. Variables such as temperature and precipitation are important factors in their distribution in the study area. Similarly, Chettri et al. (2021) found that the climatic variables are the most contributed variables for the pheasant distribution in the Himalayan landscape. For the *Francolinus francolinus* topographic variables are the second most contributed model after the climatic variables, as the species mostly recorded from the lower elevation and low steep slopes areas in the landscape. The *Alectoris chukar*, was mainly recorded from the grasslands or scrublands of the study area. Similarly, our model for the species predicted the land use variables contributed the most after the climatic variables for the species, among the landuse variables such as grassland and scrublands variables are the highest contributing variables. For species *Lophura leucomelanos* and *Arborophila torqueola*, landuse variables were contributed the second most after climatic variables. Montane_broadleaved_forest was the most contributing variable as both species mainly recorded in Oak and Temperate mixed forests and nearby in the landscape. *Lophophorus impejanus* and *Purasia macrolopha* were recorded primarily in the high elevation areas. Similarly, the models for these species predicted the topographic variables contribute the second most after climatic variables for their distribution in the landscape.

Results for the model of *Gyps himalayensis* based on its nesting, roosting, and perching locations indicating the climatic variable are contributing the most in the distribution of this species in the landscape followed by land use and topographic variables. Most of the roosting sites were recorded near the garbage dumping sites close to the human-dominated areas and on tall conifer forests on the hilltop. Similarly, our results demonstrates that the Human Footprint Index (HFI) (topographic variables) and Subtropical_needleleaved_forest (landuse variables) are the most contributing variables in their distribution in the landscape after the climatic variables.

Himalaya is one the critically effected region due the global warming. Rapidly melting glaciers and shifting of habitats towards the higher elevation areas is the reason for concern for environmentalists. We have predicted the probable distribution of pheasants and *Gyps himalayensis* in the Kailash Sacred Landscape-India. We recommended that further long term studiesstudies and regular monitoring of these threatened groups of bird species in the landscape for habitat loss and climate change effects for better management and conservation.

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Photo plate 3. Some Pheasant species in Pithoragarh district. **A.** Black Francolin, **B.** Chukar Partridge, **C.** Kalij Pheasant, **D.** Hill Partridges, **E.** Himalayan Monal, **F.** Koklass Pheasant

Photo plate 4. Some vulture species recorded from Pithoragarh District. **A.** Himalayan Vulture, **B.** Bearded Vulture, **C.** Egyptian Vulture, **D.** Red-headed Vulture, **E.** Carcass feeding Cinereous Vulture and Himalayan Vulture committee, **F.** Roosting site of Himalayan Vulture.

Checklist of bird species recorded in the whole landscape

Altogether 216 species belonging to 54 families were recorded from the landscape, including some opportunistic sightings. Among them, six species were classified as Threatened (**Critically endangered**: Red-headed Vulture, White-rumped Vulture, Slender-billed Vulture; **Endangered**: Egyptian Vulture, Steppe Eagle; **Vulnerable**: Cheer Pheasant), and five as Near Threatened (River Lapwing, Bearded Vulture, Himalayan Vulture, Cinereous Vulture, Pallid Harrier) in the IUCN Red List (IUCN 2020). Seven species are strictly protected under the Schedule-I of Indian Wildlife (Protection) Act, 1972. A total of 52 species was recorded as the forest specialist (based on Grimmett et al. 2011 and field observations), whether near 44% are Himalayan endemic (Birds of the World 2021). A total of 37 species that are common in both categories as forest specialists and Himalayan endemic have high conservation values. These species have a high threat to extinction due to land use patterns and climate change changes. A total of 36 species were first time recrded from the Pithoragarh district which were not available in previuos literature Table (A). However, the Pithoragarh district bird checklist of e-Bird (2021) have reported the most of these species except the seven species viz. Common Teal, Variable Wheatear, White-breasted Waterhen, Large Cuckooshrike, Large Woodshrike, Crow-billed Drongo and Golden-fronted Leafbird that are the exclusively new records in the Pithoragarh district.

Table A. List of bird species recorded from the Pithoragarh district.

Common name	***Scientific name***	**HE**	**IUCN**	**IWPA**	**LS**
Family Anatidae					
Common Teal[F]	*Anas crecca* (Linnaeus, 1758)		LC	IV	WV
Family Phasianidae					
Black Francolin	*Francolinus francolinus* (Linnaeus, 1766)		LC		R
Cheer Pheasant*	*Catreus wallichii* (Hardwicke, 1827)	H1	VU	I	R
Chukar Partridge	*Alectoris chukar* (J.E. Gray, 1830)		LC	IV	R
Common Hill Partridge*	*Arborophila torqueola* (Valenciennes, 1825)	H4	LC	IV	R
Kalij Pheasent*	*Lophura leucomelanos* (Latham, 1790)	H4	LC	I	R
Himalayan Monal	*Lophophorus impejanus* (Latham, 1790)	H3	LC	I	R
Koklass Pheasant*	*Pucrasia macrolopha* (Lesson, 1829)	H4	LC	IV	R
Family Columbidae					
Rock Pigeon	*Columba livia* J.F. Gmelin, 1789		LC		R
Hill Pigeon	*Columba rupestris* Pallas, 1811		LC	IV	R
Snow Pigeon	*Columba leuconota* Vigors, 1831	H4	LC	IV	R
Common Wood Pigeon*	*Columba palumbus* Linnaeus, 1758		LC	IV	WV/ LM
Oriental Turtle Dove	*Streptopelia orientalis* (Latham, 1790)		LC	IV	R
Eurasian Collared Dove	*Streptopelia decaocto* (Frivaldszky, 1838)		LC	IV	R
Spotted Dove	*Streptopelia chinensis* (Scopoli, 1786)		LC	IV	R
Wedge-tailed Green Pigeon*	*Treron sphenurus* (Vigors, 1832)	H4	LC	IV	R
Asian Emerald Dove*	*Chalcophaps indica* (Linnaeus, 1758)		LC	IV	R
Family Apodidae					
Himalayan Swiftlet	*Aerodramus brevirostris* (Horsfield, 1840)	H4	LC		R
Alpine Swift	*Takymarptis melba* (Linnaeus, 1758)		LC		SV/ LM

Indian House Swift	*Apus affinis* (Hodgson, 1837)		LC		R
White-throated Needletail	Hirundapus caudacutus (Latham, 1801)		LC		SV
Family Cuculidae					
Asian Koel[F]	*Eudynamys scolopaceus* (Linnaeus, 1758)		LC	IV	SV/ LM
Large Hawk Cuckoo*[F]	*Hierococcyx sparverioides* (Vigors, 1832)		LC	IV	R
Common Cuckoo	*Cuculus canorus* (Linnaeus, 1758)		LC	IV	SV
Family Rallidae					
White-breasted Waterhen[F]	*Amaurornis phoenicurus* (Pennant, 1769)		LC		R
Family Phalacrocoracidae					
Little Cormorant[F]	*Microcarbo niger* (Vieillot, 1817)		LC	IV	R
Great Cormorant[F]	*Phalacrocorax carbo* (Linnaeus, 1758)		LC	IV	PV/ LM
Indian Cormorant[F]	*Phalacrocorax fuscicollis* Stephens, 1826		LC	IV	WV/ LM
Family Charadriidae					
River Lapwing[F]	*Vanellus duvaucelii* (Lesson, 1826)		NT		R
Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)		LC		R
Family Scolopacidae					
Common Sandpiper[F]	*Actitis hypoleucos* (Linnaeus, 1758)		LC	IV	WV/ LM
Family Accipitridae					
Bearded Vulture	*Gypaetus barbatus* (Linnaeus, 1758)		NT	I	R
Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)		EN	IV	SV/ LM
Red-headed Vulture	*Sarcogyps calvus* (Scopoli, 1786)		CR	IV	R
Himalayan Vulture	*Gyps himalayensis* Hume, 1869		NT	IV	R
White-rumped Vulture[F]	*Gyps bengalensis* (J.F. Gmelin, 1788)		CR	I	R
Slender-billed Vulture[F]	*Gyps tenuirostris* G.R. Gray, 1844	H4	CR	I	R

Griffon Vulture	*Gyps fulvus* (Hablizl, 1783)		LC	IV	WV
Cinereous Vulture[F]	*Aegypius monachus* (Linnaeus, 1766)		NT	IV	WV
Crested Serpent Eagle*	*Spilornis cheela* (Latham, 1790)		LC		R
Mountain Hawk Eagle*	*Nisaetus nipalensis* Hodgson, 1836		LC		R
Black Eagle*	*Ictinaetus malaiensis* (Temminck, 1822)		LC		R
Steppe Eagle[F]	*Aquila nepalensis* Hodgson, 1833		EN		WV
Golden Eagle	*Aquila chrysaetos* (Linnaeus, 1758)		LC		R
Bonelli's Eagle	*Aquila fasciata* (Vieillot, 1822)		LC		R
Pallid Harrier	*Circus macrorus* (S.G. Gmelin, 1770)		NT		PV
Shikra[F]	*Accipiter badius* (J.F. Gmelin, 1788)		LC		R
Eurasian sparrowhawk	*Accipiter nisus* (Linnaeus, 1758)		LC		R
Black Kite	*Milvus migrans* (Temminck, 1822)		LC		R
Himalayan Buzzard[F]	*Buteo refectus* Portenko, 1935	H3	LC		WV/ LM
Upland Buzzard[F]	*Buteo hemilasius* Temminck & Schlegel, 1844		LC		WV/ LM
Family Falconidae					
Common Kestrel	*Falco tinnunculus* Linnaeus, 1758		LC	IV	R
Peregrine Falcon	*Falco peregrinus* Tunstall, 1771		LC	I	R
Family Strigidae					
Brown Hawk Owl	*Ninox scutulata* (Temminck, 1832)		LC	IV	R
Collered Owlet*	*Glaucidium brodiei* (E. Burton, 1836)	H4	LC	IV	R
Asian Barred Owlet	*Glaucidium cuculoides* (Vigors, 1831)	H4	LC	IV	R
Jungle Owlet[F]	*Glaucidium radiatum* (Tickell, 1833)		LC	IV	R
Mountain Scops Owl*	*Otus spilocephalus* (Blyth, 1846)	H4	LC	IV	R

Brown Wood Owl*	*Strix leptogrammica* Temminck, 1832		LC	IV	R
Family Picidae					
Speckled Piculet*	*Picumnus innominatus* E. Burton, 1836		LC	IV	R
Rufous Woodpecker	*Micropternus brachyurus* (Vieillot, 1818)		LC	IV	R
Greater Yellow-naped Woodpecker*	Chrysophlegma flavinucha (Gould, 1834)		LC	IV	R
Lesser Yellow-naped Woodpecker	Picus chlorolophus Vieillot, 1818		LC	IV	R
Grey-headed Woodpecker	*Picus canus* J.F. Gmelin, 1788		LC	IV	R
Scaly-bellied Woodpecker*	*Picus sqamatus* Vigors, 1831	H2	LC	IV	R
Grey-capped Pygmy Woodpecker*	*Picoides canicapillus* (J.F. Gmelin, 1788)		LC	IV	R
Brown-fronted Pied Woodpecker	*Dendrocopos auriceps* (Vigors, 1831)	H2	LC	IV	R
Yellow-fronted Pied woodpecker**F**	*Leiopicus mahrattensis* (Latham, 1801)		LC	IV	R
Himalayan Pied Woodpecker*	*Dendrocopos himalayensis* (Jardine & Selby, 1831)	H2	LC	IV	R
Family Megalaimidae					
Great barbet	*Psilopogon virens* (Boddaert, 1783)	H4	LC	IV	R
Blue throated barbet	*Psilopogon asiaticus* (Latham, 1790)	H4	LC	IV	R
Family Upupidae					
Common Hoopoe	*Upupa epops* Linnaeus, 1758		LC		SV/ LM
Family Meropidae					
Green Bee-eater	*Merops orientalis* Latham, 1801		LC		R
Chestnut-headed Bee-eater	*Merops leschenaulti* Vieillot, 1817		LC		SV/ LM
Family Coraciidae					
Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)		LC	IV	R
Family Alcedinidae					
Common Kingfisher**F**	*Alcedo atthis* (Linnaeus, 1758)		LC	IV	R

Crested Kingfisher	*Megaceryle lugubris* (Temminck, 1834)	H4	LC		R
White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)		LC	IV	R
Family Psittaculidae					
Slaty-headed Parakeet	*Psittacula hamlayana* (Lesson, 1832)	H3	LC	IV	R
Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)		LC	IV	R
Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)		LC	IV	R
Family Campephagidae					
Long-tailed Minivet*	*Pericrocotus ethologus* Bangs & J.C. Phillips, 1914	H4	LC	IV	R
Scarlet Minivet	*Pericrocotus flammeus* (J.R. Forster, 1781)		LC	IV	R
Large Cuckooshrike*	*Coracina macei* (Horsfield, 1821)	H4	LC		R
Family Oriolidae					
Maroon Oriole	*Oriolus traillii* (Vigors, 1832)	H4	LC	IV	R
Eurasian Golden Oriole	*Oriolus oriolus* (Linnaeus, 1758)		LC	IV	SV/ LM
Family Vandidae					
Large Woodshrike*[F]	*Tephrodornis vigratus* (Temminck, 1824)		LC		R
Family Dicruridae					
Ashy Drongo	*Dicrurus leucophaeus* Vieillot, 1817		LC	IV	SV/ LM
Crow-billed Drongo*[F]	*Dicrurus annectans* (Hodgson, 1836)	H4	LC	IV	SV
Hair-crested Drongo	*Dicrurus hottentottus* (Linnaeus, 1766)		LC	IV	R
Family Rhipiduridae					
White-throated Fantail*	*Rhipidura albicollis* (Vieillot, 1818)		LC		R
Family Stenostiridae					
Yellow-bellied Fairy-fantail*	*Chelidorhynx hypoxantha* (Blyth, 1843)	H4	LC		WV/ LM
Grey-headed Canary-flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)		LC	IV	SV/ LM

Family Laniidae					
Long-tailed Shrike	*Lanius schach* Linnaeus, 1758		LC		SV/ LM
Grey-backed Shrike	*lanius tephronotus* (Vigors, 1831)	H4	LC		SV/ LM
Family Corvidae					
Rufous Treepie[F]	*Dendrocitta vagabunda* (Latham, 1790)		LC	IV	R
Grey Treepie	*Dendrocitta formosa* Swinhoe, 1863		LC	IV	R
Yellow billed blue magpie*	*Urocissa flavirostris* (Blyth, 1846)	H4	LC	IV	R
Red billed blue magpie	*Urocissa erythrorhyncha* (Boddaert, 1783)	H4	LC	IV	R
Eurasian Jay*	*Garrulus glandarius* (Linnaeus, 1758)		LC	IV	R
Black-headed Jay	*Garrulus lanceolatus* Vigors, 1830	H2	LC	IV	R
House Crow	*Corvus splendens* Vieillot, 1817		LC	V	R
Large-billed Crow	*Corvus macrorhynchos* Wagler, 1827		LC		R
Family Monarchidae					
Indian Paradise-flycatcher	*Terpsiphone paradisi* (Linnaeus, 1758)		LC		SV/ LM
Family Dicaeidae					
Fire-breasted Flowerpecker	*Dicaeum ignipectus* (Blyth, 1843)	H4	LC	IV	R
Family Nectariniidae					
Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)		LC	IV	SV/ LM
Fire-tailed Sunbird*	*Aethopyga ignicauda* (Hodgson, 1836)	H4	LC	IV	R
Black-throated Sunbird*	*Aethopyga saturata* (Hodgson, 1836)	H4	LC	IV	R
Crimson Sunbird	*Aethopyga siparaja* (Raffles, 1822)		LC	IV	SV/ LM
Green-tailed Sunbird	*Aethopyga nipalensis* (Hodgson, 1836)	H4	LC	IV	R
Family Irenidae					
Golden-fronted Leafbird[F]	*Chloropsis aurifrons* (Temminck, 1829)		LC		R
Orange-bellied Leafbird	*Chloropsis hardwickii* Jardine & Selby, 1830	H4	LC		R

Family Prunellidae					
Rufous-breasted Accentor	*Prunella strophiata* (Blyth, 1843)	H4	LC		R
Black-throated Accentor[F]	*Prunella atrogularis* (von Brandt, 1843)		LC		WV
Family Estrildidae					
White-rumped Munia[F]	*Lonchura striata* (Linnaeus, 1766)		LC	IV	R
Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)		LC	IV	R
Family Passeridae					
House Sparrow	*Passer domesticus* (Linnaeus, 1758)		LC		R
Russet Sparrow	*Passer cinnamomeus* (Gould, 1836)	H4	LC		R
Family Motacillidae					
Olive-backed Pipit	*Anthus hodgsoni* Richmond, 1907		LC		WV/ LM
Rosy Pipit	*Anthus roseatus* Blyth, 1847	H4	LC	IV	WV/ LM
Paddyfield Pipit	*Anthus rufulus* Vieillot, 1818		LC	IV	R
Grey wagtail	*Motacilla cinerea* Tunstall, 1771		LC		SV/ LM
White-browed Wagtail[F]	*Motacilla maderaspatensis* J.F. Gmelin, 1789		LC		R
White Wagtail	*Motacilla alba* Linnaeus, 1758		LC		PV/ LM
Family Fringillidae					
Common rosefinch	*Carpodacus erythrinus* (Pallas, 1770)		LC	IV	WV/ LM
Pink-browed Rosefinch*[F]	*Carpodacus rodochroa* (Vigors, 1831)	H3	LC		WV/ LM
Dark-breasted Rosefinch	*Procarduelis nipalensis* (Hodgson, 1836)	H4	LC	IV	WV/ LM
Yellow-breasted Greenfinch	*Chloris spinoides* (Vigors, 1831)	H3	LC	IV	WV/ LM
Scarlet Finch*	*Carpodacus sipahi (Hodgson, 1836)*	H3	LC	IV	R
Family Emberizidae					
Crested Bunting	*Melophus lathami* (J.E. Gray, 1831)		LC	IV	WV/ LM
Rock Bunting	*Emberiza cia* (Linnaeus, 1766)		LC	IV	R

Family Paridae					
Green-backed Tit	*Parus monticolus* Vigors, 1831	H4	LC	IV	R
Cinereous Tit	*Parus cinereus* Vieillot, 1818		LC	IV	R
Black-lored Tit	*Parus xanthogenys* (Vigors, 1831)		LC	IV	R
Grey-crested Tit*	Lophophanes dichrous (Blyth, 1845)	H4	LC	IV	R
Coal Tit*	Periparus ater (Linnaeus, 1758)	H4	LC	IV	R
Family Cisticolidae					
Striated Prinia	*Prinia crinigera* Hodgson, 1836	H4	LC		R
Grey-breasted Prinia	*Prinia hodgsonii* Blyth, 1844		LC		R
Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)		LC		R
Family Hirundinidae					
Red-rumped Swallow	*Cecropis daurica* (Laxmann, 1769)		LC		R
Barn Swallow	*Hirundo rustica* Linnaeus, 1758		LC		SV/ LM
Family Pycnonotidae					
Ashy Bulbul	*Hemixos flavala* Blyth, 1845	H4	LC	IV	R
Mountain Bulbul*[F]	*Ixos mcclellandii* (Horsfield, 1840)	H4	LC	IV	R
Black Bulbul	*Hypsipetes leucocephalus* (J.F. Gmelin, 1789)	H4	LC	IV	R
Himalayan Bulbul	*Pycnonotus leucogenys* (J.E. Gray, 1835)	H3	LC	IV	R
Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)		LC	IV	R
Family Phylloscopidae					
Hume's Leaf Warbler	*Phylloscopus humei* (W.E. Brooks, 1878)		LC		SV/ LM
Lemon-rumped Warbler*	*Phylloscopus chloronotus* J.E. & G.R. Gray, 1847	H3	LC		WV/ LM
Buff-barred Warbler*	*Phylloscopus pulcher* (Blyth, 1845)	H4	LC		WV/ LM
Tickell's Leaf Warbler	*Phylloscopus affinis* (Tickell, 1833)		LC		WV/ LM

Greenish Leaf Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)		LC		PV/ LM
Blyth's leaf Warbler	*Phylloscopus reguloides* (Blyth, 1842)		LC		SV/ LM
Grey-hooded Leaf Warbler	*Phylloscopus xanthoschistos* (J.E. & G.R. Gray, 1847)	H3	LC		R
Ashy-throated Warbler*	*Phylloscopus maculipennis* (Blyth, 1867)	H4	LC		R
Family Scotocercidae					
Grey sided bushwarbler	*Cettia brunnifrons* (Hodgson, 1845)	H4	LC		WV/ LM
Black faced warbler*	*Abroscopus supercillaris* (J.E. & G.R. Gray, 1847)	H4	LC		R
Aberrant bushwarbler	*Horornis flavolivaceus* (Blyth, 1845)	H4	LC		R
Family Aegithalidae					
Black-throated Tit*	*Aegithalos concinnus* (Gould, 1855)	H4	LC	IV	R
Family Paradoxornithidae					
White-browed Fulvetta*	*Fulvetta vinipectus* (Hodgson, 1837)	H4	LC		
Family Zosteropidae					
Stripe-throated Yuhina*	*Yuhina gularis* Hodgson, 1836	H4	LC		R
Whiskered Yuhina	*Yuhina flavicollis* Hodgson, 1836	H4	LC		R
Oriental White-eye	*Zosterops palpebrosus* (Temminck, 1824)		LC	IV	R
Family Timaliidae					
Streak-breasted Scimitar Babbler*	*Pomatorhinus ruficollis* Hodgson, 1836	H4	LC	IV	R
Rusty-cheeked Scimitar Babbler	*Pomatorhinus erythrogenys* (Vigors, 1831)	H3	LC	IV	R
Black-chinned Babbler	*Stachyridopsis pyrrhops* (Blyth, 1844)	H2	LC	IV	R
Family Leiothrichidae					
Striated Laughingthrush*	*Grammatoptila striata* (Vigors, 1831)	H3	LC	IV	R

Jungle babbler	*Trudoides striata* (Dumont, 1823)		LC	IV	R
Rufous-chinned Laughingthrush*[F]	*Garrulax rufogularis* (Gould, 1835)	H3	LC	IV	R
White-throated Laughingthrush*	*Garrulax albogulris* (Gould, 1836)	H4	LC	IV	R
White-crested Laughingthrush	*Garrulax leucolophus* (Hardwicke, 1816)	H4	LC	IV	R
Streaked Laughingthrush	*Trochalopteron lineatum* (Vigors, 1831)	H3	LC	IV	R
Rufous Sibia	*Heterophasia capistrata* (Vigors, 1831)	H3	LC		R
Blue-winged Minla	*Minla cyanouroptera* Hodgson, 1837	H4	LC		R
Chestnut-tailed Minla	*Chrysominla strigula* (Hodgson, 1837)	H4	LC		R
Family Certhiidae					
Bar-tailed Treecreeper	*Certhia himalayana* Vigors, 1832		LC		R
Hodgson's Treecreeper	Certhia hodgsoni W.E. Brooks, 1871	H4	LC		R
Family Sittidae					
Chestnut-bellied Nuthatch	*Sitta cinnmoventris* Lesson, 1830	H4	LC		R
Velvet-fronted Nuthatch	*Sitta frontalis* Swainson, 1820		LC		R
White-tailed Nuthatch*	Sitta himalayensis Jardine & Selby, 1835	H4	LC		R
Wallcreeper	*Tichodroma muraria* (Linnaeus, 1766)		LC		WV/ LM
Family Sturnidae					
Chestnut-tailed Starling[F]	*Sturnia malabaricus* (J.F. Gmelin, 1789)	H3	LC	IV	SV/ LM
Common Myna	*Acridotheres tristis* (Linnaeus, 1766)		LC	IV	R
Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)		LC	IV	R
Spot-winged Starling[F]	*Saroglossa spiloptera* (Vigors, 1831)	H3	LC		SV/ LM
Family Cinclidae					
Brown dipper	*Cinclus pallasii* Temminck, 1820		LC		R
Family Muscicapidae					
Oriental Magpie Robin	*Copsychus saularis* (Linnaeus, 1758)		LC		R

Golden Bush-robin*	*Tarsiger chrysaeus* Hodgson, 1845	H4	LC		R
Himalayan Bush-robin	*Tarsiger rufilatus* (Hodgson, 1845)	H4	LC		R
Dark-sided Flycatcher	*Muscicapa sibirica* J.F. Gmelin, 1789		LC	IV	SV/ LM
Blue-throated Flycatcher*[F]	*Cyornis rubeculoides* (Vigors, 1831)		LC	IV	SV/ LM
Rufous-bellied Niltava*	*Niltava sundara* Hodgson, 1837	H4	LC		R
Small Niltava	*Niltava macgrigoriea* (E. Burton, 1836)	H4	LC		R
Verditer Flycatcher	*Eumiyas thalassinus* (Swainson, 1838)		LC	IV	SV/ LM
Little Forktail	*Enicurus scouleri* Vigors, 1832	H4	LC		R
Slaty-backed Forktail	*Enicurus schistaceus* (Hodgson, 1836)	H4	LC		R
Spotted Forktail	*Enicurus maculatus* Vigors, 1831	H4	LC		R
Blue Whistling-thrush	*Myphonus caeruleus* (Scopoli, 1786)	H4	LC		R
Rusty-tailed Flycatcher[F]	*Ficedula ruficauda* Swainson, 1838		LC	IV	SV/ LM
Rufous-gorgeted Flycatcher*	*Ficedula strophiata* (Hodgson, 1837)	H4	LC	IV	R
Ultramarine Flycatcher	*Ficedula superciliaris* (Jerdon, 1840)		LC	IV	SV/ LM
Slaty-blue Flycatcher	*Ficedula tricolor* (Hodgson, 1845)	H4	LC	IV	SV/ LM
Blue-fronted Redstart	*Phoenicurus frontalis* (Vigors, 1831)	H4	LC		WV/ LM
Blue-capped Redstart	*Phoenicurus caeruleocephala* (Vigors, 1831)		LC		R
White-capped Water Redstart	*Phoenicurus leucocephalus* (Vigors, 1831)	H4	LC		R
Plumbeous Water Redstart	*Phoenicurus fuliginosus* (Vigors, 1831)	H4	LC		R
Black Redstart	*Phoenicurus ochruros* (S.G. Gmelin, 1774)		LC		WV/ LM
Blue-capped Rock-thrush*	*Monticola cinclorhynchus* (Vigors, 1831)		LC		SV/ LM

Chestnut-bellied Rock-thrush	*Monticola rufiventris* (Jardine & Selby, 1833)	H4	LC		R
Siberian Stonechat[F]	*Saxicola maurus* (Pallas, 1773)		LC		SV/ LM
Pied Bushchat	*Saxicola caprata* (Linnaeus, 1766)		LC		SV/ LM
Grey Bushchat	*Saxicola ferreus* J.E. & G.R. Gray, 1847	H4	LC		R
Variable Wheatear[F]	*Oenanthe picata* (Blyth, 1847)		LC		WV
Family Turdidae					
Long-billed Thrush*[F]	*Zoothera monticola* Vigors, 1832	H4	LC	IV	SV/ LM
Grey-winged Blackbird	*Turdus boulboul* (Latham, 1790)	H4	LC		R
White-collared Blackbird	Turdus albocinctus (Royle, 1840)	H3	LC		R
Black-throated Thrush	*Turdus atrogularis* Jarocki, 1819		LC	IV	WV

Abbreviations: * = Forest specialist; [F] = First record from the district; HE = Himalayan endemic; H1 = endemic to western Himalaya; H2 = endemic to western and central Himalaya; H3 = endemic to Himalaya of south Asia (Afganistan, Pakistan east to Myanmar); H4 = endemic to Himalaya and occurring from Himalaya of South Asia to Indo-China and/or south-eastern China and/or South-east Asia; IUCN = International Union for Conservation of Nature; IWPA = Indian Wildlife (Protection) Act, 1972, Schedule; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered; MS = migration status; R = resident; WV = winter visitors; LM = local migrant; SV = summer visitor; PV = passage visitor.

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Photo plate 5. Some first time recorded bird species from Pithoragarh district (as per available literature). **A.** Common Teal **B.** White-breasted Waterhen, **C.** Large Woodshrike, **D.** Common Sandpiper, **E.** White-rumped Vulture, **F.** Cinereous Vulture.

Photo plate 6. Some first time recorded bird species from Pithoragarh district (as per available literature). **A.** Steppe Eagle, **B.** Shikra, **C.** Himalayan Buzzard, **D.** Upland Buzzard, **E.** Common Kingfisher, **F.** White-rumped Munia.

Photo plate 7. Some first time recorded bird species from Pithoragarh district (as per available literature). **A.** White-browed Wagtail, **B.** Mountain Bulbul, **C.** Chestnut-tailed Starling, **D.** Spot-winged Starling, **E.** Blue-throated Flycatcher, **F.** Siberian Stonechat

List of Publications

1. Arya, S. K., Rawat, G. S., & Gopi, G. V. (2021, June). Distribution and Abundance of Raptors in Kailash Sacred Landscape, Western Himalaya, India. In Proceedings of the Zoological Society (pp. 1-12). Springer India. https://doi.org/10.1007/s12595-021-00377-3

2. Arya, S. K., & Gopi, G. V. (2021). An annotated bird checklist of community-managed lands in Kailash Sacred Landscape-India, Kumaon Himalaya. Check List, 17, 365. https://doi.org/10.15560/17.2.365

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RESEARCH ARTICLE

Distribution and Abundance of Raptors in Kailash Sacred Landscape, Western Himalaya, India

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Abstract Raptors are high in trophic level and play an essential role in the functioning of an ecosystem, yet not much information about their distribution and abundance is available from the Indian Himalayan region. The present study was conducted in the Indian part of the Kailash sacred landscape, Western Himalayas, between February 2015–December 2017, documenting the distribution and abundance status of raptors in the landscape. Altogether, 320 km of trails were walked, and 1162 km of the vehicular survey were conducted through different habitats. A total of 506 individuals of 25 species belonging to three families were recorded. Nine Globally Threatened/Near Threatened species and eight migrant species were observed from the landscape. Himalayan vulture *Gyps himalayensis* was the most abundant and widely distributed raptor, followed by Black-eared kite *Milvus migrans lineatus* and Steppe eagle *Aquila nipalensis*. The population of raptors is declining worldwide, and in the Kailash landscape, this lesser-known group should be monitored regularly and protected by ensuring the availability of suitable and undisturbed habitat, control on forest fire, and uncontaminated food.

Keywords Raptors · Globally threatened · Pithoragarh district · Western Himalaya · Threats

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Introduction

Many bird species prey on other animals, both vertebrate and invertebrate, but the term 'birds of prey' or 'raptors' has long been applied mainly to kites, vultures, hawks, eagles, and their allies (Ferguson-Lees and Christie 2001). Raptors are known for their hunting skills and take their prey live by their armory or the tools of their trade such as sharp cutting edge with a hooked bill, strong and powerful legs for grasping its prey, acute eyesight, swiftness, and power of flight (Naoroji 2006). They serve as indicators of biodiversity and environmental health, apart from which they are considered cultural symbols (Donazar et al. 2016) and are well-known for providing ecosystem services (O'Bryan et al. 2018). Raptors are further classified as predatory and scavenging depending on their functioning in the ecosystem. The predatory group of raptors plays a vital role in structuring and functioning of ecosystems (Sergio et al. 2008), whereas the scavenging group not only guarantees the flow of nutrients in the food chain but also prevents the spread of diseases (Sekercioglu, 2006). Raptors are high in trophic levels and generally slow in life-history, which makes them more sensitive to anthropogenic pressures (Owens and Bennett 2000; Sergio et al. 2008) and extinction than other bird species (Bennett and Owens 1997; Buechley et al. 2019). There are many threats that lead to their population decline such as, habitat alteration or destruction (Thiollay 1998; Bildstein 2006; Goriup and Tucker 2007), intentional killing (Brochet et al. 2019), intentional/unintentional poisoning (Oaks et al. 2004; Ogada et al. 2016), electrocution (Lehman 2001; Mojica et al. 2018), and climate change (Iknayan and Beissinger 2018; McClure et al. 2018). In the Indian subcontinent during the 1990s, there was a catastrophic decline of the vulture population due to the introduction of diclofenac as

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a veterinary drug for cattle (Oaks et al. 2004; Green et al. 2004; Prakash et al. 2005, 2012, 2019). Further study also speculated the possibility of Diclofenac and associated NSAID's (Non-steroidal Anti-inflammatory Drugs) toxicity on other members of the Accipitridae family (Sharma et al. 2014) which had abetted to their higher decline rate.

Distribution of raptors is regulated by various factors such as landscape heterogeneity, intraspecific competition, predation, food source, and availability of nesting sites in the area (Anderson 2001; Pearlstine et al. 2006; Anoop et al. 2018). Today there are more than 550 raptor species found worldwide (Billerman et al. 2020), of which nearly 20% have been reported from India (Praveen et al. 2016). Amongst them, 74 species are diurnal (Order; Accipitriformes, Falconiformes), and 36 are nocturnal species (Order; Strigiformes) (Praveen et al. 2021). Earlier studies have reported that the Indian sub-continent harbors a rich raptor fauna (Baker 1928; Ali and Ripley 1983; Chettri et al. 2006; Kurup, 2011; Naoroji and Sangha 2013; Paliwal and Bhandarkar 2014; Anoop et al. 2018), but data on abundance and distribution is limited due to difficulties in identification, low population densities and their forest-dwelling nature (Thiollay 1994; VanBalen 1998; Naoroji 2006).

The Himalaya harbors nearly 10,000 plants and 1000 bird species (Pandit and Kumar 2013; Rana and Rawat 2017) and provides important habitats to migratory and resident raptor species. Over the past few decades, degradation and fragmentation have taken place on a large scale in the natural habitats of the Himalayas, leaving only 25% of the original habitat intact (Rana and Samant 2010). The Kailash Sacred Landscape (KSL) is a transboundary landscape covering tracts of India, Nepal, and Tibet (China) and is extremely rich in biodiversity, socio-cultural values, and transboundary historical linkages. KSL in India (KSL-India) is part of Western Himalaya and broadly covers three major physiographic zones viz., Trans Himalayan zone in the north, the Greater Himalayan zone towards the south, and the southernmost Lesser Himalayan zone in the districts of Pithoragarh ($\sim$ 96%) and Bageshwar ($\sim$ 4%) of Uttarakhand state.

The bulk of raptor related studies that have been conducted close to this landscape are in Nepal, on scavenger population, threats (Baral et al. 2005; Virani et al. 2008; Acharya et al. 2009, 2010; Harris 2013; Bhusal and Paudel 2016; Subedi et al.2018), and migration of predatory raptors (DeRoder 1989; Gurung et al. 2004; DeCandido et al. 2013; Subedi et al. 2017). In the Tibetan plateau (northernmost of KSL) where key studies (Katzner et al. 2004; Lu et al. 2009; Dixon et al. 2013; MaMing and Xu 2015; MaMing et al. 2016; Zhang et al. 2019) are on ecology, conservation, threats and abundance status.

On the Indian side of the Western Himalaya, raptor specific studies have been prevalent in the Shivalik foothills, and lesser Himalaya of Uttarakhand and Himachal Pradesh states on the migration (DenBesten 2004), assemblage, habitats, and abundance status (Naoroji 1999; Thakur and Narang 2012; Kaushik 2014; Thakur 2015; Singh et al. 2018) leaving KSL-India understudied. Few studies related to bird assemblages in the Pithoragarh district are done by Brooks (1869), Tak and Sati (1994), Tak (1995), Sultana and Khan (2000), and Arya and Gopi (2021). The present study is an effort to understand the distribution and abundance of raptors in the KSL-India.

Materials and Method

Study Area

An area of 31,175 km^2 spread over Kailash and Manasarovar (Tibet autonomous region of China) in three countries viz. China, Nepal, and India are known as Kailash Sacred Landscape (KSL). Nearly 7120 km^2 falls in India, of which 96% is in Pithoragarh and 4% in Bageshwar district in the state of Uttarakhand. Its located far East in the state, surrounded by the state's districts towards the west and south and shares International boundaries with China and Nepal towards the north and east, respectively. It comprises diverse forests like Alpine pastures, Subalpine forests, Montane grasslands, broadleaved and needle-leaved forests, Subtropical broadleaved and needle-leaved forests, Tropical broadleaved forests, and agroecosystems across an elevation gradient from 350 to 7000 m above sea level (asl.).

Raptor Surveys

The study was carried out between February 2015–December 2017 through trail walks and road transects (Bibby et al. 1998, 2000). A total of 23 villages, mainly from lower reaches of the landscape, were surveyed by trail walks during spring (February–April 2015, 2016), winter (October–December 2015), and summer seasons (May–June 2016). We walked 57 trails of 320 km (each between 3 and 8 km), passing through different forests (Subtropical mixed, *Shorea robusta, Pinus roxburghii, Quercus leucotricophora*, Temperate mixed), agriculture and grassland habitats of various localities between the elevation of 600–2500 m asl. 1162 km was the total area surveyed by way of road transects with two-wheeler at the constant speed of 25–30 km/hr during summer and winter (May 2017, October–December 2017) (Fig. 1). A temporal replicate was performed during the three seasons in the landscape. Observations were made to avoid double

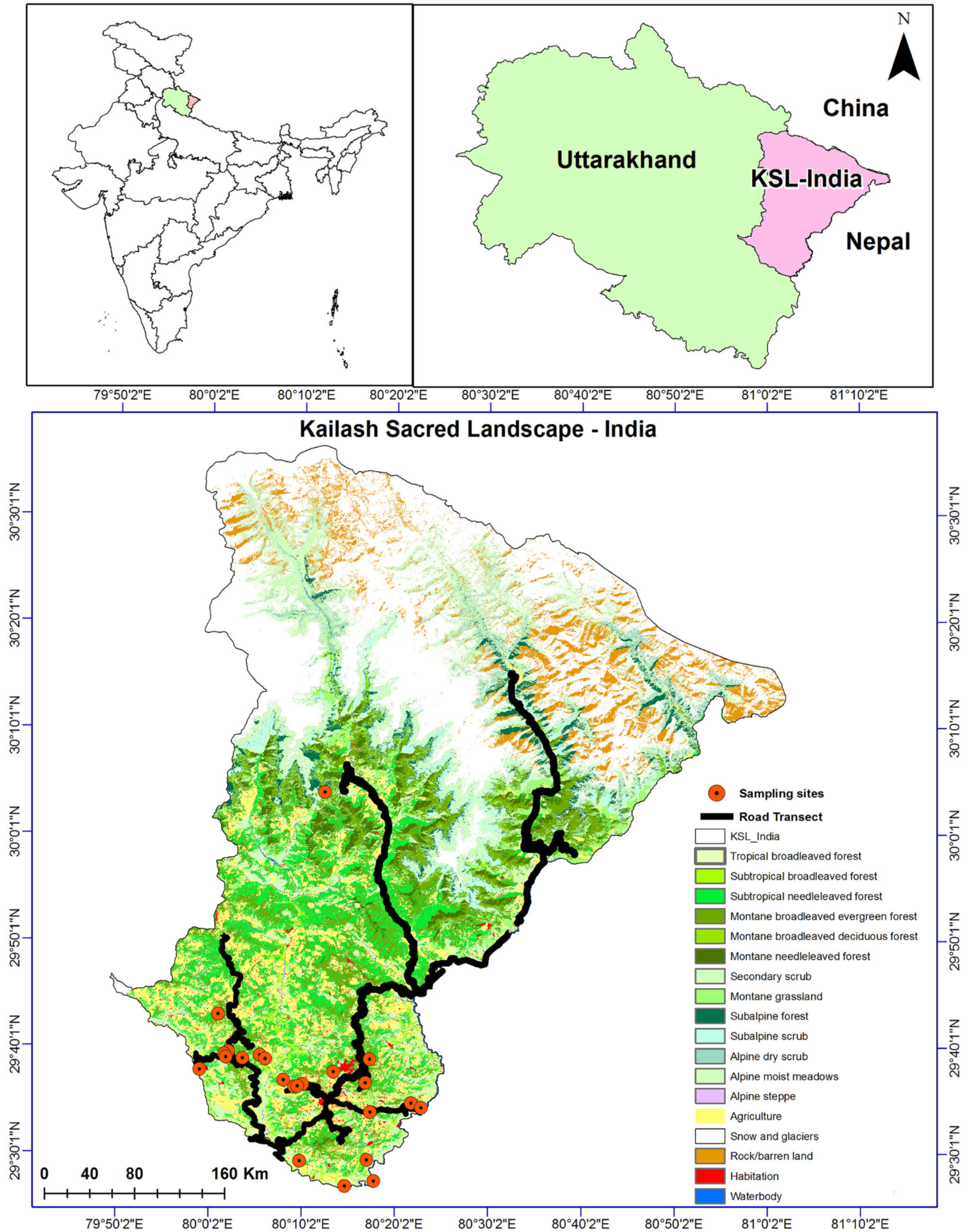

Fig. 1 Sampling sites and Road transects in the Kailash Sacred Landscape-India (Pithoragarh district). (Map Source: GIS Lab Wildlife Institute of India, Dehradun)

counting by recording the number of species, their individuals, flock size, flight direction, and time interval between successive sightings (Virani et al. 2008). Migration status was assigned to the species based on the field observations and unconfirmed by handbook of birds of the Indian subcontinent (Grimmett et al. 2011). The survey was conducted between 08.00 to 17.00 h with the help of two observers (field assistants) and, habitat type, GPS coordinates, and locality were recorded at the point of sighting of the raptor species. Bushnell's (8 × 42) binocular was used for observations and identified by using the handbook (Ferguson-Lees and Christie 2001; Naoroji 2006; Grimmett et al. 2011). Some nocturnal raptors such as owls encountered during the survey were also added to the list.

Results

Altogether 506 individuals of 25 raptor species belong to Accipitridae, Falconidae, and Strigidae families were recorded from 47 localities in the study area. Among them, five species (Red-headed vulture *Sacrogyps calvus*, Slender-billed vulture *Gyps tenuirostris*, White-rumped vulture *Gyps bengalensis*, Egyptian vulture *Neophron percnopterus* and Steppe eagle *Aquila nipalensis*) are Globally Threatened and four are Near Threatened (Bearded vulture *Gypaetus barbatus*, Cinereous vulture *Aegypius monachus*, Himalayan vulture *Gyps himalayensis* and Pallid harrier *Circus macrourus*) as per the IUCN red list (2020). A total of 17 residents and eight migratory species were recorded and amongst them, five are winter migrants, two summer and one is passage migrant. We also recorded 15 nesting and six roosting sites of raptors in the study area (Table 3).

Scavenging Raptors

Altogether 310 individuals of eight species of scavenging raptors were recorded from 30 localities and among them, 212 individuals were observed in flight (Soaring) and the rest 98 during roosting, carcass feeding or perched on trees. Three species viz. Red-headed vulture (*Sacrogyps calvus*), Slender-billed vulture (*Gyps tenuirostris*) and White-rumped vulture (*Gyps bengalensis*) belong to Critically endangered category, one species viz. Egyptian vulture (*Neophron percnopterus*) is Endangered and three species viz. Bearded vulture (*Gypaetus barbatus*), Cinereous vulture (*Aegypius monachus*) and Himalayan vulture are in the Near-threatened category. Most of the scavenging raptors prefer soaring over the open areas, for roosting they preferred pine forest or barren rocks on a hill top and for nesting rocky cliffs. Species such as Himalayan vulture, Griffon vulture and Bearded vulture have the highest encounter rate (Table 1). In terms of migration, we recorded three migratory species; Cinereous vulture and Griffon vulture (*Gyps fulvus*) are winter visitors and Egyptian vulture is a summer visitor. The remaining five species are residents in KSL-India. Here we have described the detailed information of the Globally Threatened scavenging raptors recorded from the study area.

White-rumped vulture is critically endangered and mostly seen during trail walks. A total of 12 individuals were recorded from five localities between the elevation of 1200–2000 m asl. of the landscape. They were mostly seen in flight along with Himalayan vultures.

Egyptian vulture is Endangered and a summer visitor in the landscape. A total of 12 individuals from five localities were recorded. Amongst them nine individuals were observed soaring over Agricultural field and river valleys, two were feeding on carcass of goat and one on the upper canopy of a tall tree (*Toona ciliate*) near agriculture and riverine habitats respectively. This species was mostly seen in pairs, between March to June.

Red-headed vulture also known as King vulture is a Critically endangered species and 7 individuals were recorded from six localities. Mostly observed solitary and seen as perched on the upper canopy of tall needle-leaved trees (*Cedrus deodara* and *Pinus roxburghii*). Sometimes recorded as soaring over cultivated land and open forests along with Himalayan vultures.

Slender-billed vulture is a critically endangered species and was recorded once. The individual was seen soaring over grassland in Kali river catchment area along with kettle of Himalayan vultures at an elevation of 1534 m (Fig. 2).

Predatory Raptors

A total of 196 individuals of 16 species (Fig. 3) from 36 localities were recorded among them, one is Globally Threatened species viz. Steppe eagle (Endangered) and one is Near-threatened species viz. Pallid harrier (*Circus macrourus*). Black-eared kite (*Milvus migrans lineatus*) was the most abundant species among predatory raptors, followed by Steppe eagle (*Aquila nipalensis*) and Common kestrel (*Falco tinnunculus*) (Table 2). A total of seven nesting locations were recorded during the survey, among them two each of Himalayan buzzard (*Buteo buteo burmanicus*), Common kestrel (*Falco tinnunculus*), Asian barred owlet (*Glaucidium cuculoides*) and one of Brown-wood owl (*Strix leptogrammica*). Roosting sites of Steppe eagle and Black-eared kite were also recorded. The Threatened and Near threatened species are described below.

Steppe eagle is Endangered and a winter visitor in the landscape. It was the second most abundant species with 54

Table 1 Habitat and threat observations of Scavenging raptors along with encounter rates

Species	Encounter rate (ind/km)		Habitat observations	Threat observations
	Trail walks	Vehicle survey		
Himalayan vulture	0.36	0.081	Soaring over the meadows, grasslands, river valleys and agricultural lands. Nests on steep rocky cliffs in temperate and subalpine climatic zones. Mostly roosts on hilltops (barren rocks or tall needle leaved trees)	Human disturbance near nesting and roosting sites. Toxin consumption
Griffon vulture	0.037	0.024	Soaring over grasslands, open forests and agricultural lands. Roosting along with Himalayan vulture	Human disturbance near roosting sites, Toxin consumption
Bearded vulture	0.056	0.005	Mostly seen while soaring, single or in pairs over grasslands, open forests, river valleys and agricultural lands. Nests on steep rocky cliffs near subtropical pine and temperate oak forests	Habitat loss, Forest fire, Human disturbance near nesting sites
White-rumped vulture	0.012	0.006	Soaring over open forests and agricultural lands. Two individuals were seen roosting along with Himalayan vultures on a tall dry tree in a Subtropical mixed forest	Human disturbance near the roosting site, Toxin consumption
Egyptian vulture	0.012	0.007	Soaring over Agricultural lands and river valleys	Human disturbance near roosting site, Toxin consumption
Red-headed vulture	0.016	0.002	Perching on top of tall needle-leaved trees and soaring over cultivated land and open forests	Habitat loss, Toxin consumption
Cinereous vulture	0.006	0.0026	Soaring over open forests, grassland and agricultural land	Toxin consumption
Slender-billed vulture	0.003	0	Soaring over grassland	Toxin consumption

individuals from nine localities (Fig. 3). It was recorded between 800 to 2600 m of elevation, soaring over a wide variety of habitats. Two roosting sites of the species with Black-eared kites near the dumping areas of Pithoragarh and Dharchula were also recorded.

Pallid harrier is a Near-threatened, and Passage migrant in the study area. It is a widespread winter visitor in the Indian sub-continent, and an individual was recorded at the junction of agricultural field and mixed forest, perched on the upper canopy of a *Toona ciliata* tree.

Discussion

Out of 710 species of birds in the Uttarakhand state, 78 are raptor species (Mohan and Sondhi 2017). Earlier bird assemblages' studies in the Pithoragarh districts have observed 24 raptor species (Brooks 1869; Tak and Sati 1994; Tak 1995; Sultana and Khan 2000). A total of 25 raptor species were recorded in the present study area, of which eight are scavenging, and 17 are predatory raptors. Of the nine species of vultures recorded in India (Ali and Ripley 1987; Naoroji 2006), eight species were recorded in the present study, superseding an earlier bird assemblage studies that have recorded only six species from the Pithoragarh district (Sultana and Khan, 2000). Most of the bird assemblages and raptor related studies have been conducted in the Shivalik foothills area of Indo-Gangetic plains of the state, which has high avifaunal richness, including raptor species (Naoroji 1999; Singh 2000; Mohan and Kumar 2010; Kidwai et al. 2013; Kaushik 2014; Joshi and Bhatt 2015). Present study has been conducted in the mountainous district of Uttarakhand and recorded near 32% of the state's raptor species.

Our observations pointed to the Himalayan vulture being the most abundant and widely distributed scavenging raptor in the study area, followed by the Griffon vulture, which was seen exclusively in the winter season. A study carried out by Kaushik (2014) also recorded Griffon vulture as the second most abundant species in the Rajaji National Park afterward of Himalayan vulture.

Among predatory raptors, Black-eared kite and Steppe eagle were the most abundant species, both were recorded mainly near dumping sites, but Steppe eagle was more widely distributed as compared to Black-eared kite. Similarly, Singh et al. (2018) also reported Steppe eagle and Black-eared kite as the most abundant raptors around Nainital lake of Uttarakhand.

Black eagle, Crested serpent eagle and Mountain hawk-eagle were exclusively recorded soaring over the forest habitat, whereas Brown-wood owl was observed in the dense forest. A plausible reason for this observation is that

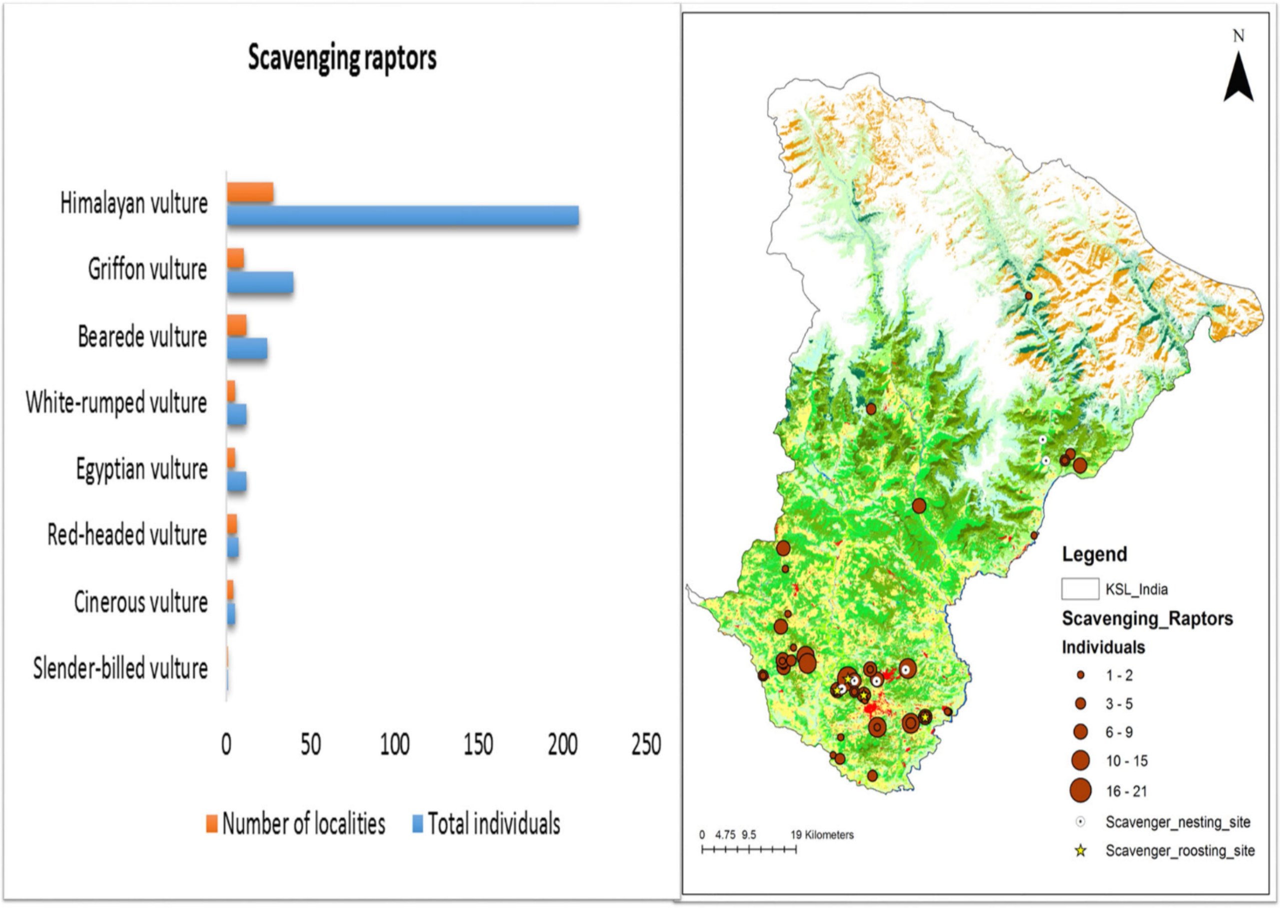

Fig. 2 Scavenging raptor distribution and abundance status in the KSL-India

these species prefer forest habitats and mostly depend on tree snakes, lizards, rodents and small birds from the forest canopy for diet (Ali and Ripley 1978). Our results indicate that the lower reaches of the landscape are rich in terms of raptor fauna which could be due to our sampling efforts being higher in the lower reaches. Another factor aiding this indication could be the density of human settlement and livestock being higher in the lower reaches of the landscape, which leads to the ready availability of dump-sites and livestock carcasses (biomass) in this region, attracting most of the scavenging raptors. The presence of matrixes of open areas (agricultural land, Fellow land and grasslands) and forest habitats provide effective visibility to scan for prey and suitable habitats for breeding and nesting, respectively to some predatory raptors such as Himalayan buzzard, Common kestrel and Shikra.

The presence of active nesting (15) and roosting (6) sites of raptors are indicative of the population persistence of the species in the landscape. The nesting sites need to be protected as they are critical areas for ensuring raptor occupancy and perseverance in the area (Jiménez-Franco et al. 2018). The areas are crucial for population maintenance since raptors are limited by the quality of habitats available for breeding which also influence individual fitness (Tapia and Zuberogoitia 2018).

Over the past few decades, there has been a rapid decline in raptor populations, especially in Asia and Africa (Buechley and Sekercioglu 2016), and in the Indian Himalayan region, information of this avifaunal group is very limited. For their conservation and better management, it is important to get the baseline information and potential threats. Here our results highlight the abundance and distribution status of raptors in the Indian part of Kailash Sacred landscape. The potential threats elucidated herewith for the raptors in the landscape are based on the field observations:

Habitat Loss

Habitat destruction and alteration via agricultural expansion and logging is the most prominent cause of declining population of raptors (Bildstein 2006; Goriup and Tucker 2007; McClure et al. 2018; Grande et al. 2018). It was observed during the survey that the lower reaches of the

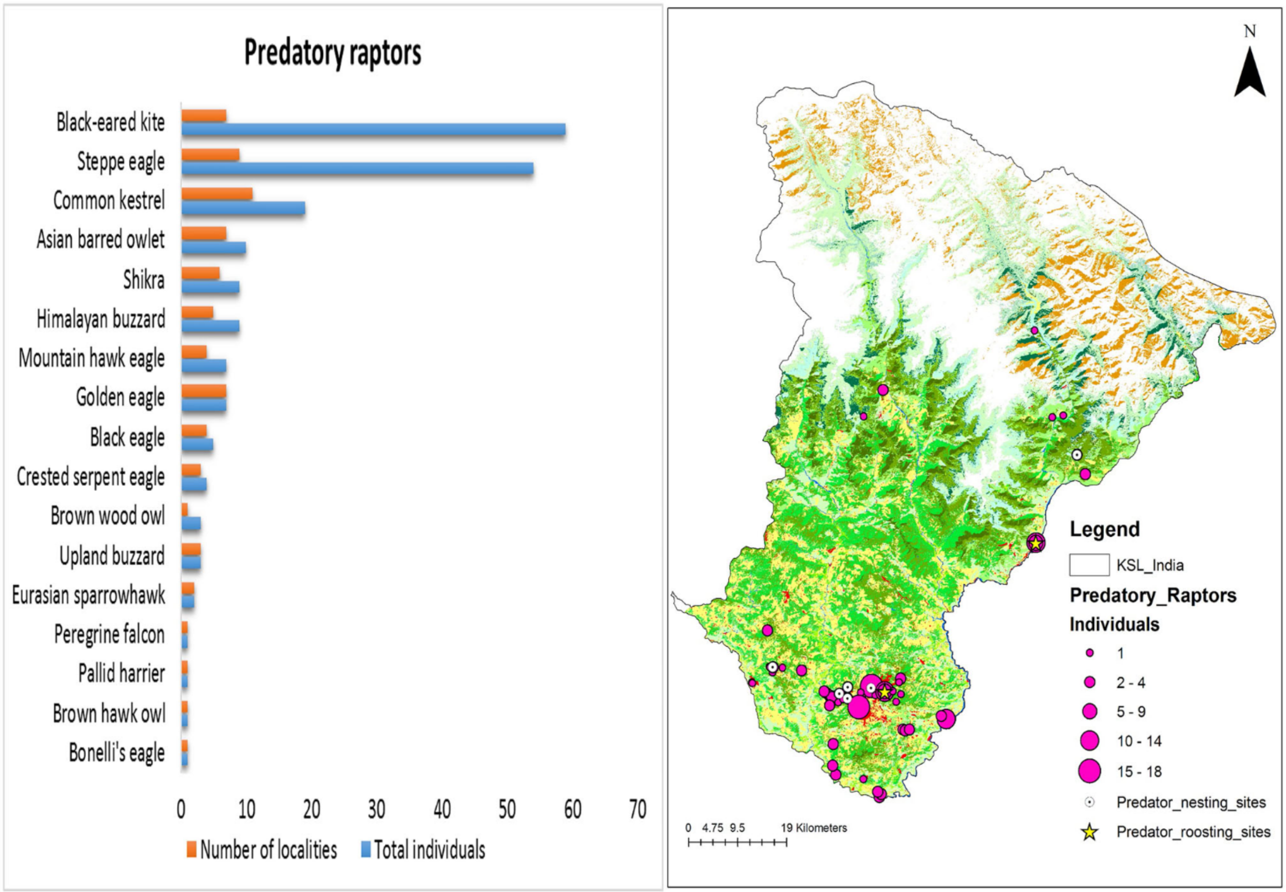

Fig. 3 Predatory raptor distribution and abundance in KSL-India

study area have sizeable agricultural activity and human habitations than the upper reaches. Anthropogenic activities like fuelwood and timber wood collections from the forest were higher in these reaches. Linear infrastructure projects, agricultural expansion, urbanization, etc., are degrading the forests and leading to habitat destruction which could potentially alter the forest-dwelling raptors in the study area.

Forest Fire

Forest fires are common in the study area during the dry seasons, and in recent times they are emerging as a serious threat to the habitats, prey base, ecology and environment of the raptors in the landscape. We observed during the study that freshly burnt forest patches were unattractive to birds that form a significant portion of prey base to predatory raptors.

Disturbance

Human population is higher in the lower reaches of KSL-India, and scavenging raptors may be consonant to the presence of human settlement and their cattle. Some nesting and roosting sites of raptors were recorded close to the habitation which increases the chances of human and cattle interferences. Apart from interferences, quarrying activities (slate stone and sand mining) were also recorded during the survey in Asurchula and Gurura villages nearby Pithoragarh city where Himalayan vultures and Common kestrel nesting sites were present. Free-ranging dogs and Rhesus macaques which were synchronous with settlements in the study area have potential to threaten raptor nesting and roosting sites.

Electrocution

High voltage power lines are passing through some places in the landscape and some predatory raptors use these lines or poles to perch, search or locate their prey, hence the risk of their electrocution. We also found two dead individuals of predatory raptors viz. Black-eared kite and Common kestrel due to electrocution within 0.25 km of these high tension power lines.

Table 2 Habitat and threat observations of predatory raptors along with encounter rates

Species	Encounter rate (ind/km)		Habitat observations	Threat observations
	Trail walks	Vehicle survey		
Black-eared Kite	0.05	0.037	Near garbage dumping sites, soaring over agricultural land and grasslands near human habitation	Electrocution, Toxin consumption
Steppe Eagle	0.05	0.033	Soaring over dumpsites, agricultural lands, grasslands, human habitations, river valleys and alpine meadows. Roosting near dumpsites	Toxin consumption, Human disturbance
Common Kestrel	0.044	0.004	Open forests and agricultural land	Electrocution, Human disturbance near nesting sites
Asian barred Owlet	0.03	0	Subtropical and temperate forests and nearby agricultural lands	Habitat loss, Forest fire
Shikra	0.025	0.001	Soaring over grassland and agricultural land. Perching in subtropical forests (Sal and mixed) or temperate oak forest	Habitat loss, Forest fire
Himalayan Buzzard	0.01	0.004	Open forests and agricultural land	Human disturbance near nesting sites
Black Eagle	0.006	0.003	Soaring over the dense forests	Habitat loss, Forest fire
Mountain-hawk Eagle	0.009	0.003	Soaring over temperate forests or grasslands	Habitat loss, Forest fire
Golden Eagle	0.006	0.004	Soaring over the edge of forest, open forests, meadows and agricultural land	Habitat loss
Crested-serpent Eagle	0.013	0	Sub-tropical forests (Chir pine, Sal, Mixed)	Habitat loss, Forest fire
Brown Wood Owl	0.009	0	Nesting in dense oak forest	Habitat loss
Upland Buzzard	0.006	0.001	Soaring over the open forest and grasslands	–
Eurasian Sparrowhawk	0	0.002	Soaring over open forest and agriculture	–
Peregrine Falcon	0.003	0	Open mixed forest	–
Pallid Harrier	0.003	0	Agriculture land	–
Brown-hawk Owl	0.003	0	Edge of sub-tropical mixed forest and agriculture land	Habitat loss, Forest fire
Bonelli's Eagle	0.003	0	Soaring over the edge of sub-tropical mixed forests and agricultural land	Habitat loss, Forest fire

Toxin Consumption

The population of Gyps vultures declined rapidly in the Indian subcontinent during 1990 because of poisoning due to the use of the non-steroidal anti-inflammatory veterinary drug "Diclofenac" (Oaks et al. 2004; Prakash et al. 2012). This drug is one of the most devastating environmental toxicants in recent times (Naidoo and Swan 2009; Harris 2013), after banning the drug in the country in 2006 the rate of population decline has slowed down (Prakash et al. 2012). However, few studies mention that the use of nimesulide drugs is also a potential threat to vulture mortality (Cuthbert et al. 2016), which is widely available in the Indian subcontinent. Cattle depredation by large carnivores is increasing in KSL-India (Hussain et al. 2018). Moreover, in a few instances targeted poisoning of carnivores have also occurred in the study area. Since raptors such as vultures feed communally, it's plausible that even a small number of drug-infested carcasses could have serious consequences for their health and decline.

In conclusion, KSL-India supports 25 raptor species, of which nine species are globally threatened or near-threatened. Presence of different nesting and roosting sites in the study area is indication of the critical importance of the landscape for providing suitable habitat for breeding and resting to these rapidly declining avifaunal group. There are various potential threats existing in the landscape and in-depth information is unavailable viz-a-viz raptors in the Indian Himalayan region, making it pertinent to monitor this group of avifaunal species. The present study will provide baseline information on the distribution, abundance and critical areas of raptors in the Kailash landscape

(Pithoragarh district, Uttarakhand), Western Himalaya. We recommend further detailed study to these lesser known avifaunal group in the Kailash landscape.

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Appendix

See Table 3.

Table 3 List of Raptor species recorded from the Kailash Sacred Landscape—India

Family/common name	Scientific name	TI	AFS	Mode of record		No. L	Nest Locations	Local Status	Altitude Range (meter)		IUCN Status
				Perch	Flight				LL	UL	
Accipitridae											
Black eagle	*Ictinaetus malayensis*	5	1	1	4	4	–	R	928	1678	LC
Black-eared kite	*Milvus migrans lineatus*	59	7.4	14	45	7	–	SV	1678	2076	LC
Bonelli's eagle	*Aquila fasciata*	1	1	–	1	1	–	R	1742		LC
Crested serpent eagle	*Spilornis cheela*	4	1.3	4	–	3	–	R	1018	1674	LC
Eurasian sparrowhawk	*Accipiter nisus*	2	1	1	1	2	–	R	1704	1872	LC
Golden eagle	*Aquila chrysaetos*	7	1	–	7	7	–	R	801	3363	LC
Mountain-hawk eagle	*Nisaetus nipalensis*	7	1.2	2	5	4	–	R	857	3248	LC
Pallid harrier	*Circus macrourus*	1	1	1	–	1	–	PV	1554		NT
Himalayan buzzard	*Buteo burmanicus*	9	1.5	6	3	5	2	WV	1631	3211	LC
Upland buzzard	*Buteo hemilasius*	3	1		3	3	–	WV	1762	2210	LC
Shikra	*Accipiter badius*	9	1.5	6	3	6	–	R	818	1672	LC
Steppe eagle	*Aquila nipalensis*	54	5.4	25	29	9	–	WV	857	2512	EN
Bearded vulture	*Gypaetus barbatus*	24	1.8	2	22	12	4	R	951	3363	NT
Cinereous vulture	*Aegypius monachus*	5	1.3	3	2	4	–	WV	1184	1712	NT
Egyptian vulture	*Neophron percnopterus*	12	2.4	3	9	5	–	SV	702	1678	EN
Griffon vulture	*Gyps fulvus*	40	4	15	25	10	–	WV	801	2421	LC
Himalayan vulture	*Gyps himalayensis*	210	6.8	72	138	28	4	R	939	3250	NT
Red-headed vulture	*Sacrogyps calvus*	7	1.2	3	4	6	–	R	801	1811	CR
Slender-billed vulture	*Gyps tenuirostris*	1	1	–	1	1	–	R	1534		CR
White-rumped vulture	*Gyps bengalensis*	12	2.4	1	11	5	–	R	1250	1922	CR
Falconidae											
Common kestrel	*Falco tinnunculus*	19	1.7	9	10	11	2	R	681	2134	LC
Paragreen faclon	*Falco peregrinus*	1	1	1	–	1	–	R	1919		LC
Strigidae											
Asian-barred owlet	*Glaucidium cuculoides*	10	1.4	10	–	7	2	R	1270	2229	LC
Brown hawk owl	*Ninox scutulata*	1	1	1	–	1	–	R	1227		LC
Brown wood owl	*Strix leptogrammica*	3	3	3	–	1	1	R	1492		LC

TI total individuals, *AFS* average flock size, *NoL* number of localities, *Local Status*: *R* resident, *SV* summer visitor, *PV* passage visitor, *WV* winter visitor, *Elevation range*: *LL* lower limit, *UL* upper limit. *IUCN status*: *LC* least concern, *NT* near threatened, *EN* endangered, *CR* critically endangered

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Check List the journal of biodiversity data

ANNOTATED LIST OF SPECIES

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PENSOFT

An annotated bird checklist of community-managed lands in Kailash Sacred Landscape-India, Kumaon Himalaya

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Abstract

In the Indian Himalayan region, community-managed lands such as community-managed forests and agriculture lands play an important role in conserving native biodiversity. Our avifaunal surveys done between 2013 and 2016 recorded 205 species belonging to 52 families. Two species were first records from Pithoragarh district. Six species are classified as Threatened and five as Near Threatened in the IUCN Red List. Six are Schedule-I species under the Indian Wildlife (Protection) Act, 1972. In total, 63 migratory (local/altitudinal and long-range) and 81 Himalayan endemic species were observed. Overall, our observations reveal a niche providing both transient and perennial havens for resident and migrant avifauna in our study site's landscape. Our findings suggest that despite human persistence in the landscape, diversity within avifaunal guilds is rich in the community-managed lands. We recommend further research to focus on understanding the factors governing the bird distribution and co-occurrence in the landscape.

Keywords

Agricultural land, avifaunal diversity, community managed forests, globally threatened, Himalayan endemic, Western Himalaya

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Introduction

The Himalaya is one of the most biodiverse places on Earth (Olson and Dinnerstein 1998; Myers et al. 2000; Brooks et al. 2006) and has nearly 10% of the world's bird species and around 330 Important Bird Areas (Elsen et al. 2016; Pandit et al. 2014). Kailash Sacred Landscape (KSL) is a part of the Himalayan region and spread over China, Nepal, and India. The Indian part of the landscape is mostly within the Pithoragarh district of Uttarakhand state.

The area of Uttarakhand is 71% forested (Forest Survey of India 2019), with 14% of the forest managed by the local communities in collaboration with the Forest Department (Negi et al. 2008). These community-managed forests are locally known as "Van panchayats" (Negi et al. 2012). These forests are important for the maintenance of biodiversity and meeting the biomass demand of local people (Negi et al. 2012), but they are lesser known for their avifauna. The state hosts more than 50% of India's bird species (Mohan and Sondhi 2015), but bird-related studies in KSL-India (Pithoragarh district) have been few (Brooks 1869; Walton 1900; Whymper 1902a, 1902b; Koelz 1954; Tak and Sati 1994, 2006; Tak 1995; Sultana and Khan 2000; Raza 2005; Elsen et al. 2017) in comparison to nearby districts of the Kumaon region (Irby 1861; Sharpe 1890; Osmaston 1916; Hudson 1930; Ganguli 1966; Sridharan 1974; Narang and Lamba 1979; Yahya 1990; Sultana 2007; Ahmed 2010; Bhatt and Joshi 2011; Palita et al. 2011; Joshi et al. 2012; Shahabuddin et al. 2017; Menon et al. 2019). We have selected different community-managed lands in the lower reaches of KSL-India to document the avifauna, as these areas are relatively unexplored in comparison to the upper reaches.

Study Area

Kailash Sacred Landscape (KSL) is spread over 31,175 km^2 across three countries, and around 7,120 km^2 is India (KSL-India; Fig. 1), with 98% area in Pithoragarh and 2% in Bageshwar district. KSL-India harbours

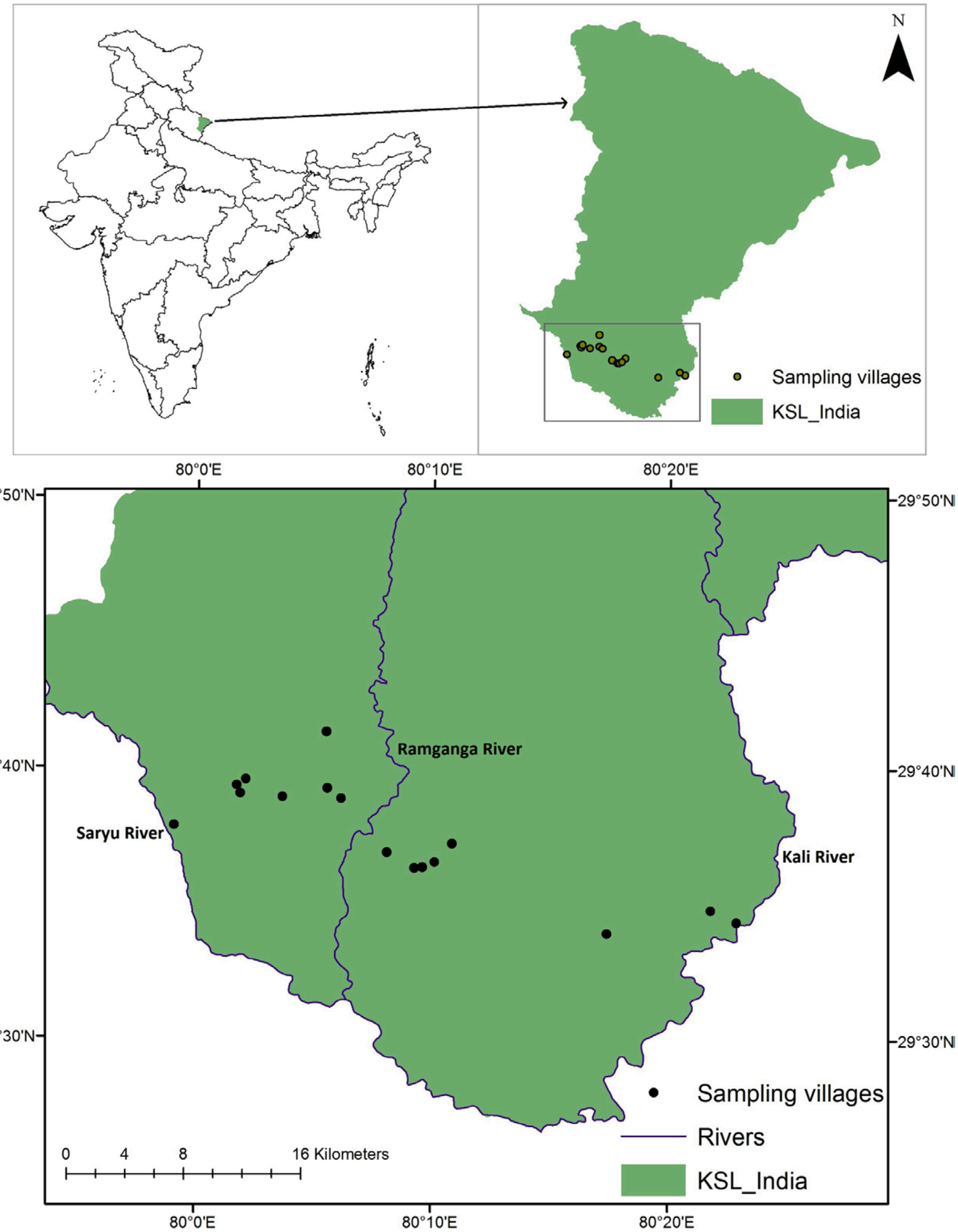

Figure 1. Sampling sites in KSL-India (Pithoragarh district).

diverse ecosystems, such as forests, grasslands, alpine meadows, wetlands, and agroecosystems along a wide altitudinal gradient of 350–7800 m a.s.l. Our study area is in Pithoragarh district, which is surrounded by Chamoli, Bageshwar, Almora, and Champawat districts to the west and south, and to the north and east, it shares international boundaries with China and Nepal, respectively. In the north-eastern side of Pithoragarh district there is a protected area; Askot Wildlife Sanctuary covers most of the upper reaches of the landscape. We surveyed in the community-managed lands of 17 villages and nearby areas in the lower reaches of the Pithoragarh district (500–2200 m a.s.l.); our study area covers nearly 300 km^2. The lower reaches of the landscape are mainly drained by the Saryu, Ramganga and Kali rivers. The vegetation in this area is mainly dominated by Subtropical mixed (*Emblica officinalis* Gaertn., *Toona cilata* M. Roem, *Macaranga pustulata* King ex. Hook. f., *Erythrina suberosa* Roxb.), Sal (*Shorea robusta* Gaertn.), Chir pine (*Pinus roxburghii* Sarg.), Banj Oak (*Quercus leucotrichophora* A. Camus and *Myrica esculenta* Buch.-Ham), and Temperate mixed forests (*Q. floribunda* Lindl. ex A. Camus, *Q. lanuginosa* Lam., *Rhododendron arboreum* J.E. Smith and *Cedrus deodara* (Lamb.) G. Don). Faunal diversity in the region is high, and mammal species such as *Panthera pardus fusca* (Meyer, 1794), *Ursus thibetanus laniger* (Pocock 1932), *Vulpus vulpus* (Linnaeus, 1758), *Muntiacus muntjak* (Zimmermann, 1780), and *Rusa unicolor* (Kerr, 1792) are commonly found. Among the avifauna, *Lophura leucomelanos* (Latham, 1790), *Arborophila torqueola* (Valenciennes, 1825), *Urocissa erythrorhyncha* (Boddaert, 1783), *Psilopogon virens* (Boddaert, 1783), and *Gyps himalayensis* Hume, 1869 are common in the landscape.

Methods

We conducted our survey between October 2013 and June 2016 in morning (07h00–11h00) and evening sessions (15h30–18h30) when birds are known to be more active (Trnka et al. 2006). Fixed-width point counts of 25 m radius (Bibby et al. 2000) and MacKinnon species richness methods (MacKinnon and Phillipps 1993) were used. A total of 597 point counts were conducted, of which 181 were done during winter, 272 during spring, and 145 in summer (119 in 2013, 225 in 2014, 136 in 2015, and 145 in 2016). Total 46 species richness lists were prepared, of which 15 were in winter, 18 in spring, and 13 in summer (6 in 2013, 17 in 2014, 10 in 2015, and 13 in 2016) (Table 1).

We maintained a distance of 150–200 m between each point to avoid double counting. All species seen or heard within 15 minutes were recorded (Menon et al. 2019). For MacKinnon species richness, we prepared a list of 20 distinct species by walking on existing trails in the community-managed forests and cultivated lands and once 20 species was reached, another list was prepared (Ahmed et al. 2019). Birds were observed by the aid of 8 × 42 Bushnell binoculars and identified using Grimmett et al. (2011). Some opportunistic sightings were also added to the list (Srinivasan et al. 2010; Shahabuddin et al. 2017).

Migration status to the species was assigned based on the field observations and Grimmett et al. (2011). Species frequently seen throughout the year were assigned as Resident, if seen during March to July only as a Summer visitor, between October and February only as Winter visitor, and for unconfirmed migration status, we followed Grimmet et al. (2011).

We used observations from both methods and assigned the abundance categories based on the number of individuals of a species encountered. These categories are Abundant (A), Common (C), Fairly common (Fc), and Rare (R) where, A $\geq$ 100, C = 60–99, Fc = 20–59, and R < 20.

Species that are recorded for the first time from the Pithoragarh district are marked with an asterisk (*).

Table 1. Sampling scheme along with geographic locations and major vegetation types.

Sampling villages	Latitude (°N)	Longitude (°E)	Altitude Range (m)	Major vegetation	Point counts/species richness lists
Lali	29.6558	080.0281	1600–1800	Oak, chir pine	62/5
Hanera	29.6508	080.0308	1650–1950	Temperate mixed	18/2
Rawal gaon	29.6595	080.0346	1400–1600	Temperate mixed, oak, chir pine	27/3
Kuntola	29.6310	079.9840	550–850	Sal, subtropical mixed	31/3
Simalkot	29.6489	080.0600	1500–1700	Oak, temperate mixed	20/2
Patal-bhuvaneshwar	29.6889	080.0913	1400–1700	Oak, temperate mixed	22/3
Pali	29.6543	080.0920	1000–1400	Chir pine, subtropical mixed	49/4
Boyal	29.6480	080.1018	750–1050	Sal, subtropical mixed	39/3
Jhulaghat	29.5724	080.3812	500–800	Sal, subtropical mixed	41/4
Munakot	29.5652	080.2897	1350–1500	Oak, temperate mixed	35/2
Majirkanda	29.5797	080.3628	1000–1500	Chir pine, temperate mixed	27/2
Jajurauli	29.6149	080.1343	650–1050	Chir pine, subtropical mixed	58/3
Bans	29.6052	080.1535	1000–1700	Oak, sal, chir pine	75/4
Nakot	26.6091	080.1772	1600–1800	Oak	26/2
Gurura	29.6204	080.1801	1600–1900	Oak, chir pine	34/2
Jagtar	29.6059	080.1594	1900–2150	Oak, temperate mixed	18/1
Sintoli	29.6090	080.1681	1650–1800	Oak	15/1

Results

We recorded 205 species belonging to 52 families. We report two species for the first time from the Pithoragarh district. Of the six Threatened species, three are Critically Endangered, two are Endangered, one is Vulnerable, and five are Near Threatened according to the IUCN Red List (IUCN 2020). Most of these threatened species belong to the family Accipitridae (Table 2). The Indian Wildlife (Protection) Act, 1972 provides protection to 114 species, and six of them are listed under Schedule I and are strictly protected (Table 2). Eighty-one species are Himalayan endemics, of which *Catreus wallichii* (Hardwicke, 1827) is endemic to western Himalaya and five species are endemic in western to central Himalaya (Birds of the World 2020) (Table 2). Nearly 30% of the recorded species are classified as local/altitudinal migratory species or long-range migratory species. Of the long-range migratory species, 31 are summer visitors, 28 are winter visitors, and four are passage migrants in the lower reaches of the landscape (Fig. 2).

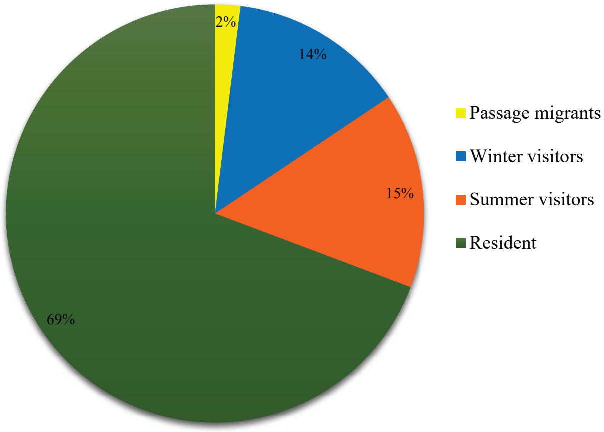

Figure 2. Bird migration status in lower reaches of KSL-India.

Table 2. List of bird species recorded from the KSL-India (Pithoragarh district). Abbreviations: HE = Himalayan endemic; H1 = endemic to western Himalaya; H2 = endemic to western and central Himalaya; H3 = endemic to Himalaya of south Asia (Afganistan, Pakistan east to Myanmar); H4 = endemic to Himalaya and occurring from Himalaya of South Asia to Indo-China and/or south-eastern China and/or South-east Asia; IUCN = International Union for Conservation of Nature; IWPA = Indian Wildlife (Protection) Act, 1972, Schedule; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered; MS = migration status; R = resident; WV = winter visitors; LM = local migrant; SV = summer visitor; PV = passage visitor; LA = local abundance; R = rare; FC = fairly common; C = common; A = abundant.

Common name	Scientific name	HE	IUCN	IWPA	MS	LA
Family Anatidae						
*Common Teal	*Anas crecca* Linnaeus, 1758		LC	IV	WV	R
Family Phasianidae						
Black Francolin	*Francolinus francolinus* (Linnaeus, 1766)		LC		R	C
Cheer Pheasant	*Catreus wallichii* (Hardwicke, 1827)	H1	VU	I	R	R
Chukar Partridge	*Alectoris chukar* (J.E. Gray, 1830)		LC	IV	R	FC
Common Hill Partridge	*Arborophila torqueola* (Valenciennes, 1825)	H4	LC	IV	R	C
Kalij Pheasant	*Lophura leucomelanos* (Latham, 1790)	H4	LC	I	R	C
Family Columbidae						
Rock Dove	*Columba livia* J.F. Gmelin, 1789		LC		R	FC
Hill Pigeon	*Columba rupestris* Pallas, 1811		LC	IV	R	FC
Snow Pigeon	*Columba leuconota* Vigors, 1831	H4	LC	IV	R	FC
Common Wood Pigeon	*Columba palumbus* Linnaeus, 1758		LC	IV	WV/LM	R
Oriental Turtle Dove	*Streptopelia orientalis* (Latham, 1790)		LC	IV	R	C
Eurasian Collared Dove	*Streptopelia decaocto* (Frivaldszky, 1838)		LC	IV	R	R
Spotted Dove	*Spilopelia chinensis* (Scopoli, 1786)		LC	IV	R	A
Wedge-tailed Green Pigeon	*Treron sphenurus* (Vigors, 1832)	H4	LC	IV	R	FC
Asian Emerald Dove	*Chalcophaps indica* (Linnaeus, 1758)		LC	IV	R	FC
Family Apodidae						
Himalayan Swiftlet	*Aerodramus brevirostris* (Horsfield, 1840)	H4	LC		R	FC
Alpine Swift	*Tachymarptis melba* (Linnaeus, 1758)		LC		SV/LM	R
Little Swift	*Apus affinis* (J.E. Gray, 1830)		LC		R	FC
White-throated Needletail	*Hirundapus caudacutus* (Latham, 1801)		LC		SV	R
Family Cuculidae						
Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)		LC	IV	SV/LM	R
Large Hawk-Cuckoo	*Hierococcyx sparverioides* (Vigors, 1832)		LC	IV	R	FC
Common Cuckoo	*Cuculus canorus* Linnaeus, 1758		LC	IV	SV	FC
Family Rallidae						
*White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)		LC		R	R
Family Phalacrocoracidae						
Little Cormorant	*Microcarbo niger* (Vieillot, 1817)		LC	IV	R	FC
Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)		LC	IV	PV/LM	R
Indian Cormorant	*Phalacrocorax fuscicollis* Stephens, 1826		LC	IV	WV/LM	R

Common name	Scientific name	HE	IUCN	IWPA	MS	LA
Family Charadriidae						
River Lapwing	*Vanellus duvaucelii* (R. Lesson, 1826)		NT		R	R
Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)		LC		R	FC
Family Scolopacidae						
Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)		LC	IV	WV/LM	R
Family Accipitridae						
Bearded Vulture	*Gypaetus barbatus* (Linnaeus, 1758)		NT	I	R	C
Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)		EN	IV	SV/LM	C
Red-headed Vulture	*Sarcogyps calvus* (Scopoli, 1786)		CR	IV	R	R
Himalayan Vulture	*Gyps himalayensis* Hume, 1869		NT	IV	R	A
White-rumped Vulture	*Gyps bengalensis* (J.F. Gmelin, 1788)		CR	I	R	R
Slender-billed Vulture	*Gyps tenuirostris* G.R. Gray, 1844	H4	CR	I	R	R
Griffon Vulture	*Gyps fulvus* (Hablizl, 1783)		LC	IV	WV	FC
Cinereous Vulture	*Aegypius monachus* (Linnaeus, 1766)		NT	IV	WV	R
Crested Serpent Eagle	*Spilornis cheela* (Latham, 1790)		LC		R	FC
Mountain Hawk-Eagle	*Nisaetus nipalensis* Hodgson, 1836		LC		R	C
Black Eagle	*Ictinaetus malaiensis* (Temminck, 1822)		LC		R	FC
Steppe Eagle	*Aquila nipalensis* Hodgson, 1833		EN		WV	C
Golden Eagle	*Aquila chrysaetos* (Linnaeus, 1758)		LC		R	FC
Bonelli's Eagle	*Aquila fasciata* Vieillot, 1822		LC		R	R
Pallid Harrier	*Circus macrourus* (Gmelin, SG, 1770)		NT		PV	R
Shikra	*Accipiter badius* (J.F. Gmelin, 1788)		LC		R	FC
Eurasian Sparrowhawk	*Accipiter nisus* (Linnaeus, 1758)		LC		R	FC
Black Kite	*Milvus migrans* (Boddaert, 1783)		LC		R	A
Himalayan Buzzard	*Buteo burmenicus* Hume, 1875	H3	LC		WV/LM	FC
Upland Buzzard	*Buteo hemilasius* Temminck & Schlegel, 1845		LC		WV/LM	R
Family Falconidae						
Common Kestrel	*Falco tinnunculus* Linnaeus, 1758		LC	IV	R	C
Peregrine Falcon	*Falco peregrinus* Tunstall, 1771		LC	I	R	FC
Family Strigidae						
Brown Hawk Owl	*Ninox scutulata* (Ruffles, 1822)		LC	IV	R	R
Collared Owlet	*Glaucidium brodiei* (Burton, 1836)	H4	LC	IV	R	R
Asian Barred Owlet	*Glaucidium cuculoides* (Vigors, 1830)	H4	LC	IV	R	FC
Jungle Owlet	*Glaucidium radiatum* (Tickell, 1833)		LC	IV	R	R
Mountain Scops Owl	*Otus spilocephalus* (Blyth, 1846)	H4	LC	IV	R	FC
Brown Wood Owl	*Strix leptogrammica* Temminck, 1832		LC	IV	R	R
Family Picidae						
Speckled Piculet	*Picumnus innominatus* Burton, 1836		LC	IV	R	FC
Rufous Woodpecker	*Micropternus brachyurus* (Vieillot, 1818)		LC	IV	R	R
Greater Yellow-naped Woodpecker	*Chrysophlegma flavinucha* (Gould, 1834)		LC	IV	R	FC
Lesser Yellow-naped Woodpecker	*Picus chlorolophus* Vieillot, 1818		LC	IV	R	R
Grey-headed Woodpecker	*Picus canus* J.F. Gmelin, 1788		LC	IV	R	FC
Scaly-bellied Woodpecker	*Picus squamatus* Vigors, 1831	H2	LC	IV	R	FC
Grey-capped Pygmy Woodpecker	*Yungipicus canicapillus* (Blyth, 1845)		LC	IV	R	R
Brown-fronted Woodpecker	*Dendrocoptes auriceps* (Vigors, 1831)	H2	LC	IV	R	C
Yellow-fronted Woodpecker	*Leiopicus mahrattensis* (Latham, 1801)		LC	IV	R	R
Himalayan Woodpecker	*Dendrocopos himalayensis* (Jardine & Selby, 1831)	H2	LC	IV	R	R
Family Megalaimidae						
Great barbet	*Psilopogon virens* (Boddaert, 1783)	H4	LC	IV	R	A
Blue-throated barbet	*Psilopogon asiaticus* (Latham, 1790)	H4	LC	IV	R	C
Family Upupidae						
Common Hoopoe	*Upupa epops* Linnaeus, 1758		LC		SV/LM	FC
Family Meropidae						
Green Bee-eater	*Merops orientalis* Latham, 1801		LC		R	FC
Chestnut-headed Bee-eater	*Merops leschenaulti* Vieillot, 1817		LC		SV/LM	R
Family Coraciidae						
Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)		LC	IV	R	R
Family Alcedinidae						
Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)		LC	IV	R	R
Crested Kingfisher	*Megaceryle lugubris* (Temminck, 1834)		LC		R	FC
White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)		LC	IV	R	FC
Family Psittaculidae						
Slaty-headed Parakeet	*Psittacula himlayana* (R. Lesson, 1831)	H3	LC	IV	R	A

Common name	Scientific name	HE	IUCN	IWPA	MS	LA
Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)		LC	IV	R	C
Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)		LC	IV	R	R
Family Campephagidae						
Long-tailed Minivet	*Pericrocotus ethologus* Bangs & J.C. Phillips, 1914	H4	LC	IV	R	C
Scarlet Minivet	*Pericrocotus speciosus*(Latham, 1790)		LC	IV	R	R
Large Cuckooshrike	*Coracina macei* (R. Lesson, 1831)		LC		R	R
Family Oriolidae						
Maroon Oriole	*Oriolus traillii* (Vigors, 1832)	H4	LC	IV	R	R
Indian Golden Oriole	*Oriolus kundoo* (Sykes, 1832)		LC	IV	SV/LM	R
Family Dicruridae						
Ashy Drongo	*Dicrurus leucophaeus* Vieillot, 1817		LC	IV	SV/LM	C
Crow-billed Drongo	*Dicrurus annectens* (Hodgson, 1836)	H4	LC	IV	SV	R
Hair-crested Drongo	*Dicrurus hottentottus* (Linnaeus, 1766)		LC	IV	R	C
Family Rhipiduridae						
White-throated Fantail	*Rhipidura albicollis* (Vieillot, 1818)		LC		R	FC
Family Stenostiridae						
Yellow-bellied Fairy-fantail	*Chelidorhynx hypoxanthus* (Blyth, 1843)	H4	LC		WV/LM	FC
Grey-headed Canary-flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)		LC	IV	SV/LM	FC
Family Laniidae						
Long-tailed Shrike	*Lanius schach* Linnaeus, 1758		LC		SV/LM	C
Grey-backed Shrike	*Lanius tephronotus* (Vigors, 1831)	H4	LC		SV/LM	R
Family Corvidae						
Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)		LC	IV	R	R
Grey Treepie	*Dendrocitta formosae* Swinhoe, 1863		LC	IV	R	C
Yellow-billed Blue Magpie	*Urocissa flavirostris* (Blyth, 1846)	H3	LC	IV	R	FC
Red-billed Blue Magpie	*Urocissa erythrorhyncha* (Boddaert, 1783)	H4	LC	IV	R	A
Eurasian Jay	*Garrulus glandarius* (Linnaeus, 1758)		LC	IV	R	R
Black-headed Jay	*Garrulus lanceolatus* Vigors, 1830	H2	LC	IV	R	C
House Crow	*Corvus splendens* (Vieillot, 1817)		LC	V	R	R
Large-billed Crow	*Corvus macrorhynchos* (Wagler, 1827)		LC		R	A
Family Monarchidae						
Indian Paradise-flycatcher	*Terpsiphone paradisi* (Linnaeus, 1758)		LC		SV/LM	FC
Family Dicaeidae						
Fire-breasted Flowerpecker	*Dicaeum ignipectus* (Blyth, 1843)	H4	LC	IV	R	FC
Family Nectariniidae						
Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)		LC	IV	SV/LM	FC
Fire-tailed Sunbird	*Aethopyga ignicauda* (Hodgson, 1836)	H3	LC	IV	R	R
Black-throated Sunbird	*Aethopyga saturata* (Hodgson, 1836)	H4	LC	IV	R	FC
Crimson Sunbird	*Aethopyga siparaja* (Raffles, 1822)		LC	IV	SV/LM	R
Green-tailed Sunbird	*Aethopyga nipalensis* (Hodgson, 1836)	H4	LC	IV	R	FC
Family Irenidae						
Golden-fronted Leafbird	*Chloropsis aurifrons* (Temminck, 1829)		LC		R	R
Orange-bellied Leafbird	*Chloropsis hardwickii* (Jardine & Selby, 1830)	H4	LC		R	FC
Family Prunellidae						
Rufous-breasted Accentor	*Prunella strophiata* (Blyth, 1843)	H4	LC		R	FC
Black-throated Accentor	*Prunella atrogularis* (J.F. Brandt, 1843)		LC		WV	FC
Family Estrildidae						
White-rumped Munia	*Lonchura striata* (Linnaeus, 1766)		LC	IV	R	FC
Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)		LC	IV	R	R
Family Passeridae						
House Sparrow	*Passer domesticus* (Linnaeus, 1758)		LC		R	C
Russet Sparrow	*Passer cinnamomeus* (Gould, 1836)		LC		R	C
Family Motacillidae						
Olive-backed Pipit	*Anthus hodgsoni* Richmond, 1907		LC		WV/LM	R
Rosy Pipit	*Anthus roseatus* Blyth, 1847	H4	LC	IV	WV/LM	FC
Paddyfield Pipit	*Anthus rufulus* Vieillot, 1818		LC	IV	R	R
Grey wagtail	*Motacilla cinerea* Tunstall, 1771		LC		SV/LM	FC
White-browed Wagtail	*Motacilla maderaspatensis* J.F. Gmelin, 1789		LC		R	R
White Wagtail	*Motacilla alba* Linnaeus, 1758		LC		PV/LM	FC
Family Fringillidae						
Common rosefinch	*Carpodacus erythrinus* (Pallas, 1770)		LC	IV	WV/LM	FC
Pink-browed Rosefinch	*Carpodacus rodochroa* (Vigors, 1831)	H3	LC		WV/LM	R
Dark-breasted Rosefinch	*Procarduelis nipalensis* (Hodgson, 1836)	H4	LC	IV	WV/LM	FC

Common name	Scientific name	HE	IUCN	IWPA	MS	LA
Yellow-breasted Greenfinch	*Chloris spinoides* (Vigors, 1831)	H3	LC	IV	WV/LM	C
Family Emberizidae						
Crested Bunting	*Emberiza lathami* (Gray, JE, 1831)		LC	IV	WV/LM	FC
Rock Bunting	*Emberiza cia* (Linnaeus, 1766)		LC	IV	R	C
Family Paridae						
Green-backed Tit	*Parus monticolus* Vigors, 1831	H4	LC	IV	R	C
Cinereous Tit	*Parus cinereus* Vieillot, 1818		LC	IV	R	C
Black-lored Tit	*Machlolophus xanthogenys* (Vigors, 1831)	H3	LC	IV	R	C
Family Cisticolidae						
Striated Prinia	*Prinia crinigera* Hodgson, 1836	H4	LC		R	FC
Grey-breasted Prinia	*Prinia hodgsonii* Blyth, 1844		LC		R	C
Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)		LC		R	R
Family Hirundinidae						
Red-rumped Swallow	*Cecropis daurica* (Laxmann, 1769)		LC		R	C
Barn Swallow	*Hirundo rustica* Linnaeus, 1758		LC		SV/LM	C
Family Pycnonotidae						
Ashy Bulbul	*Hemixos flavala* Blyth, 1845	H4	LC	IV	R	R
Mountain Bulbul	*Ixos mcclellandii* (Horsfield, 1840)	H4	LC	IV	R	R
Black Bulbul	*Hypsipetes leucocephalus* (J.F. Gmelin, 1789)	H4	LC	IV	R	C
Himalayan Bulbul	*Pycnonotus leucogenys* (Gray, JE, 1835)	H3	LC	IV	R	A
Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)		LC	IV	R	A
Family Phylloscopidae						
Hume's Leaf Warbler	*Phylloscopus humei* (W.E. Brooks, 1878)		LC		SV/LM	C
Lemon-rumped Warbler	*Phylloscopus chloronotus* (J.E. Gray & G.R. Gray, 1847)	H3	LC		WV/LM	C
Buff-barred Warbler	*Phylloscopus pulcher* Blyth, 1845	H4	LC		WV/LM	R
Tickell's Leaf Warbler	*Phylloscopus affinis* (Tickell, 1833)		LC		WV/LM	FC
Greenish Leaf Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)		LC		PV/LM	R
Blyth's Leaf Warbler	*Phylloscopus reguloides* (Blyth, 1842)	H4	LC		SV/LM	R
Grey-hooded Leaf Warbler	*Phylloscopus xanthoschistos* (J.E. Gray & G.R. Gray, 1847)	H3	LC		R	A
Grey-sided bush Warbler	*Cettia brunnifrons* (Hodgson, 1845)	H4	LC		WV/LM	FC
Black-faced Warbler	*Abroscopus schisticeps* (J.E. Gray & G.R. Gray, 1847)	H4	LC		R	FC
Aberrant bush Warbler	*Horornis flavolivaceus* (Blyth, 1845)	H4	LC		R	R
Family Aegithalidae						
Black-throated Tit	*Aegithalos concinnus* (Gould, 1855)	H4	LC	IV	R	C
Family Zosteropidae						
Stripe-throated Yuhina	*Yuhina gularis* Hodgson, 1836	H4	LC		R	FC
Whiskered Yuhina	*Yuhina flavicollis* Hodgson, 1836	H4	LC		R	R
Oriental White-eye	*Zosterops palpebrosus* (Temminck, 1824)		LC	IV	R	C
Family Timaliidae						
Streak-breasted Scimitar Babbler	*Pomatorhinus ruficollis* Hodgson, 1836		LC	IV	R	R
Rusty-cheeked Scimitar Babbler	*Erythrogenys erythrogenys* (Vigors, 1831)	H3	LC	IV	R	FC
Black-chinned Babbler	*Cyanoderma pyrrhops* (Blyth, 1844)	H2	LC	IV	R	C
Family Leiothrichidae						
Striated Laughingthrush	*Grammatoptila striata* (Vigors, 1831)	H3	LC	IV	R	FC
Jungle babbler	*Argya striata* (Dumont, 1823)		LC	IV	R	C
Rufous-chinned Laughingthrush	*Ianthocincla rufogularis* (Gould, 1835)	H3	LC	IV	R	FC
White-throated Laughingthrush	*Pterorhinus albogulris* (Gould, 1836)	H4	LC	IV	R	C
White-crested Laughingthrush	*Garrulax leucolophus* (Hardwicke, 1816)	H4	LC	IV	R	C
Streaked Laughingthrush	*Trochalopteron lineatum* (Vigors, 1831)	H3	LC	IV	R	A
Rufous Sibia	*Heterophasia capistrata* (Vigors, 1831)	H3	LC		R	C
Blue-winged Minla	*Actinodura cyanouroptera* (Hodgson, 1837)	H4	LC		R	R
Chestnut-tailed Minla	*Actinodura strigula* (Hodgson, 1837)	H4	LC		R	FC
Family Certhiidae						
Bar-tailed Treecreeper	*Certhia himalayana* Vigors, 1832		LC		R	C
Family Sittidae						
Chestnut-bellied Nuthatch	*Sitta cinnamoventris* Blyth, 1842	H4	LC		R	C
Velvet-fronted Nuthatch	*Sitta frontalis* Swainson, 1820		LC		R	R
Wallcreeper	*Tichodroma muraria* (Linnaeus, 1766)		LC		WV/LM	FC
Family Sturnidae						
Chestnut-tailed Starling	*Sturnia malabarica* J.F. Gmelin, 1789)		LC	IV	SV/LM	R
Common Myna	*Acridotheres tristis* (Linnaeus, 1766)		LC	IV	R	A
Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)		LC	IV	R	FC
Spot-winged Starling	*Saroglossa spiloptera* (Vigors, 1831)	H4	LC		SV/LM	R

Common name	Scientific name	HE	IUCN	IWPA	MS	LA
Family Cinclidae						
Brown dipper	*Cinclus pallasii* Temminck, 1820		LC		R	FC
Family Muscicapidae						
Oriental Magpie Robin	*Copsychus saularis* (Linnaeus, 1758)		LC		R	FC
Golden Bush-robin	*Tarsiger chrysaeus* Hodgson, 1845	H4	LC		R	R
Himalayan Bush-robin	*Tarsiger rufilatus* (Hodgson, 1845)	H4	LC		R	FC
Dark-sided Flycatcher	*Muscicapa sibirica* J.F. Gmelin, 1789		LC	IV	SV/LM	FC
Blue-throated Flycatcher	*Cyornis rubeculoides* (Vigors, 1831)		LC	IV	SV/LM	R
Rufous-bellied Niltava	*Niltava sundara* Hodgson, 1837	H4	LC		R	FC
Small Niltava	*Niltava macgrigoriae* (Burton, 1836)	H4	LC		R	FC
Verditer Flycatcher	*Eumyias thalassinus* (Swainson, 1838)		LC	IV	SV/LM	C
Little Forktail	*Enicurus scouleri* Vigors, 1832	H4	LC		R	R
Slaty-backed Forktail	*Enicurus schistaceus* (Hodgson, 1836)	H4	LC		R	FC
Spotted Forktail	*Enicurus maculatus* Vigors, 1831	H4	LC		R	FC
Blue Whistling-thrush	*Myophonus caeruleus* (Scopoli, 1786)	H4	LC		R	A
Rusty-tailed Flycatcher	*Ficedula ruficauda* (Swainson, 1838)		LC	IV	SV/LM	FC
Rufous-gorgeted Flycatcher	*Ficedula strophiata* (Hodgson, 1837)	H4	LC	IV	R	R
Ultramarine Flycatcher	*Ficedula superciliaris* (Jerdon, 1840)		LC	IV	SV/LM	FC
Slaty-blue Flycatcher	*Ficedula tricolor* (Hodgson, 1845)	H4	LC	IV	SV/LM	FC
Blue-fronted Redstart	*Phoenicurus frontalis* Vigors, 1831	H4	LC		WV/LM	C
Blue-capped Redstart	*Phoenicurus coeruleocephala* (Vigors, 1831)		LC		R	FC
White-capped Water Redstart	*Phoenicurus leucocephalus* Vigors, 1831	H4	LC		R	C
Plumbeous Water Redstart	*Phoenicurus fuliginosus* Vigors, 1831	H4	LC		R	C
Black Redstart	*Phoenicurus ochruros* (S.G. Gmelin, 1774)		LC		WV/LM	FC
Blue-capped Rock-thrush	*Monticola cinclorhyncha* (Vigors, 1831)		LC		SV/LM	R
Chestnut-bellied Rock-thrush	*Monticola rufiventris* (Jardine & Selby, 1833)	H4	LC		R	FC
Siberian Stonechat	*Saxicola maurus* (Pallas, 1773)		LC		WV/LM	FC
Pied Bushchat	*Saxicola caprata* (Linnaeus, 1766)		LC		SV/LM	R
Grey Bushchat	*Saxicola ferreus* J.E. Gray & G.R. Grey, 1847	H4	LC		R	C
Variable Wheatear	*Oenanthe picata* (Blyth, 1847)		LC		WV	R
Family Turdidae						
Long-billed Thrush	*Zoothera monticola* Vigors, 1832	H3	LC	IV	SV/LM	R
Grey-winged Blackbird	*Turdus boulboul* (Latham, 1790)	H4	LC		R	C
Black-throated Thrush	*Turdus atrogularis* Jarocki, 1819		LC	IV	WV	FC

Family Anatidae

***Anas crecca* Linnaeus, 1758**
Common Teal
Figure 3A

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Jajurauli; 29.6282°N 80.1229°E; alt. 630 m a.s.l.; 28 Nov. 2015.

Identification. Males were identified by the chestnut head and green band behind eyes, and the white stripe along with the scapulars. Females were identified by the uniform head and prominent white streak at the side of under tail coverts. If a pale loral spot and dark cheek bar were lacking, then we identified birds as a female of *Anas querquedula*.

Family Rallidae

***Amaurornis phoenicurus* (Pennant, 1769)**
White-breasted Waterhen
Figure 3B

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Bans; 29.6228°N, 80.1391°E; alt. 990 m a.s.l.; 14 Apr. 2014 • Bin block; Jajurauli; 29.6208, 80.1217; alt. 850 m a.s.l.; 13 Feb. 2016.

Identification. The species was readily identified by its grey upperparts and white face, foreneck, and breast. Bill and legs are greenish-yellow, and the upper mandible has a reddish base.

Family Accipitridae

***Sarcogyps calvus* (Scopoli, 1786)**
Red-headed Vulture
Figure 3C

Observation. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Hanera; 29.6505°N, 80.0295°E; alt. 1800 m a.s.l.; 3 Nov. 2013 • Lali; 29.6585°N 80.0274°E; alt. 1720 m a.s.l.; 16 Nov. 2013 • Kuntola; 29.6338°N, 79.9844°E; alt.790 m a.s.l.; 18 Nov. 2013 • Bin Block; Bans; 29.6082°N 80.1392°E; alt. 1400 m a.s.l.; 10 Feb. 2016 • Nakot; 29.6082°N, 80.17764°E; alt. 1690 m a.s.l.; 12 Mar. 2016.

***Gyps bengalensis* (J.F. Gmelin, 1788)**
White-rumped Vulture
Figure 3D

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Kuntola; 29.6338°N, 79.9844°E; alt.790 m a.s.l.; 18 Nov. 2013 • Munakot block; Majir-

Figure 3. Birds recorded from the KSL-India (Pithoragarh district). **A.** *Anas crecca.* **B.** *Amaurornis phoenicurus.* **C.** *Sarcogyps calvus.* **D.** *Gyps bengalensis.* **E.** *Neophron percnopterus.* **F.** *Aquila nipalensis.* **G.** *Gypaetus barbatus.* **H.** *Aegypius monachus.* **I.** *Gyps himalayensis.* **J.** *Spilornis cheela.* **K.** Ictinaetus malaiensis. **L.** *Buteo hemilasius.*

kanda; 29.5783°N, 80.3663°E; alt. 1340 m a.s.l.; 3 Apr. 2014 • Munakot; 29.5652°N, 80.2897°E; alt. 1500 m a.s.l.; 8 Apr. 2014 • Jhulaghat; 29.5746°N 80.3826°E; alt. 590 m a.s.l.; 4 Oct. 2015.

***Neophron percnopterus* (Linnaeus, 1758)**
Egyptian Vulture
Figure 3E

Observations. INDIA • Uttarakhand; Pithoragarh district; Munakot block; Jhulaghat; 29.5746°N 80.3826°E; alt. 590 m a.s.l.; 8 Oct. 2015 • Bin Block; Bans; 29.6082°N 80.1391°E; alt. 1400 m a.s.l.; 10 Feb. 2016 • Nakot; 29.6082°N, 80.1776°E; alt. 1690 m a.s.l.; 19 Mar. 2016.

***Aquila nipalensis* Hodgson, 1833**
Steppe Eagle
Figure 3F

Observations. INDIA • Uttarakhand; Pithoragarh district; Munakot block; Munakot; 29.5652°N, 80.2897°E; alt. 1500 m a.s.l.; 8 Apr. 2014 • Jhulaghat; 29.5746°N

80.3826°E; alt. 590 m a.s.l.; 8 Oct. 2015 • Bin Block; Bans; 29.6082°N 80.1391°E; alt. 1400 m a.s.l.; 10 Feb. 2016 • Pithoragarh; 29.6206°N 80.2518°E; alt. 1670 m a.s.l.; 27 Feb. 2015 • Nakot; 29.6082°N, 80.1776°E; alt. 1690 m a.s.l.; 15 Mar. 2016.

***Gypaetus barbatus* (Linnaeus, 1758)**
Bearded Vulture
Figure 3G

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.65849°N 80.0274°E; alt. 1720 m a.s.l.; 16 Nov. 2013 • Hanera; 29.6505°N, 80.0295°E; alt. 1800 m a.s.l.; 3 Dec. 2013 • Bin block; Nakot; 29.6091°N, 80.1771°E; alt. 1680 m a.s.l.; 10 Oct. 2015 • Bans; 29.6082°N 80.1391°E; alt. 1400 m a.s.l.; 10 Feb. 2016 • Pithoragarh; 29.6206°N 80.2518°E; alt. 1670 m a.s.l.; 27 Feb. 2015 • Munakot block; Munakot; 29.5588°N 80.2958°E; alt. 1530 m a.s.l.; 6 Apr. 2014.

***Aegypius monachus* (Linnaeus, 1766)**
Cinereous Vulture
Figure 3H

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Futsil 29.6794°N, 80.0494°E; alt. 1720 m a.s.l.; 2 Oct. 2015 • Bin block; Pithoragarh; 29.5954°N 80.1997°E; alt. 1640 m a.s.l.; 20 Nov. 2015.

***Gyps himalayensis* Hume, 1869**
Himalayan vulture
Figure 3I

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6585°N 80.0274°E; alt. 1720 m a.s.l.; 16 Nov. 2013 • Kuntola; 29.6338°N, 79.9844°E; alt.790 m a.s.l.; 18 Nov. 2013 • Rawal gaon; 29.6610°N 80.0335°E; alt. 1760 m a.s.l.; 19 Dec. 2013 • Pali; 29.6595°N 80.0861°E; alt.1350 m asl.; 7 Mar. 2014 • Patal-bhuvaneshwar; 29.6865°N, 80.0907°E; alt. 1700 m a.s.l.; 12 Mar. 2015 • Bin block; Bans; 29.6082°N 80.1391°E; alt. 1400 m a.s.l.; 10 Feb. 2016 • Nakot; 29.6082°N, 80.1776°E; alt. 1690 m a.s.l.; 15 Mar. 2016 • Munakot block; Majirkanda; 29.5783°N, 80.3663°E; alt. 1340 m a.s.l.; 3 Apr. 2014 • Munakot; 29.5652°N, 80.2897°E; alt. 1500 m a.s.l.; 8 Apr. 2014 • Jhulaghat; 29.5746°N 80.3826°E; alt. 590 m a.s.l.; 4 Oct. 2015.

***Spilornis cheela* (Latham, 1790)**
Crested Serpent Eagle
Figure 3J

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin Block; Nakot; 29.6089°N, 80.1799°E; alt. 1672 m a.s,l.; 10 Apr. 2015 • Jajurauli; 29.6177°N, 80.1331°E; alt. 1036 m a.s,l.; 11 May. 2015 • Bans; 29.6037°N, 80.1439°E; alt. 1536 m a.s.l.; 13 May 2016.

***Ictinaetus malaiensis* (Temminck, 1822)**
Black Eagle
Figure 3K

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Nakot; 29.6053°N, 80.1794°E; alt. 1755 m a.s.l.; 23 Mar. 2015 • Sintoli; 29.6084°N, 80.1686°E; alt. 1681 m a.s.l.; 16 Apr. 2015 • Pithoragarh; 29.5771 N, 80.1842°E; alt. 1659 m a.s.l.; 6 Feb. 2016 • Jagtar; 29.6028°N, 80.1602°E; alt. 1943 m a.s.l.; 16 Mar. 2016.

***Buteo hemilasius* Temminck & Schlegel, 1845**
Upland Buzzard
Figure 3L

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6560°N, 80.0265°E; alt. 1762 m a.s.l.; 18 Dec. 2013 • Hanera; 29.6478°N, 80.0286°E; alt. 1831 m a.s.l.; 17 Jan. 2014.

***Buteo burmanicus* Hume, 1875**
Himalayan Buzzard
Figure 4A

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6587°N, 80.0277°E; alt. 1720 m a.s.l.; 24 Nov. 2013 • Bin block; Gurura; 29.6119°N 80.1784°E; alt. 1630 m a.s.l.; 5 Feb. 2015 • Nakot; 29.6080°N, 80.1768°E; alt. 1700 m a.s.l.; 15 Apr. 2015.

Family Phasianidae

***Catreus wallichii* (Hardwicke, 1827)**
Cheer Pheasant
Figure 4B

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Gurura; 29.6255°N 80.1838°E; alt. 2020 m a.s.l.; 5 Feb. 2015.

***Lophura leucomelanos* (Latham, 1790)**
Kalij Pheasant
Figure 4C

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6603°N, 80.0277°E; alt. 1660 m a.s.l.; 22 Nov. 2013 • Simalkot; 29.6508°N, 80.0546°E; alt. 1550 m a.s.l.; 7 Dec. 2013 • Pali; 29.6501°N 80.0811°E; alt. 1150 m a.s.l.; 7 Mar. 2014 • Munakot block; Munakot; 29.5615°N 80.2948°E; alt. 1470 m a.s.l.; 8 Apr. 2014 • Bin block; Jajurauli; 29.6249°N 80.1246°E; alt. 710 m a.s.l.; 14 Apr. 2014 • Bans; 29.6114°N, 80.1523°E; alt. 1500 m a.s.l.; 10 Feb. 2016.

***Alectoris chukar* (Gray, JE, 1830)**
Chukar Partridge
Figure 4D

Observations. INDIA • Uttarakhand; Pithoragarh district; Munakot block; Majirkanda; 29.5822°N, 80.3683°E; alt. 1249 m a.s.l.; 1 Apr. 2014 • Bin block; Pithoragarh; 29.5869°N, 80.2675°E; alt. 1647 m a.s.l.; 25 May 2015 • Bans; 29.6042°N, 80.1417°E; alt. 1512 m a.s.l.; 28 Apr. 2016.

Figure 4. Birds recorded from the KSL-India (Pithoragarh district). **A.** *Buteo burmanicus*. **B.** *Catreus wallichii*. **C.** *Lophura leucomelanos*. **D.** *Alectoris chukar*. **E.** *Vanellus duvaucelii*. **F.** *Vanellus indicus*. **G.** *Streptopelia decaocto*. **H.** *Phalacrocorax carbo*. **I.** *Actitis hypoleucos*. **J.** *Strix leptogrammica*. **K.** *Glaucidium cuculoides*. **L.** *Picus squamatus*.

Family Charadriidae

***Vanellus duvaucelii* (R. Lesson, 1826)**
River Lapwing
Figure 4E

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Jajurauli; 29.6311°N, 80.1205°E; alt. 650 m a.s.l.; 22 Oct. 2015.

***Vanellus indicus* (Boddaert, 1783)**
Red-wattled Lapwing
Figure 4F

Observations. INDIA • Uttarakhand; Pithoragarh district; Munakot block; Munakot; 29.5591°N, 80.2957°E; alt. 1537 m a.s.l.; 7 Apr. 2014 • Bin block; Nakot; 29.6126°N, 80.1805°E; alt. 1626 m a.s.l.; 8 Jun. 2015 • Bans; 29.6138°N, 80.1478°E; alt. 1315 m a.s.l.; 17 Apr. 2016.

Family Columbidae

***Streptopelia decaocto* (Frivaldszky, 1838)**
Eurasian Collared Dove
Figure 4G

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Jajurauli; 29.6184°N, 80.141°E; alt. 1012 m a.s.l.; 13 Apr. 2016.

Family Phalacrocoracidae

***Phalacrocorax carbo* (Linnaeus, 1758)**
Great Cormorant
Figure 4H

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Kuntola; 29.6411°N, 79.9720°E; alt. 629 m a.s.l.; 28 Mar. 2014 • Munkot block; Jhulaghat; 29.5721°N, 80.3689°E; alt. 575 m a.s.l.; 8 Apr. 2016.

Family Scolopacidae

***Actitis hypoleucos* (Linnaeus, 1758)**
Common Sandpiper
Figure 4I

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Jajurauli; 29.6282°N 80.1229°E; alt. 630 m a.s.l.; 28 Nov. 2015.

Family Strigidae

***Strix leptogrammica* Temminck, 1832**
Brown Wood Owl
Figure 4J

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Bans; 29.6147°N, 80.1634°E; alt. 1552 m a.s.l.; 16 Apr. 2016.

***Glaucidium cuculoides* (Vigors, 1830)**
Asian barred Owlet
Figure 4K

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6584°N, 80.0294°E; alt. 1739 m a.s.l.; 12 Nov. 2013 • Hanera; 29.6472°N, 80.0286°E; alt. 1821 m a.s.l.; 17 Dec. 2013 • Rawal gaon; 29.6567°N, 80.0476°E; alt. 1687 m a.s.l.; 19 Dec. 2013 • Pali; 29.6499°N, 80.0875°E; alt. 1360 m a.s.l.; 9 Mar. 2014 • Bin block; Bans; 29.6104°N, 80.1440°E; alt. 1350 m a.s.l.; 8 Oct. 2015 • Nakot; 29.6047°N, 80.1783°E; alt. 1767 m a.s.l.; 24 Feb. 2016.

Family Picidae

***Picus squamatus* Vigors, 1831**
Scaly-bellied Woodpecker
Figure 4L

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6601°N, 80.0280°E; alt. 1680 m a.s.l.; 22 Nov. 2013 • Bin block; Jagtar; 29.6015°N, 80.1574°E; alt. 1920 m a.s.l.; 25 Apr. 2014 • Bin block; Bans; 29.6097°N, 80.1525°E.; alt. 1600 m a.s.l.; 8 Oct. 2015.

***Dendrocoptes auriceps* (Vigors, 1831)**
Brown-fronted Woodpecker
Figure 5A

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6591°N, 80.0292°E; alt. 1710 m a.s.l.; 29 Oct. 2013 • Hanera; 29.6523°N, 80.0275°E; alt. 1770 m a.s.l.; 3 Dec. 2013 • Kuntola; 29.6319°N, 79.9853°E; alt. 830 m a.s.l.; 18 Nov. 2013 • Pali; 29.6499°N, 80.0875°E; alt. 1360 m a.s.l.; 7 Mar. 2014 • Boyal; 29.6360°N 80.1092°E; alt. 1020 m a.s.l.; 10 Mar. 2014 • Munakot block; Majirkanda; 29.5852°N, 80.3475°E; 1450 m a.s.l.; 3 Apr. 2014 • Bin block; Jajurauli; 29.6260°N, 80.1233°E; alt. 680 m a.s.l.; 14 Apr. 2014 • Bans; 29.6185°N 80.1497°E; alt. 1370 m a.s.l.; 10 Feb. 2016.

***Dendrocopos himalayensis* (Jardine & Selby, 1831)**
Himalayan Woodpecker
Figure 5B

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6588°N, 80.0285°E; alt. 1730 m a.s.l.; 24 Nov 2013 • Bin block; Jagtar, 29.6015°N, 80.1574°E; alt. 1920 m a.s.l.; 25 Apr. 2014.

Family Upupidae

***Upupa epops* Linnaeus, 1758**
Common hoopoe
Figure 5C

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Bans; 29.6131°N, 80.1489°E; alt. 1345 m a.s.l. 15 Mar. 2015 • Jajurauli; 29.6176°N, 80.1364°E; alt. 1025 m a.s.l.; 11 May 2015 • Nakot; 29.6121°N, 80.1816°E; alt. 1632 m a.s.l.; 8 May 2016.

Family Coraciidae

***Coracias benghalensis* (Linnaeus, 1758)**
Indian Roller
Figure 5D

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin Block; Jajurauli; 29.6193°N, 80.1338°E; alt. 992 m a.s.l.; 11 Apr. 2016.

Family Alcedinidae

***Alcedo atthis* (Linnaeus, 1758)**
Common Kingfisher
Figure 5E

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Nakot; 29.6128°N, 80.1793°E; alt. 1624 m a.s.l.; 15 Mar. 2016 • Jajurauli; 29.6284°N, 80.1231°E; alt. 637 m a.s.l.; 2 June. 2016.

***Halcyon smyrnensis* (Linnaeus, 1758)**
White-throated Kingfisher
Figure 5F

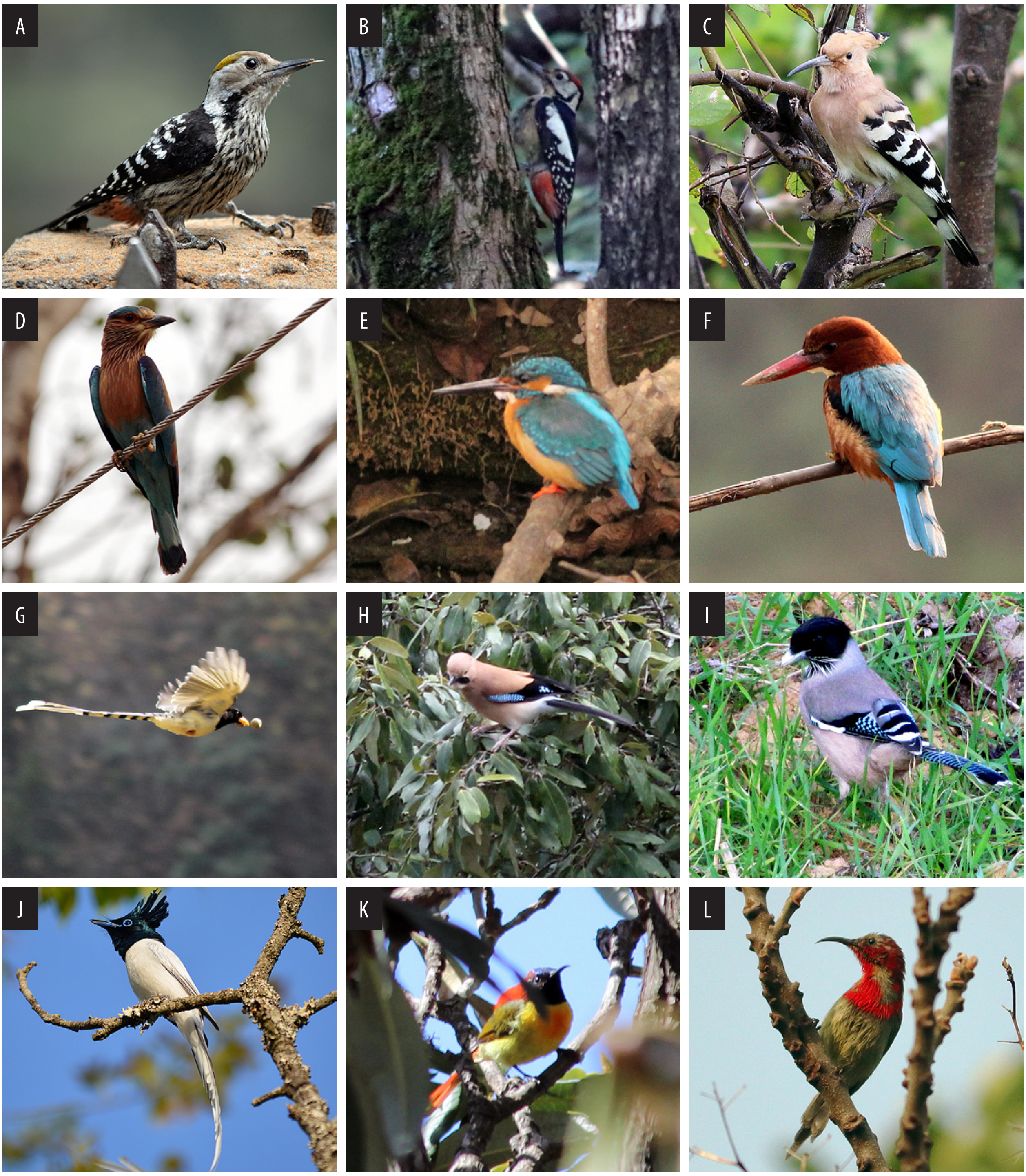

Figure 5. Birds recorded from the KSL-India (Pithoragarh district). **A.** *Dendrocoptes auriceps*. **B.** *Dendrocopos himalayensis*. **C.** *Upupa epops*. **D.** *Coracias benghalensis*. **E.** *Alcedo atthis*. **F.** *Halcyon smyrnensis*. **G.** *Urocissa flavirostris*. **H.** *Garrulus glandarius*. **I.** *Garrulus lanceolatus*. **J.** *Terpsiphone paradise*. **K.** *Aethopyga ignicauda*. **L.** *Aethopyga siparaja*.

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6578°N, 80.0282°E; alt. 1736 m a.s.l. 18 Oct 2013 • Kuntola; 29.6322°N, 79.9846°E; Alt. 815 m a.s.l.; 18 Nov. 2013.

Family Corvidae

Urocissa flavirostris **(Blyth, 1846)**
Yellow-billed Blue Magpie
Figure 5G

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6594°N, 80.0269°E; alt. 1710 m a.s.l.; 24 Nov. 2013 • Bin block; Bans; 29.6105°N, 80.1523°E; alt. 1557 m a.s.l.; 18 Nov. 2015.

Garrulus glandarius **(Linnaeus, 1758)**
Eurasian Jay
Figure 5H

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Nakot; 29.6046°N, 80.1785°E; alt. 1775 m a.s.l.; 10 Oct. 2015 • Jagtar; 29.6028°N, 80.1602°E; alt. 1943 m a.s.l.; 16 Mar. 2016.

***Garrulus lanceolatus* Vigors, 1830**
Black-headed Jay
Figure 5I

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6594°N, 80.0269°E; alt. 1710 m a.s.l.; 24 Nov. 2013 • Hanera; 29.6534°N, 80.0261°E; alt. 1720 m a.s.l.; 2 Dec. 2013 • Rawal gaon; 29.6633°N, 80.0284°E; alt. 1560 m a.s.l.; 19 Dec. 2013 • Bin Block; Bans; 29.6082°N 80.1391°E; alt. 1400 m a.s.l.; 15 Apr. 2014 • Sintoli 28.6079°N, 80.1696°E; alt. 1690 m a.s.l.; 22 Apr. 2014 • Nakot; 29.6093°N, 80.1745°E; alt. 1660 m a.s.l.; 10 Oct. 2015 • Jajurauli; 29.6149°N 80.1343°E; alt. 1110 m a.s.l.; 13 Feb. 2016 • Munakot block; Majirkanda 29.5816°N, 80.3040°E; alt. 1330 m a.s.l.; 3 Apr. 2014 • Munakot; 29.5583°N, 80.2863°E; alt. 1470 m a.s.l.; 7 Apr. 2014.

Family Monarchidae

***Terpsiphone paradisi* (Linnaeus, 1758)**
Indian Paradise-flycatcher
Figure 5J

Observations. INDIA • Uttarakhand; Pithoragarh district; Munakot block; Majirkanda; 29.5806°N, 80.3655°E; alt. 1330 m a.s.l.; 3 Apr. 2014 • Bin block; Jajurauli; 29.6260°N, 80.1233°E; alt. 680 m a.s.l.; 14 Apr. 2014 • Bans; 29.6138°N, 80.1478°E; alt. 1315 m a.s.l.; 17 Apr. 2016.

Family Nectariniidae

***Aethopyga ignicauda* (Hodgson, 1836)**
Fire-tailed Sunbird
Figure 5K

Observations. INDIA • Uttarakhand; Pithoragarh district; Nakot; 29.6082°N, 80.17764°E; alt. 1690 m a.s.l.; 12 Mar. 2016 • Jagtar; 29.6028°N, 80.1602°E; alt. 1943 m a.s.l.; 16 Mar. 2016.

***Aethopyga siparaja* (Raffles, 1822)**
Crimson Sunbird
Figure 5L

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Bans; 29.6161°N, 80.1446°E; alt. 1178 m a.s.l.; 12 May 2015.

Family Motacillidae

***Motacilla maderaspatensis* J.F. Gmelin, 1789**
White-browed Wagtail
Figure 6A

Observations. INDIA • Uttarakhand; Pithoragarh district. Gangolihat block; Kuntola; 29.6411°N, 79.9720°E; alt. 629 m a.s.l.; 18 Nov. 2013 • Bin block; Jajurauli; 29.6279°N, 80.1229°E; alt. 631 m a.s.l.; 11 Apr. 2016

Family Fringillidae

***Carpodacus rodochroa* (Vigors, 1831)**
Pink-browed Rosefinch
Figure 6B

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6594°N, 80.0269°E; alt. 1710 m a.s.l.; 24 Nov. 2013 • Bin block; Bans; 29.6105°N, 80.1514°E; alt. 1534 m a.s.l.; 15 Dec. 2015 • Nakot; 29.6052°N, 80.1784°E; alt. 1753 m a.s.l.; 26 Dec. 2015.

***Procarduelis nipalensis* (Hodgson, 1836)**
Dark-breasted Rosefinch
Figure 6C

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Gurura; 29.6121°N 80.1790°E; alt. 1633 m a.s.l.; 5 Feb. 2015 • Nakot; 29.6052°N, 80.1784°E; alt. 1753 m a.s.l.; 7 Dec. 2015 • Bans; 29.6105°N, 80.1514°E; alt. 1534 m a.s.l.; 15 Dec. 2015.

Family Emberizidae

***Emberiza lathami* (Gray, JE, 1831)**
Crested Bunting
Figure 6D

Observations. INDIA • Uttarakhand; Pithoragarh district; Munakot block; Majirkanda; 29.5806°N, 80.3655°E; alt. 1330 m a.s.l.; 3 Apr. 2014 • Munakot; 29.5651°N, 80.2892°E; alt. 1499 m a.s.l.; 8 Apr. 2014 • Bin block; Bans; 29.6161°N, 80.1478°E; alt. 1300 m a.s.l.; 3 Feb. 2015 • Jajurauli; 29.6159°N, 80.1347°E; alt. 1082 m a.s.l.; 27 Jan. 2016.

Family Cisticolidae

***Orthotomus sutorius* (Pennant, 1769)**
Common Tailorbird
Figure 6E

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Kuntola; 29.6329°N, 79.9841°E; alt.786 m a.s.l.; 18 Nov. 2013 • Bin block; Jajurauli; 29.6192°N, 80.1249°E; alt. 970 m a.s.l.; 12 Feb. 2016.

***Erythrogenys erythrogenys* (Vigors, 1831)**
Rusty-cheeked Scimitar Babbler
Figure 6F

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6591°N, 80.0292°E; alt. 1710 m a.s.l.; 29 Oct. 2013 • Pali; 29.6554°N, 80.0862°E; alt. 1270 m a.s.l.; 6 Mar. 2014 • Munakot block; Majirkanda; 29.5852°N, 80.3475°E; 1450 m a.s.l.; 3 Apr. 2014 • Munakot; 29.5615°N 80.2948°E; alt. 1470 m a.s.l.; 8 Apr. 2014 • Bin block; Bans; 29.6228, 80.1391; alt. 990 m a.s.l.; 14 Apr. 2014 • Nakot; 29.6082°N, 80.17764°E; alt. 1690 m a.s.l.; 12 Mar. 2016.

Figure 6. Birds recorded from the KSL-India (Pithoragarh district). **A.** *Motacilla maderaspatensis.* **B.** *Carpodacus rodochroa.* **C.** *Procarduelis nipalensis.* **D.** *Emberiza lathami.* **E.** *Orthotomus sutorius.* **F.** *Erythrogenys erythrogenys.* **G.** *Cyanoderma pyrrhops.* **H.** *Actinodura cyanouroptera.* **I.** *Tichodroma muraria.* **J.** *Sturnia malabarica.* **K.** *Saroglossa spiloptera.* **L.** *Cyornis rubeculoides.*

Family Timaliidae

Cyanoderma pyrrhops **(Blyth, 1844)**
Black-chinned Babbler
Figure 6G

Observations. INDIA • Uttarakhand; Pithoragarh district; Munakot block; Majirkanda; 29.5806°N, 80.3655°E; alt. 1330 m a.s.l.; 3 Apr. 2014 • Munakot; 29.5585°N, 80.2866°E; alt. 1470 m a.s.l.; 7 Apr. 2014 • Bin block; Bans; 29.6161°N; 80.1478°E; alt 1300 m a.s.l.; 15 Apr. 2014 • Nakot; 29.6091°N, 80.1771°E; alt. 1680 m a.s.l.; 15 Apr. 2015 • Jajurauli; 29.6192°N, 80.1249°E; alt. 970 m a.s.l.; 12 Feb. 2016.

Family Leiothrichidae

Actinodura cyanouroptera **(Hodgson, 1837)**
Blue-winged Minla
Figure 6H

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Nakot; 29.6052°N, 80.1784°E; alt. 1753 m a.s.l.; 7 Dec. 2015.

Family Sittidae

Tichodroma muraria **(Linnaeus, 1766)**
Wallcreeper
Figure 6I

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Kuntola; 29.6411°N, 79.9720°E; alt. 629 m a.s.l.; 18 Nov. 2013 • Bin block; Pithoragarh; 29.5692°N, 80.2071°E; alt. 1561 m a.s.l.; 22 Feb. 2014 • Bans; 29.6142°N, 80.1424°E; alt. 1278 m a.s.l.; 16 Feb. 2016.

Family Sturnidae

Sturnia malabarica **(J.F. Gmelin, 1789)**
Chestnut-tailed Starling
Figure 6J

Observations. INDIA • Uttarakhand; Pithoragarh district; Munakot block; Jhulaghat; 29.5747°N, 80.3798°E; alt. 620 m a.s.l.; 8 Apr. 2016.

Identification. It has grey head and upperparts with whitish forehead and throat, and yellow bill with bluish base.

Saroglossa spiloptera **(Vigors, 1831)**
Spot-winged Starling
Figure 6K

Observations. INDIA • Uttarakhand; Pithoragarh district; Munakot block; Jhulaghat; 29.5747°N, 80.3798°E; alt. 620 m a.s.l.; 8 Apr. 2016.

Family Muscicapidae

Cyornis rubeculoides **(Vigors, 1831)**
Blue-throated Flycatcher
Figure 6L

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin Block; Gurura; 29.6204°N, 80.1807°E; alt. 1701 m a.s.l.; 12 May 2016.

Enicurus scouleri **Vigors, 1832**
Little Forktail
Figure 7A

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Pithoragarh; 29.5869°N, 80.2675°E; alt. 1647 m a.s.l.; 25 May 2015.

Monticola cinclorhyncha **(Vigors, 1831)**
Blue-capped Rock-thrush
Figure 7B

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat; Pali; 29.6539°N, 80.0912°E; alt. 1398 m a.s.l.; 7 Mar. 2014 • Boyal; 29.6360°N 80.1092°E; alt. 1020 m a.s.l.; 10 Mar. 2014 • Bin block, Pithoragarh; 29.6239°N, 80.2148°E; alt. 1794 m a.s.l.; 14 May 2015 • Jajurauli; 29.6192°N, 80.1249°E; alt. 970 m a.s.l.; 12 Feb. 2016.

Ficedula superciliaris **(Jerdon, 1840)**
Ultramarine Flycatcher
Figure 7C

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Gurura; 29.6237°N, 80.1826°E; Alt. 1856 m a.s.l.; 5 Feb 2015 • Jajurauli; 29.6177°N, 80.1331°E; alt. 1036 m a.s,l.; 11 May. 2015 • Nakot; 29.6047°N, 80.1783°E; alt. 1767 m a.s.l.; 24 Feb. 2016 • Bans; 29.6037°N, 80.1439°E; alt. 1536 m a.s.l.; 13 May 2016.

Ficedula tricolor **(Hodgson, 1845)**
Slaty-blue Flycatcher
Figure 7D

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Pali; 29.6539°N, 80.0912°E; alt. 1398 m a.s.l.; 7 Mar. 2014 • Bin block; Bans; 29.6161°N; 80.1478°E; alt 1300 m a.s.l.; 15 Apr. 2014 • Gurura; 29.6237°N, 80.1826°E; Alt. 1856 m a.s.l.; 5 Feb 2015 • Jajurauli; 2014 29.6177°N, 80.1331°E; alt. 1036 m a.s,l.; 11 May. 2015.

Saxicola caprata **(Linnaeus, 1766)**
Pied Bushchat
Figure 7E

Observations. INDIA • Uttarakhand; Pithoragarh district; Bin block; Jajurauli; 2014 29.6177°N, 80.1331°E; alt. 1036 m a.s,l.; 11 May. 2015 • Bans; 29.6042°N, 80.1417°E; alt. 1512 m a.s.l.; 28 Apr. 2016 • Munakot block; Jhulaghat; 29.5747°N, 80.3798°E; alt. 620 m a.s.l.; 8 Apr. 2016.

Saxicola maurus **(Pallas, 1773)**
Siberian Stonechat

Observations. INDIA • Uttarakhand; Pithoragarh district; Gangolihat block; Lali; 29.6585°N 80.0274°E; alt. 1720 m a.s.l.; 16 Nov. 2013 • Pali; 29.6595°N 80.0861°E; alt.1350 m asl.; 7 Mar. 2014 • Patal-bhuvaneshwar; 29.6865°N, 80.0907°E; alt. 1700 m a.s.l.; 10 Mar. 2015 • Bin block; Jajurauli; 29.6167°N, 80.1329°E; alt. 1069 m a.s.l.; 27 Nov. 2015 • Nakot; 29.6052°N, 80.1784°E; alt. 1753 m a.s.l.; 7 Dec. 2015 • Bans; 29.6105°N, 80.1514°E; alt. 1534 m a.s.l.; 15 Dec. 2015.

Discussion

Earlier studies in the landscape by Tak (1995), and Sultana and Khan (2000) reported 82 and 162 species, respectively. Subsequent studies by Tak and Sati (2006) and an eBird compilation (until July 2020) listed 212 and 364 species, respectively, from Pithoragarh district, Uttarakhand. In comparison, our study recorded 205 species exclusively from the lower reaches of the landscape, highlighting the rich avifaun in the matrices of the landscape, as compared to previous studies which included a wider altitude range (Tak 1995; Sultana and Khan 2000;

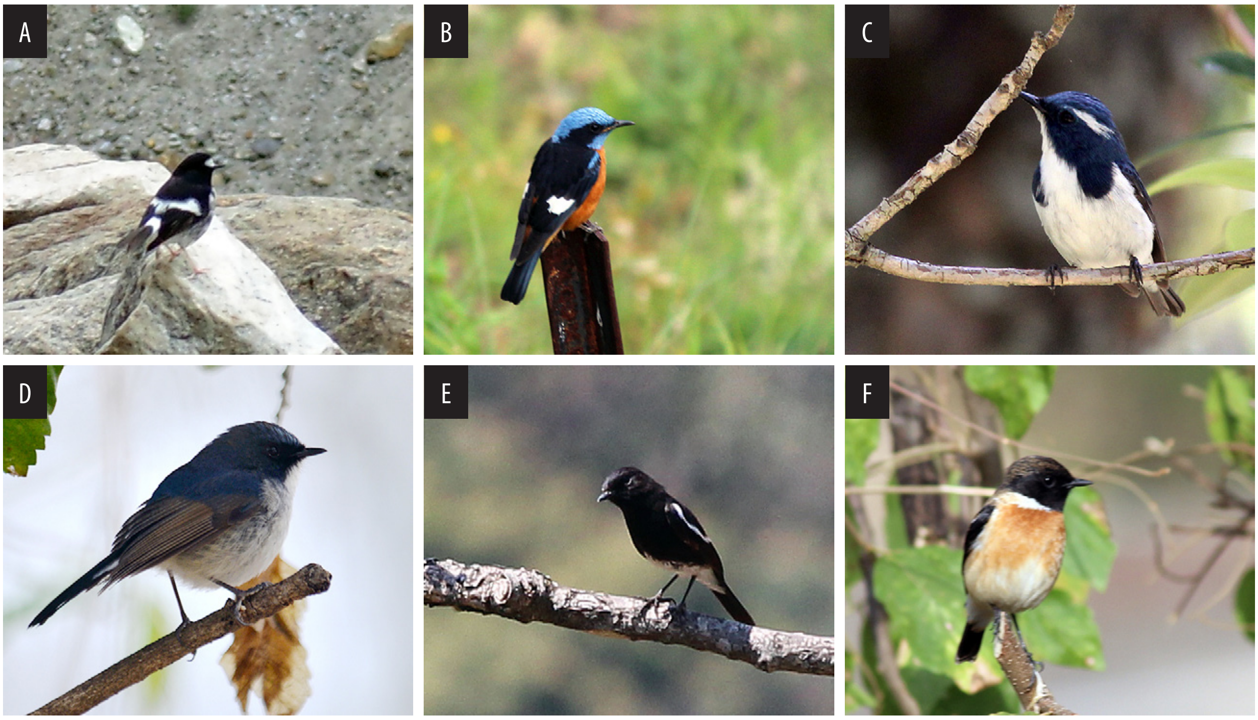

Figure 7. Birds recorded from the KSL-India (Pithoragarh district). **A.** *Enicurus scouleri.* **B.** *Monticola cinclorhyncha.* **C.** *Ficedula superciliaris.* **D.** *Ficedula tricolor.* **E.** *Saxicola caprata.* **F.** *Saxicola maurus.*

Tak and Sati 2006). Due to seasonality and the wide elevation range of the Himalaya, several species migrate from higher to lower elevation areas and vice versa to achieve suitable habitat and food during fluctuations in temperature and other climatic conditions (Grimmett et al. 1998; Naithani and Bhatt 2010). We documented 63 migratory species, including winter, summer, and passage migrants. Our study area lies between the mid- to low-elevation ranges of the Himalaya, which supports winter migrants as well as summer migrants (Dixit et al. 2016).

Species such as *Spilopelia chinensis*, *Psilopogon virens*, *Psittacula himlayana*, *Urocissa erythrorhyncha*, *Corvus macrorhynchos*, *Pycnonotus leucogenys*, *Phylloscopus xanthoschistos*, and *Trochalopteron lineatum* are abundant and were mostly seen in agricultural lands and forest edges. All these species are resident in the study area and in nearby open agricultural lands; hence, the chances of encountering these species are higher. *Aquila nipalensis* and *Neophron percnopterus* were mostly observed soaring over agriculture lands, valleys, and open forests, or sometimes roosting near a garbage dump site, but *Chloris spinoides*, *Dicrurus leucophaeus*, *Lanius schach*, *Phylloscopus humei*, and *Eumyias thalassinus* were mainly recorded from the agricultural lands and forest edges. *Phylloscopus chloronotus*, *Arborophila torqueola*, and *Lophura leucomelanos* are also common, but they were mostly recorded from the forest interior or at forest edges.

Two species were first records from the Pithoragarh district. Both are water-dependent and rare in the study area. Three individuals of *Anas crecca* were recorded from the Ramganga River in winter. This species is a widespread winter visitor in India and mostly found in fresh and brackish water. These three individuals may have taken a brief stopover while migrating towards a large water body, because the birds were not present the next day in the same area. *Anas crecca* was previously recorded by Mohan et al. (2016), Saini et al. (2017), and Sinha et al. (2019) in the Himalayan foothills of Dehradun, Haridwar, and Rudraprayag, respectively, nearly 200 km west from our study area. The second species which was newly recorded from Pithoragarh district is *Amaurornis phoenicurus*, a resident species which is widely distributed in the Indian plains and mostly found near bodies of fresh water. We recorded it near streams in agricultural land. This species was previously reported from Dehradun district, in the Himalaya foothills, by Kumar and Kumar (2009) and Mohan et al. (2016) (200 km west of our study area) and about 130 km west in Garhwal Himalayas by Kukreti and Bhatt (2014). Most recently, it has also been recorded in the Terai arc region by Ahmed et al. (2019) from Nainital district, nearly 100 km south-west from the present record.

Our records of the avifauna come from underexplored field sites in community-managed land in Pithoragarh district, in contrast to the better-known upper reaches of the landscape. This could account for previous studies not finding the two species that were newly recorded by us. However, another possible reason could be that these species have expanded their range due to habitat conversion and climate change (Forero-Medina et al. 2011).

The presence of 11 globally threatened species (IUCN 2020), six Schedule I species under the Indian Wildlife (Protection) Act, 81 Himalayan endemic species (Birds of the World 2020), and a high percentage (nearly 30%)

of migratory species, indicate that the community-managed lands has a rich avifauna. This highlights the importance of niche requirements in the landscape matrix for transient and permanent resident bird species, despite the constant human presence. Detailed information on avifaunal community assemblages within these matrices in the western Himalaya are limited, and further exploration is needed, both qualitatively and quantitatively.

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Authors' Contributions

SKA: Field methodology, Formal analysis, Data Curation, Writing - original draft, Writing - review & editing. GVG: Conceptualization, Writing - review & editing, Supervision.

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List of conferences

1. Participated in National seminar on “Researches in Environment and Biosciences: Current Scenario and Future Perspectives” held in Department of Zoology, D.A.V. (P.G) College, Dehradun on 22 – 23 June 2018, and Paper presented on the title “**Birds of community managed lands in Kailash Sacred Landscape – India**”.

2. Participated in National workshop on Sensitization Program on “Recent Technique of Water Conservation with Special Reference to Uttarakhand State” held in Haridwar on 28th December 2019, and paper presented on the title “**Riverine Birds as Indicator of Water Quality – A Case Study in Pithoragarh District**”.

REB-2018

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NATIONAL SEMINAR
ON
Researches in Environment and Biosciences: Current Scenario and Future Perspectives

Organized by: Department of Zoology, D.A.V. (P.G.) College, Dehradun, Uttarakhand
In Association with: Indian Academy of Environmental Sciences (IAES), Haridwar
Sponsored by: ***Uttarakhand State Council for Science and Technology (UCOST), Dehradun and Uttarakhand Science Education and Research Centre (USERC), Dehradun***

22 - 23 June, 2018

Certificate of Participation

This is to certify that ~~Prof./Dr.~~/Mr./~~Ms.~~ SUMIT KUMAR ARYA

from WII, DEHRADUN

participated in the National Seminar. He/She has chaired/ co-chaired a session/ delivered an invited lecture/ made an oral/ poster presentations entitled "Birds of community managed lands in Kailash Sacred Landscape - India"

Prof. B.D. Joshi	*Dr. Pushpendra Kr. Sharma*	*Dr. Vivek Kumar Tyagi*
President, IAES	**Convener**	**Organising Secretary**

S. M. J. N. (P.G.) COLLEGE, HARIDWAR

उत्तराखण्ड शासन

NATIONAL WORKSHOP ON

Reg. No. NW/ENV/83

"SENSITIZATION PROGRAM ON RECENT TECHNIQUES OF WATER CONSERVATION WITH SPECIAL REFERENCE TO UTTARAKHAND STATE"

This is to certify that ~~Prof.~~ / ~~Dr.~~ / Mr. / ~~Ms.~~ SUMIT KUMAR ARYA

From WII - DEHRADUN

actively participated in the scientific deliberations and also delivered invited ~~lecture~~ / presented ✓ a paper / ~~poster~~ on the topic entitled "RIVERINE BIRDS AS INDICATOR OF WATER QUALITY - A CASE STUDY IN PITHORAGARH DISTRICT" in the session II

of the National Workshop held at S. M. J. N. (PG) College, Haridwar on 28th December, 2019.

Shri Mahant Ravindra Puri Secretary, College Management Committee S.M.J.N (PG) College, Haridwar	**Dr. Vijay Sharma** Organizing Secretary, National Workshop District Coordinator, USERC	**Dr. Sanjay Maheshwari** Convener, National Workshop S.M.J.N. (PG) College, Haridwar	**Dr. Sunil Kumar Batra** Principal S.M.J.N. (PG) College, Haridwar