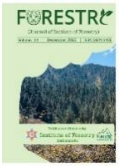
FORESTRY
(Journal of Institute of Forestry, Nepal)
Journal homepage: www.nepjol.info/index.php/forestry



Original research article

Diversity and factors affecting habitat utilization of birds in Lumbini Sacred Garden, Nepal

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A R T I C L E I N F O

Keywords:
Bird conservation
Bird diversity
Farmlands
Habitat utilization
Threats

A B S T R A C T

Lumbini in Rupandehi District in southern Nepal is not only a culturally significant site but also rich in biodiversity with diverse habitats such as wetlands, forests and farmlands. It lies along the Central Asian Flyway, which makes it an important stopover for many resident and migratory bird species. The study was conducted in the Lumbini Sacred Garden (LSG) of Rupandehi District, to explore the bird diversity and habitat utilization. For the bird survey, the point count method was used. Altogether 994 individuals belonging to 111 species, representing 15 orders and 41 families, were recorded, in which 79 species were resident and 32 were winter visitor. Passeriformes (48 species) were found to be the dominant order. The Shannon diversity index in LSG was 3.686, whereas the Simpson diversity index was 0.9721, and the evenness value was 0.8867. The habitat utilization rate was higher, with the utilization rate of 0.46, than in grassland and wetland. Carnivores did not show significant relationship with the habitat type, whereas frugivores were associated with forest, herbivores were strongly associated with wetlands, insectivores and omnivores showed significant relationship with forest and grassland habitats. Feeding guild of the species also drives the habitat utilization pattern of the avifauna. The presence of people and livestock had a significant effect on the diversity and abundance of birds. This study suggests that humans are the key factors for degrading the habitat, which negatively impacts the distribution, diversity and abundance of birds in the reservoirs, which helps to develop climate change mitigation strategies and sustainable forest management policies.

INTRODUCTION

Nepal's biodiversity is well reflected by the country's high number of bird species. So far, 892 species of birds have been recorded in Nepal, which is about 8.87% of the total bird species found worldwide (DNPWC, 2022). Among them, 42 species are globally threatened, 35 globally near threatened and one endemic species (DNPWC, 2022). Furthermore, 172 species are nationally threatened, 68 Critically Endangered species, 38 Endangered species and 66 Vulnerable species (Inskipp et al., 2017). Nine bird species are Nationally Protected according to the National Parks and Wildlife Conservation Act 1973 (DNPWC, 1973) and 113 birds are enlisted in the Convention on International Trade in Endangered Species of Wild Fauna and Flora or the CITES category (DNPWC, 2022). Birds prefer different habitat types for various purposes. In the context of Nepal, 53% of the country's nationally threatened birds inhabit in forests, 27% in wetlands, 15% in grasslands, 8% in cultivated lands, 5% in shrubs, 9% in open canopies, 3% near human habitations, and 1% in semi-desert areas (Inskipp et al., 2013). Birds select their habitats based on protection, arrays of foraging opportunities and nesting sites. The availability of food and suitable cover and nesting sites, adaptation and tolerance level of species, degree of threat or prey vulnerability are the factors influencing habitat preference by birds (Girma et al., 2017). Vegetation structure, floristic composition as

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doi: https://doi.org/10.3126/forestry.v22i1.83379
Received:23 Sept 2025; Revised in received form:25 Nov 2025 Accepted: 8 Dec 2025

well as vegetation cover for nesting or shelter are also determinants for habitat selection for birds (Jones, 2001).

Among all the species present on this earth, birds are one of the most sensitive species that show quick response towards habitat change. The diversity of birds and their presence provide strong bioindication signals (Sekercioglu, 2006; Urfi, 2011). Birds are one of the indicators of environmental health (Bilgrami, 1995; Burel et al., 1998; Robledano et al., 2010), and they provide various ecosystem services, like seed dispersal, scavenging, controlling pest population and enhancing habitat quality (Sekercioglu, 2006; Aynalem & Bekele, 2008; Seymour & Simmons, 2008).

Habitat loss, fragmentation and degradation are the major threats to avifauna (Inskipp et al., 2017). Illegal trade, secondary poisoning, overfishing, food scarcity, overgrazing and use of pesticides, domestic pollution, industrial discharges and agricultural runoff are seriously degrading the habitats of birds in Nepal and posing serious threats to them (Inskipp et al., 2016). Farming practices, such as loss of crop diversity, destruction of grasslands, and excessive use of pesticides and fertilizers, have led to the degradation of agricultural and semi-natural habitats and are also causing decline in biodiversity across huge areas (Inskipp et al., 2013).

The use of natural habitats by birds was the primary focus of most of the earlier research. Since the effects of urbanization are now evident, a lot of research is being done on how urban environments affect birds. However, semi-urban areas, such as the Lumbini Sacred Garden (LSG), are usually overlooked. Despite its small area and nearby human settlements, diverse bird species can be found in the LMPA. LSG includes many ponds inside its boundary; so, this area offers a good habitat for resident bird species. Therefore, before introducing any changes inside this area, the LSG management must be aware of their probable impacts on these birds. Hence, this study focuses on how diverse the LSG is, how birds are using this area and what major factors are affecting the habitat utilization by birds in this area.

MATERIALS AND METHODS

Study area

The study was conducted in Lumbini Sacred GardenLSG (27.462°N, 83.276°E to 27.506°N, 83.277°E), Lumbini Sanskritik Municipality of Rupandehi District of Lumbini Province, Nepal (Figure 1). It lies in an elevation of 100 m asl. (Rupakheti et al., 2017). The garden area of Lumbini consists of an area of 770 hectares. It was declared as the world cultural heritage site by United Nations Educational, Scientific and Cultural Organization (UNESCO)in 1997. The climate of this region is tropical type. The temperature is highest on average in May, at around 36.4 minimum temperature on average in January is around 8.8°C in cold winter. The most precipitation falls in July with an average of 545.6 mm. The least rainfall occurs in November with an average rainfall of 8.2 mm (BMFD, 2020).

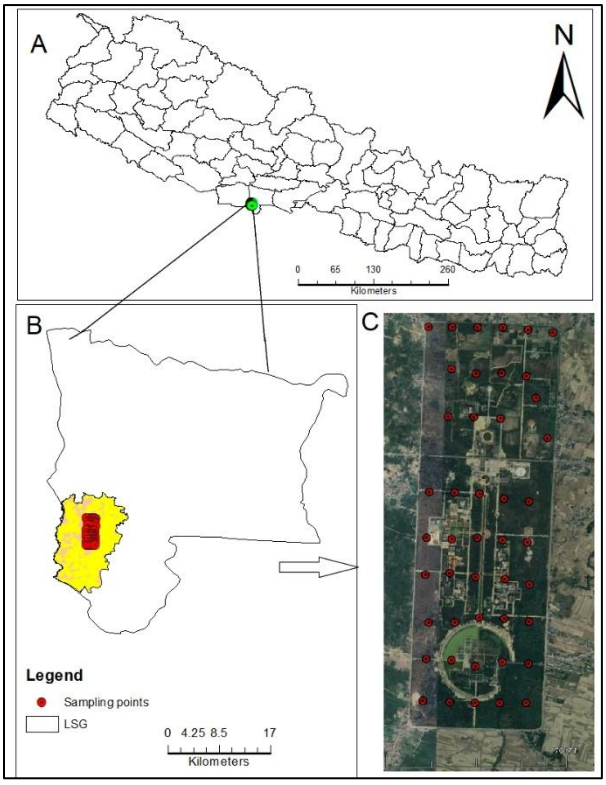

Figure 1: Location map of study area (A- Country, B- Location of Rupandehi in map of Nepal, C-Google earth satellite view of (LSG); Sampling points are the GPS points set to survey the birds)

The study area consists of different types of habitat, like forest, grassland and wetland. A total of 355 species belonging to 75 families and 245 genera of plants were documented in the LSG and adjoining areas, including the tropical forest. The major vegetation types are Sal (*Shorea robusta*), North Indian rosewood (*Dalbergia sisso*), Indian Oak (*Tectona grandis*), and Black cutch (*Acacia catechu*) and some fruiting trees, like Burflower tree (*Neolamarckia cadamba*) and Indian jujube (*Zigyphus mauritiana*). The grassland of this region comprises Sabai grass (*Eulaliopsis binate*) and Cogongrass (*Imperata cylindrica*) (Siwakoti, 2008). Fauna consists of Nilgai (*Boselaphus tragocamelus*), wild boar (*Sus scrofa*), Jungle cat (*Felis chaus*), and more than 100 species of birds. Sarus crane (*Antigone antigone)* is one of the protected breeding species in the LSG (Baral, 2018).

LSG is mostly surrounded by agricultural land and some built-up areas. Tharu and Madhesi are the major ethnic groups living around the LSG, and these groups cultivate paddy (*Oryza sativa*), wheat (*Triticum* spp.), potato (*Solanum tubersome*), and sugarcane (*Saccharum officinarum*). Livestock rearing is practised on a small scale and forms an important component of the agricultural system (Baral, 2018).

In January 2021, a bird survey was carried out by the point count method (Bibby, 2000; Waltert, Mardiastuti, & Mühlenberg, 2004). We first selected a random point at an edge of the LSG and used it to deploy a 1.5 km-long transect inwards (east–west) with the help of ArcGIS 10.5. Taking this transect as reference, we deployed nine transects running parallel and 500 m

apart from each other. Along each transect, we put point count stations at every 300 m. This yielded total five point count sites in each transect and total 45-point count stations. A few point count stations happened to lie in unreachable areas, like temples and ponds; therefore, we used the nearest reachable area from that point for the survey. The Garmin eTrex 10 GPS device was used to locate each point count station.

We recorded birds in point count stations from 7:00 to 11:00 am and 14:00 to 17:00, pm as birds are usually active in the morning and evening (Robbins, 1981), when the weather generally is most suitable for foraging. We, first, set an imaginary circle of radius 50 m from the set coordinates and recorded all the birds seen within the circle for 20 minutes (Wilcox & Beck, 2007). High-flying birds crossing the points were ignored. We used binoculars (Bushnell 20×50) to scan the birds inside the set circle. Birds were photographed with a digital camera (Nikon 900, 83X optical zoom). Later, these photographs were used for comparing with field guide images and identifying the birds (Grimmett et al., 2010).

Habitat types were classified by visual estimation, based on key habitat features such as eg grassland, forest, shrubland, wetland, farmland, etc). The comparative diversity indices of Avifauna were noted in different habitats.

Data analysis

We calculated diversity indices (Shannon-Weiner index and Simpson's index) for the bird diversity as follows:

$$Shannon\ -Weiner\ Diversity\ index\ (H) = -\sum p_i . \ln\ p_i$$

$$Simpson's\ Index\ of\ Diversity\ (D) = 1 - \sum p_i^2$$

The habitat utilization rates of birds of all habitat types were calculated as (Zhao et al. 2013)

Ui=Ni/N

Where Ui is the utilization rate of the specific habitat type by birds, Ni is the number of individuals of birds in the specific habitat type and N is the total number individuals of birds in all habitat types.

We performed Generalized Linear Model (GLM) to test the species response to different habitat types and disturbance variables. The GLMs were fitted with normal distribution and identity link functions. Since the Canonical Correspondence Analysis (CCA) gives better insights into the community response to environmental variables, we further used CCA. Before conducting CCA, Detrended Correspondence Analysis (DCA) was employed to evaluate the appropriate test (Correa-Metrio et al., 2014). Ordination plots were drawn using CANOCO v4 (Ter Braak & Smilauer, 1998). Monte Carlo permutation test was carried out by using 499 permutations, and the result was presented in the form of a biplot. Feeding guilds were classified based on the food habits of the birds as mentioned in Inskipp et al. (2016), and bird species profiles of the Birdlife International database (https://datazone.birdlife.org/). In the analysis, the guild was excluded if there were fewer than three species because of the lower statistical power (Weiher, Clarke, & Keddy, 1998).

RESULTS

Species richness and composition of birds

A total of 994 individuals from 111 species representing 15 orders and 41 families were observed, with 79 species resident and 32 species winter visitors. Passeriformes were found to be dominant over other orders, accounting for 48 species (Figure 2). Lesser Whistling-duck (83) was the most common species, followed by Jungle babbler (74).

Total four globally endangered (IUCN Red List) species, which constitute 4.4% of the total species found in the study area, and 4 species of the Near Threatened category were recorded (Appendix 2). Among them, 8 were Nationally Threatened species. Only White-rumped vulture (*Gyps bengalensis*) was Critically Endangered species, both nationally and globally. In the context of feeding guilds, insectivores (34) constituted the highest number, followed by carnivores (33), whereas nectarivores constituted the lowest number (1) (Figure 3).

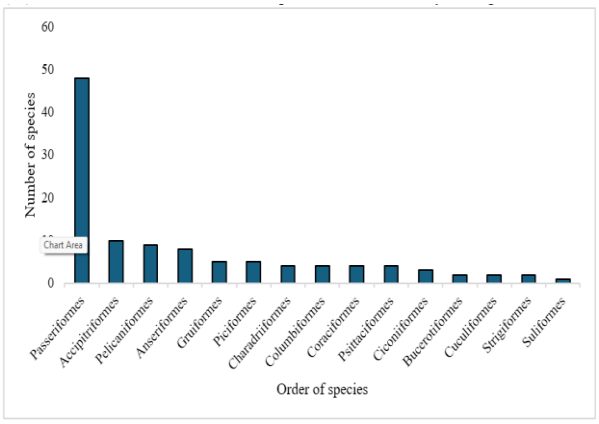

Figure 1: Order-wise species richness of birds

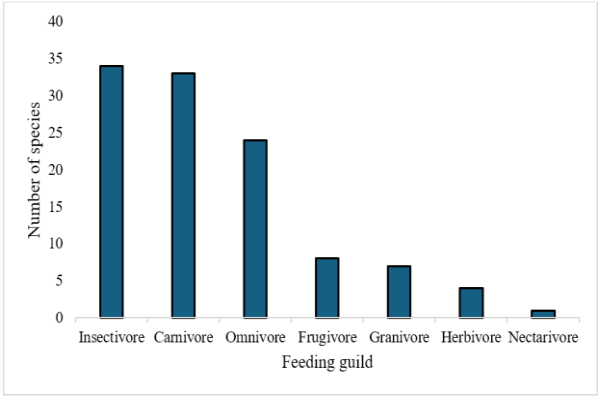

Figure 2: Feeding guild-wise species richness of birds

Avian diversity in different habitats

The diversity indices (Shannon and Simpson) were highest in grassland, followed by forest, and least in wetland habitats (Table 1). However, the evenness of species was found to be highest in wetland habitat. The highest habitat utilization rate was found in forests

(0.46) with 21 sampling sites, followed by grassland (0.30) with 21 sampling points, and the lowest in wetlands (0.24) with 3 sampling.

Table 1: Diversity indices in different habitat types

	Species richness		
Diversity indices	**Forest**	**Grassland**	**Wetland**
Dominance_D	0.05826	0.05671	0.3488
Simpson_1-D	0.9417	0.9433	0.6512
Shannon_H	2.935	2.949	1.074
Evenness_e^H/S	0.8962	0.9087	0.9756

Species richness in relation to different habitats and disturbance variables

To the disturbance variables, the GLM showed that the presence of people and presence of livestock around the habitat negatively affect the species richness of birds ($p<0.05$). Distance to road, however, showed no effect on the species richness of birds

There were 24 species found in forest, 31 in open grassland and forest, 28 in open grassland only, 23 in wetlands, 4 in open wooded grassland and wetland, and one in both forest and wetland. Because a single species can live in a variety of environments, these habitats are chosen based on its needs.

Feeding guild composition in relation to habitat types

The feeding guild composition of the species was investigated for three habitat types: forest, grassland, and wetland. The Monte-Carlo permutation test of significance for all canonical axes demonstrated a significant preference of herbivorous species (Trace=1.134, F-ratio=2.194, P=0.010) for various habitat types (Figure 5). Wetlands were known to be home to herbivorous animals. Similarly, frugivorous individuals showed a significant preference (Trace=0.589, F-ratio=2.592, P=0.0080) for various habitat types (Figure 5). Frugivores were mostly associated with woodlands. Insectivore (Trace=0.259, F-ratio=1.649, P=0.05) and omnivorous species (Trace=1.313, F-ratio=3.228, P=0.0020) (Figure 8) were significantly associated with various habitat types. Insectivores and omnivores were associated to forests and grasslands. However, the Monte-Carlo permutation test of significance for all canonical axes revealed no significant association between carnivorous species (Trace=0.265, F-ratio=1.886, P=0.096) and habitat types (Figure 5). Nectarivore was excluded as it consists of only one species which is not sufficient for statistical analysis.

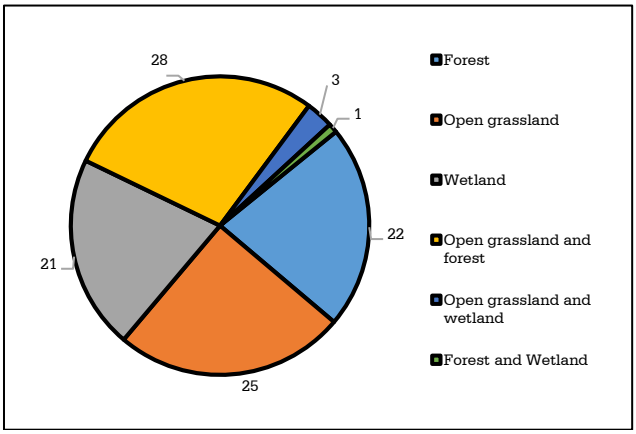

Figure 3: Habitats used by bird species

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Table 2: Generalized Linear Model showing species' response to different habitat types and disturbance variables

Variables	**Habitat types**			**Disturbance variables**		
	Forest	**Open grassland**	**Wetland**	**Distance to road**	**Number of people**	**Number of livestock grazing**
Intercept (b)	7.0417	8.125	7.0417	6.867	6.266	7.809
Slope (a)	0.19643	-2.125	7.7143	0.0078531	0.20744	-0.155
P-value	0.85852	*0.043*	*0.000003*	0.59117	***0.010367***	***0.025***

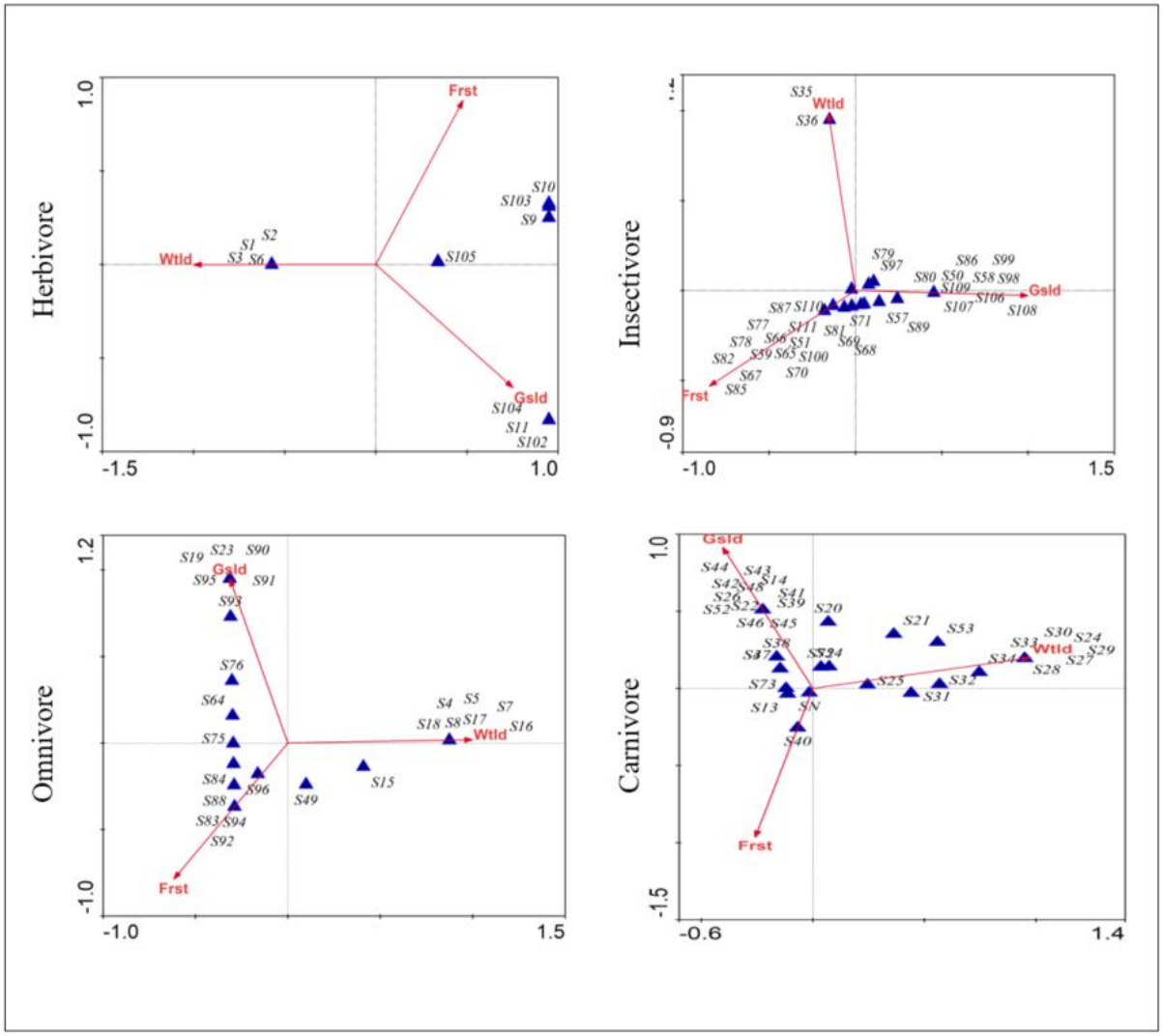

Figure 5: CCA diagram (biplot) showing different feeding guild's species response to habitat types (Frst=Forest, Gsld=Grassland, Wtld=Wetland)

The CCA diagram showed that bird diversity was more influenced by the Number of livestock grazing (NoL) and Number of people presence (NoP) and less influenced by the Distance to nearest road (DR). There was a strong correlation between the species–disturbance variables. The Monte Carlo permutation test of significance of all the canonical axes showed a negative significant relation between the species–disturbances variables (Trace = 1.310, F-ratio = 1.364, P = 0.0240). Among the species, Black-throated Thrush (*Turdus atrogularis*) and Indian Cuckoo-shrike (*Coracina macei*), were more tolerant to distance to human trails and less tolerant towards number of people. The maximum abundance of species such as Cattle Egret (*Bubulcus ibis*), White-throated Kingfisher (*Halcyon smyrnensis*) and Common Pigeon (*Columba livia*) showed more tolerance to number of livestock grazing, whereas White Wagtail (*Motacilla alba*) and White-browed Wagtail (*Motacilla maderaspatensis*) showed more tolerance to number of people. Among all the variables, the association of maximum abundance of species was higher with distance to human trail.

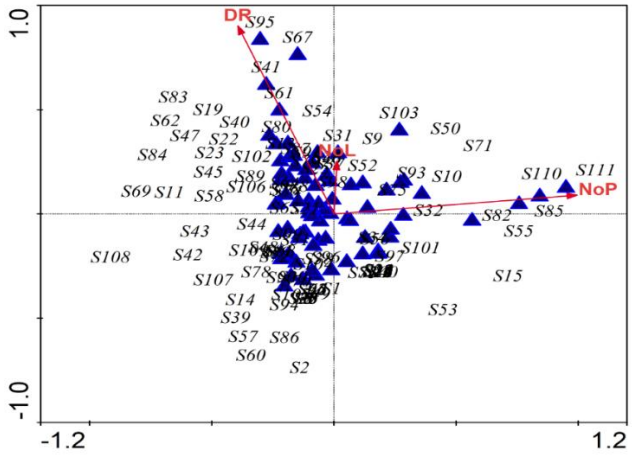

Figure 6: CCA diagram (biplot) showing species response to different disturbance variables (NoP= Number of people, NoL= Number of livestock grazing, DR= Distance to nearest road)

DISCUSSION

Bird diversity

Despite being a comparatively small area, the study area supported a relatively high number of bird species, suggesting that this site is a hub for avifauna. The Shanon index value (3.686) is high biodiversity in the LSG as this index ranges between 1.5 and 3.5 and rarely exceeds 4.5 (Gaines, 1999). Species richness and evenness both influence diversity indices (Supriatna, 2018). A balanced distribution of species can be expected in that area with such high diversity indices, and this can be attributed to heterogeneity of habitat providing various services like, foraging opportunity, nesting and roosting sites (Basnet et al., 2016).

We found Order Passeriformes to be the most abundant in our study. Passeriformes birds like sparrows, tits, magpie, babblers, crows, etc are gregarious; so, their abundance remains high in habitats, like the LSG (Kiros, Afework, & Legese, 2018; Ghimire et al., 2021; Bhattarai et al., 2024). Among the families, Accipitridae showed the highest species richness (n = 10). Some species of Accipitridae are apex predators and can prey upon various animals, and some species are scavengers. The LSG has a mosaic habitat and offers a lot of prey to hunt down as it has large trees to roost and wide open grasslands. Farmers living near the LSG leave dead animals unburied near small forest areas, which attracts scavengers. Although the site harbours a variety of species, their abundance is low, which may be related to the limited food resources, as well as the cutting and harvesting of tall grasses disrupting the nesting sites for many birds, and fire causing the death of incubating eggs and newly hatched babies (Baral, 2001). The Lesser Whistling-duck (*Dendrocygna javanica*) was the most common species (8.35%), probably because it is sedentary and sociable and tends to live in groups (Zakaria et al., 2020). The Jungle Babbler (*Turdoides striata*), whose high abundance can be linked to its aggregation behaviour and generalist feeding approach, came next (7.44%) (Anthal & Sahi, 2013). On the other hand, a relatively large number of species were rare, which is a common feature of ecological communities (Gaston, 1994).

Among the most seen species were the Red-vented Bulbul (*Pycnonotus cafer*), Jungle Babbler (Turdoides striata) and Large-billed Crow (*Corvus culminatus*), which demonstrate their adaptability to a range of habitat conditions. Insectivores dominated the community in terms of feeding guilds, which is consistent with previous findings (Jamil et al., 2020; Kumar & Sahu, 2020). Insectivorous species probably have enough food sources due to the large variety of insect groups. Conversely, the foraging guild with the lowest representation was nectarivores. The presence of nectar-producing blooming plants is a major factor in the occurrence of nectarivorous birds. Even though the LSG is home to a large variety of flowering plant species, no notable blossoming was seen during the study period, which took place in the winter. Since floral resources are usually limited in the winter, it is common to see fewer nectarivorous birds during this season (Chatterjee et al., 2018; Katuwal et al., 2018).

Additionally, the number of birds varied depending on the habitat type. The largest bird population (45.57%) was found in the mixed forest. Although certain species were found to share comparable habitats, species diversity differed significantly among habitat types. High-productivity wetlands function as crucial staging and stopover locations, offering vital resting and feeding spaces for successful migration (Ma et al., 2013). While some species, like Psittacula and Pericrocotus species, are frequently found in mixed forest settings, others, like Phylloscopus spp., prefer bushy places within forests. Overall, the availability of food resources and the feeding habits of bird species have a significant impact on their habitat usage patterns.

Jungle Babbler, Large-billed Crow, Red-vented Bulbul and Ashy Drongo utilize all types of habitats. Due to resource partitioning, interspecific competition, as well as adaptation capacity, some species become generalists and have the ability to use different habitat types (Wesolowski & Fuller, 2012). The lowest number of birds were recorded from wetlands as the was a limited number of wetlands. The large number of visitors, the ongoing construction work inside the LSG and frequent movement of vehicles near wetlands must have limited the number of bird species. Despite being highly suitable foraging sites for many species, fewer species have been recorded in similar wetlands (Bajagain et al., 2020; Pradhan, Mishra, & Behera, 2016).

The feeding guild of species also drives the habitat utilization of bird species. There was no significant association of carnivores with habitat types (Panda et al., 2021), except for resource availability (Barbaro et al., 2014; Lakatos et al., 2025). The ordination analysis revealed the significant relationship of frugivore, insectivore, herbivore and omnivore to specific habitats. Grassland supports granivores and carnivores, which can be attributed to the abundance of seed-bearing grasses and small vertebrate prey. Granivores are non-forest species and non-opportunistic to food resources as they have limited dietary plasticity and rely on grasslands for food (Gray et al., 2007). Similarly, carnivorous birds are benefitted by prey detection and capturing efficiency on open grasslands.

Given their need for fruiting and flowering plants for sustenance, frugivores and nectarivores showed high affinity towards forest settings. Forest habitats provide these guilds with nesting and roosting locations, as well as complex vegetation structures that support a steady supply of fruits and nectar. Fruit availability is a major factor in habitat selection and spatial distribution, and it directly affects the richness and abundance of frugivores (Mulwa et al., 2013). Therefore, the diversity of plant species and the phenology of fruiting trees are essential for maintaining frugivore assemblages.

Wetland environments were closely linked to omnivorous and herbivorous species, probably because of the high primary productivity and resource variety characteristics of these systems. Wetlands support both the specialized dietary needs of herbivores and the flexible foraging methods of

omnivores by offering a variety of food resources such as aquatic vegetation, invertebrates and debris (Balwan and Kour, 2021).

In line with their generalist foraging habits, insectivorous species showed a wider preference for habitats. Insectivores make use of a range of microhabitats, such as marshes, shrublands and forest edges, as insect populations change throughout the year (Muller et al., 2024). Overall, the observed pattern highlights how the availability of food resources particular to a given habitat significantly affects the spatial distribution and habitat usage of birds based on their feeding guilds.

The GLM between the habitat types and species richness shows the significant difference between grassland habitat and wetlands. Height, cover and density of grasses are strongly associated for the grassland species with food accessibility (Macías-Duarte et al., 2017). In case of wetland birds, emergent vegetation cover, open water bodies and combined habitat support wetland species (Elliott, Igl, & Johnson, 2020).

Livestock pressure and human disturbances are the major threats to the bird species in the study area. The number of people present in the study area causes a significant difference in the species richness of birds. It shows that when the number of people, both local and tourist, in the habitat decreases, there is an increase in the richness of species. The presence of livestock in the habitat causes a significant decrease in the richness of birds. Adhikari, Bhattarai & Thapa (2019) also described livestock presence and human disturbance as major threats to birds in the Chitwan National Park. Species richness decreased due to the human disturbance factors, like habitat loss, land use change, alien invasion (Murphy & Romanuk, 2014). Collection of fodder, forest products and habitat destruction were the major activities of people causing disturbances to bird species.

CONCLUSION

This study found 111 species of birds (12.44% of total birds of Nepal) inside the LSG within a single season. This area supports significant number of globally threatened and near threatened species as it has a heterogeneous habitat. Human activities are the major threats to these species; therefore, effective conservation activities are needed to protect these species and their associated habitat.

ACKNOWLEDGEMENTS

We are thankful to Dr Hem Sagar Baral for providing his suggestions and support in carrying out this research. We would like to thank Mr Bibek Aryal and Mr Laxman Timalsina for helping us with the fieldwork.

We have not received any financial support to carry out research.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATAREPOSITORY: https://www.scidb.cn/en/s/IfIfeu

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