



Altitudinal Differences of Bird Assemblages, Profusion, and Feeding Guilds in Khunjerab, Lal Suhanra and Hingol National Parks

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ABSTRACT

Studying avian diversity across different altitudes reveals how altitude impacts species distribution and adaptation, informing conservation strategies and ecological knowledge. This study presents a comprehensive analysis of avian species diversity, abundance, and feeding guilds across Khunjerab (KNP), Lal Suhanra (LSNP), and Hingol National Parks (HNP), with different elevations. KNP, LSNP, HNP located in distinct geographical area, were surveyed using point count method between April 2021 and April 2023. Six surveys were conducted at each site for primary data collection. Equipment such as GPS, binoculars, cameras, and field guides facilitated accurate data collection and bird identification. The results revealed that LSNP exhibited the highest species richness with 179 species, followed by HNP with 120 species, and KNP with 51 species. For KNP, LSNP and HNP, the Simpson's Index values are 0.89, 0.92, and 0.91, indicating high diversity within the studied populations. The Shannon-Wiener Index values of 3.46, 4.94, and 4.47 further support this, demonstrating substantial species richness and evenness. With reference to elevation gradient, LSNP has the mid elevation and exhibited the maximum species richness as compared to KNP and HNP. Similarity indices showed a high overlap in species composition between HNP and LSNP, suggesting similar ecological conditions, while KNP showed low similarity with the other parks. According to feeding habits, carnivores were most abundant in LSNP (78) and HNP (63), followed by omnivores whereas omnivores were most prevalent in KNP (20) followed by insectivores. The findings provide a critical baseline for future research and conservation efforts across the elevation gradient.

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Authors' Contribution

KA and ZA conceptualized the study. KA, ZA, RA, UA, ZI and AB collected primary data from field. KA, ZA and RA assembled and analyzed the dataset. KA drafted the manuscript. ZA reviewed and improved the manuscript.

Key words

Avian diversity, Khunjerab, Lal Suhanra, Hingol, National Parks, Feeding guilds

INTRODUCTION

Birds play pivotal role as the biological indicator of an ecosystem and provide invaluable information regarding environmental changes, feeding guilds, species abundance and diversity of an ecosystem (Mekonen, 2017). The key determinants of any bird assemblage or community are their elevation range and heterogeneity of their habitat (Ding *et al.*, 2019). The research reveals the insights of an ecological study that how habitat heterogeneity impacts the bird's diversity, abundance and

feeding guilds within varied altitudinal gradients of Khunjerab, Lal Suhanra, and Hingol National parks in Pakistan considering the complex ecosystem structures. The aspects like composition, structure and function shows significant change fueled by different abiotic and biotic factors (Bisht and Bhat, 2013; Liu *et al.*, 2021; Zhou *et al.*, 2021; Wani and Akash, 2022). Specifically, the topographical attributes like edaphic conditions, slope, elevation and aspect play key part in molding the structures of community and distribution of different species particularly in mountain eco-regions (Gairola *et al.*, 2011; Dar and Sundarapandian, 2016).

The habitat conditions are greatly impacted by the alterations in the topographical regions of an ecosystem as in mountainous areas, coastal and plain areas, as changes in these factors induce change in moisture and temperature of the eco-region (Raulings *et al.*, 2010). Complex environmental conditions impact the local topology by affecting solar radiations, exposure to wind, hydrology and interaction within biotic factors, thereby significantly impacting distribution and richness patterns of the species

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(Moeslund *et al.*, 2013). The afore-mentioned mega-climatic changes along with micro-climatic changes lead towards prominent alterations over spatial scales in terms of species distribution and richness patterns (McCain and Grytnes, 2010).

At the habitat level, the abundance or availability of the species are directly linked with the edaphic gradients, management of habitat and type or structure of vegetation, that directly influence the overall gradient of the habitat by controlling the distribution of endemic and migrant species and the overall composition of the habitat (Khuroo *et al.*, 2011; Somveille *et al.*, 2013). Seasonal climate variations and altitudinal gradients in different topological areas give natural conditions for studying the temporal changes in species in terms of ecological and evolutionary impacts of environmental changes that are described by changes in temperature, altitude and feeding guilds (Barry, 2008; McCain and Grytnes, 2010; McCain and Colwell, 2011). Elevation significantly controls the temperature and precipitation and, therefore, the fauna of the eco-region, which directly impacts the feeding habit, food availability and habitat (Carnicer *et al.*, 2012; Sohail and Sharma, 2020; Kumar *et al.*, 2022).

Besides, feeding guilds, species richness and habitat species associations are used as factors that determine avian diversity and abundance (Lee and Marsden, 2008; Mekonen, 2017). Similar to previous research works conducted in different regions of the world, it has been identified that avian feeding guilds are greatly affected by the habitat heterogeneity (Ding *et al.*, 2019; Panda *et al.*, 2021). Therefore, feeding guilds provide insights and help us understand the avian communities' shifts in response to the changes in the environment (Bhat *et al.*, 2023). Previous researches revealed that feeding guilds are significantly impacted by change in elevation gradient and that some are elevation-specific (Kissling *et al.*, 2012; Bhat *et al.*, 2023).

In this broader ecological framework, this paper aims to discuss the interactions between habitat heterogeneity, avian feeding guilds, and bird species diversity and abundance in the Khunjerab, Lal Suhanra, and Hingol National Parks in Pakistan. Extensive review of literature and ecological research laid the foundation of this comprehensive investigation of how selected national parks are impacted by different ecological parameters like elevation, temperature and vegetation, providing a detailed view of the ecological process and factors involved. The amalgamation of insights from diverse ecological studies sets the stage for a comprehensive exploration of how these national parks respond to varying ecological parameters, offering a nuanced understanding of the ecological dynamics at play in these unique ecosystems.

This research gap is the reason why the present study seeks to investigate avian species diversity and distribution patterns in the selected study sites and further postulate that changes in elevation and the different habitat types affect the species diversity, abundance, and feeding guilds differently. This will also contribute to understanding the factors that impact the ecology, hence fostering avian communities' conservation.

MATERIALS AND METHODS

Study site

The present study was carried out in three distinct national parks of Pakistan which are Khunjerab (KNP), Lal Suhanra (LSNP), and Hingol National Parks (HNP), having different habitat conditions. KNP is situated in Hunza Gilgit-Baltistan, LSNP is in Bahawalpur district of Punjab and HNP is in Awaran, Lasbela and Gwadar districts of Balochistan as shown in Figure 1.

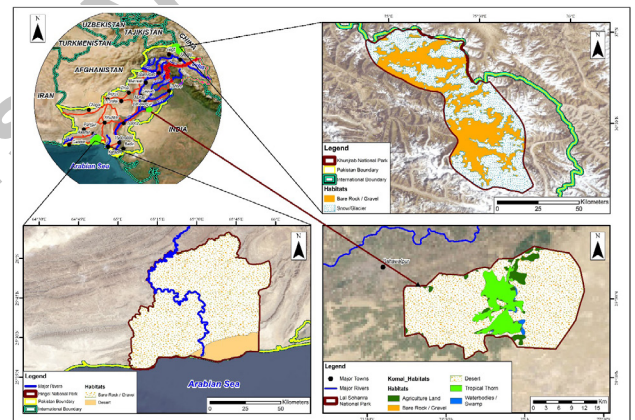


Fig. 1. Study area map showing different habitats of KNP, LSNP and HNP.

Khunjerab National Park (KNP)

KNP is located at Latitude: 36°30'N; Longitude: 75°30'E (ICIMOD, 2020), and stands at the elevation of 3310–7460 meters above sea level (asl) (FWEGB, 2020). KNP was established in 1975 (Qureshi *et al.*, 2011), and it is the third largest national park of Pakistan covering an area of 560,714 acres (226,913 hectares) (ICIMOD, 2020). KNP is known to have cold climate throughout the year with winter temperatures ranging between 2°C -7°C and summers temperatures at between 19°C - 32°C.

Lal Suhanra National Park (LSNP)

LSNP is located at coordinates of 29° 19 N 71° 55 E, and stands at an altitude between 110 and 145 meters asl, covering an area of 162,568 acres (65,789 hectares) and was

established in 1972. It has also been declared as UNESCO Biosphere Reserve. LSNP has a rather different climate: the hottest month is July, with temperature reaching 50°C, while the lowest temperatures are in January, which range between 6 and 10 °C.

Hingol National Park (HNP)

HNP is located at 25° 36'N 65° 40'E and has an altitude ranging between 27m-1500m covering an area of 1,507,343 acres (610,474 hectares). This Park was established in 1988 and is characterized by a hot climate, hot and dry or hot and humid depending on the season. The annual average temperature of HNP varies between 5°C in winter and 34 ° C in summer, and during summer it ranges between 25°C to 50°C (Khan *et al.*, 2010).

Materials/equipment

The tools used in the present study are GPS to record elevation asl latitude and longitude coordinates of the survey and observation points; binoculars were used when observing the birds and surroundings without disturbing the birds; Nikon p-900 camera was used for taking pictures of the birds and the environment and spotting scope was used for close observation of birds.

Identification of the birds both during the fieldwork as well as later on was done with the help of field guides. Firstly, with regards to the specific habitats and locations, the information was gathered using a geographic information system (GIS) where all the important habitats and the preferences of certain species can be found were recorded in order to avoid redundancy of the data while ensuring maximum coverage of the habitat.

Survey methods

The surveys were conducted between April 2021 to April 2023, to cover the numerous habitats involved in the study. Six surveys were conducted at each National Park for primary data collection. Bird census was performed with the point count technique (Bibby *et al.*, 2001). Point count method was used for the estimation of density of a bird species. Bird calls were also noted on the same fixed mid-point within a defined area of one-hundred-meter radius. A digital range finder was used to calculate the 100m radius for observation. The observation period for each point was different due to the habitat where the points were present. In dense forests (tropical), the observation time was 40 min, and for open areas like deserts, snow, and waterbodies, the observation time was 20 min. A Bushnell Falcon 10x50 mm wide-angle binocular was used for observation, along with a Nikon P900 camera for photographic record. Different field guides were used for bird identification, including birds of Pakistan (Roberts, 1991, 1992, 1997), birds of

Pakistan (Grimmett *et al.*, 2008), and the birds of the Indian sub-continent (Grimmett *et al.*, 1998). Birds were observed from dawn (30 min) to 11:30 AM and again from 3:00 to 3:30 PM before sunset, following the methodology of He *et al.* (2019). Surveys were not conducted at midday or during harsh weather due to low bird activity (He *et al.*, 2019).

Habitat types

For the current study, land cover/land use was extracted using Karra *et al.* (2021). Number of points selected in each habitat varied due to the overall area available and accessible. For KNP two types of habitats were observed: bare rock or gravel comprising 1498.19 km² and snow or glacier comprising 1806.06 km². Overall bare rock or gravel covered 45.3% and snow and glaciers covered the majority of the areas; 54.7% as shown in Figure 1. For LSNP we observed five types of habitats: agricultural land comprising 31.66 km², desert comprising 521.27 km², bare rock/ gravel comprising 0.25 km², tropical thorns comprising 78.46 km² and water bodies or swamps comprising 3.91 km². Overall agricultural land, desert, bare rock / gravel, tropical thorns and water bodies or swamps covered 5.0%, 82.0%, 0.04%, 12.3% and 0.6% area, respectively (Fig. 1). For HNP we observed two types of habitats; bare rock or gravel comprising 5148.35 km² and desert comprising 479.40 km². Overall bare rock or gravel covered 91.5% and desert covered 8.5% of the area, as shown in Figure 1. The various habitats encountered in the present study have the following characteristics.

Agricultural land: Fertile soil, dry, and hot climate in plain areas, and a cooler climate in hilly areas are characteristics of agricultural land. It comprises cultivated land that is used for crops growing and a natural mix of vegetation.

Bare rock/Gravel: Extreme temperatures with rocky and gravelly terrain. The vegetation is very scarce, or in some areas, there is no vegetation cover. The soil is usually poor in nutrients and thin.

Desert: Harsh environmental conditions include low water availability, extreme temperatures, and high winds. The climate is usually hot with sandy terrains, and thin vegetation cover. Species with high adaptivity to harsh conditions are present.

Tropical thorns: Harsh environmental conditions include low water availability and extreme temperatures. Thin vegetation containing thorny shrubs in arid areas. Species with high adaptivity to harsh conditions are present.

Snow/Glacier: Vegetation is limited, and wildlife is well-adapted to colder conditions and extreme climatic conditions with peaks covered with snow and glaciers.

Water bodies/ Swamps: Provides important breeding grounds for birds and animals and has a diverse ecosystem.

Data analysis

The Shannon-Wiener Index was used to quantify the diversity of a community using the following formula: $H' = -\sum (p_i \cdot \ln p_i)$, Where H' Shannon-Wiener index; p_i is the relative abundance of each species in the community (the proportion of individuals of a species in the community, expressed as a fraction), and \ln is the natural logarithm.

Simpson's Index was used to quantify the dominance of individual species within a community, using the formula: Simpson's Index = $1 - \frac{\sum (n(n-1))}{N(N-1)}$, Where, \sum is summation symbol, N is total number of individuals, and n is number of individuals of single species.

Pielou's Index was used to measure species evenness within a community using the formula: Index = Shannon-Wiener Index/ $\log(N)$, where N is the total number of individuals in the community.

Margalef's diversity index was computed for the study area by applying the following formula:

$$D_{Mg} = \frac{S - 1}{\ln N}$$

Where, D_{Mg} is Margalef's Diversity Index, S is No. of Species, N is the total no. of individuals in the sample.

Menhinick's diversity index was computed for the study area with the help of following mathematical equation:

$$D_{Mn} = \frac{S}{\sqrt{N}}$$

Where, D_{Mn} is Menhinick's Diversity index, S is No. of species, N is the total no. of individuals in the sample
Relative abundance was mathematically, computed using the formula:

$$RA = \frac{n}{N} \times 100$$

Where, RA is relative abundance, n is Number of individuals of the species in the specific area, and N is the total number of individuals of all species in a specific area.

Sorenson's similarity index (SSI) was used to determine the interspecific linkages between species in different habitats (Sørensen, 1948). SSI between two was calculated using the formula (Nath *et al.*, 2005): $SSI = \frac{2C}{(a+b)} \times 100$, Where, C is number of species in both habitats a and b , a is the number of species in habitat a , b = number of species in habitat b

Jaccard similarity index determined and compared the similarities between various habitats. It was calculated using the following formula (Magurran, 2021): $C_j = \frac{a}{a + b + c}$, Where, a is the number of common species in both habitats, b is the number of species in habitat a , not in habitat b while c is the number of species in habitat b , not present in habitat a .

RESULTS

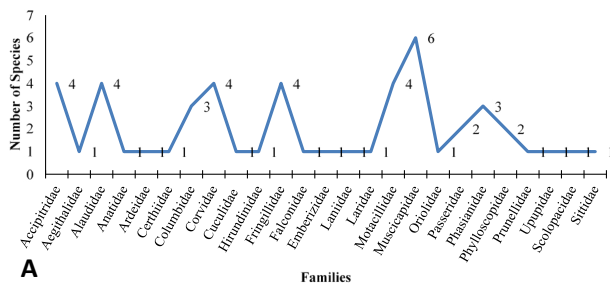
The species richness of three altitudinally different National parks; KNP, LSNP and HNP was 51, 179 and 120, respectively (Table I). Although selected national parks were on different geographical locations, have different habitats and environmental conditions, seven avian species were common in the selected national parks: common sandpiper, eurasian golden oriole, common gull-billed tern, house sparrow, long-tailed shrike, oriental skylark, and rock pigeon. These seven species can be referred to as the generalist species, as they were present in three selected study areas.

Table I. Species diversity, ecological indices, IUCN status, occurrence, and feeding guilds of Khunjerab National Park (KNP), Lal Suhanra National Park (LSNP), and Hingol National Park (HNP) birds.

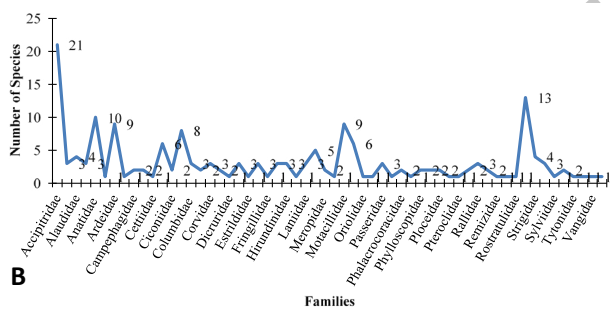
| National parks | KNP | LSNP | HNP |
|--|-----------|---------|-----------|
| Species richness | 51 | 179 | 120 |
| Number of families | 25 | 62 | 54 |
| Number of orders | 10 | 18 | 20 |
| IUCN status | | | |
| Least concern (LC) | 49 | 161 | 104 |
| Near threatened (NT) | 2 | 8 | 11 |
| Vulnerable (VU) | - | 4 | 2 |
| Endangered (EN) | - | 4 | 3 |
| Critically endangered (CR) | - | 2 | - |
| Occurrence | | | |
| Breeding resident (BR) | 18 | 73 | 42 |
| Passage migrant (PM) | 01 | 20 | 14 |
| Summer visitor (SV) | 21 | 10 | 6 |
| Winter visitor (WV) | 11 | 76 | 58 |
| Topographical parameters | | | |
| Area (acres) | 560,71 | 162,568 | 1,507,343 |
| Elevation (meters above sea level (asl)) | 3310-7460 | 110-145 | 27-1500 |
| Ecological indices | | | |
| Pielou's index | 0.503 | 0.577 | 0.555 |
| Simpson's index | 0.891 | 0.921 | 0.916 |
| Shannon-wiener index | 3.460 | 4.949 | 4.472 |
| Margalef's index | 7.269 | 20.766 | 24.899 |
| Menhinick's index | 1.636 | 2.463 | 2.136 |
| Census index | 0.294 | 8.304 | 0.560 |
| Feeding guilds | | | |
| Herbivore | 02 | 05 | 04 |
| Granivore | 03 | 04 | 04 |
| Omnivore | 20 | 42 | 26 |
| Insectivore | 14 | 40 | 15 |
| Piscivore | - | 09 | 08 |
| Carnivore | 12 | 78 | 63 |

KNP

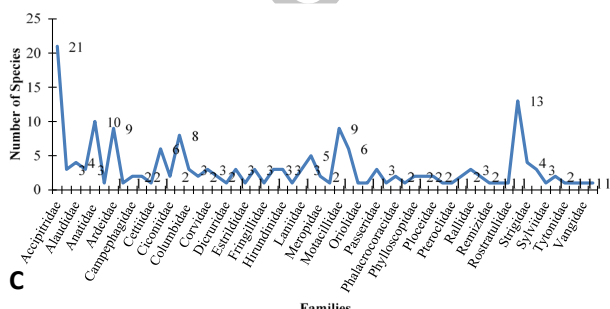
The total 971 individuals of 51 species (Table II) were recorded belonging to 25 families (Fig. 2A) and 10 orders. Out of 51 avian species the most abundant were long-tailed shrike (75), white wagtail (58), house sparrow (58), and common hoopoe (56), belonging to family Laniidae, Motacillidae, Passeridae, and Upupidae, respectively. While the least abundant species included, hill pigeon, snow pigeon, white-browed tit-warbler, great rosefinch, and northern wheatear, belonging to Family Columbidae (02) and Aegithalidae (03), respectively. KNP has two distinct habitats, Bare rock/Gravel and Snow/Glaciers. Seventeen species were observed in both habitats while 34 species were recorded in only one habitat (Table II).



A



B



C

Fig. 2. Dominant bird families of KNP (A), LSNP (B) and HNP (C).

According to IUCN red list, two species are near threatened; Himalayan vulture and bearded vulture, while 49 species are least concern. With respect to population

trend, 20 species showed decreasing trend, six species showed increasing trend. Stable population trend was observed in 21 species, while three species showed trend showed unknown trend. Eighteen species are breeding resident, 21 species summer visitor and 11 species are winter visitor and one species is passage migrant (northern wheatear).

The ecological indices provide further insight into the park’s diversity and stability. Pielou’s Index of 0.503 suggests a lower evenness, indicating that certain species dominate. Simpson’s Index of 0.891 points to relatively high species diversity, albeit with some dominance. The Shannon-Wiener Index of 3.460 reflects moderate species diversity with variable distribution. Margalef’s Index of 7.269 and Menhinick’s Index of 1.636 indicate moderate species richness relative to the number of individuals. The Census Index of 0.294 highlights a moderate abundance of bird species within KNP.

The park supports variety of species with different feeding guilds, including 20 omnivores, 14 insectivores, 12 carnivores, three granivores (rock pigeon, snow pigeon, and chukar) and two herbivores (hill pigeon and Brandt’s mountain finch).

LNP

The total 5278 individuals of 179 species (Table III) were recorded belonging to 62 families (Fig. 2B) and 18 orders. Out of 179 avian species the most abundant were white-throated kingfisher (99), Asian green bee-eater (92) and black kite (87), belonging to the family Alcedinidae, Meropidae, and Accipitridae, respectively. While the least abundant species included, Indian skimmer (one), eurasian thick-knee (two), and common reed bunting (two), belonging to Family Laridae, Burhinidae and Emberizidae, respectively. According to Landcover/land use, there are five habitats in LSNP. Agriculture land, desert, bare rock/gravel, tropical thorn and waterbodies/streams with 85, 106, 61, 42 and 101 species, respectively. Eight species were observed in all habitats while 58 species were recorded in only one habitat (Table III).

Out of 179, 161 avian species are least concern (LC), eight species are near-threatened (NT), four species are vulnerable (VU) including eastern imperial eagle, tawny eagle, common pochard, and river tern, four species are endangered (EN) (Egyptian vulture, steppe eagle, black-bellied tern, and Indian skimmer). There were two critically endangered (CR) birds: red-headed vulture and white-rumped vulture.

With respect to population trend 64 species showed decreasing trend, while 34 species showed increasing trends. Total of 58 species showed stable population trend and 23 species showed unknown trend. Out of total, 73 species

Table II. Bird species recorded in KNP during field Surveys.

| Order/ Family | Common name (Scientific name) | IUCN status | Trend | Occurrence | Count |
|------------------------|--|-------------|------------|------------|-------|
| Accipitriformes | | | | | |
| Accipitridae | Eurasian sparrowhawk (<i>Accipiter nisus</i>) | LC | Stable | SV | 31 |
| | Golden eagle (<i>Aquila chrysaetos</i>) | LC | Stable | BR | 9 |
| | Himalayan griffon (<i>Gyps himalayensis</i>) | NT | Decreasing | BR | 11 |
| | Bearded vulture (<i>Gypaetus barbatus</i>) | NT | Decreasing | BR | 2 |
| Anseriformes | | | | | |
| Anatidae | Ruddy shelduck (<i>Tadorna ferruginea</i>) | LC | Unknown | WV | 13 |
| Bucerotiformes | | | | | |
| Upupidae | Common hoopoe (<i>Upupa epops</i>) | LC | Decreasing | SV | 54 |
| Charadriiformes | | | | | |
| Laridae | Common gull-billed tern (<i>Gelochelidon nilotica</i>) | LC | Decreasing | WV | 32 |
| Scolopacidae | Common sandpiper (<i>Actitis hypoleucos</i>) | LC | Decreasing | SV | 41 |
| Columbiformes | | | | | |
| Columbidae | Hill pigeon (<i>Columba rupestris</i>) | LC | Decreasing | SV | 1 |
| | Rock pigeon (<i>Columba livia</i>) | LC | Decreasing | BR | 23 |
| | Snow pigeon (<i>Columba leuconota</i>) | LC | Stable | BR | 1 |
| Cuculiformes | | | | | |
| Cuculidae | Common cuckoo (<i>Cuculus canorus</i>) | LC | Decreasing | SV | 13 |
| Falconiformes | | | | | |
| Falconidae | Common kestrel (<i>Falco tinnunculus</i>) | LC | Decreasing | BR | 43 |
| Galliformes | | | | | |
| Phasianidae | Chukar (<i>Alectoris chukar</i>) | LC | Stable | BR | 6 |
| | Common quail (<i>Coturnix coturnix</i>) | LC | Decreasing | WV | 9 |
| Phasianidae | Himalayan snowcock (<i>Tetraogallus himalayensis</i>) | LC | Stable | BR | 5 |
| Passeriformes | | | | | |
| Aegithalidae | White-browed tit warbler (<i>Leptopoecile sophiae</i>) | LC | Stable | WV | 1 |
| Alaudidae | Eurasian skylark (<i>Alauda arvensis</i>) | LC | Decreasing | WV | 5 |
| | Greater short-toed lark (<i>Calandrella brachydactyla</i>) | LC | Unknown | WV | 10 |
| | Horned lark (<i>Eremophila alpestris</i>) | LC | Decreasing | BR | 2 |
| | Oriental skylark (<i>Alauda gulgula</i>) | LC | Decreasing | SV | 7 |
| Certhiidae | Bar-tailed treecreeper (<i>Certhia himalayana</i>) | LC | Decreasing | BR | 13 |
| Corvidae | Common raven (<i>Corvus corax</i>) | LC | Increasing | BR | 15 |
| | Large-billed crow (<i>Corvus macrorhynchos</i>) | LC | Stable | BR | 31 |
| | Red-billed chough (<i>Pyrrhocorax pyrrhocorax</i>) | LC | Decreasing | BR | 3 |
| | Yellow-billed chough (<i>Pyrrhocorax graculus</i>) | LC | Stable | BR | 4 |
| Emberizidae | Rock bunting (<i>Emberiza cia</i>) | LC | Increasing | SV | 37 |
| Fringillidae | Brandt's mountain-finch (<i>Leucosticte brandti</i>) | LC | Stable | BR | 2 |
| | European goldfinch (<i>Carduelis carduelis</i>) | LC | Decreasing | WV | 6 |
| | Red-fronted serin (<i>Serinus pusillus</i>) | LC | Stable | BR | 3 |
| | Great rosefinch (<i>Carpodacus rubicilla</i>) | LC | Stable | WV | 1 |

Table continued on next page.....

| Order/ Family | Common name (Scientific name) | IUCN status | Trend | Occurrence | Count |
|-----------------------|--|--|------------|------------|-------|
| Hirundinidae | Asian house martin (<i>Delichon dasypus</i>) | LC | Increasing | SV | 4 |
| Laniidae | Long-tailed shrike (<i>Lanius schach</i>) | LC | Unknown | SV | 81 |
| Motacillidae | Citrine wagtail (<i>Motacilla citreola</i>) | LC | Increasing | SV | 51 |
| | Grey wagtail (<i>Motacilla cinerea</i>) | LC | Stable | SV | 24 |
| | Rosy pipit (<i>Anthus roseatus</i>) | LC | Stable | SV | 11 |
| | White wagtail (<i>Motacilla alba</i>) | LC | Stable | SV | 59 |
| | Muscicapidae | Black redstart (<i>Phoenicurus ochruros</i>) | LC | Increasing | WV |
| Muscicapidae | Blue rock thrush (<i>Monticola solitarius</i>) | LC | Stable | SV | 22 |
| | Bluethroat (<i>Luscinia svecica</i>) | LC | Stable | SV | 51 |
| | Northern wheatear (<i>Oenanthe oenanthe</i>) | LC | Decreasing | PM | 1 |
| | Pied wheatear (<i>Oenanthe pleschanka</i>) | LC | Stable | SV | 2 |
| | Variable wheatear (<i>Oenanthe picata</i>) | LC | Stable | WV | 51 |
| Oriolidae | Eurasian golden oriole (<i>Oriolus oriolus</i>) | LC | Stable | SV | 3 |
| Passeridae | House sparrow (<i>Passer domesticus</i>) | LC | Decreasing | BR | 59 |
| | Spanish sparrow (<i>Passer hispaniolensis</i>) | LC | Decreasing | WV | 12 |
| Phylloscopidae | Greenish warbler (<i>Phylloscopus trochiloides</i>) | LC | Increasing | SV | 22 |
| | Mountain chiffchaff (<i>Phylloscopus sindianus</i>) | LC | Stable | SV | 4 |
| Prunellidae | Alpine accentor (<i>Prunella collaris</i>) | LC | Stable | SV | 2 |
| Sittidae | Wallcreeper (<i>Tichodroma muraria</i>) | LC | Stable | BR | 13 |
| Pelecaniformes | | | | | |
| Ardeidae | Black-crowned night-heron (<i>Nycticorax nycticorax</i>) | LC | Decreasing | SV | 20 |

* LC, Least Concern; NT=Near threatened; ** BR, Breeding resident; PM; Passage migrant; SV, Summer visitor; WV, Winter visitor.

Table III. Bird species recorded in LSNP during field surveys.

| Order/ Family | Common name/ Scientific name | IUCN status | Trend | Occurrence | Count |
|------------------------|---|-------------|------------|------------|-------|
| Accipitriformes | | | | | |
| Accipitridae | Black kite (<i>Milvus migrans</i>) | LC | Stable | BR | 87 |
| | Black-winged kite (<i>Elanus caeruleus</i>) | LC | Stable | BR | 40 |
| | Brahminy kite (<i>Haliastur indus</i>) | LC | Decreasing | BR | 61 |
| | Cinereous vulture (<i>Aegypius monachus</i>) | NT | Decreasing | WV | 21 |
| | Egyptian vulture (<i>Neophron percnopterus</i>) | EN | Decreasing | BR | 19 |
| | Eurasian buzzard (<i>Buteo buteo</i>) | LC | Increasing | WV | 14 |
| | Griffon vulture (<i>Gyps fulvus</i>) | LC | Increasing | WV | 29 |
| | Western marsh-harrier (<i>Circus aeruginosus</i>) | LC | Stable | WV | 51 |
| | Eurasian sparrowhawk (<i>Accipiter nisus</i>) | LC | Stable | WV | 36 |
| | Eastern imperial eagle (<i>Aquila heliaca</i>) | VU | Decreasing | WV | 21 |
| | Long-legged buzzard (<i>Buteo rufinus</i>) | LC | Stable | WV | 52 |
| | Montagu's harrier (<i>Circus pygargus</i>) | LC | Decreasing | WV | 13 |
| | Northern goshawk (<i>Accipiter gentilis</i>) | LC | Unknown | PM | 3 |
| | Pallid harrier (<i>Circus macrourus</i>) | NT | Decreasing | WV | 16 |
| | Red-headed vulture (<i>Sarcogyps calvus</i>) | CR | Decreasing | PM | 7 |

Table continued on next page.....

| Order/ Family | Common name/ Scientific name | IUCN status | Trend | Occurrence | Count |
|-------------------------|--|-------------|------------|------------|-------|
| | Shikra (<i>Accipiter badius</i>) | LC | Stable | BR | 45 |
| | Short-toed snake eagle (<i>Circaetus gallicus</i>) | LC | Stable | BR | 24 |
| | Steppe eagle (<i>Aquila nipalensis</i>) | EN | Decreasing | WV | 62 |
| | Tawny eagle (<i>Aquila rapax</i>) | VU | Decreasing | BR | 19 |
| | White-eyed buzzard (<i>Butastur teesa</i>) | LC | Stable | BR | 22 |
| | White-rumped vulture (<i>Gyps bengalensis</i>) | CR | Decreasing | BR | 3 |
| Pandionidae | Osprey (<i>Pandion haliaetus</i>) | LC | Increasing | WV | 35 |
| Anseriformes | | | | | |
| Anatidae | Common pochard (<i>Aythya ferina</i>) | VU | Decreasing | WV | 20 |
| | Common teal (<i>Anas crecca</i>) | LC | Unknown | WV | 39 |
| | Cotton pygmy-goose (<i>Nettapus coromandelianus</i>) | LC | Stable | PM | 6 |
| | Ferruginous pochard (<i>Aythya nyroca</i>) | NT | Decreasing | WV | 15 |
| | Lesser whistling-duck (<i>Dendrocygna javanica</i>) | LC | Decreasing | SV | 15 |
| | Mallard (<i>Anas platyrhynchos</i>) | LC | Increasing | WV | 25 |
| | Northern pintail (<i>Anas acuta</i>) | LC | Decreasing | WV | 15 |
| | Red-crested pochard (<i>Netta rufina</i>) | LC | Unknown | PM | 9 |
| | Ruddy shelduck (<i>Tadorna ferruginea</i>) | LC | Unknown | WV | 11 |
| | Indian spot-billed duck (<i>Anas poecilorhyncha</i>) | LC | Decreasing | BR | 8 |
| Bucerotiformes | | | | | |
| Upupidae | Common hoopoe (<i>Upupa epops</i>) | LC | Decreasing | BR | 56 |
| Caprimulgiformes | | | | | |
| Apodidae | Little swift (<i>Apus affinis</i>) | LC | Increasing | BR | 19 |
| Caprimulgidae | European nightjar (<i>Caprimulgus europaeus</i>) | LC | Decreasing | WV | 8 |
| | Sykes's nightjar (<i>Caprimulgus mahrattensis</i>) | LC | Stable | BR | 6 |
| Charadriiformes | | | | | |
| Burhinidae | Eurasian thick-knee (<i>Burhinus oedicephalus</i>) | LC | Decreasing | BR | 2 |
| Charadriidae | Grey plover (<i>Pluvialis squatarola</i>) | LC | Decreasing | PM | 21 |
| | Kentish plover (<i>Charadrius alexandrinus</i>) | LC | Decreasing | WV | 28 |
| | Little ringed plover (<i>Charadrius dubius</i>) | LC | Stable | WV | 50 |
| Charadriidae | Northern lapwing (<i>Vanellus vanellus</i>) | NT | Decreasing | WV | 12 |
| | Red-wattled lapwing (<i>Vanellus indicus</i>) | LC | Unknown | BR | 77 |
| | White-tailed lapwing (<i>Vanellus leucurus</i>) | LC | Unknown | WV | 29 |
| Glareolidae | Collared pratincole (<i>Glareola pratincola</i>) | LC | Decreasing | SV | 13 |
| | Indian courser (<i>Cursorius coromandelicus</i>) | LC | Stable | WV | 3 |
| | Little pratincole (<i>Glareola lactea</i>) | LC | Unknown | SV | 16 |
| Jacaniidae | Pheasant-tailed jacana (<i>Hydrophasianus chirurgus</i>) | LC | Decreasing | SV | 36 |
| Laridae | Black-bellied tern (<i>Sterna acuticauda</i>) | EN | Decreasing | WV | 5 |
| | Caspian gull (<i>Larus cachinnans</i>) | LC | Increasing | WV | 20 |
| | Common gull-billed tern (<i>Gelochelidon nilotica</i>) | LC | Decreasing | WV | 37 |
| | Indian skimmer (<i>Rynchops albicollis</i>) | EN | Decreasing | SV | 1 |
| Laridae | River tern (<i>Sterna aurantia</i>) | VU | Decreasing | WV | 38 |

Table continued on next page.....

| Order/ Family | Common name/ Scientific name | IUCN status | Trend | Occurrence | Count | |
|--|--|--------------------------------------|------------|------------|-------|----|
| Recurvirostridae | Black-winged stilt (<i>Himantopus himantopus</i>) | LC | Increasing | BR | 71 | |
| | Pied avocet (<i>Recurvirostra avosetta</i>) | LC | Unknown | WV | 15 | |
| Rostratulidae | Greater painted-snipe (<i>Rostratula benghalensis</i>) | LC | Decreasing | BR | 19 | |
| Scolopacidae | Common greenshank (<i>Tringa nebularia</i>) | LC | Stable | WV | 24 | |
| | Common redshank (<i>Tringa totanus</i>) | LC | Unknown | WV | 23 | |
| | Common sandpiper (<i>Actitis hypoleucos</i>) | LC | Decreasing | WV | 38 | |
| | Common snipe (<i>Gallinago gallinago</i>) | LC | Decreasing | WV | 28 | |
| | Dunlin (<i>Calidris alpina</i>) | LC | Decreasing | WV | 13 | |
| | Eurasian curlew (<i>Numenius arquata</i>) | NT | Decreasing | WV | 28 | |
| | Green sandpiper (<i>Tringa ochropus</i>) | LC | Increasing | WV | 41 | |
| | Jack snipe (<i>Lymnocyptes minimus</i>) | LC | Stable | WV | 10 | |
| | Little stint (<i>Calidris minuta</i>) | LC | Increasing | PM | 35 | |
| | Marsh sandpiper (<i>Tringa stagnatilis</i>) | LC | Decreasing | WV | 24 | |
| | Spotted redshank (<i>Tringa erythropus</i>) | LC | Stable | WV | 13 | |
| | Temminck's stint (<i>Calidris temminckii</i>) | LC | Unknown | WV | 22 | |
| | Wood sandpiper (<i>Tringa glareola</i>) | LC | Stable | WV | 37 | |
| | Ciconiiformes | | | | | |
| | Ciconiidae | Black stork (<i>Ciconia nigra</i>) | LC | Unknown | PM | 16 |
| Painted stork (<i>Mycteria leucocephala</i>) | | LC | Increasing | WV | 18 | |
| Columbiformes | | | | | | |
| Columbidae | Red collared dove (<i>Streptopelia tranquebarica</i>) | LC | Decreasing | SV | 22 | |
| | Rock pigeon (<i>Columba livia</i>) | LC | Decreasing | BR | 25 | |
| | Eurasian collared dove (<i>Streptopelia decaocto</i>) | LC | Increasing | BR | 65 | |
| Coraciiformes | | | | | | |
| Alcedinidae | Common kingfisher (<i>Alcedo atthis</i>) | LC | Unknown | BR | 58 | |
| | Pied kingfisher (<i>Ceryle rudis</i>) | LC | Unknown | BR | 64 | |
| | White-throated kingfisher (<i>Halcyon smyrnensis</i>) | LC | Increasing | BR | 99 | |
| Coraciidae | European roller (<i>Coracias garrulus</i>) | LC | Decreasing | PM | 29 | |
| | Indian roller (<i>Coracias benghalensis</i>) | LC | Increasing | BR | 48 | |
| Meropidae | Blue-cheeked bee-eater (<i>Merops persicus</i>) | LC | Stable | SV | 25 | |
| | Asian green bee-eater (<i>Merops orientalis</i>) | LC | Increasing | BR | 92 | |
| Cuculiformes | | | | | | |
| Cuculidae | Pied cuckoo (<i>Clamator jacobinus</i>) | LC | Stable | SV | 30 | |
| | Greater coucal (<i>Centropus sinensis</i>) | LC | Stable | BR | 34 | |
| Falconiformes | | | | | | |
| Falconidae | Laggar falcon (<i>Falco jugger</i>) | NT | Decreasing | BR | 4 | |
| | Peregrine falcon (<i>Falco peregrinus</i>) | LC | Increasing | WV | 11 | |
| | Red-necked falcon (<i>Falco chicquera</i>) | NT | Decreasing | BR | 10 | |
| Galliformes | | | | | | |
| Phasianidae | Common quail (<i>Coturnix coturnix</i>) | LC | Decreasing | WV | 8 | |
| Gruiformes | | | | | | |
| Rallidae | Common coot (<i>Fulica atra</i>) | LC | Increasing | WV | 28 | |
| | Common moorhen (<i>Gallinula chloropus</i>) | LC | Stable | BR | 41 | |

Table continued on next page.....

| Order/ Family | Common name/ Scientific name | IUCN status | Trend | Occurrence | Count |
|----------------------|--|-------------|------------|------------|-------|
| | Water rail (<i>Rallus aquaticus</i>) | LC | Decreasing | WV | 10 |
| Passeriformes | | | | | |
| Acrocephalidae | Blyth's reed warbler (<i>Acrocephalus dumetorum</i>) | LC | Increasing | PM | 19 |
| | Clamorous reed warbler (<i>Acrocephalus stentoreus</i>) | LC | Stable | WV | 26 |
| | Moustached warbler (<i>Acrocephalus melanopogon</i>) | LC | Stable | WM | 14 |
| Alaudidae | Black-crowned sparrow lark (<i>Eremopterix nigriceps</i>) | LC | Increasing | BR | 13 |
| | Crested lark (<i>Galerida cristata</i>) | LC | Decreasing | BR | 47 |
| | Greater short-toed lark (<i>Calandrella brachydactyla</i>) | LC | Unknown | WV | 11 |
| | Oriental skylark (<i>Alauda gulgula</i>) | LC | Decreasing | BR | 8 |
| Campephagidae | Long-tailed minivet (<i>Pericrocotus ethologus</i>) | LC | Decreasing | WV | 19 |
| | Small minivet (<i>Pericrocotus cinnamomeus</i>) | LC | Stable | BR | 20 |
| Cettiidae | Cetti's warbler (<i>Cettia cetti</i>) | LC | Increasing | WV | 7 |
| Cisticolidae | Ashy prinia (<i>Prinia socialis</i>) | LC | Stable | BR | 25 |
| | Common tailorbird (<i>Orthotomus sutorius</i>) | LC | Stable | BR | 35 |
| | Graceful prinia (<i>Prinia gracilis</i>) | LC | Stable | BR | 3 |
| | Plain prinia (<i>Prinia inornata</i>) | LC | Stable | BR | 70 |
| | Rufous-fronted prinia (<i>Prinia buchanani</i>) | LC | Stable | BR | 26 |
| | Striated prinia (<i>Prinia crinigera</i>) | LC | Stable | BR | 17 |
| | Yellow-bellied prinia (<i>Prinia flaviventris</i>) | LC | Decreasing | BR | 32 |
| | Zitting cisticola (<i>Cisticola juncidis</i>) | LC | Increasing | BR | 19 |
| Corvidae | Common raven (<i>Corvus corax</i>) | LC | Increasing | BR | 14 |
| | House crow (<i>Corvus splendens</i>) | LC | Stable | BR | 57 |
| | Rufous treepie (<i>Dendrocitta vagabunda</i>) | LC | Decreasing | BR | 47 |
| Dicruridae | Black drongo (<i>Dicrurus macrocercus</i>) | LC | Unknown | BR | 81 |
| Emberizidae | Red-headed bunting (<i>Emberiza bruniceps</i>) | LC | Stable | PM | 9 |
| | Reed bunting (<i>Emberiza schoeniclus</i>) | LC | Decreasing | PM | 2 |
| | Rock bunting (<i>Emberiza cia</i>) | LC | Increasing | WV | 32 |
| Estrildidae | Red avadavat (<i>Amandava amandava</i>) | LC | Stable | BR | 14 |
| Fringillidae | Common rosefinch (<i>Carpodacus erythrinus</i>) | LC | Decreasing | PM | 19 |
| Hirundinidae | Barn swallow (<i>Hirundo rustica</i>) | LC | Decreasing | WV | 34 |
| | Pale martin (<i>Riparia diluta</i>) | LC | Unknown | WV | 10 |
| | Wire-tailed swallow (<i>Hirundo smithii</i>) | LC | Increasing | SV | 24 |
| Laniidae | Bay-backed shrike (<i>Lanius vittatus</i>) | LC | Stable | BR | 48 |
| | Long-tailed shrike (<i>Lanius schach</i>) | LC | Unknown | BR | 75 |
| | Isabelline shrike (<i>Lanius isabellinus</i>) | LC | Stable | WV | 62 |
| Monarchidae | Indian paradise-flycatcher (<i>Terpsiphone paradisi</i>) | LC | Stable | PM | 46 |
| Motacillidae | Citrine wagtail (<i>Motacilla citreola</i>) | LC | Increasing | WV | 49 |
| | Grey wagtail (<i>Motacilla cinerea</i>) | LC | Stable | WV | 27 |
| | Paddyfield pipit (<i>Anthus rufulus</i>) | LC | Stable | BR | 46 |
| | Rosy pipit (<i>Anthus roseatus</i>) | LC | Stable | WV | 15 |
| | Tawny pipit (<i>Anthus campestris</i>) | LC | Stable | WV | 21 |

Table continued on next page.....

| Order/ Family | Common name/ Scientific name | IUCN status | Trend | Occurrence | Count |
|-----------------------|--|-------------|------------|------------|-------|
| | Tree pipit (<i>Anthus trivialis</i>) | LC | Decreasing | PM | 23 |
| | White wagtail (<i>Motacilla alba</i>) | LC | Stable | WV | 56 |
| | White-browed wagtail (<i>Motacilla maderaspatensis</i>) | LC | Stable | WV | 29 |
| | Western yellow wagtail (<i>Motacilla flava</i>) | LC | Decreasing | PM | 35 |
| Muscicapidae | Black redstart (<i>Phoenicurus ochruros</i>) | LC | Increasing | WV | 41 |
| | Bluethroat (<i>Luscinia svecica</i>) | LC | Stable | WV | 49 |
| | Desert wheatear (<i>Oenanthe deserti</i>) | LC | Stable | WV | 27 |
| | Pied buschhat (<i>Saxicola caprata</i>) | LC | Stable | BR | 68 |
| | Red-breasted flycatcher (<i>Ficedula parva</i>) | LC | Increasing | PM | 29 |
| | Variable wheatear (<i>Oenanthe picata</i>) | LC | Stable | WV | 50 |
| Oriolidae | Eurasian golden oriole (<i>Oriolus oriolus</i>) | LC | Stable | PM | 4 |
| Passeridae | House sparrow (<i>Passer domesticus</i>) | LC | Decreasing | BR | 58 |
| | Sind sparrow (<i>Passer pyrrhonotus</i>) | LC | Stable | BR | 22 |
| | Spanish sparrow (<i>Passer hispaniolensis</i>) | LC | Decreasing | WV | 19 |
| Phylloscopidae | Brook's leaf warbler (<i>Phylloscopus subviridis</i>) | LC | Stable | WV | 3 |
| | Common chiffchaff (<i>Phylloscopus collybita</i>) | LC | Increasing | WV | 52 |
| Ploceidae | Baya weaver (<i>Ploceus philippinus</i>) | LC | Stable | BR | 35 |
| | Streaked weaver (<i>Ploceus manyar</i>) | LC | Stable | BR | 38 |
| Pycnonotidae | Red-vented bulbul (<i>Pycnonotus cafer</i>) | LC | Increasing | BR | 83 |
| | White-eared bulbul (<i>Pycnonotus leucotis</i>) | LC | Decreasing | BR | 48 |
| Remizidae | White-crowned penduline tit (<i>Remiz coronatus</i>) | LC | Decreasing | WV | 6 |
| Rhipiduridae | White-browed fantail (<i>Rhipidura aureola</i>) | LC | Stable | BR | 26 |
| Sturnidae | Bank myna (<i>Acridotheres ginginianus</i>) | LC | Increasing | BR | 41 |
| | Common myna (<i>Acridotheres tristis</i>) | LC | Increasing | BR | 81 |
| | Rosy starling (<i>Pastor roseus</i>) | LC | Unknown | PM | 35 |
| Sylviidae | Yellow-eyed babbler (<i>Chrysomma sinense</i>) | LC | Stable | BR | 22 |
| Vangidae | Common woodshrike (<i>Tephrodornis pondicerianus</i>) | LC | Stable | BR | 24 |
| Zosteropidae | Indian white-eye (<i>Zosterops palpebrosus</i>) | LC | Decreasing | BR | 62 |
| Pelecaniformes | | | | | |
| Ardeidae | Black-crowned night-heron (<i>Nycticorax nycticorax</i>) | LC | Decreasing | SV | 29 |
| | Cattle egret (<i>Bubulcus ibis</i>) | LC | Increasing | BR | 38 |
| | Great bittern (<i>Botaurus stellaris</i>) | LC | Decreasing | WV | 5 |
| | Grey heron (<i>Ardea cinerea</i>) | LC | Unknown | WV | 32 |
| | Indian pond-heron (<i>Ardeola grayii</i>) | LC | Unknown | BR | 82 |
| | Little bittern (<i>Ixobrychus minutus</i>) | LC | Decreasing | WV | 5 |
| | Little egret (<i>Egretta garzetta</i>) | LC | Increasing | BR | 51 |
| | Purple heron (<i>Ardea purpurea</i>) | LC | Decreasing | BR | 25 |
| | Yellow bittern (<i>Ixobrychus sinensis</i>) | LC | Unknown | BR | 21 |
| Pelecanidae | Dalmatian pelican (<i>Pelecanus crispus</i>) | NT | Decreasing | PM | 24 |
| Threskiornithidae | Eurasian spoonbill (<i>Platalea leucorodia</i>) | LC | Unknown | WV | 21 |
| | Glossy ibis (<i>Plegadis falcinellus</i>) | LC | Decreasing | PM | 27 |

Table continued on next page.....

| Order/ Family | Common name/ Scientific name | IUCN status | Trend | Occurrence | Count |
|-------------------------|--|-------------|------------|------------|-------|
| Piciformes | | | | | |
| Picidae | Eurasian wryneck (<i>Jynx torquilla</i>) | LC | Decreasing | WV | 17 |
| | Sind woodpecker (<i>Dendrocopos assimilis</i>) | LC | Stable | BR | 8 |
| Psittaciformes | | | | | |
| Psittacidae | Rose-ringed parakeet (<i>Alexandrinus krameri</i>) | LC | Increasing | BR | 38 |
| Pteroclidiformes | | | | | |
| Pteroclididae | Chestnut-bellied sandgrouse (<i>Pterocles exustus</i>) | LC | Stable | BR | 14 |
| Strigiformes | | | | | |
| Strigidae | Indian scops-owl (<i>Otus bakkamoena</i>) | LC | Stable | BR | 25 |
| | Northern long-eared owl (<i>Asio otus</i>) | LC | Decreasing | WV | 4 |
| | Short-eared owl (<i>Asio flammeus</i>) | LC | Decreasing | WV | 8 |
| | Spotted owlet (<i>Athene brama</i>) | LC | Stable | BR | 43 |
| Tytonidae | Common barn owl (<i>Tyto alba</i>) | LC | Stable | BR | 12 |
| Suliformes | | | | | |
| Phalacrocoracidae | Great cormorant (<i>Phalacrocorax carbo</i>) | LC | Increasing | WV | 37 |
| | Indian cormorant (<i>Phalacrocorax fuscicollis</i>) | LC | Unknown | BR | 5 |

* LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; CR, critically endangered. ** BR, breeding resident; PM, passage migrant; SV, summer visitor; WV, winter visitor.

are breeding resident, 20 passage migrant, 10 species summer visitor and 76 species are winter visitor. The park sustains diverse feeding guilds, including 78 carnivores, 42 omnivores, five herbivores, 41 insectivores, nine piscivores and four granivores (red collared dove, rock pigeon, red avadavat, and chestnut-bellied sandgrouse), all contributing to the ecological balance.

Ecological indices portray a high level of diversity and complexity in LSNP. Pielou's Index of 0.577 indicates moderate evenness. Simpson's Index of 0.921 reflects high species diversity with even distribution. The Shannon-Wiener Index of 4.949 signifies high species diversity with relatively even species abundances. Margalef's Index of 20.766 and Menhinick's Index of 2.463 indicate high species richness. The Census Index of 8.304 suggests a high abundance of bird species within the national park.

HNP

The total 3,155 individuals of 120 species (Table IV) were recorded from 54 families (Fig. 2C) and 20 orders, where most abundant were white-throated kingfisher (99), Asian green bee-eater (96) and black kite (81), belonging to the family Alcedinidae, Meropidae, and Accipitridae, respectively. The least abundant species included brown noddly (one), red-throated loon (one), and black-bellied sandgrouse (one), belonging to Family Laridae, Gaviidae, and Pteroclididae, respectively. HNP has two distinct habitats. Bare rock/gravel and desert. Twenty-six species were observed in both habitats while 94 species were recorded in only one habitat (Table IV). Bare rock/gravel inhabited

108 species while 38 species were recorded in the desert.

For population trend 50 species showed a decreasing trend including, 19 species showing increasing trend, 35 species showed stable population trend and 16 species showed Unknown trend. The HNP species are classified into least concern, near threatened or vulnerable, underscoring the need for conservation efforts. Out of 120, 104 avian species are LC, 11 species are NT category, three species are EN including, Egyptian vulture and Steppe eagle and two species fall under VU category including Eastern imperial eagle and MacQueen's bustard. Forty-two species are breeding resident, 14 passage migrant, six species are summer visitor and 58 species are winter visitor

Ecological indices for HNP reveal a healthy ecosystem with significant diversity. Pielou's Index of 0.555 shows moderate evenness. Simpson's Index of 0.916 indicates high species diversity with even distribution. The Shannon-wiener index of 4.472 reflects high species diversity. Margalef's index of 24.899 and Menhinick's index of 2.136 suggest high species richness relative to the number of individuals. The Census Index of 0.560 indicates a moderate abundance of bird species within the national park.

Hingol supports diverse feeding guilds, including 63 carnivores, 26 omnivores, 15 insectivores, eight piscivores, four herbivores (eurasian teal, marbled duck, eurAsian collared dove and see-see partridge), and four granivores (rock dove, black-bellied sandgrouse, chestnut-bellied sandgrouse, and Lichtenstein's sandgrouse).

Table IV. Bird species recorded in HNP during field surveys.

| Order/ Family | Common name (Scientific name) | IUCN status | Trend | Occurrence | Count |
|------------------------|--|-------------|------------|------------|-------|
| Accipitriformes | | | | | |
| Accipitridae | Black kite (<i>Milvus migrans</i>) | LC | Stable | BR | 81 |
| | Brahminy kite (<i>Haliastur indus</i>) | LC | Decreasing | BR | 59 |
| | Cinereous vulture (<i>Aegypius monachus</i>) | NT | Decreasing | WV | 19 |
| | Egyptian vulture (<i>Neophron percnopterus</i>) | EN | Decreasing | BR | 20 |
| | Eurasian buzzard (<i>Buteo buteo</i>) | LC | Increasing | WV | 13 |
| | Griffon vulture (<i>Gyps fulvus</i>) | LC | Increasing | WV | 31 |
| | Golden eagle (<i>Aquila chrysaetos</i>) | LC | Stable | BR | 5 |
| | Eastern imperial eagle (<i>Aquila heliaca</i>) | VU | Decreasing | WV | 18 |
| | Long-legged buzzard (<i>Buteo rufinus</i>) | LC | Stable | WV | 49 |
| | Pallid harrier (<i>Circus macrourus</i>) | NT | Decreasing | WV | 11 |
| | Shikra (<i>Accipiter badius</i>) | LC | Stable | SV | 45 |
| | Short-toed snake eagle (<i>Circaetus gallicus</i>) | LC | Stable | BR | 24 |
| | Steppe eagle (<i>Aquila nipalensis</i>) | EN | Decreasing | WV | 58 |
| | White-eyed buzzard (<i>Butastur teesa</i>) | LC | Stable | BR | 23 |
| Anseriformes | | | | | |
| Anatidae | Common teal (<i>Anas crecca</i>) | LC | Unknown | WV | 37 |
| | Mallard (<i>Anas platyrhynchos</i>) | LC | Increasing | WV | 24 |
| | Marbled duck (<i>Marmaronetta angustirostris</i>) | NT | Decreasing | WV | 11 |
| Caprimulgiformes | Northern pintail (<i>Anas acuta</i>) | LC | Decreasing | WV | 10 |
| Caprimulgidae | European nightjar (<i>Caprimulgus europaeus</i>) | LC | Decreasing | WV | 7 |
| | Sykes's nightjar (<i>Caprimulgus mahrattensis</i>) | LC | Stable | BR | 5 |
| Charadriiformes | | | | | |
| Burhinidae | Eurasian thick-knee (<i>Burhinus oedicnemus</i>) | LC | Decreasing | BR | 2 |
| | Great thick-knee (<i>Esacus recurvirostris</i>) | NT | Decreasing | BR | 2 |
| Charadriidae | Greater sand plover (<i>Charadrius leschenaultii</i>) | LC | Decreasing | WV | 11 |
| | Grey plover (<i>Pluvialis squatarola</i>) | LC | Decreasing | WV | 18 |
| | Kentish plover (<i>Charadrius alexandrinus</i>) | LC | Decreasing | WV | 29 |
| | Siberian sandplover (<i>Charadrius mongolus</i>) | EN | Decreasing | WV | 19 |
| | Little ringed plover (<i>Charadrius dubius</i>) | LC | Stable | WV | 45 |
| Dromadidae | Crab-plover (<i>Dromas ardeola</i>) | LC | Stable | PM | 7 |
| Glareolidae | Collared pratincole (<i>Glareola pratincola</i>) | LC | Decreasing | SV | 11 |
| | Cream-coloured courser (<i>Cursorius cursor</i>) | LC | Decreasing | WV | 12 |
| Haematopodidae | Eurasian oystercatcher (<i>Haematopus ostralegus</i>) | NT | Decreasing | WV | 8 |
| Laridae | Brown noddy (<i>Anous stolidus</i>) | LC | Stable | PM | 1 |
| | Caspian gull (<i>Larus cachinnans</i>) | LC | Increasing | WV | 22 |
| | Common gull-billed tern (<i>Gelochelidon nilotica</i>) | LC | Decreasing | WV | 31 |
| | White-cheeked tern (<i>Sterna repressa</i>) | LC | Decreasing | SV | 4 |
| Laridae | Common tern (<i>Sterna hirundo</i>) | LC | Unknown | SV | 13 |
| Recurvirostridae | Black-winged stilt (<i>Himantopus himantopus</i>) | LC | Increasing | BR | 63 |

Table continued on next page.....

| Order/ Family | Common name (Scientific name) | IUCN status | Trend | Occurrence | Count |
|----------------------|---|-------------|------------|------------|-------|
| | Pied avocet (<i>Recurvirostra avosetta</i>) | LC | Unknown | BR | 17 |
| Scolopacidae | Red-necked phalarope (<i>Phalaropus lobatus</i>) | LC | Decreasing | WV | 14 |
| | Ruddy turnstone (<i>Arenaria interpres</i>) | LC | Decreasing | WM | 7 |
| Scolopacidae | Bar-tailed godwit (<i>Limosa lapponica</i>) | NT | Decreasing | WV | 10 |
| | Common redshank (<i>Tringa totanus</i>) | LC | Unknown | WV | 19 |
| | Common sandpiper (<i>Actitis hypoleucos</i>) | LC | Decreasing | WV | 51 |
| | Curlew sandpiper (<i>Calidris ferruginea</i>) | NT | Decreasing | WV | 18 |
| | Dunlin (<i>Calidris alpina</i>) | LC | Decreasing | WV | 11 |
| | Green sandpiper (<i>Tringa ochropus</i>) | LC | Increasing | WV | 37 |
| | Little stint (<i>Calidris minuta</i>) | LC | Increasing | WV | 29 |
| | Marsh sandpiper (<i>Tringa stagnatilis</i>) | LC | Decreasing | PM | 29 |
| | Sanderling (<i>Calidris alba</i>) | LC | Unknown | WV | 9 |
| | Terek sandpiper (<i>Xenus cinereus</i>) | LC | Decreasing | WV | 16 |
| | Whimbrel (<i>Numenius phaeopus</i>) | LC | Decreasing | WV | 9 |
| Stercorariidae | Parasitic jaeger (<i>Stercorarius parasiticus</i>) | LC | Stable | WM | 6 |
| | Pomarine jaeger (<i>Stercorarius pomarinus</i>) | LC | Stable | WM | 1 |
| Ciconiiformes | | | | | |
| Ciconiidae | Painted stork (<i>Mycteria leucocephala</i>) | LC | Increasing | WV | 21 |
| Columbiformes | | | | | |
| Columbidae | Rock pigeon (<i>Columba livia</i>) | LC | Decreasing | BR | 27 |
| | Eurasian collared dove (<i>Streptopelia decaocto</i>) | LC | Increasing | SV | 59 |
| Coraciiformes | | | | | |
| Alcedinidae | Common kingfisher (<i>Alcedo atthis</i>) | LC | Unknown | BR | 56 |
| | White-throated kingfisher (<i>Halcyon smyrnensis</i>) | LC | Increasing | BR | 99 |
| Coraciidae (Rollers) | European roller (<i>Coracias garrulus</i>) | LC | Decreasing | PM | 25 |
| | Indian roller (<i>Coracias benghalensis</i>) | LC | Increasing | BR | 43 |
| Meropidae | Blue-cheeked bee-eater (<i>Merops persicus</i>) | LC | Stable | PM | 22 |
| | Asian green bee-eater (<i>Merops orientalis</i>) | LC | Increasing | BR | 96 |
| Falconiformes | | | | | |
| Falconidae | Common kestrel (<i>Falco tinnunculus</i>) | LC | Decreasing | WV | 35 |
| | Laggar falcon (<i>Falco jugger</i>) | NT | Decreasing | BR | 3 |
| | Peregrine falcon (<i>Falco peregrinus</i>) | LC | Increasing | WV | 11 |
| Galliformes | | | | | |
| Phasianidae | See-see partridge (<i>Ammoperdix griseogularis</i>) | LC | Stable | BR | 5 |
| Gaviiformes | | | | | |
| Gaviidae | Red-throated loon (<i>Gavia stellata</i>) | LC | Decreasing | WV | 1 |
| Gruiformes | | | | | |
| Rallidae | Common coot (<i>Fulica atra</i>) | LC | Increasing | WV | 22 |
| Otidiformes | | | | | |
| Otididae | Little bustard (<i>Tetrax tetrax</i>) | NT | Decreasing | PM | 3 |
| | Macqueen's bustard (<i>Chlamydotis macqueenii</i>) | VU | Decreasing | WV | 2 |

Table continued on next page.....

| Order/ Family | Common name (Scientific name) | IUCN status | Trend | Occurrence | Count |
|-----------------------|--|-------------|------------|------------|-------|
| Passeriformes | | | | | |
| Alaudidae | Black-crowned sparrow lark (<i>Eremopterix nigriceps</i>) | LC | Increasing | BR | 18 |
| | Crested lark (<i>Galerida cristata</i>) | LC | Decreasing | BR | 54 |
| | Greater hoopoe lark (<i>Alaemon alaudipes</i>) | LC | Decreasing | BR | 11 |
| | Hume's lark (<i>Calandrella acutirostris</i>) | LC | Stable | SV | 2 |
| | Oriental skylark (<i>Alauda gulgula</i>) | LC | Decreasing | BR | 9 |
| Campephagidae | Small minivet (<i>Pericrocotus cinnamomeus</i>) | LC | Stable | BR | 21 |
| Cisticolidae | Common tailorbird (<i>Orthotomus sutorius</i>) | LC | Stable | BR | 29 |
| | Rufous-fronted prinia (<i>Prinia buchanani</i>) | LC | Stable | BR | 25 |
| Corvidae | House crow (<i>Corvus splendens</i>) | LC | Stable | BR | 63 |
| Dicruridae | Black drongo (<i>Dicrurus macrocercus</i>) | LC | Unknown | BR | 88 |
| Emberizidae | Black-headed bunting (<i>Emberiza melanocephala</i>) | LC | Unknown | PM | 15 |
| | Grey-necked bunting (<i>Emberiza buchanani</i>) | LC | Stable | WV | 26 |
| | Striolated bunting (<i>Emberiza striolata</i>) | LC | Increasing | BR | 35 |
| Fringillidae | Trumpeter finch (<i>Bucanetes githagineus</i>) | LC | Stable | BR | 9 |
| Hirundinidae | Barn swallow (<i>Hirundo rustica</i>) | LC | Decreasing | WV | 39 |
| Laniidae | Bay-backed shrike (<i>Lanius vittatus</i>) | LC | Stable | BR | 56 |
| | Long-tailed shrike (<i>Lanius schach</i>) | LC | Unknown | BR | 69 |
| | Isabelline shrike (<i>Lanius isabellinus</i>) | LC | Stable | WV | 54 |
| Motacillidae | Tawny pipit (<i>Anthus campestris</i>) | LC | Stable | WV | 27 |
| | Water pipit (<i>Anthus spinoletta</i>) | LC | Stable | WV | 26 |
| Muscicapidae | Desert wheatear (<i>Oenanthe deserti</i>) | LC | Stable | WV | 34 |
| | Red-breasted flycatcher (<i>Ficedula parva</i>) | LC | Increasing | PM | 31 |
| | Rufous-tailed scrub robin (<i>Cercotrichas galactotes</i>) | LC | Stable | PM | 8 |
| | Variable wheatear (<i>Oenanthe picata</i>) | LC | Stable | WV | 61 |
| Oriolidae | Eurasian golden oriole (<i>Oriolus oriolus</i>) | LC | Stable | PM | 3 |
| Passeridae | Eurasian tree sparrow (<i>Passer montanus</i>) | LC | Decreasing | WV | 19 |
| | House sparrow (<i>Passer domesticus</i>) | LC | Decreasing | BR | 65 |
| Phylloscopidae | Common chiffchaff (<i>Phylloscopus collybita</i>) | LC | Increasing | WV | 56 |
| Pycnonotidae | White-eared bulbul (<i>Pycnonotus leucotis</i>) | LC | Decreasing | BR | 50 |
| Sturnidae | Rosy starling (<i>Pastor roseus</i>) | LC | Unknown | PM | 32 |
| Vangidae | Common wood shrike (<i>Tephrodornis pondicerianus</i>) | LC | Stable | BR | 22 |
| Pelecaniformes | | | | | |
| Ardeidae | Grey heron (<i>Ardea cinerea</i>) | LC | Unknown | WV | 39 |
| | Indian pond-heron (<i>Ardeola grayii</i>) | LC | Unknown | BR | 89 |
| | Little egret (<i>Egretta garzetta</i>) | LC | Increasing | BR | 63 |
| | Western reef egret (<i>Egretta gularis</i>) | LC | Stable | BR | 31 |
| Pelecanidae | Dalmatian pelican (<i>Pelecanus crispus</i>) | NT | Decreasing | WV | 19 |
| | Great white pelican (<i>Pelecanus onocrotalus</i>) | LC | Unknown | WV | 15 |
| Threskiornithidae | Eurasian spoonbill (<i>Platalea leucorodia</i>) | LC | Unknown | WV | 19 |
| Piciformes | | | | | |
| Picidae | Eurasian wryneck (<i>Jynx torquilla</i>) | LC | Decreasing | PM | 21 |
| | Sind woodpecker (<i>Dendrocopos assimilis</i>) | LC | Stable | BR | 5 |

Table continued on next page.....

| Order/ Family | Common name (Scientific name) | IUCN status | Trend | Occurrence | Count |
|--------------------------|---|-------------|------------|------------|-------|
| Podicipediformes | | | | | |
| Podicipedidae | Great crested grebe (<i>Podiceps cristatus</i>) | LC | Unknown | WV | 9 |
| Procellariiformes | | | | | |
| Procellariidae | Persian shearwater (<i>Puffinus persicus</i>) | LC | Decreasing | PM | 2 |
| Pteroclidiformes | | | | | |
| Pteroclididae | Black-bellied sandgrouse (<i>Pterocles orientalis</i>) | LC | Decreasing | WV | 1 |
| | Chestnut-bellied sandgrouse (<i>Pterocles exustus</i>) | LC | Stable | BR | 19 |
| | Lichtenstein's sandgrouse (<i>Pterocles lichtensteinii</i>) | LC | Stable | BR | 9 |
| Strigiformes | | | | | |
| Strigidae | Short-eared owl (<i>Asio flammeus</i>) | LC | Decreasing | WV | 8 |
| | Spotted owl (<i>Athene brama</i>) | LC | Stable | BR | 39 |
| Suliformes | | | | | |
| Phalacrocoracidae | Great cormorant (<i>Phalacrocorax carbo</i>) | LC | Increasing | WV | 31 |
| | Indian cormorant (<i>Phalacrocorax fuscicollis</i>) | LC | Unknown | BR | 9 |
| Sulidae | Masked booby (<i>Sula dactylatra</i>) | LC | Decreasing | PM | 9 |

*LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; **BR, breeding resident; PM, passage migrant; SV, summer visitor; WV, winter visitor.

Table V. Similarity between selected sites with respect to Sorensen and Jaccard similarity index.

| National parks | Sørensen similarity index | Jaccard similarity index |
|----------------|---------------------------|--------------------------|
| HNP vs. LSNP | 0.655 | 0.480 |
| HNP vs. KNP | 0.116 | 0.062 |
| LSNP vs. KNP | 0.208 | 0.116 |

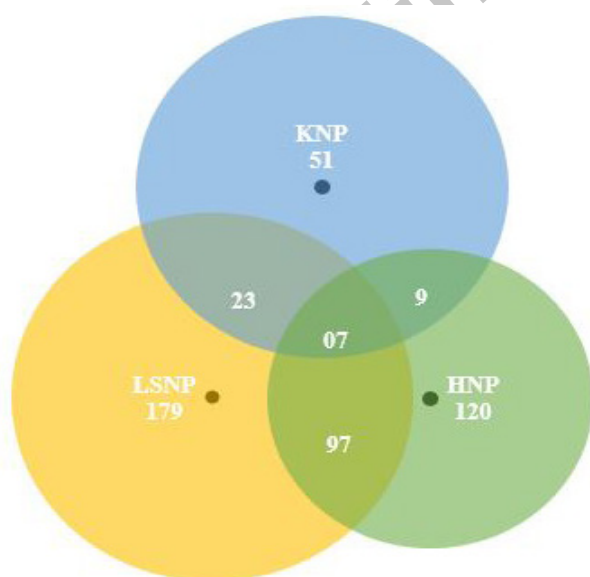


Fig. 3. Overlapping of avian species among KNP, LSNP and HNP.

The Sørensen and Jaccard similarity indices indicate varying degrees of similarity in avian species composition across HNP, LSNP and KNP. The indices revealed a high similarity between HNP and LSNP. This suggests that there is 48% overlap in species composition and likely similar ecological conditions. Ninety-seven bird species are common in HNP and LSNP (Fig. 3). The indices showed low similarity between HNP and KNP and only 6.2% species overlap is there (Table V). Only 9 species are common in HNP and KNP; common sandpiper, eurasian golden oriole, common gull-billed tern, house sparrow, long-tailed shrike, oriental skylark, rock dove, common kestrel, and golden eagle. For LSNP and KNP, there was low similarity in avian species composition. The value indicates 1.16% overlap but still reflects significant differences in the avian communities and ecological settings of these two national parks. Total 23 species are common between LSNP and KNP. In terms of common species, only 7 species are common in selected altitudinally different national parks, common sandpiper, eurasian golden oriole, common gull-billed tern, house sparrow, long-tailed shrike, oriental skylark and rock dove.

DISCUSSION

The comparative analysis of avian diversity across three national parks, KNP, LSNP and HNP, has revealed the ecological dynamics and conservation status of these regions. The species richness was highest in LSNP (179) followed by 120 species in HNP and 51 in KNP. The mid elevation (LSNP) was found to be most rich in avian

diversity. Several studies have shown that species richness is greater at mid-elevation ranges compared to both lower and higher elevations (Hu *et al.*, 2018; Ding *et al.*, 2019; Pandey *et al.*, 2020). Khan *et al.* (2018) reported 74 bird species with 7443 individuals in LSNP. A total of 204 species were recorded by Ghalib *et al.* (2008) in HNP while Qureshi *et al.* (2011) reported forty bird species from KNP. This difference in the number of species between the three national parks may be attributed to the types of environments, climatic factors and geographical position of the national parks. HNP with coastal and desert habitats, is moderately rich in species, whereas KNP in the extremely high-altitude mountainous region, is the poorest in species richness. A similar trend was also noted in other studies (Neupane *et al.*, 2020). Currently, there are only two habitats in HNP and KNP while there are five habitats in LSNP. Out of all the surveyed national parks, LSNP offered the greatest opportunities in species richness because of the varying types of land use, which include agricultural land, wetland, and forest (Schaub *et al.*, 2010; Acharya *et al.*, 2011; Ferger *et al.*, 2014). Available habitats in LSNP such as agricultural land are chief sources of food for many bird species such as fruits, grains, insects, and rodents that are known to enhance bird richness (Chettri *et al.*, 2005; Kunwar *et al.*, 2023). On the other hand, higher elevation is associated with lower productivity of habitats and hence the associated invertebrate resources are diminished and patchily distributed. This scarcity of food resources reduces the existing bird species in the higher elevation zones (Hu *et al.*, 2018).

The occurrence data also provided necessary information about the distribution of avian species in the national parks related to the seasonal aspects. KNP despite the extreme condition such as high altitude was able to offer habitats for resident birds and acted as a breeding and belt stopover site for migrants (Qureshi *et al.*, 2011). This suggests that KNP provides suitable habitats for both resident and migratory avian species, despite its high-altitude alpine and subalpine ecosystems (Williamson and Witt, 2021). LSNP supported a diverse avian community throughout the year, with significant numbers of both resident and migratory species. These results are consistent with Khan *et al.* (2018). HNP is home to many species of birds with high number of passage migrants and winter migrants implying that the climatic conditions favor these areas and therefore, the habitats offered at the site are favorable for these birds (McGrann and Furnas, 2016). Additionally, there are notable numbers of passage migrants and winter migrants, indicating the national park's importance as a stopover site and wintering ground for migratory birds.

The diversity and variety of bird life in KNP displays

its unique alpine landscape. Many birds found here belong to distinct groups, unlike those in HNP and LSNP. This habitat, with high evenness and richness of species, suggests that there is a well-balanced bird community that manages to thrive in a challenging alpine setting (Achmad *et al.*, 2021). Conversely, LSNP has more variety in species, and diversity statistics suggests that it hosts a broader array of habitats suitable for various bird populations to varying degrees (Kusumoarto *et al.*, 2020).

Within each national park, the bird guild analysis reveals that how different species of birds coexist based on their feeding strategies and habitat use. KNP has a lower diversity of avian guilds compared to other national parks; carnivores and insectivores dominate likely because of the high insect population at this elevation (Katuwal *et al.*, 2016). Herbivores and granivores are few due to limited plant-based food sources in this harsh environment (Santhakumar *et al.*, 2018). LSNP stands out with the highest guild diversity, rich vegetation provides various food resources supporting insectivores, carnivores, omnivores, herbivores, piscivores, and granivores. This guild diversity highlights the complex food web interactions within LSNP's ecosystem (Blondel, 2003). HNP's feeding guild composition lies between KNP and LSNP. Piscivorous birds such as gulls and terns are likely found in HNP because it is a coastal landscape park. In addition, the abundance of insectivore and carnivore species at mid elevations like LSNP has been reported by Katuwal *et al.* (2016).

CONCLUSION

This study highlights the avian species richness across KNP, LSNP, and HNP, each showcasing unique ecological characteristics. Khunjerab hosts 51 species with moderate diversity and richness, while Lal Suhanra, with its diverse habitats, is the richest, harboring 179 species. Hingol, with bare rock/gravel and desert habitats, supports 120 species. Despite distinct geographical and ecological differences, seven generalist avian species were common across all national parks, indicating ecological resilience. Similarity indices show high species composition overlap between Hingol and Lal Suhanra, suggesting similar ecological conditions, while Khunjerab's unique environment shows low overlap with the other national parks.

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IRB approval

The Advanced Studies and Research Board of University of the Punjab, Lahore, Pakistan approved this study (D. No. 8471/Acad, dated: 30/10/2023).

Statement of conflict of interest

The authors have declared no conflict of interest.

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