Bulletin of Pure and Applied Sciences
Zoology (Animal Science), Vol.43A, No.2,
July-December 2024: P.310-329

Print version ISSN 0970 0765
Online version ISSN 2320 3188

Original Article *Content Available online at: https://www.bpasjournals.com/*

Distribution and diversity patterns of birds along the elevation gradient of the Aravalli Hills of Mount Abu Wildlife Sanctuary, Rajasthan, India

[1]Narayan Lal Choudhary* and [2]Nadim Chishty

Author's Affiliation:
[1]Assistant Professor, Department of Zoology, Adarsh Mahavidhyalaya (Affiliated to Jai Narain Vyas University) Jodhpur, Rajasthan-342008, India
E-mail: narayanlalchoudhary1995@gmail.com
[2]Professor, Wildlife, Limnology and Toxicology Research Laboratory, Department of Zoology, Government Meera Girls College (Affiliated to Mohanlal Sukhadia University) Udaipur, Rajasthan 313001, India.
E-mail: nadimchishty@gmail.com

***Corresponding author:**
Dr. Narayan Lal Choudhary,
Department of Zoology, Adarsh Mahavidhyalaya (Affiliated to Jai Narain Vyas University) Jodhpur, Rajasthan- 342008, India
E-mail: narayanlalchoudhary1995@gmail.com

Received on 11.07.2024
Revised on 22.11.2024
Accepted on 12.12.2024

ABSTRACT:
Study was carried out on the distribution, species richness, diversity and abundance of bird communities along the altitudinal gradient of the Aravalli ranges of Mount Abu Wildlife Sanctuary (MA-WLS). Study area's altitude varies from 280 to 1722 meters above sea level (m.a.s.l.). The study area was categorized into three altitudinal ranges: Range I or lower altitudinal range (B). Range II or middle altitudinal range and (C). Range III or higher altitudinal range. This categorization was done on the basis of vegetation composition and types of forests along altitude, we observed 201 bird species from three altitudinal ranges and habitats in MA-WLS, representing 63 families and 19 orders. Out of these 19 orders of birds, the Passeriformes order was most diverse in terms of species richness with 86 species followed by Charadriiformes (17), Anseriformes (15), Pelecaniformes and Accipitriformes (13 species for each order). Selected three altitudinal ranges, the most diverse range in terms of bird species richness, individuals and diversity was the altitudinal range I (species = 190; bird individuals = 25888; Simpson diversity index = 0.987; Shannon diversity index = 4.719) followed by range II (species = 152; bird individuals = 17850; Simpson diversity index = 0.983; Shannon diversity index = 4.471) and the lowest species richness and bird individuals were observed in the altitudinal range III (species = 124; bird individuals = 11198; Simpson diversity index = 0.980; Shannon diversity index = 4.327). It was observed that the species richness, diversity and abundance exhibit a monotonic decline pattern along the increase in altitudinal gradient. The relative abundance of each species also differs according to the altitudinal variation. The diverse range of habitats found across the altitudinal gradient in MA-WLS contributes to a high diversity and abundance of bird species. The existence of seasonal and perennial water bodies, as well as variations in floral composition across different altitudes, sustains a variety of aquatic and terrestrial species that reside or migrate in MA-WLS.

Keywords:
Mount Abu Wildlife Sanctuary, Bird, Altitude, Species richness, Diversity, Relative Abundance.

How to cite this article: Choudhary N.L. and Chishty N. (2024). Distribution and diversity patterns of birds along the elevation gradient of the Aravalli Hills of Mount Abu Wildlife Sanctuary, Rajasthan, India. *Bulletin of Pure and Applied Sciences-Zoology*, 43A (2), 310-329.

1. INTRODUCTION

Avian species serve as crucial biomarkers for evaluating the condition of ecosystem health and alterations or changes in their community composition can be attributed to modifications in habitat resulting from either natural or human-induced disturbances (Rahayuninagsih *et al.,* 2007; Rajpar and Zakaria, 2011; Choudhary and Chishty, 2024). Various taxa widely observe the general phenomenon of species richness and diversity decreasing along elevation level (Kattan and Franco, 2004; Basnet and Badola, 2012; Neupane *et al.,* 2020; Ghimire *et al.,* 2021; Kunwar *et al.,* 2023; Mahata and Sharma, 2023). This pattern resembles the latitudinal gradient pattern of species richness and diversity. A monotonic decline in species richness is a common pattern at smaller spatial scales, whereas a hump-shaped pattern is prevalent at larger spatial scales (Rahbek, 2005). In general, three patterns of species richness and diversity along altitudinal gradients are observed: monotonic decline (decrease with elevation), hump-shaped pattern or mid-elevation peak or mid-domain effect and species richness and diversity increasing with elevation. Two of these three patterns, monotonic decline and mid-domain peak, are the most frequently observed (Rahbek, 1995; McCain, 2009; Pandey *et al.,* 2020; Dendup *et al.,* 2021; Kunwar *et al.,* 2023; Mahata and Sharma, 2023). The third pattern, where species and diversity increase with elevation level, was rarely observed (Stevens, 1992; Rahbek, 1995; Alvarez-Alvarez *et al.,* 2020). Furthermore, peaks of species richness and diversity along elevation gradients were varied across types of targeted taxonomic groups or species, along the location of mountain ranges, spatial scales and the proportion of the entire gradient has been studied (Nogues-Bravo *et al.,* 2008; McCain, 2009; Kluge *et al.,* 2017).

Patterns of diversity, richness and abundance of any organism, including birds are influenced by physical environmental factors along with elevation gradients (Korner and Paulsen, 2004). The species diversity and composition in particular areas are influenced by their habitat, altitudes and other environmental factors such as temperature and rainfall (Sanchez-Gonzalez and Lopez-Mata, 2005). Distribution patterns along elevation gradients have been widely studied among animal taxa, including invertebrates (Carneiro *et al.,* 2014; Acharya and Vijayan, 2015), herpatofauna (Fu *et al.,* 2007; Chettri *et al.,* 2010), birds (McCain, 2009; Acharya *et al.,* 2011; Cavarzere and Silveira, 2012; Wu *et al.,* 2017; Ghimire *et al.,* 2021) and mammals (Rickart, 2001; McCain, 2004, 2005 and 2007). Therefore, study was made to examine the impact of altitudinal variation on the avian community in the Aravalli hills of Mount Abu Wildlife Sanctuary, Rajasthan, India.

2. MATERIAL AND METHODS

Study Area

Mount Abu Wildlife Sanctuary (MA-WLS) is situated in the southernmost region of the Aravalli ranges in Sirohi district and their geographic location is between (24°33′N-24°43′N, 72°38′E-72°53′E). The altitude of sanctuary areas varies from 280 meters above sea level (m.a.s.l.) at the foothills to 1722 meters above sea level (m.a.s.l.) at Guru Shikhar. The Mount Abu ridge encompasses a length of 19 kilometers and has a narrow shape, measuring between 5 to 8 kilometers in width. Temperature in the Sanctuary area varies from -4°C to 18°C in winter and 24°C to 35°C in summer. Monsoon season typically begins after mid-June and ends in September with the average annual rainfall in this area above 1500 mm. The sanctuary's lower altitudinal ranges are warmer than the higher altitudinal range, which includes the Mount Abu municipal area.

Mount Abu exhibits a diverse range of floral biodiversity, encompassing approximately 820 plant species from 449 genera and 112 families, out of which 157 are monocot species and 663 are dicot species (Mehta, 1979). We classify the study area into three altitudinal ranges based on the vegetation composition and types of forests along altitude. We categorized the study area into three altitude ranges. These ranges were (A). Range I (280 m.a.s.l. to 760 m.a.s.l.) represents the lower altitudinal range (B). The second altitudinal range, from 761 m.a.s.l. to

1240 m.a.s.l., represents the middle altitudinal range, while the third altitudinal range, from 1241 m.a.s.l. to 1722 m.a.s.l., represents the higher altitudinal range.

The forest on the lower slope consists of a combination of xeromorphic thorny trees. The nearby plains and lower areas of the Aravalli Mountain range commonly host this type of flora. The higher elevations and valleys are heavily forested with abundant subtropical evergreen species (Mehta, 1979). Lower altitudinal ranges received less annual precipitation than higher altitudinal ranges. Variation in rainfall is the primary factor that causes differences in vegetation and plant communities along the MA-WLS altitudinal gradient.

In Mount Abu, an account of the vegetation has been published by Mahabale and Kharadi (1946), cited in Champion and Seth (1968), from which it is evident that whatever it may have been originally, there is now no sub-tropical evergreen to be found through some of the higher valleys, including *Syzygium cumini*, *Ixora arborea* and *Strobilanthes spp.,* while the presence of numerous species of Himalayan origin also suggests subtropical conditions (Champion and Seth, 1968). A revised survey of Indian forest types (Champion and Seth, 1968) classified Indian forests into 16 classes. Out of these, Rajasthan has three types of forests. Name of these forests are Tropical Dry Deciduous Forest, Dry Thorny Forest and Subtropical Broad Leaved Hill Forest (Sharma, 2021). Mount Abu is home to all three types of forest along the various altitudinal ranges. Dry Thorny Forest occurs in lower altitudinal ranges, while Tropical Dry Deciduous Forest and its representative species are present in middle altitudinal ranges and Subtropical Broad Leaved Hills Forest occurs in higher altitudinal ranges. Lower altitudinal vegetation compositions also exhibit xeromorphic characteristics due to low rainfall and other climatic conditions as compared to higher altitudinal ranges (Mehta, 1979; Sharma, 2021). Table 1 shows the floral species composition along the MA-WLS's altitudinal range.

Table 1: Floral species distribution and occurrence along the altitudinal gradient of MA-WLS Aravalli ranges.

S.no.	Altitudinal	Distribution and occurrence of major floral species
1	Up to- 400 m	*Acacia leucophloea*, *Bauhinia varigata* and *Prosopis julifora.*
2	400-500 m	*Anogeissus pendula*, *Butea monosperma*, *Dichrostachya cinerea*, *Acacia spp*., and *Securinega leucopyrus*
3	500-600 m	*Butea monosperma-Anogeissus pendula* association dominates. *Acacia leucophloen*, *Wrightia tinctoria*, *Moringa concanensis*, *Cassia auriculata* and *Dichrostachya cinerea*. Shrubs and herbs like: *Cassia tora*, *Zizypius nummularia*, *Xanthium strumarium*, *Achyranthes aspera*, *Apluda mutica* and *Sorghum halepense.*
4	600-700 m	*Anogeissus latifolia*, *Wrightia tinctoria*, *Aegle marmelos*, *Dendrocalmus strictus*, *Holoptelea integrifolia* and *Mitragyna parviflora*. Other plant species: *Abutia indicum*, *Cyperus paniecus*, *Apluda mutica*, *Dichanthium annulatum*, *Heteropogon contortus*, *Tephrosia pumila* and *Impatiens balsamina*.
5	700-900 m	*Anogeissus latifolia*, *Boswellia serrata*, *Dalbergia latifolia*, *Bombax ceiba*, *Kydia calycina*, *Mallotus philippensis*, *Anogeissus latifolia*, *Lannea coromandelica* and *Wrightia tomentosa.* Other large trees: *Ficus spp., Helicteres isora, Nyctanthes arbor-tristis, Sterculia urens, Toona ciliata, Boswellia serrata, Phyllanthus emblica, Mallotus phillipensis, Kydia calycina, Cassia fistula* and *Albizia odoratissima.*
6	900-1100 m	*Erythrina suberosa, Bauhinia purpurea, Bauhinia variegate, Syzyium cumini and Mangifera indica, Ficus spp., Kydia calycina*, *Mallotus phillippensis* and *Anogeissus spp.,* are common plant species found in the periphery of forests and hilly regions between 900 to 1100 meters. Shrubs species: *Carissa*

		spinarum, *Carissa carndas* and *Capparis grandis.*
7	1100-1400 m	*Grevillea robusta*, *Toona ciliata*, *Mangifera indica*, *Syzygium cumini*, Albizia *lebbeck*, *Bahunia purpurea*, *Phoenix sylvestris, Ficus spp.,* as well as introduced or cultivated *Eucalyptus* species, *Lantana camara* and other *Lantana spp*.
8	Above 1400 m elevation to Guru Sikhar	*Qnuntia elatior*, *Euphorbia spp*., *Eucalyptus spp., Lantana camara* and other *Lantanta* species.

Study Duration and Methods

The study was conducted for three years, from September 2020 to September 2023. Primary survey started from September 2020 to September 2021 after that every month, seven days of regular and systematic field surveys were carried out from October 2021 to September 2023 to assess the distribution, diversity and abundance of bird species in different altitudinal ranges and habitats of MA-WLS. We conducted all bird-related observations with extreme caution, ensuring a suitable distance from each individual bird to prevent any disturbance to the birds or their habitats. Throughout the entire duration of the study, we carefully adhered to the rules and regulations outlined in the Wildlife Protection Act of 1972.

We conducted field surveys from 7:00 a.m. to 11:00 a.m. in the morning and 3:00 p.m. to 6:00 p.m. in the evening during the winter season and from 6:00 a.m. to 10:00 a.m. in the morning and 4:00 p.m. to 7:00 p.m. in the evening during the summer season. During the rainy season, we conducted field surveys in clear weather with no precipitation. We conducted field surveys throughout the days following the morning rainfall. Nomenclature was followed as per the provided by Praveen *et al.* (2016), Praveen and Jayapal (2023), Birdlife International (2023) and IUCN Red List (2024) for the common name, scientific name, families and order of birds. Identification and field diagnosis of birds were done using standard field guides: birds of the Indian Subcontinent (Grimmett *et al.,* 2011), Birds of Rajasthan (Vyas, 2013) and Birds of India (Majumder *et al.,* 2022).

We observed birds directly with Nikon 8x42 binoculars and took photographs of them using a Nikon P1000 and a Canon 700D with a Sigma 150-500 mm lens at an appropriate distance to avoid disturbing them. Point count is a widely used survey technique for assessing the species diversity and abundance of birds in a particular habitat or ecosystem (Thompson and Schwalbach, 1995; Rosenstock *et al.,* 2002). In this method, stand at one place and count all the birds seen and heard. Various locations in the study area utilize the simple point count method to compile a comprehensive list of the various species inhabiting a specific region. During the study, we counted bird individuals of each species within a circle of 25 meters in dense forest habitat and 50 meters in open habitat, such as rocky-sloppy mountain and grassland areas, at each point count station. At every point count station, spend five minutes observing species and individuals in a circle: 25 meters in dense forest habitat and 50 meters in open areas. Length of the circles was measured by the laser rangefinder. We completed the point count station counting process quickly during the study to minimize the risk of double counting and to maximize the number of visit able point count stations within the study area. Distance between two point-count stations was approximately more than 200 meters.

We used a Garmin 72H GPS to determine the location and altitudes of the point count stations. During the study, a total of 240 fixed point count stations were fixed for assessing the distribution, diversity and abundance of resident and migratory species in different altitudinal levels. Number of fixed point stations was 100 in altitudinal range I, followed by 80 in altitudinal range II and 60 in altitudinal range III (Figure 1). We determined the number of point count stations based on the area of specific altitudinal ranges, as lower altitudinal ranges or foothill regions have larger areas than middle and higher altitudinal ranges. Figure 1 displays these fixed point count stations. Additionally,

the randomly selected point count stations in the study area also collected some data. During the study, we analyzed data collected from different elevation levels using MS Excel and Past software (4.03 versions) for various diversity indices, such as the Simpson diversity index and Shannon diversity index (Hammer *et al.*, 2001).

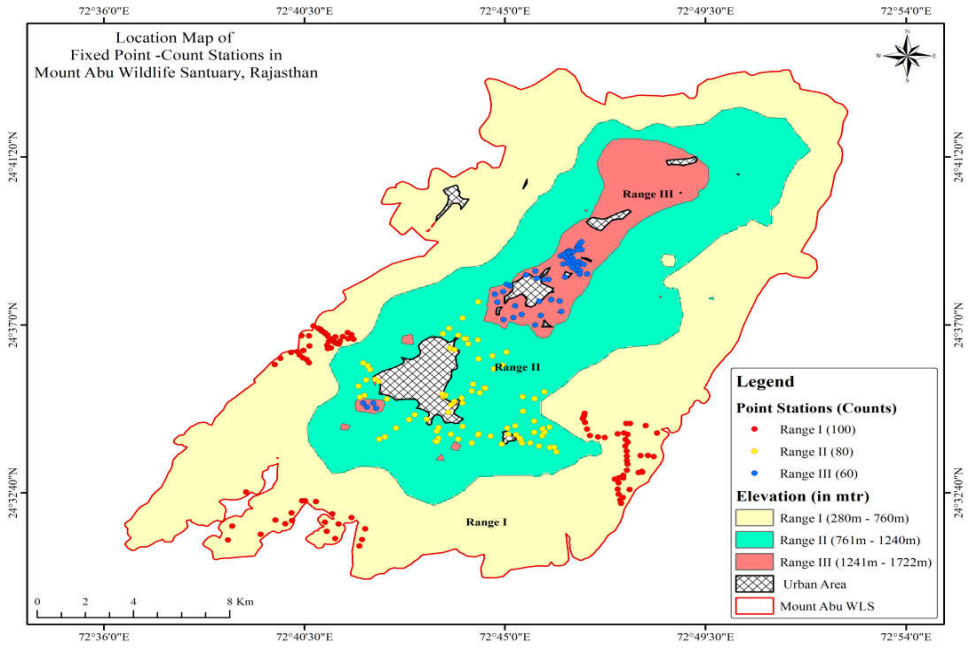

Figure 1: Location map of the fixed point count station in MA-WLS

Formulas of Various Diversity Indices and Species Relative Abundance

A. Species richness (S): Species richness is a simple measure of the number of species present in a particular habitat, community, defined area or in particular seasons. It is represented by S.

B. Simpson diversity index (D): Value of Simpson diversity index is calculated by using the following formula (Simpson, 1949):

$$D = 1 - \left(\frac{\Sigma n\ (n-1)}{N(N-1)}\right)$$

Where D= Simpson diversity index; N- Total number of individuals of all species; n = Total number of individuals of a particular species

C. Shannon diversity index (H'): It is used to quantify the diversity of species in a community or specific area (Shannon and Weaver, 1949). Value of Shannon diversity index is calculated by using the following formula.

$$H' = -\sum_{i=1}^{S} \quad (pi^*\ ln\ ln\ pi)$$

Where H' =Shannon's diversity index; S= Total number of species in the community; pi= relative abundance of species i^{th} species; In – natural log to base 2.

D. Species relative abundance: Study of species relative abundances has great significance in conservation biology and management. It provides detailed information related to the effects of habitat disturbance or ecosystem fragmentation. It is widely recognized that disturbed and fragmented habitat tends to have much lower species diversity and abundance as compared to undisturbed or less distributed habitat (Regan *et al.*, 2003; Guisan and Thuiller, 2005). Relative abundance of each species was calculated by using following formula:

$$Species\ Relative\ Abudance\ (\%) = \frac{ISi}{\Sigma Nsi} X\ 100$$

Where, Isi= Total number of individuals of particular species or given species in particular habitat or seasons or altitudinal ranges; ΣNsi =Total number of individuals of all species in

particular habitat or seasons or altitudinal ranges.

3. RESULT

Bird Community of MA-WLS

During study, a total of 201 species of birds belonging to 63 families and 19 orders were observed from different altitudinal ranges and habitats in MA-WLS (Table 2). Out of these 19 orders of birds, the Passeriformes order was most diverse in terms of species richness with 86 species followed by Charadriiformes (17), Anseriformes (15), Pelecaniformes and Accipitriformes (13 species for each order). There were seven species each in four orders: Galliformes, Columbiformes, Coraciiformes and Piciformes. In addition, the Cuculiformes were represented by six species followed by the Suliformes and Ciconiiformes orders, which had four species each. Three orders, namely Gruiformes, Psittaciformes and Strigiformes were represented by three species each. Two orders, namely Caprimulgiformes and Bucerotiformes had two species each. Podicipediformes and Falconiformes orders were represented by single species each and were poorly diverse in terms of species richness in the study area under consideration.

Distribution of Bird Species along Altitudinal Ranges I, II AND III

The study area was categorized into three altitudinal ranges, namely range I, range II and range III. We observed a total of 201 bird species in all three altitudinal ranges of MA-WLS. Out of these altitudinal ranges, the maximum number of species were observed in the lower altitudinal range (range I = 190 species) followed by the middle altitudinal range (range II = 152 species) and minimum number of species were observed in the higher altitudinal range (range III = 124 species) (Table 1; Figure 2). It was observed that the 121 bird's species were common in all three altitudinal ranges and their distribution ranged from lower altitudinal ranges to higher altitudinal ranges. During study, it was found that there were 49 bird species that were distributed only in the altitudinal range I and their presence was not observed in the altitudinal ranges II and III. Similarly, 20 bird species distribution and presence were observed from altitudinal ranges I and II, but these species were not observed from altitudinal range III. During study, eight such species were observed, whose distribution and presence were found only in altitudinal range II, but their distribution and occurrence were not observed in altitudinal ranges I and III. Names of these species were Alexandrine Parakeet, Indian Scops-owl, Blue-cheeked Bee-eater, Indian Pygmy Woodpecker, Indian Blackbird, Desert Wheatear, Red-breasted Flycatcher and Tickell's Blue-flycatcher. During study, three such species were seen whose distribution was observed in altitudinal ranges II and III. But the distribution of these species was not observed in altitudinal range I. These species were Booted Warbler, Greenish Warbler and Green Avadavat.

Species Richness, Individuals and Diversity along the Altitudinal Gradient (Range I, II AND III):

Selected three altitudinal ranges, the most diverse range in terms of number of bird species and individuals was the altitudinal range I (species =190; bird individuals = 25888) followed by range II (species = 152; bird individuals = 17850) and the lowest species richness and bird individuals were observed in the altitudinal range III (species = 124; bird individuals = 11198) **(**Figure 2, 3). Species richness and individuals exhibit monotonic decline with an increase in altitude (Figure 2, 3). Maximum value of the Simpson diversity index was found in altitudinal range I (0.987) followed by range II (0.9834) and the minimum value of the Simpson diversity index was found in range III (0.9802) (Figure 4). Maximum value of the Shannon diversity index was observed in altitudinal range I (4.719) followed by range II (4.471) and the minimum value of the Shannon diversity index was observed in range III (4.327) (Figure 5).

Table 2: Species distribution and relative abundance of species in different altitudinal ranges (I, II and III) of MA-WLS

S.no	Common Name	Zoological name	Species relative abundance (%)		
			Range I	Range II	Range III
1. Family- Podicipedidae [Order- Podicipediformes]					
1	Little Grebe	*Tachybaptus ruficollis*	1.132	0.487	0.598
2. Family- Phalacrocoracidae [Order- Suliformes]					
2	Little Cormorant	*Microcarbo niger*	1.313	1.160	1.348
3	Indian Cormorant	*Phalacrocorax fuscicollis*	0.680	0.521	0.679
4	Great Cormorant	*Phalacrocorax carbo*	0.344	0.387	0.000
3. Family- Anhingidae [Order-Suliformes]					
5	Oriental Darter	*Anhinga melanogaster*	0.413	0.151	0.000
4. Family- Ardeidae [Order-Pelecaniformes]					
6	Little Egret	*Egretta garzetta*	1.595	1.277	0.536
7	Intermediate Egret	*Ardea intermedia*	0.564	0.000	0.000
8	Cattle Egret	*Bubulcus ibis*	1.904	1.541	1.197
9	Great White Egret	*Ardeola alba*	0.722	0.000	0.000
10	Indian Pond Heron	*Ardeola grayii*	1.649	1.496	1.313
11	Grey Heron	*Ardea cinerea*	0.904	0.000	0.000
12	Purple Heron	*Ardea purpurea*	0.394	0.000	0.000
13	Black-crowned Night-heron	*Nycticorax nycticorax*	0.085	0.000	0.000
14	Striated Heron	*Butorides striata*	0.089	0.314	0.143
5. Family- Threskiornithidae [Order-Pelecaniformes]					
15	Red-napped Ibis	*Pseudibis papillosa*	0.699	0.000	0.000
16	Black-headed Ibis	*Threskiornis melanocephalus*	0.626	0.000	0.000
17	Glossy Ibis	*Plegadis falcinellus*	0.375	0.000	0.000
18	Eurasian Spoonbill	*Platalea leucorodia*	0.421	0.000	0.000
6. Family- Ciconiidae [Order-Ciconiiformes]					
19	Painted Stork	*Mycteria leucocephala*	0.251	0.000	0.000
20	Asian openbill	*Anastomus oscitans*	0.228	0.000	0.000
21	Asian Woolly-necked Stork	*Ciconia episcopus*	0.340	0.123	0.170
22	Black Stork	*Ciconia nigra*	0.058	0.039	0.000
7. Family- Anatidae [Order-Anseriformes]					
23	Knob billed Duck	*Sarkidiornis melanotos*	0.633	0.437	0.491
24	Indian Spot-billed Duck	*Anas poecilorhyncha*	0.379	0.471	0.447
25	Northern Pintail	*Anas acuta*	0.444	0.459	0.330
26	Northern Shoveler	*Spatula clypeata*	0.189	0.185	[illegible]
27	Gadwall	*Mareca strepera*	0.336	0.179	0.170

28	Mallard	*Anas platyrhynchos*	0.131	0.067	0.054
29	Eurasian Wigeon	*Mareca penelope*	0.243	0.179	0.000
30	Common Teal	*Anas crecca*	0.301	0.258	0.000
31	Ruddy Shelduck	*Tadorna ferruginea*	0.267	0.000	0.000
32	Red-Crested Pochard	*Netta rufina*	0.085	0.000	0.000
33	Tufted Duck	*Aythya fuligula*	0.062	0.045	0.000
34	Common Pochard	*Aythya ferina*	0.104	0.000	0.000
35	Lesser Whistling Duck	*Dendrocygna javanica*	0.834	0.000	0.000
36	Greylag Goose	*Anser anser*	0.297	0.000	0.000
37	Bar-headed Goose	*Anser indicus*	0.394	0.000	0.000
8. Family: Accipitridae [Order-Accipitriformes]					
38	Black-winged Kite	*Elanus caeruleus*	0.251	0.487	0.679
39	Black Kite	*Milvus migrans*	0.066	0.000	0.000
40	Egyptian Vulture	*Neophron percnopterus*	0.178	0.056	0.000
41	Short-toed Snake-eagle	*Circaetus gallicus*	0.081	0.045	0.000
42	Crested Serpent Eagle	*Spilornis cheela*	0.162	0.448	0.321
43	Western Marsh Harrier	*Circus aeruginosus*	0.089	0.000	0.000
44	Shikra	*Accipiter badius*	0.576	0.543	0.920
45	Oriental Honey Buzzard	*Pernis ptilorhynchus*	0.085	0.073	0.000
46	White-eyed Buzzard	*Butastur teesa*	0.093	0.000	0.000
47	Long-legged Buzzard	*Buteo rufinus*	0.062	0.000	0.000
48	Common Buzzard	*Buteo buteo*	0.031	0.000	0.000
49	Bonelli's Eagle	*Aquila fasciata*	0.050	0.000	0.000
50	Changeable Hawk-eagle	*Nisaetus cirrhatus*	0.070	0.101	0.134
9. Family-Falconidae [Order-Falconiformes]					
51	Common Kestrel	*Falco tinnunculus*	0.147	0.157	0.268
10. Family- Phasianidae [Order-Galliformes]					
52	Grey Francolin	*Ortygornis pondicerianus*	1.043	1.681	1.536
53	Rain Quail	*Coturnix coromandelica*	0.077	0.151	0.205
54	Rock Bush-quail	*Perdicula argoondah*	0.174	0.454	0.339
55	Jungle Bush-quail	*Perdicula asiatica*	0.112	0.140	0.116
56	Aravalli Red-Spurfowl	*Galloperdix spadicea caurina*	1.047	2.706	2.858
57	Grey Junglefowl	*Gallus sonneratii*	0.409	1.182	0.938
58	Indian Peafowl	*Pavo cristatus*	0.900	1.770	0.822
11. Family- Rallidae [Order-Gruiformes]					
59	White-breasted Waterhen	*Amaurornis phoenicurus*	0.224	0.230	0.000
60	Common Moorhen	*Gallinula chloropus*	0.158	0.056	0.000
61	Common Coot	*Fulica atra*	2.302	1.081	1.732
12. Family- Rostratulidae [Order-Charadriiformes]					

62	Greater Painted-Snipe	*Rostratula benghalensis*	0.556	0.000	0.000
13. Family- Charadriidae [Order-Charadriiformes]					
63	Little Ringed Plover	*Charadrius dubius*	0.417	0.314	0.366
64	Red-wattled Lapwing	*Vanellus indicus*	2.538	2.319	1.697
65	Yellow-wattled Lapwing	*Vanellus malabaricus*	0.050	0.000	0.000
14. Family- Scolopacidae [Order-Charadriiformes]					
66	Black-tailed Godwit	*Limosa limosa*	0.151	0.000	0.000
67	Common Redshank	*Tringa totanus*	0.174	0.073	0.080
68	Common Greenshank	*Tringa nebularia*	0.193	0.090	0.116
69	Green Sandpiper	*Tringa ochropus*	0.189	0.174	0.232
70	Wood Sandpiper	*Tringa glareola*	0.066	0.123	0.098
71	Common Sandpiper	*Actitis hypoleucos*	0.104	0.090	0.277
72	Ruff	*Calidris pugnax*	0.093	0.000	0.000
73	Common Snipe	*Gallinago gallinago*	0.170	0.062	0.063
15. Family- Recurvirostridae [Order-Charadriiformes]					
74	Black-winged Stilt	*Himantopus himantopus*	2.573	1.557	1.063
75	Pied Avocet	*Recurvirostra avosetta*	0.031	0.000	0.000
16. Family- Burhinidae [Order-Charadriiformes]					
76	Great Thick-knee	*Esacus recurvirostris*	0.070	0.000	0.000
17. Family- Glareolidae [Order-Charadriiformes]					
77	Small Pratincole	*Glareola lactea*	0.182	0.000	0.000
18. Family- Laridae [Order-Charadriiformes]					
78	River Tern	*Sterna aurantia*	0.340	0.269	0.375
19. Family- Columbidae [Order-Columbiformes]					
79	Rock Pigeon	*Columba livia*	3.160	2.824	3.938
80	Yellow-footed Green-Pigeon	*Treron phoenicopterus*	0.313	0.347	0.170
81	Laughing Dove	*Spilopelia senegalensis*	1.317	1.681	1.509
82	Spotted Dove	*Spilopelia suratensis*	0.722	0.992	0.964
83	Eurasian Collared-dove	*Streptopelia decaocto*	0.792	1.132	1.572
84	Red Turtle-dove	*Streptopelia tranquebarica*	0.722	0.375	0.447
85	Oriental Turtle Dove	*Streptopelia orientalis*	0.494	0.790	0.866
20. Family- Psittacidae [Order-Psittaciformes]					
86	Plum headed Parakeet	*Himalayapsitta cyanocephala*	0.807	1.193	0.839
87	Rose-ringed Parakeet	*Alexandrinus krameri*	1.024	2.779	1.170
88	Alexandrine Parakeet	*Palaeornis eupatria*	0.000	0.246	0.000
21. Family- Cuculidae [Order- Cuculiformes]					
89	Jacobins Cuckoo	*Clamator jacobinus*	0.039	0.050	0.027
90	Common Hawk-Cuckoo	*Hierococcyx varius*	0.031	0.000	0.000
91	Indian Cuckoo	*Cuculus micropterus*	0.015	0.000	0.000

92	Grey-bellied Cuckoo	*Cacomantis passerinus*	0.039	0.000	0.000
93	Asian Koel	*Eudynamys scolopaceus*	0.267	0.241	0.188
94	Greater Coucal	*Centropus sinensis*	0.259	0.291	0.473
22. Family- Strigidae [Order-Strigiformes]					
95	Jungle Owlet	*Glaucidium radiatum*	0.023	0.000	0.000
96	Spotted Owlet	*Athene brama*	0.394	0.359	0.250
97	Indian Scops-owl	*Otus bakkamoena*	0.000	0.028	0.000
23. Family- Caprimulgidae [Order-Caprimulgiformes]					
98	Jungle Nightjar	*Caprimulgus indicus*	0.093	0.157	0.000
24. Family- Apodidae [Order-Caprimulgiformes]					
99	Little Swift	*Apus affinis*	0.286	0.000	0.000
25. Family- Alcedinidae [Order-Coraciiformes]					
100	Common Kingfisher	*Alcedo atthis*	0.413	0.308	0.527
101	Pied Kingfisher	*Ceryle rudis*	0.274	0.090	0.089
102	White-breasted Kingfisher	*Halcyon smyrnensis*	0.294	0.218	0.321
26. Family- Meropidae [Order-Coraciiformes]					
103	Asian Green Bee-eater	*Merops orientalis*	0.579	0.336	0.527
104	Blue-cheeked Bee-eater	*Merops persicus*	0.000	0.073	0.000
27. Family- Coraciidae [Order-Coraciiformes]					
105	Indian Roller	*Coracias benghalensis*	0.491	0.314	0.232
106	European Roller	*Coracias garrulus*	0.236	0.224	0.000
28. Family- Upupidae [Order-Bucerotiformes]					
107	Common Hoopoe	*Upupa epops*	0.630	0.347	0.000
29. Family- Bucerotidae [Order-Bucerotiformes]					
108	Indian Grey Hornbill	*Ocyceros birostris*	0.444	0.745	0.348
30. Family- Megalaimidae [Order-Piciformes]					
109	Coppersmith Barbet	*Psilopogon haemacephalus*	0.549	0.493	0.536
110	Brown-headed Barbet	*Psilopogon zeylanicus*	0.444	0.779	0.634
31. Family- Picidae [Order-Piciformes]					
111	Eurasian Wryneck	*Jynx torquilla*	0.108	0.000	0.000
112	Yellow-crowned Woodpecker	*Leiopicus mahrattensis*	0.321	0.000	0.000
113	White-napped Woodpecker	*Chrysocolaptes festivus*	0.104	0.168	0.098
114	Black-rumped Flameback	*Dinopium benghalense*	0.267	0.207	0.196
115	Indian Pygmy Woodpecker	*Picoides nanus*	0.000	0.123	0.000
32. Family- Alaudidae [Order-Passeriformes]					
116	Ashy-crowned Sparrow-Lark	*Eremopterix griseus*	0.212	0.000	0.000
33. Family- Hirundinidae [Order-Passeriformes]					

117	Dusky Crag Martin	*Ptyonoprogne concolor*	0.286	0.252	0.286
118	Wire-tailed Swallow	*Hirundo smithii*	1.279	0.588	0.848
119	Red-rumped Swallow	*Cecropis daurica*	0.220	0.644	0.536
120	Barn Swallow	*Hirundo rustica*	0.742	0.000	0.000
34. Family- Motacillidae [Order-Passeriformes]					
121	White browned Wagtail	*Motacilla maderaspatensis*	0.537	0.560	0.831
122	White Wagtail	*Motacilla alba*	0.649	0.745	0.634
123	Yellow Wagtail	*Motacilla flava*	0.475	0.398	0.607
124	Grey Wagtail	*Motacilla cinerea*	0.301	0.387	0.438
125	Citrine Wagtail	*Motacilla citreola*	0.089	0.000	0.000
126	Tree Pipit	*Anthus trivialis*	0.301	0.319	0.447
127	Paddyfield Pipit	*Anthus rufulus*	0.711	0.319	0.214
128	Olive-backed Pipit	*Anthus hodgsoni*	0.421	0.392	0.411
35. Family- Vangidae [Order-Passeriformes]					
129	Common Wood shrike	*Tephrodornis pondicerianus*	0.282	0.179	0.241
36. Family- Campephagidae [Order-Passeriformes]					
130	Large Cuckooshrike	*Coracina javensis*	0.085	0.045	0.054
131	Small Minivet	*Pericrocotus cinnamomeus*	0.328	0.218	0.098
37. Family- Pycnonotidae [Order-Passeriformes]					
132	Red-vented Bulbul	*Pycnonotus cafer*	2.920	4.370	6.421
133	White-eared Bulbul	*Pycnonotus leucotis*	0.158	0.118	0.000
134	Rajasthan Red-Whiskered Bulbul	*Pycnonotus jocosus abuensis*	1.047	2.919	4.438
38. Family- Aegithinidae [Order-Passeriformes]					
135	Common Iora	*Aegithina tiphia*	1.263	1.389	0.804
39. Family- Laniidae [Order-Passeriformes]					
136	Bay-backed Shrike	*Lanius vittatus*	0.521	0.218	0.179
137	Long-tailed Shrike	*Lanius schach*	0.332	0.224	0.098
138	Great Grey Shrike	*Lanius excubitor*	0.077	0.000	0.000
139	Isabelline Shrike	*Lanius isabellinus*	0.147	0.129	0.000
40. Family- Turdidae [Order-Passeriformes]					
140	Indian Blackbird	*Turdus simillimus*	0.000	0.303	0.000
41. Family- Muscicapidae [Order-Passeriformes]					
141	Blue-rock Thrush	*Monticola solitarius*	0.143	0.162	0.000
142	Bluethroat	*Luscinia svecica*	0.151	0.129	0.134
143	Oriental Magpie Robin	*Copsychus saularis*	1.070	0.986	0.839
144	Indian Robin	*Copsychus fulicatus*	1.039	1.238	1.018
145	Black Redstart	*Phoenicurus ochruros*	0.236	0.314	0.286
146	Siberian Stonechat	*Saxicola maurus*	0.282	0.151	0.598
147	Pied Bushchat	*Saxicola caprata*	0.093	0.000	0.000

148	Brown Rockchat	*Oenanthe fusca*	0.521	0.633	1.063
149	Desert Wheatear	*Oenanthe deserti*	0.000	0.202	0.000
150	Red-breasted Flycatcher	*Ficedula parva*	0.000	0.426	0.000
151	Tickell's Blue-flycatcher	*Cyornis tickelliae*	0.000	0.207	0.000
42. Family- Leiothrichidae [Order-Passeriformes]					
152	Common Babbler	*Argya caudata*	2.650	3.496	2.429
153	Jungle Babbler	*Argya striata*	3.488	2.269	1.554
154	Large Grey Babbler	*Argya malcolmi*	2.136	0.908	0.580
43. Family- Paradoxornithidae [Order-Passeriformes]					
155	Yellow-eyed Babbler	*Chrysomma sinense*	0.278	0.224	0.339
44. Family- Sylviidae [Order-Passeriformes]					
156	Lesser Whitethroat	*Curruca curruca*	0.124	0.218	0.429
45. Family- Timaliidae [Order-Passeriformes]					
157	Mount Abu White-throated Babbler	*Dumetia hyperythra abuensis*	0.305	0.258	0.143
158	Mount Abu Scimitar Babbler	*Pomatorhinus schisticeps obscurs*	0.116	0.252	0.161
46. Family- Acrocephalidae [Order-Passeriformes]					
159	Booted Warbler	*Iduna caligata*	0.000	0.078	0.107
47. Family- Cisticolidae [Order-Passeriformes]					
160	Plain Prinia	*Prinia inornata*	0.491	0.437	0.563
161	Ashy Prinia	*Prinia socialis*	0.483	0.549	0.670
162	Jungle Prinia	*Prinia sylvatica*	0.317	0.476	0.536
163	Grey-breasted Prinia	*Prinia hodgsonii*	0.205	0.269	0.375
164	Common Tailorbird	*Orthotomus sutorius*	0.545	0.930	1.715
165	Zitting Cisticola	*Cisticola juncidis*	0.050	0.067	0.107
48. Family- Phylloscopidae [Order-Passeriformes]					
166	Siberian Chiffchaff	*Phylloscopus tristis*	0.151	0.162	0.572
167	Sulphur-bellied Warbler	*Phylloscopus griseolus*	0.189	0.443	0.875
168	Greenish Warbler	*Phylloscopus trochiloides*	0.000	0.050	0.063
49. Family- Stenostiridae [Order-Passeriformes]					
169	Grey-headed Canary Flycatcher	*Culicicapa ceylonensis*	0.081	0.078	0.000
50. Family- Monarchidae [Order-Passeriformes]					
170	Indian Paradise-Flycatcher	*Terpsiphone paradisi*	0.015	0.039	0.000
51. Family- Rhipiduridae [Order-Passeriformes]					
171	White-browned Fantail	*Rhipidura aureola*	0.398	0.415	0.482
172	White-spotted Fantail	*Rhipidura albogularis*	0.290	0.443	0.330
52. Family- Paridae [Order-Passeriformes]					
173	Great Tit	*Parus major*	0.058	0.252	0.402
174	Black-lored Tit	*Machlolophus xanthogenys*	0.309	1.076	0.768

53. Family- Nectariniidae [Order-Passeriformes]					
175	Purple Sunbird	*Cinnyris asiaticus*	0.545	0.555	0.634
176	Purple-rumped Sunbird	*Leptocoma zeylonica*	0.158	0.000	0.000
54. Family- Zosteropidae [Order-Passeriformes]					
177	Indian White-eye	*Zosterops palpebrosus*	0.502	1.109	0.947
55. Family- Emberizidae [Order-Passeriformes]					
178	Crested Bunting	*Emberiza lathami*	0.340	0.190	0.420
179	Grey-necked Bunting	*Emberiza buchanani*	0.019	0.000	0.000
180	White-capped Bunting	*Emberiza stewarti*	0.143	0.134	0.393
181	Red-headed Bunting	*Emberiza bruniceps*	0.070	0.000	0.000
56. Family- Fringillidae [Order-Passeriformes]					
182	Common Rosefinch	*Carpodacus erythrinus*	0.158	0.129	0.295
57. Family- Estrildidae [Order-Passeriformes]					
183	Red Avadavat	*Amandava amandava*	0.100	0.000	0.000
184	Green Avadavat	*Amandava formosa*	0.000	2.588	3.009
185	Indian Silverbill	*Euodice malabarica*	2.275	2.543	2.759
186	Scaly-breasted Munia	*Lonchura punctulata*	1.553	1.709	2.143
187	Tricoloured Munia	*Lonchura malacca*	0.077	0.000	0.000
58. Family- Passeridae [Order-Passeriformes]					
188	House Sparrow	*Passer domesticus*	2.352	3.916	3.715
189	Yellow-throated Sparrow	*Gymnoris xanthocollis*	2.376	3.064	4.028
59. Family- Ploceidae [Order-Passeriformes]					
190	Baya Weaver	*Ploceus philippinus*	0.409	0.415	0.339
60. Family- Sturnidae [Order-Passeriformes]					
191	Rosy Starling	*Pastor roseus*	1.433	0.000	0.000
192	Brahminy Starling	*Sturnia pagodarum*	0.761	1.373	1.366
193	Indian Pied Starling	*Gracupica contra*	0.680	0.723	1.179
194	Common Myna	*Acridotheres tristis*	1.340	0.734	0.723
195	Bank Myna	*Acridotheres ginginianus*	0.270	0.297	0.000
61. Family- Oriolidae [Order-Passeriformes]					
196	Indian Golden Oriole	*Oriolus kundoo*	0.027	0.000	0.000
62. Family- Dicruridae [Order-Passeriformes]					
197	Black Drongo	*Dicrurus macrocercus*	1.066	1.289	1.482
198	White-bellied Drongo	*Dicrurus caerulescens*	0.525	0.924	0.947
63. Family- Corvidae [Order-Passeriformes]					
199	Rufous Treepie	*Dendrocitta vagabunda*	0.568	0.515	1.036
200	House Crow	*Corvus splendens*	0.633	0.739	0.464
201	Large-billed Crow	*Corvus macrorhynchos*	0.301	0.381	0.420

Altitudinal Range-Wise Species Relative Abundance:

A. Species relative abundance in altitudinal range I

Over the course of the study, we observed 190 species in altitudinal range I (Table 2). Out of these species, the most abundant species in this altitudinal range I were Jungle Babbler (3.488%) followed by Rock Pigeon (3.160%), Red-vented Bulbul (2.920%), Common Babbler (2.650%), Black-winged Stilt (2.573%), Red-wattled Lapwing (2.538%), Yellow-throated Sparrow (2.376%) and House Sparrow (2.352%). Least abundant species such as Indian Cuckoo and Indian Paradise-Flycatcher (0.015% for each species) were observed in altitudinal range I (Table 2).

B. Species relative abundance in altitudinal range II

Over the course of the study, we observed 152 species in altitudinal range II (Table 2).Out of these species, most abundant species in this altitudinal range were Red-vented Bulbul (4.370%) followed by House Sparrow (3.916%), Common Babbler (3.496%), Yellow-throated Sparrow (3.064%), Rajasthan Red-Whiskered Bulbul (2.919%), Rock Pigeon (2.824%) and Rose-ringed Parakeet (2.779%). Least abundant species such as Black Stork and Indian Paradise-Flycatcher (0.039% for each species) and Indian Scops-owl (0.028%) were observed from altitudinal range II (Table 2).

C. Species relative abundance in altitudinal range III

Over the course of the study, we observed 124 species in altitudinal range III (Table 2). Out of these species, most abundant species in this altitudinal range were Red-vented Bulbul (6.421%) followed by Rajasthan Red-Whiskered Bulbul (4.438%), Yellow-throated Sparrow (4.028%), Rock Pigeon (3.938%), House Sparrow (3.715%), Green Avadavat (3.009%) and Aravalli Red-Spurfowl (2.858%). Least abundant species such as Mallard and Large Cuckooshrike (0.054% for each species) and Jacobins Cuckoo (0.027%) were observed from altitudinal range III (Table 2).

4. DISCUSSION

Various factors, such as temperatures, characteristics and features of habitat and geographic areas, availability of food materials, slopes of mountains, annual rainfall, climatic conditions and ecosystem productivity, as well as types of forest and vegetation, broadly influenced the distribution and diversity patterns of birds along the altitudinal gradient (Lee *et al.*, 2004; Acharya *et al.*, 2011; Basnet *et al.*, 2016; Katuwal *et al.*, 2016). Mountain ranges, which hold a remarkable amount of biodiversity, are currently facing threats due to changes in climatic and environmental conditions (Quintero and Jetz, 2018). Predicting the effects of environmental degradation and climate change in the future and conserving biodiversity depend on recognizing the species distribution patterns of various taxa at the spatial level (Vetaas and Grytnes, 2002; Wu *et al.*, 2017). In comparison to other bird orders, the study revealed that the Passeriformes order dominated in terms of bird families and species numbers. Similarly, several studies were also conducted in India and abroad which as per their observations concluded that the Passeriformes order was most diverse as compared to other bird orders (Norbu *et al.*, 2021; Parajuli, 2022; Choudhary, 2024). Various biotic communities have been found to exhibit different distribution patterns along elevation gradients (Gaston, 2000; McCain and Grytnes, 2010). Monotonic decline in species richness and diversity along the altitudinal gradient is the most common observed pattern among the various faunal groups, including the birds (Navarro, 1992; McCain and Grytnes, 2010).

During study, it was observed that bird species richness, diversity and abundance declined with an increase in altitudinal levels. Highest number of bird species and individuals was found in the lower altitudinal range (range I: species = 190; individuals = 25888) followed by the middle altitudinal level (range II: species = 152; individuals = 17850) and the least number of bird species and individuals were found at the higher altitudinal level (range III: species = 124; individuals = 11198) (Figure 2, 3). Similarly, the population and abundance of bird individuals

also vary along the altitudinal gradient. In other words, bird species richness, abundance and diversity along the altitudinal gradient exhibit a monotonic decline with an increase in altitudinal level in MA-WLS (Figure 2, 3, 4, 5). Similarly, Hawkins (1999) studied bird distribution and species richness patterns along the altitudinal and latitudinal gradients in the forest habitat of east Malagasy and found that bird species richness declined with an increase in the altitudinal level. Subsequently, Kattan and Franco (2004) conducted a study on bird diversity along the altitudinal gradient in the Andes region of Colombia. They observed a decline in bird species as the gradient increased, concluding that the number of bird species was higher at lower altitudinal ranges and decreased at higher altitudinal levels. Basnet and Badola (2012) studied bird diversity along various elevation zones in Fambong Lho Wildlife Sanctuary, Gangtok district of Sikkim. They found 139 bird species representing 28 families, and bird diversity declined with an elevation increase. Santhakumar *et al.* (2018) conducted a study on the distribution pattern of birds along the altitudinal level of Sutlej River Basin, western Himalaya and found a total of 203 bird species and found a monotonic decline pattern and species richness decline with increasing altitude and concluded that the vegetation composition and climatic conditions determined the species distribution pattern along the altitudinal gradient of Sutlej River basin. Similarly, Neupane *et al.* (2020) also found the impact of altitudinal variation on the bird's community in river basin areas of Kaligandaki, central Himalaya and concluded that the bird's species richness declined with the increase in altitudinal level. Kunwar *et al.* (2023) studied the avian community along an elevation level in Shivapuri Nagarjun National Park, Nepal and found that bird species richness and diversity were significantly higher at lower altitudinal levels as compared to mid and higher altitudinal levels and similarly observed a monotonic decline pattern for species richness and diversity of birds along the altitudinal gradient.

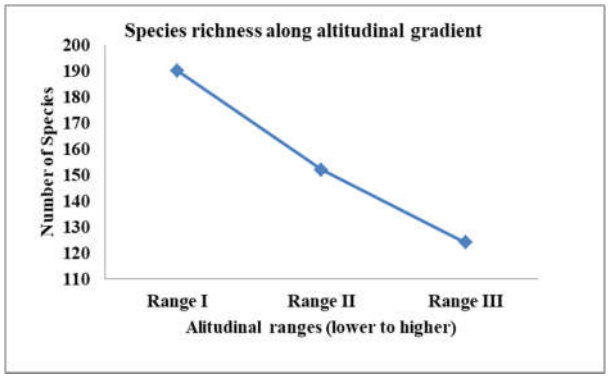

Figure 2: Altitudinal variation in species richness of birds along altitudinal ranges I, II and III in MA-WLS.

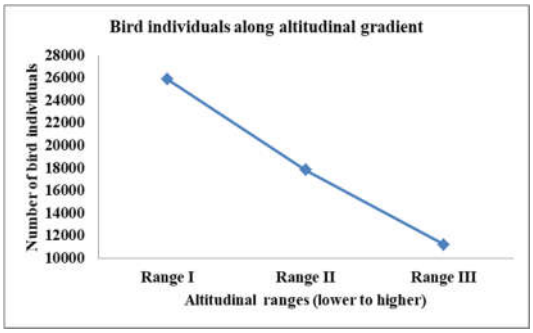

Figure 3: Altitudinal variation in individuals of birds along altitudinal ranges I, II and III in MA-WLS.

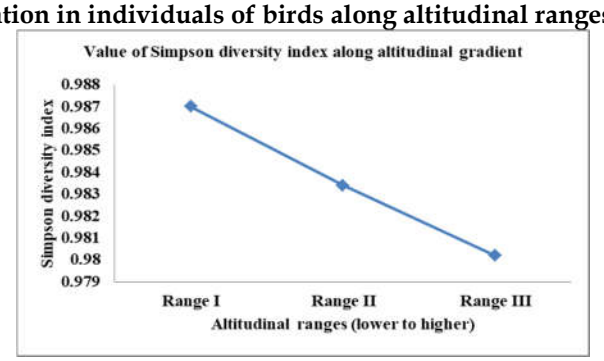

Figure 4: Value of Simpson Diversity Index along altitudinal ranges I, II and III in MA-WLS

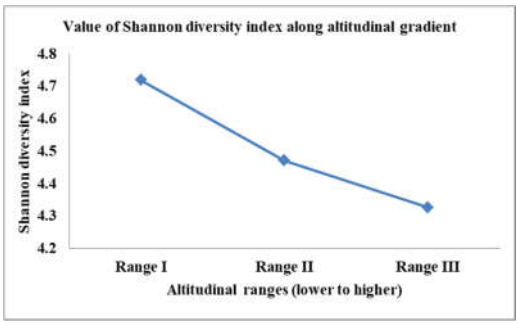

Figure 5: Value of Shannon Diversity Index along altitudinal ranges I, II and III in MA-WLS

The study also observed a continuous decrease in the species richness and diversity of birds along the altitudinal gradient (Figure 2, 3, 4, 5). Maximum species richness and diversity were found in the lower altitudinal range or range I (Species= 190; Simpson diversity index=0.9870; Shannon diversity index=4.719) followed by the middle altitudinal range or range II (Species=152; Simpson diversity index=0.9834; Shannon diversity index=4.471) and minimum species richness and diversity were found at the higher altitudinal level or range III (Species= 124; Simpson diversity index=0.9802; Shannon diversity index=4.327) (Figure 4, 5). Rahbek (2005) and McCain (2009) also noted high species richness and diversity at the lower altitudinal level, concluding that favorable biophysical conditions, such as warm temperatures, suitable nesting sites, diverse habitats (including agricultural farms), abundant food sources, and effective predator protection, may contribute to the lower altitudinal level. Variation in geological, physical and climatic conditions of mountain ecosystems varies along the altitudinal gradient, which further influences the distribution, diversity and abundance of birds along the altitudinal gradient (Korner, 2007). Population

trends and abundance of bird species also vary according to the altitudinal gradient. In the Aravalli ranges of MA-WLS, species richness and diversity decreased along the altitudinal gradient, displaying a monotonic decline pattern. The presence of various types of habitat along the altitudinal gradient supports a higher number of bird species in MA-WLS. The presence of seasonal and perianal water bodies along the altitudinal gradient also supports several aquatic and terrestrial resident and migratory species in MA-WLS.

Acknowledgement
Authors express his gratitude to the University Grant Commission (UGC) for financing in the form of junior and senior research scholarships. The authors would also like to thank the Forest Department of Rajasthan (India) for permitting him to undertake fieldwork at the Mount Abu Wildlife Sanctuary. The authors also thank Dr. Satish Kumar Sharma (Rted. RFS) and Dr. Asad R. Rahmani (Ex-director BNHS) for their important ideas for the study on the entire topic. The authors are grateful to Mr. Pushkar Kumawat for his assistance during the field visit.

REFERENCES

Acharya, B.K. and Vijayan, L. (2015). Butterfly diversity along the elevation gradient of Eastern Himalaya, India. *Ecological Research,* 30, 909-919.

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

Alvarez-Alvarez, E.A., Rodriguez-Godinez, R., Sierra-Morales, P., Medina-Valdivia, S.A., Vazquez-Salgado, E., Brito-Millan, M. and AlmazanNunez, R.C. (2020). Patterns of bird diversity and endemism along an elevational gradient in the Southern Mexican highlands. *Zoological Studies,* 59 (69), 1-13.

Basnet, K. and Badola, H.K. (2012). Birds of Fambong Lho Wildlife Sanctuary, Sikkim, India: a baseline survey for conservation and area management. *NeBIO,* 3(2), 1-12.

Basnet, T.B., Rokaya, M.B., Bhattarai, B.P. and Munzbergova, Z. (2016). Heterogeneous landscapes on steep slopes at low altitudes as hotspots of bird diversity in a Hilly Region of Nepal in the Central Himalayas. *PloS One*, 11(3), 1-19.

BirdLife International (2023). IUCN Red List for birds. Downloaded from http://www.birdlife.org on 17/05/2023.

Carneiro, E., Mielke, O.H.H., Casagrande, M.M. and Fiedler, K. (2014). Skipper richness (Hesperiidae) along elevational gradients in Brazilian Atlantic Forest. *Neotropical Entomology,* 43, 27-38.

Cavarzere, V. and Silveira, L.F. (2012). Bird species diversity in the Atlantic Forest of Brazil is not explained by the Mid-domain Effect. *Zoologia (Curitiba),* 29, 285-292.

Champion, H.G. and Seth, S.K. (1968). A revised survey of the forest types of India. Manager of publications. Natraj Publishers, Dehra Dun, India, Pp 1-404.

Chettri, B., Bhupathy, S. and Acharya, B.K. (2010). Distribution pattern of reptiles along an eastern Himalayan elevation gradient, India. *Acta Oecologica,* 36(1), 16-22.

Choudhary, N.L. (2024). Altitudinal avian diversity and abundance in Mount Abu Wildlife Sanctuary, Sirohi district, Rajasthan. Ph.D. Thesis- Department of Zoology, Mohanlal Sukhadia University, Udaipur.

Choudhary, N.L. and Chishty, N. (2024). Nesting and breeding aspects of terrestrial avifauna of Mount Abu Wildlife Sanctuary and its vicinity. *International Journal of Zoological Investigations,* 10(2), 215-226.

Dendup, P., Wangdi, L., Jamtsho, Y., Kuenzang, P., Gyeltshen, D., Tashi, T., Rigzin, U., Jamtsho, Y., Dorji, R., Dorji, R., Jamtsho, Y., Lham, C. and Tshering, B. (2021). Bird diversity and conservation threats in Jigme Dorji National Park, Bhutan. *Global Ecology and Conservation,* 30, 1-12.

Fu, C., Wang, J., Pu, Z., Zhang, S., Chen, H., Zhao, B., Chen, J. and Wu, J. (2007).

Elevational gradients of diversity for lizards and snakes in the Hengduan Mountains, China. *Biodiversity and Conservation,* 16. 707-726.

Gaston, K.J. (2000). Global patterns in biodiversity. *Nature,* 405, 220-227.

Ghimire, A., Rokaya, M.B., Timsina, B., Bila, K., Shrestha, U.B., Chalise, M.K. and Kindlmann, P. (2021). Diversity of birds recorded at different altitudes in central Nepal Himalayas. *Ecological Indicators,* 127:1-7.

Grimmett, R., Inskipp, C. and Inskipp, T. (2011). Birds of the Indian Subcontinent. India: Oxford University Press.

Guisan, A. and Thuiller, W. (2005). Predicting species distribution: offering more than simple habitat models. *Ecology Letters,* 8(9), 993-1009.

Hammer, O., David, A.T.H. and Ryan, P.D. (2001). Past: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica,* 4(1), 1-9.

Hawkins, A.F.A. (1999). Altitudinal and latitudinal distribution of east Malagasy forest bird communities. *Journal of Biogeography*, 26(3), 447-458.

IUCN (2024). The IUCN Red List of Threatened Species. Version 2023-1. https://www.iucnredlist.org.

Kattan, G.H. and Franco, P. (2004). Bird diversity along elevational gradients in the Andes of Colombia: area and mass effects. *Global Ecology and Biogeography,* 13(5), 451-458.

Katuwal, H.B., Basnet, K., Khanal, B., Devkota, S., Rai, S.K., Gajurel, J.P., Scheidegger, C. and Nobis, M.P. (2016). Seasonal changes in bird species and feeding guilds along elevational gradients of the Central Himalayas, Nepal. *PLoS One,* 11(7), 1-17.

Kluge, J., Worm, S., Lange, S., Long, D., Bohner, J., Yangzom, R. and Miehe, G. (2017). Elevational seed plants richness patterns in Bhutan, Eastern Himalaya. *Journal of Biogeography,* 44(8), 1711-1722.

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

Korner, C. and Paulsen, J. (2004). A world-wide study of high altitude treeline temperatures. *Journal of Biogeography,* 31(5), 713-732.

Kunwar, N., Pandey, N., Singh, K.D. and Bhattarai, B. (2023). Bird diversity along an elevational gradient in Shivapuri Nagarjun National Park, Nepal. *Our Nature,* 21(1), 1-15.

Lee, P.F., Ding, T.S., Hsu, F.H. and Geng, S. (2004). Breeding bird species richness in Taiwan: distribution on gradients of elevation, primary productivity and urbanization. *Journal of Biogeography,* 31(2), 307-314.

Mahabale, T.S. and Kharadi, R.G. (1946). On some Ecological Features of the Vegetation at Mt. Abu. *Proceding of National Academy of Science,* 16(1).

Mahata, N. and Sharma, H.P. (2023). Birds along the Bagmati river corridor in urban areas and factors affecting their abundance. *Environmental Challenges,* 11, 1-9.

Majumder, A., Maheswaran, G., Alam, I., Chandra, K., Alfred, J.R.B. and Choudhury, B. (2022). Field Guide-Birds of India. *Zoological Survey of India,* 1-600.

McCain, C.M. and Grytnes, J.A. (2010). Elevational Gradients in Species Richness. In: Encyclopedia of Life Sciences (ELS). John Wiley & Sons, Ltd: Chichester.

McCain, C.M. (2004). The mid-domain effect applied to elevational gradients: species richness of small mammals in Costa Rica. *Journal of Biogeography* **31**(1), 19-31.

McCain, C.M. (2005). Elevational gradients in diversity of small mammals. *Ecology* 86(2), 366-372.

McCain, C.M. (2007). Area and mammalian elevational diversity. *Ecology,* 88(1), 76-86.

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

Mehta, M.R. (1979). Flora of Mount Abu. Ph.D. Thesis. Department of Botany, University of Jodhpur, Jodhpur. Volume I and II.

Navarro, S.A.G. (1992). Altitudinal distribution of birds in the Sierra Madre del Sur, Guerrero, Mexico. *The Condor,* 94(1), 29-39.

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

Nogues-Bravo, D., Araujo, M.B., Romdal, T. and Rahbek, C. (2008). Scale effects and human impact on the elevational species richness gradients. *Nature,* 453, 216-219.

Norbu, L., Thinley, P., Wangchuck, T., Dechen, U., Dorji, L., Choephel, T. and Dorji, P. (2021). On the high bird diversity in the non-protected regions of Trashiyangtse District in Bhutan. *Journal of Threatened Taxa,* 13(9), 19274–19292.

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

Parajuli, K. (2022). Assessment of Bird Diversity and Abundance in Karra River Basin, Hetauda, Makawanpur. *International Research Journal of MMC (IRJMMC),* 3(3), 18-33.

Praveen, J. and Jayapal, R. (2023). Checklist of the birds of India (v7.0). Website: http://www.indianbirds.in/india/ [Date of publication: 28 February 2023].

Praveen, J., Jayapal, R. and Pittie, A. (2016). A checklist of the birds of India. *Indian Birds*, 11 (5 & 6), 113-172.

Quintero, I. and Jetz, W. (2018). Global elevational diversity and diversification of birds. *Nature*, 555, 246–250.

Rahayuninagsih, M., Mardiastuti, A., Prasetyo, L. and Mulyani, Y. (2007). Bird community in Burungisland, Karimunjawa National Park, Central Java. *Biodiversity,* 8, 183-187.

Rahbek, C. (1995). The elevational gradient of species richness: A uniform pattern? *Ecography*, 18, 200-205.

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

Rajpar, M.N. and Zakaria, M. (2011). Bird species abundance and their correlation ship with microclimate and habitat variables at Natural Wetland Reserve, Peninsular Malaysia. *International Journal of Zoology,* 1-17.

Regan, H.M., Auld, T.D., Keith, D.A. and Burgman, M.A. (2003). The effects of fire and predators on the long-term persistence of an endangered shrub, *Grevillea caleyi*. *Biological Conservation,* 109(1), 73-83.

Rickart, E.A. (2001). Elevational diversity gradients, biogeography and the structure of montane mammal communities in the intermountain region of North America. *Global Ecology and Biogeography,* 10(1), 77-100.

Rosenstock, S.S., Anderson, D.R., Giesen, K.M., Leukering, T. and Carter, M.F. (2002). Landbird counting techniques: current practices and an alternative. *The Auk* 119(1), 46-53.

Sanchez-Gonzalez, A. and Lopez-Mata, L. (2005). Plant species richness and diversity along an altitudinal gradient in the Sierra Nevada, Mexico. *Diversity and Distributions,* 11(6), 567-575.

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

Shannon, C.E. and Weaver, W. (1949). The Mathematical Theory of Communication. University of Illinois Press, Urbana.

Sharma, S.K. (2021). Forest types of Rajasthan. Published at Rajasthan Biodiversity, a Tiger Watch, Initiative. https://rajasthanbiodiversity.org/forest-types-of-rajasthan/.

Simpson, E.H. (1949). Measurement of diversity. *Nature*, 163, 688.

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

Thompson, F.R. and Schwalbach, M.J. (1995). Analysis of sample size, counting time, and plot size from an avian point count survey on Hoosier National Forest, Indiana. In: Ralph, C. John; Sauer, John R.; Droege, Sam, technical editors. Monitoring bird populations by point counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station: Pp. 45-48.

Vetaas, O.R. and Grytnes, J.A. (2002). Distribution of vascular plant species richness and endemic richness along the Himalayan elevation gradient in Nepal. *Global Ecology and Biogeography,* 11(4), 291-301.

Vyas, R. (2013). Birds of Rajasthan. Bombay Natural History Society and Oxford University Press Pp xiv+326.

Wu, Y., DuBay, S.G., Colwell, R.K., Ran, J. and Lei, F. (2017). Mobile hotspots and refugia of avian diversity in the mountains of south-west China under past and contemporary global climate change. *Journal of Biogeography*, 44(3), 615-626.

****