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RESEARCH

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Influence of habitat heterogeneity on avian diversity in the Rajparian Wildlife Sanctuary, Kashmir Himalaya

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Abstract

Background The value of local and regional landscapes for avian conservation requires a thorough understanding of the diversity and structure of bird communities. Avifauna serves as an important biological indicator in monitoring the health of an ecosystem or environment. The present study was conducted to examine the relationship between avian diversity, richness, composition and habitat characteristics at the Rajparian Wildlife Sanctuary.

Results Using geographic information systems and remote sensing techniques, we analyzed habitat heterogeneity based on land use and land cover classification. For sampling birds, extensive surveys were conducted in different land-use types from 2019 to 2021, following the line transect method. During the study period, 102 bird species were recorded from the five studied vegetation types of the study area, including one near threatened (Bearded Vulture) and one vulnerable (Kashmir Flycatcher) bird species. The highest numbers of avian species were recorded from the forest (71 species) (42.61 ± 16; mean ± SD) and the lowest from the rocky land-use type (12 species) (7.83 ± 1.95). The individual rarefaction and extrapolation curves showed higher species richness for forest and the lowest for rocky habitats. Numerous pairwise comparisons revealed significant differences in species richness among studied habitat types, except for riverine vs. grassland, scrub vs. grassland and rocky vs. riverine land uses. The partitioning of the spatio-temporal β-diversity patterns revealed a relatively large contribution of the turnover component to the observed overall dissimilarity compared to the nestedness component.

Conclusions It can be concluded that avian communities in the Rajparian Wildlife Sanctuary are influenced by habitat heterogeneity, topography, and the availability of water. The results of the present study indicate that the Rajparian Wildlife Sanctuary provides an important habitat for the conservation of birds, as it harbors a rich avian diversity. The study is the first scientific survey of the avian habitat associations in the protected area and will serve as a baseline for future avian research, as well as for management implications in the region.

Keywords Habitat heterogeneity, Beta diversity, Land use land cover

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Background

Avifauna is considered the most significant component of any ecosystem and contributes immensely to ecological balance (Dhindsa & Saini, 1994). It is being used to monitor the ecosystem and environmental health (Bilgrami, 1995; Canterbury et al., 2000; Mistry et al., 2008; Slabbekoorn & Ripmeester, 2008). From an ecological perspective, birds play an important role as scavengers, seed dispersers, predators and pollinators (Sodhi et al., 2011; Bibi & Ali, 2013). A well-documented pattern in community ecology relates habitat heterogeneity to avian species diversity (Tews et al., 2004). Birds always inhabit specific habitats and vegetation structure affects their composition and structure (Caziani & Derlindati, 2000; Brawn et al., 2001; Gabbe et al., 2002; Seymour & Simmons, 2008; Earnst & Holmes, 2012; Nsor et al., 2018).

Several studies (Slater, 1995; Hino, 2000; Ruiz-Jaén & Aide, 2005) have demonstrated how bird species are influenced by vegetation structure. Changes in the structure of the vegetation, either naturally or induced by humans, are often accompanied by changes in the avian communities (Maurer et al., 1981; Wiens, 1992; Rahayuningsih et al., 2007). Species diversity and the heterogeneity of habitat provide information on the spatial ecology of birds. However, habitat heterogeneity may influence their ecological processes, ultimately affecting species diversity and richness (Smith et al., 2014; Leveau et al., 2015; Lorenzón et al., 2016). Communities can vary along a gradient of habitats (beta-diversity) based on two distinct phenomena: spatial species turnover and the nestedness of communities (Baselga, 2012; Baselga et al., 2017; Jesus et al., 2017). There is growing concern about the effect of deforestation on avian communities (Schulte & Niemi, 1998). An increase in human population growth is often accompanied by an increase in anthropogenic pressures like human settlements, cropland and wood products that ultimately alter vital wildlife habitats, bird diversity patterns and overall biodiversity around the world (Miller et al., 2003; Julliard et al., 2004). Therefore, it is necessary to consider changing habitats to gain a better understanding of bird community structures and how they are influenced by changes in vegetation types (Wiens & Rotenberry, 1981). Identifying priority areas for conservation interventions, such as defining and delineating protected areas, depends on knowledge of the spatial variability of biodiversity (Soulé, 1991; Reid, 1998; Carroll et al., 2003).

Located within the north western mountain ranges of the Himalayas, Jammu and Kashmir is bestowed with rich natural resources and harbour more than half the biodiversity found in the Indian Himalayas (Dar & Khuroo, 2020). Among the chordates of the state, birds contribute the most and are the group with the highest amount of endemism (Ahmedullah, 1997). Rahmani et al. (2012) have designated 21 Important Bird Areas or IBAs (now Important Biodiversity Areas) and identified seven potential IBAs in Jammu and Kashmir. A number of studies have been conducted on bird diversity in the Kashmir region (Price et al., 2003; Pfister, 2004; Rahmani et al., 2012; Suhail et al., 2020), but there is no information regarding the diversity and richness of bird species in the Rajparian Wildlife Sanctuary. The aim of the present study was to understand species diversity, richness, and assemblage composition of bird species and the patterns of partitioned beta-diversity in different land use types of the sanctuary, employing several diversity indices that may provide deeper insights into the richness of avifauna in the Himalayan region.

Methods

Study area

Rajparian Wildlife Sanctuary, also known as Daksum Wildlife Sanctuary (Fig. 1), is located in district Anantnag of Jammu and Kashmir between 33° 36′ 30″ and 33° 42′ 30″ N latitude and 75° 25′ 30″ to 75° 31′ 15″ E longitudes at an elevation ranging from 2360 to 4270 m above sea level. The Sanctuary is located almost 100 km from Srinagar and about 41 km from Anantnag in the south east

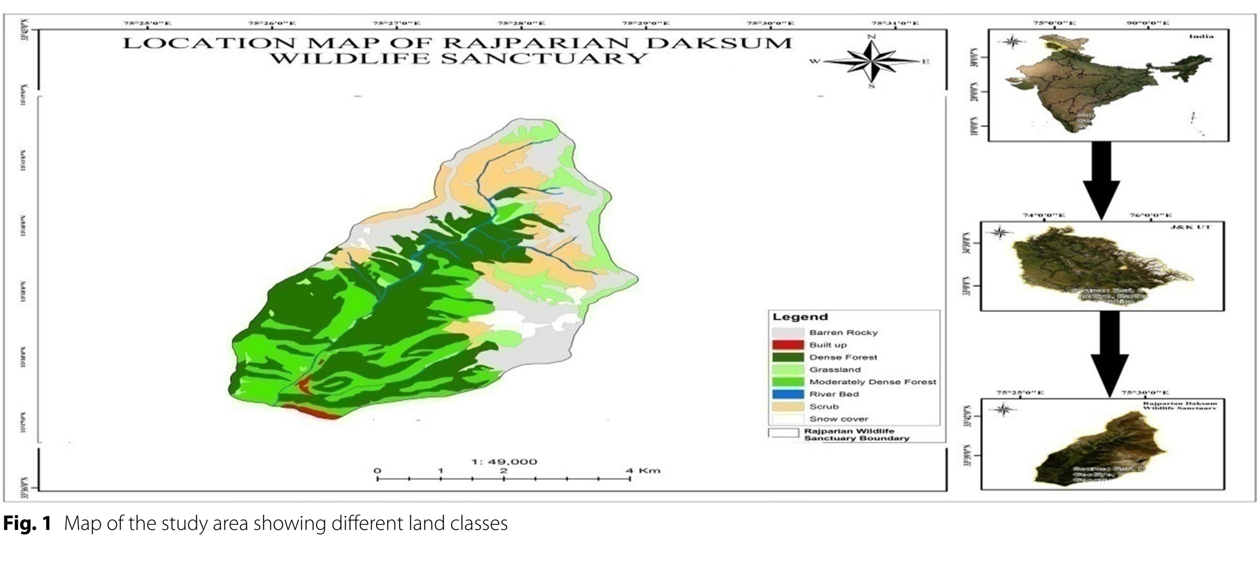

Fig. 1 Map of the study area showing different land classes

direction at Anantnag-Semthan-Kishtwar Road (NH-1B) and covers an area of 48.27 km^2. The sanctuary is named after the Rajparian Nallah that drains through it and forms an important catchment area of the Bringi River, a tributary of the River Jhelum. The sanctuary was earlier protected as a game reserve for Hangul (*Cervus hanglu hanglu*) in 1948 and was upgraded to the Rajparian Wildlife Sanctuary in 1981. The variations in altitude, slope and soil conditions have brought about various vegetation structures in the wildlife sanctuary. The dominant vegetation includes *Pinus wallichiana*, *Picea smithiana*, *Betula utilis*, *Aesculus indica*, *Juglanus regia*, and *Ulmus wallichiana*, whereas *Juniperus squamata, Primula denticulata, Vibernum grandiflorium* and *Rhododendron campanulatum* are thinly scattered at several places. Four seasons characterize the climate of the study area: spring (March–April), summer (May–August), autumn (September–November) and winter (December–February).

Sampling procedure

For sampling birds, the sanctuary was divided into different study sites based on vegetation structure. The habitat heterogeneity was assessed by mapping land use and land cover (LULC) of the study area using geographic information system (GIS) and remote sensing techniques. A Landsat image with a spatial resolution of 30 m was obtained for the year 2019 from the United States Geological Survey (USGS) earth explorer. The image was classified using supervised maximum likelihood classification after pre-processing and enhancement techniques. A combination of map analysis, personal experience, and fieldwork was used to identify the different LULC types. The entire study area was classified into different land classes including, dense forest, grassland, scrub vegetation, barren rocky and riverine areas.

Each study site was surveyed weekly from July 2019 to December 2021, covering all seasons and following the line transect method (Bibby et al., 2000). A total of 28 linear transects varying in length from 100 to 500 m and in width from 25 to 50 m were laid in the study area, covering all habitat types (5 transects each in grassland, scrub, riverine areas and rocky habitats and 8 transects in forest areas). Transects varied in length depending on the total area of the study site, its vegetation and the accessibility of the area. The sampling points were taken along the transects through a stratified random method. A distance of approximately 250 m was maintained between the two sampling points. Sampling was done mainly during the morning (6:00–10:00 am) and evening hours (5:30–7:00 pm), when birds are found to be most active. Bird species were observed using binoculars and photographs were taken with a digital camera (Nikon D5600 with 60–300 mm lens kit). Birds were identified with the help of available literature, especially by consulting field guides by Grimmett et al. (2011) and Ali (2002).

Data analysis

Species diversity

The Renyi diversity profile approach was adopted to calculate the species diversity of the studied vegetation or land use types using the vegan 2.5-7 package (Oksanen et al., 2020). The Renyi diversity profile values (H_α) were calculated from the average abundance values of the three-year data and a scaling parameter (α) that range from zero to infinity (Legendre & Legendre, 1998; Kindt & Coe, 2005), according to the formula:

$$H_\alpha = 1\frac{1}{1-\alpha}\ln\sum_{i=1}^{S}\mathrm{pi}^{\alpha}$$

where pi represents the average abundance of each bird species and α scaling parameter (Legendre & Legendre, 1998; Kindt & Coe, 2005; Oksanen et al., 2020). The values of the Renyi profile at the scales of 0, 1, 2 and infinity (∞) reflect species richness, the Shannon diversity index, the Simpson diversity index and the Berger-Parker diversity index, respectively (Legendre & Legendre, 1998; Kindt & Coe, 2005; Ahmad et al., 2019).

Species richness

Sample (i.e., individual) and coverage-based rarefaction and extrapolation curves were computed based on the abundance data using the *iNext* 2.0.20 R package (Hsieh et al., 2016; Chao and Jos 2012). To study whether the species richness between the studied vegetation or land use types differed significantly, the richness data was first subjected to the Levene's and Shapiro–Wilk test for checking the homogeneity of variance and normality of distribution assumptions, respectively. We applied Tukey Honest Significant Differences (Tukey HSD) test for multiple pairwise-comparison between the means of studied vegetation or land use type to evaluate which pairs show significant differences in the species richness.

Species composition

The observed bird records collected over the three-year time period for each vegetation or landuse type were used to create a species-site matrix. To evaluate the observed difference in the bird species composition between the studied vegetation or land use types, a non-metric multidimensional scaling (NMDS) was performed based on the Bray Curtis dissimilarity metric using the vegan 2.5-7 package in R Software (Oksanen et al., 2020). The associated stress value was calculated for the NMDS in order to evaluate its efficiency. The associated NMDS graphs were also plotted where each ellipse (with its associated centroid) corresponds to a given vegetation or land use type and the distance between any two centroids represents the degree of dissimilarity in bird species composition between these vegetation or land-use types. Also, the size of each ellipse is proportional to the degree of dissimilarity among the replicates (here, in our case, transects) within a particular vegetation or land-use category (Shahabuddin et al., 2021). Further, we also quantified the degree of compositional differences between the studied vegetation or land-use types using the Permutational Analysis of Variance (PERMANOVA), wherein we adopted both abundance-based Bray–Curtis and incidence-based Jaccard indices to investigate whether these patterns in species compositional dissimilarity were driven by species relative abundances or simply by the presence and/or absence of species (Shahabuddin et al., 2021). The associated statistical significance was assessed by an alpha of 0.05 based on 999 permutations.

β-diversity pattern and its underlying components

The overall and pairwise beta diversity components were also computed for the studied vegetation or land use types, arising from the turnover and nestedness components based on the presence absence data and Sørensen index using the betapart 1.5.4 package (Baselga et al., 2017).

We also explored the temporal compositional differences along with the relative contribution of nestedness for the studied vegetation or land use types between 2019 and 2021 using the *beta.tem* function of betapart 1.5.4 package (Baselga et al., 2017).

Results

Species diversity

The Renyi diversity profiles indicated that among all the studied vegetation or land use types, forest showed the highest species diversity with respect to all the values of the scaling parameter (α) chosen. In contrast, the lowest species diversity was seen in case of the Rocky habitats (Fig. 2).

Species richness

The sample (individual)-based species rarefaction and extrapolation curve showed that among all the studied vegetation or land-use types, forest had a higher species richness while as rocky habitat shows the lowest species richness. Also, most of the studied vegetation or land-use types showed clear asymptotic curves (Fig. 3). However, the coverage-based rarefaction and extrapolation curve revealed that all the studied vegetation or landuse types showed an adequate sampling effort with sample coverage of more than 95% (Fig. 4).

A total of 102 bird species were recorded from the five studied vegetation types of the study area (Additional file 1). The highest number of bird species were recorded from forest (71 species) (42.61 ± 16; mean ± SD) and lowest from the rocky land use type (12 species) (7.83 ± 1.95) (Fig. 5). The results of the Welch one-way test showed that the observed bird species richness varied significantly among the studied vegetation types ($F = 33.35$, $df\ (n) = 4$, $df\ (d) = 37.75$, $p < 0.001$). In addition, the multiple pairwise comparisons (Tukey HSD) revealed significant differences

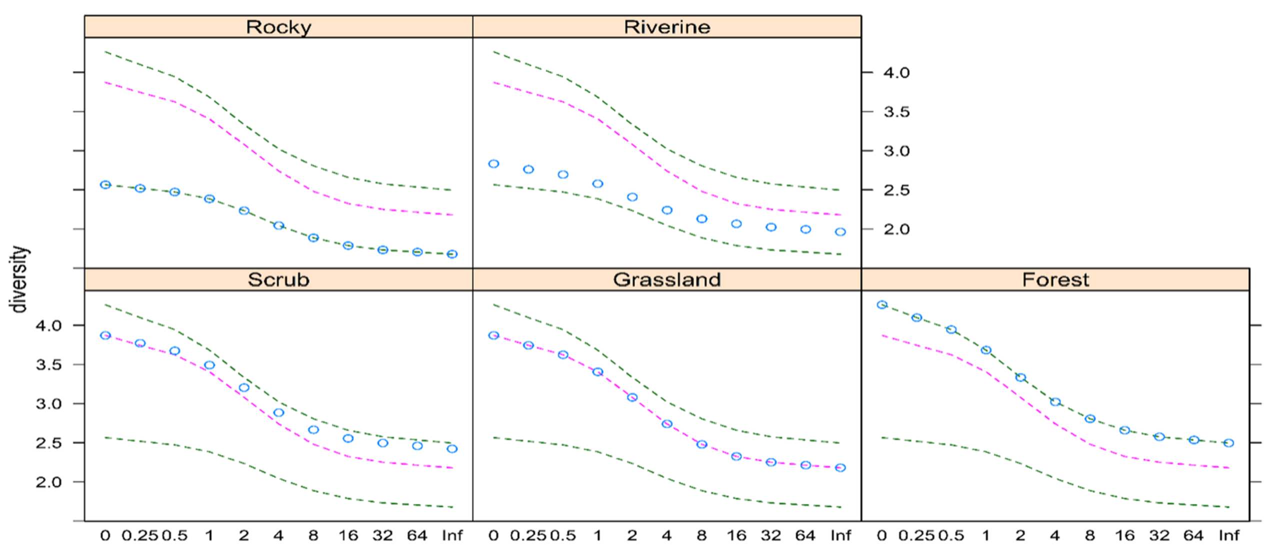

Fig. 2 Renyi diversity profiles of birds in the studied five vegetation or land use types based on the Trellis graphics with a separate panel for each vegetation or land use category. The dots denote the diversity value for the vegetation or land use types, the outer two dashed lines the extremes and the inner pink line the median in the data

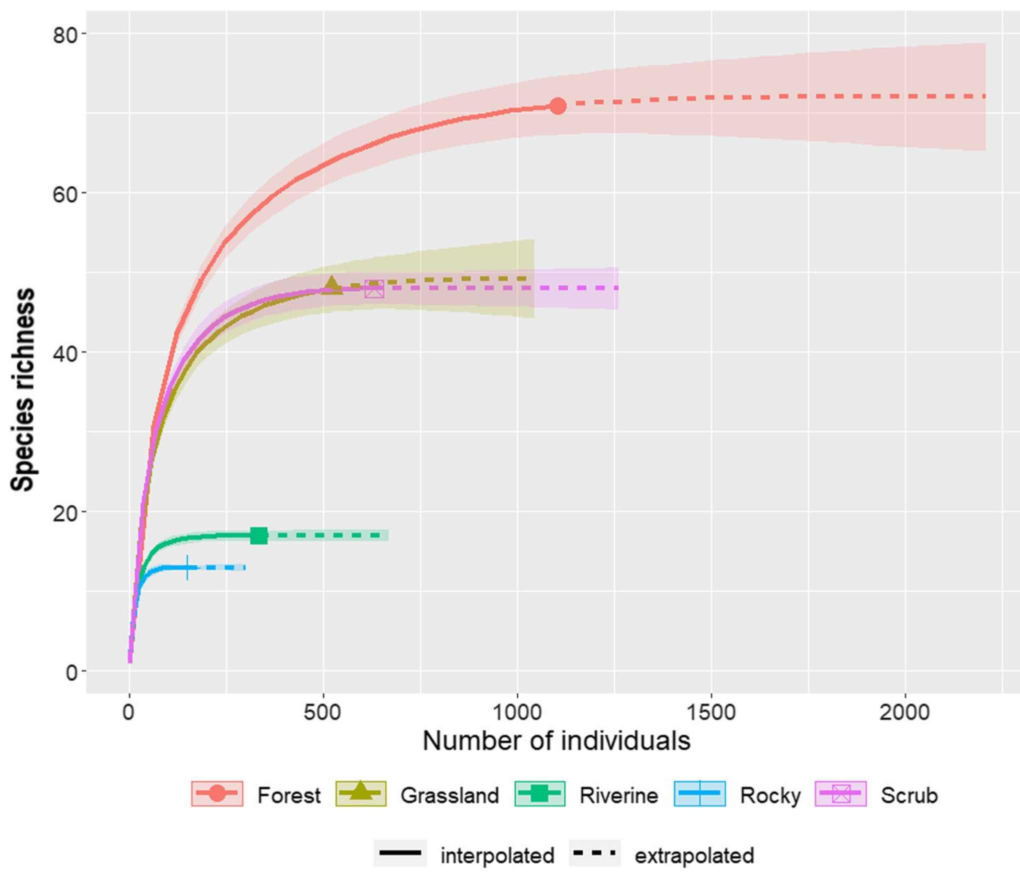

Fig. 3 Individual-based rarefaction and extrapolation curves of bird species for the studied vegetation or land use types. The shaded areas are the 95% confidence intervals of species richness

in species richness for all the pair-wise comparisons except for riverine versus grassland, scrub vs. grassland and rocky vs. riverine land use types (Table 1).

Species composition

The NMDS analysis showed that there was a considerable difference in the bird species composition between the studied vegetation or land use types, as evidenced by the associated inter-centroid distances and non-overlapping ellipses (Fig. 6). Also, the stress level for NMDS was low, (0.18). Further, the results of the PERMANOVA confirmed that the studied vegetation or land use types were significantly different from each other in terms of their bird species composition, as shown by both the Bray–Curtis ($F = 21.39$; $p < 0.01$) and the Jaccard ($F = 12.61$, $p < 0.01$) indices. This result suggests that both species number and relative abundances are driving the observed significant changes in species composition across all the studied vegetation or land-use types.

Spatio-temporal β-diversity patterns

The overall multiple-site Sorensen dissimilarity index among the studied vegetation or land use types was high ($\beta_{SOR} = 0.73$). More specifically, the replacement or turnover component ($\beta_{SIM} = 0.55$) was found to have a relatively large contribution to the observed overall dissimilarity compared to the nestedness component ($\beta_{SNE} = 0.18$), thereby reflecting that the resulting dissimilarity is more likely a consequence of species replacement (turnover) than richness difference (nestedness) (Fig. 7a). Also, the pair-wise Sorensen dissimilarity index varied considerably, with the lowest dissimilarity seen between forest and scrub land use types ($\beta_{SOR} = 0.33$) and the highest dissimilarity observed between forest and riverine land use types ($\beta_{SOR} = 0.95$) (Table 2). This pair-wise dissimilarity was more likely due to species turnover than nestedness in the majority of comparisons (Table 2). Moreover, the cluster analysis based on the turnover component of dissimilarity (β_{SIM}) showed riverine habitat to be highly dissimilar from the rest of land use types in terms of bird species composition, followed by forest and

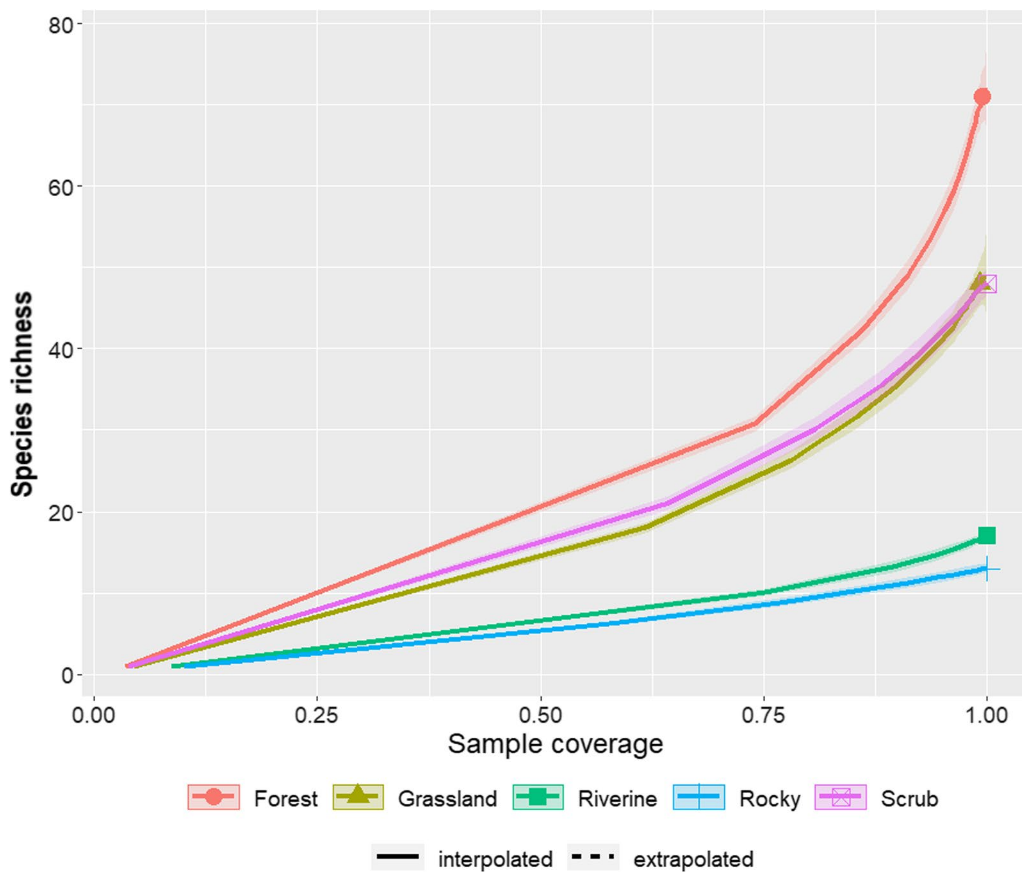

Fig. 4 Coverage-based rarefaction and extrapolation curves of bird species for the studied vegetation or land use types. The shaded areas are the 95% confidence intervals of species richness

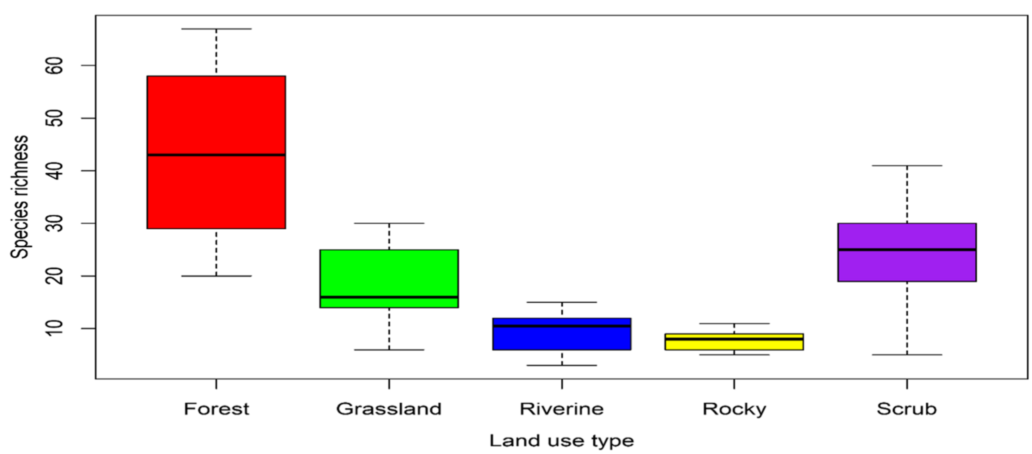

Fig. 5 Boxplot of the observed bird species richness across studied land use types sites during the study period

scrub (Fig. 7b). In contrast, the cluster analysis based on the nestedness component of dissimilarity (β_{SNE}) showed scrub and grassland to be highly dissimilar from the rest of land use types (Fig. 7c). Further, the temporal variation of β-diversity patterns among the studied vegetation or land use types between the years 2019 and 2021 showed a significant contribution of both the turnover and nestedness components to the overall dissimilarity (Fig. 7d).

Table 1 Multiple pair-wise bird richness comparisons between the studied land use types

Land use pair	Difference	*P* value
Grassland-Forest	24.38889	0
Riverine-Forest	32.77778	0
Rocky-Forest	34.77778	0
Scrub-Forest	19.02288	1.3E−06
Riverine-Grassland	8.388889	0.080737
Rocky-Grassland	10.38889	0.040236
Scrub-Grassland	5.366013	0.47846
Rocky-Riverine	2	0.981153
Scrub-Riverine	13.7549	0.000663
Scrub-Rocky	15.7549	0.00044

More specifically, the riverine land use category showed both negligible turnover and nestedness between the years 2019 and 2021. The rocky and scrub showed only nestedness of species, thus reflecting significant species loss or gain between the two-time intervals, while the forest and grassland vegetation types showed both species turnover and nestedness, with the highest values of turnover observed for grassland as compared to nestedness but vice versa for forest (Fig. 7d).

Discussion

The results of the present study indicate that Rajparian WLS is home to many avian species. During the study period, 102 bird species were recorded from the sanctuary. The highest numbers of bird species were present in forest habitats, followed by scrub vegetation, and the lowest numbers of bird species were present in rocky habitats. The results of the present study revealed that the presence of forests significantly influenced bird diversity in diverse environments. The results are in accordance with other studies (MacArthur & Levins, 1964; Dawson et al., 2011; Subasinghe et al., 2014). Rich avian diversity in the area could be attributed to the variety of habitat types found in the area and these habitat types may be responsible for different foraging and nesting opportunities available in the area. There are evidences that heterogeneous habitats enable the co-existence of more species because they either meet the habitat necessities or it may also be attributed to reduced competition by spatial isolation (Martin, 1986; May, 1986). Despite low biodiversity at sites, the spatial distribution of habitat types determines high species turnover and larger regional pools of species in heterogeneous landscapes (Söderström et al., 2001; Schall et al., 2018).

The Sanctuary exhibits a rich diversity of vegetation due to its varied altitude, aspect, and soil conditions. The forest covers the maximum area of the wildlife sanctuary and is of mixed type, consisting mainly of *Pinus wallichiana, Picea smithiana, Abies pindrow, Acer caesium, Ulmus wallichiana, Juglans regia, Salix alba,* and *Aesculus indica*, while the understory is made up of shrubs, ferns, mosses, and other plant species. In addition to providing food, nesting and breeding habitats, these plants also provide protection against predators, offering a kind of edge habitat for different bird guilds. Mixed forests are preferred habitats for generalists and opportunistic species that consume insects, fruits and seeds (Ralph et al., 1995). Species-area relationship can also affect species richness patterns. It proposes that increasing area can

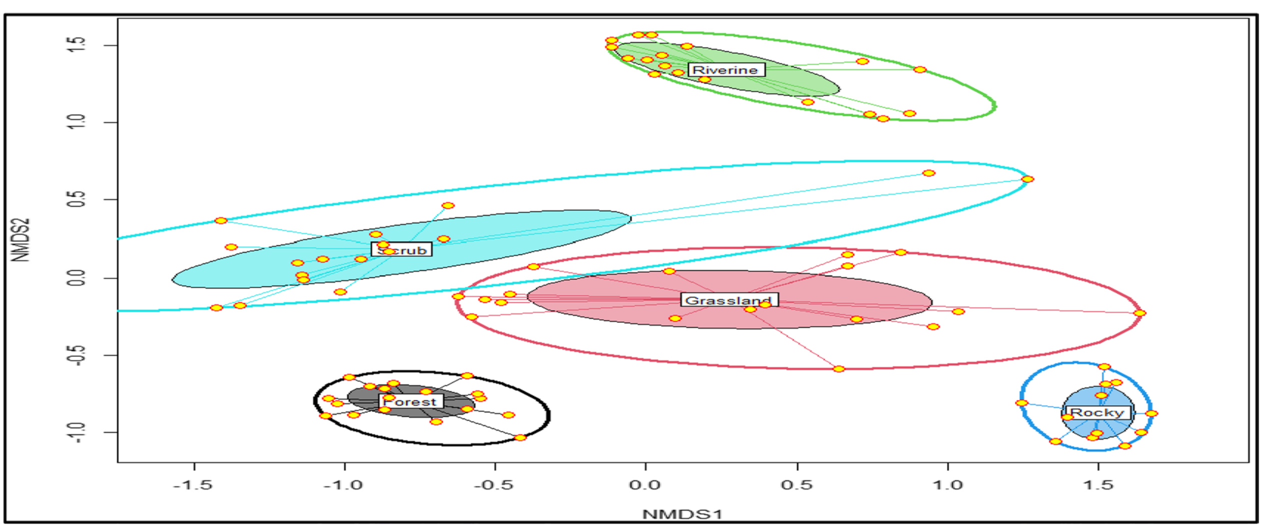

Fig. 6 Non-metric Dimensional Scaling (NMDS) plot showing difference in bird species composition between studied vegetation or land use types. The size of each ellipse is proportional to within-group dissimilarity of the given vegetation or land use category while as the degree of overlap between the two ellipses shows the associated community similarity between their respective vegetation or land uses types

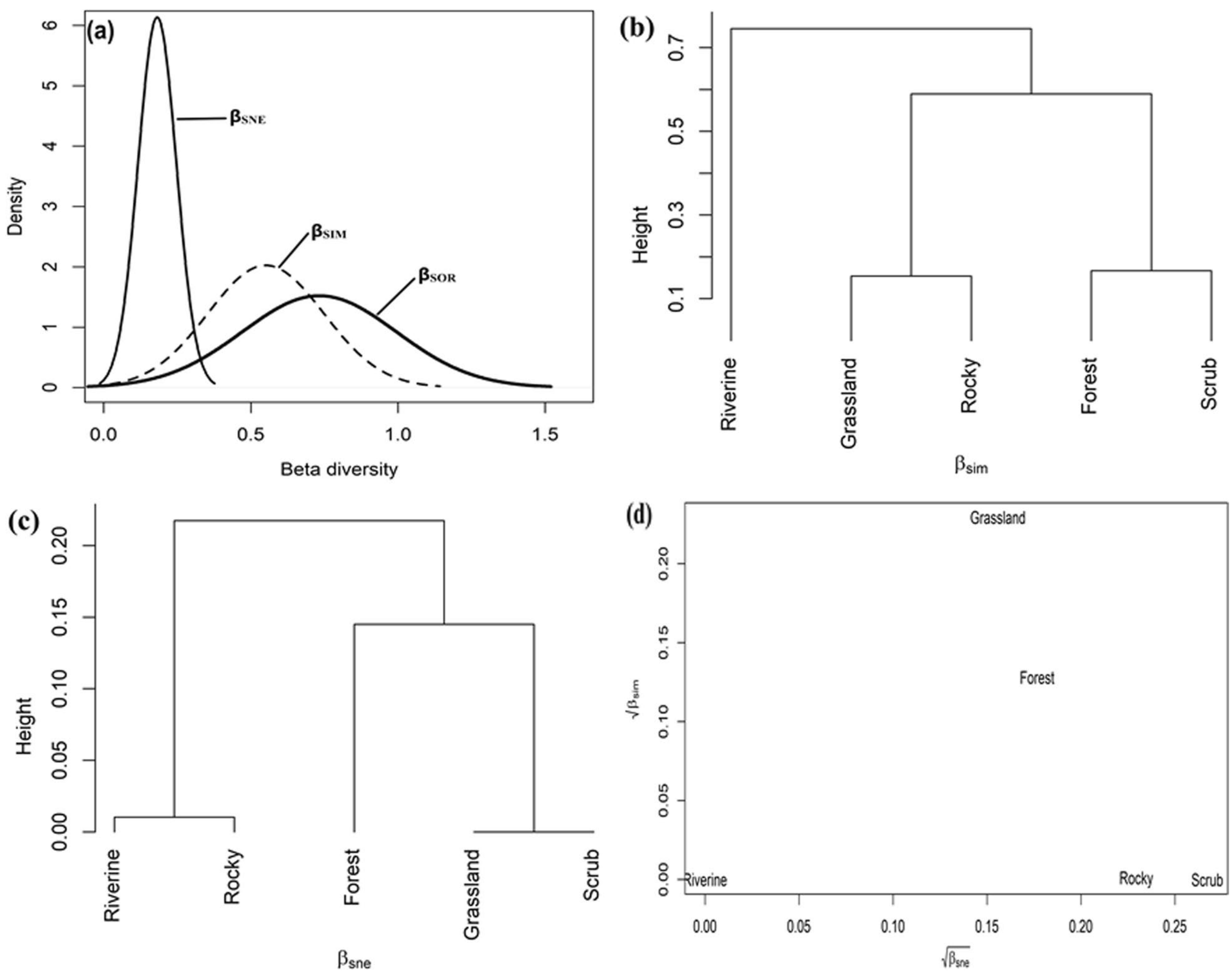

Fig. 7 Multiple-site dissimilarities across the five studied vegetation or land use types based on bird species composition. Shown are the partitioning of total dissimilarity (β_{SOR}-black solid line) into species turnover or replacement (β_{SIM}-dashed line) and nestedness (β_{SNE}-grey solid line) components (**a**) average clustering of β_{SIM} (**b**) and β_{SNE} (**c**) components of species dissimilarity among the vegetation or land use types and comparison of the square root transformed β_{SIM} and β_{SNE} components of β_{SOR} between the year 2019 and 2021 for the study area by vegetation or land use type (**d**)

increase species diversity as well as habitat complexity and thus provide a variety of opportunities to exploit environmental resources (Wilson & MacArthur, 1967). A mixed forest with more types of breeding sites provides a variety of habitats for different tree dwelling species of birds, which is not provided by a pure woodland forest (Díaz, 2006). The strong correlation between avian diversity and habitat diversity indicates that birds rely on the heterogeneity of trees, shrubs, and herbs and their compositional complexity. Based on these results, it can be concluded that bird communities are strongly correlated with the species diversity of plants, confirming the results of (Block & Brennan, 1993; Augenfeld et al., 2008; Earnst & Holmes, 2012; Tanalgo et al., 2015). According to Hutto, birds select or avoid the habitat that will be most or least beneficial to them, and the factors that influence their choice are more likely to be based on geographic position, type of habitat, previous experience in a habitat, and random exploration of new territories rather than actively picking a habitat (Hutto, 1985).

Based on our findings, it was confirmed that forest and shrub-land habitats supported the highest bird diversity and abundance than other habitat types, mainly due to vegetation cover for sheltering and nesting, food availability and lack of predation accessibility. In other words, we can say that forest and shrub-land ecosystems act as micro-refuges for birds, which results in the higher richness and diversity of bird species in these habitats. Low species richness at the peaks of mountain ranges can be attributed to lesser area, harsh climatic conditions, lesser

Table 2 Pair-wise Sorenson dissimilarity (β_{SOR}) along with the turnover (β_{SIM}) and nestedness (β_{SNE}) components

Sorenson dissimilarity (β_{SOR})				
	Forest	**Grassland**	**Scrub**	**Riverine**
Grassland	0.46			
Scrub	0.33	0.56		
Riverine	0.95	0.75	0.82	
Rocky	0.88	0.64	0.93	0.93
Turnover component of dissimilarity (β_{SIM})				
	Forest	**Grassland**	**Scrub**	**Riverine**
Grassland	0.33			
Scrub	0.17	0.56		
Riverine	0.82	0.53	0.65	
Rocky	0.62	0.15	0.85	0.92
Nestedness component of dissimilarity (β_{SNE})				
	Forest	**Grassland**	**Scrub**	**Riverine**
Grassland	0.13			
Scrub	0.16	0.00		
Riverine	0.07	0.22	0.17	
Rocky	0.27	0.49	0.09	0.01

productivity and resource constraints (Acharya et al., 2011; Hu et al., 2018). However, the higher altitudes were inhibited by some occasionally sighted raptors, including the near-threatened Bearded Vulture (*Gypaetus barbatus*), Himalayan Griffon Vulture (*Gyps himalayensis*), Golden Eagle (*Aquila chrysaetos)* and Black-eared Kite (*Milvus migrans*).

Among a wide range of habitat types and species, this analysis provides the first quantitative synthesis of beta-diversity and its underlying components. Spatio-temporal β-diversity patterns using multiple-site Sorensen dissimilarity revealed that the turnover component has a relatively large contribution to the observed overall dissimilarity compared to the nestedness component, confirming the results of Soininen et al. (2018). There were considerable variations in the pair-wise Sorensen dissimilarity index, with the lowest dissimilarity found between forest and scrub land types and the highest between forest and riverine land use types. According to (Magurran, 2004), species richness is the most commonly used estimation of species diversity however; β-diversity or spatial species turnover is often neglected (Koleff et al., 2003). To assess beta-diversity patterns, one must be able to separate the fractions of dissimilarity resulting from species turnover or from nestedness (Baselga, 2010).

In terms of bird species composition, cluster analysis based on the turnover component of dissimilarity (β_{SIM}) confirmed that riverine habitat is highly dissimilar from the rest of the land use types. By contrast, the nestedness component of dissimilarity (β_{SNE}) revealed that scrub and grassland were highly dissimilar from the rest of the land use types. Moreover, between the years 2019 and 2021, the temporal variation of β-diversity patterns among the studied vegetation or land use types was significantly influenced by both turnover and nestedness. It can be concluded that avian communities in the Rajparian Wildlife Sanctuary are influenced by mixed tree species, habitat quality and habitat heterogeneity, topography, and the availability of water.

Conclusions

The present study revealed that the Rajparian Wildlife Sanctuary harbors a rich avian diversity. A total of 102 bird species were recorded from five vegetation types. Among all the habitat types present in the sanctuary, the highest numbers of bird species were recorded from the forest ecosystem. This study is the first baseline but most important step ahead towards filling the knowledge gap on Himalayan avifauna. More scientific studies on birds are necessary for long-term monitoring and conservation planning in the region.

Abbreviations

IBAs	Important Bird Areas
GIS	Geographic information system
USGS	United States Geological Survey
LULC	Land use land cover
HSD	Honest Significant Differences
ANOVA	Analysis of variance

NMDS Non-metric multidimensional scaling
PERMANOVA Permutational Analysis of Variance
WLS Wild life sanctuary

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41936-023-00326-w.

Additional file 1: Table S1. Systematic list and status of birds recorded from Rajparian Wildlife Sanctuary, Kashmir.

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Author contributions
AHB designed the study and carried out the field study; AHM and SAC supervised the whole study and finalized the manuscript. AHB wrote the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
Not applicable.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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