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Research Article

Wildlife diversity and community structure in northern deciduous forest of Bangladesh

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ABSTRACT

Monitoring wildlife communities in protected areas is pivotal to successful conservation efforts. This study employed a direct observations-based approach to examine the diversity and community structure of wildlife in four protected deciduous national parks (Ramsagar, Birganj, Singra, and Nawabganj) in the northern Dinajpur district of Bangladesh. This study assessed the wildlife assemblage structures by measuring α diversity and β diversity. This research recorded a total of 159 wildlife species under 29 orders. Singra National Park displayed the highest species richness (N=73) and was found to be more diverse (H=3.36 ± 0.16) and even in distribution (J=0.9 ± 0.01). Analysis of Similarity test showed significant differences across all study sites (R=0.5216; p=0.0001). Whittaker Plot ranked *Dendrocygna javanica* as dominating, species making the community uneven. We found significant differences in species richness among seasons ($F_{2,\ 9}$=17.8, p=0.0001). For example, winter and rainy seasons were significantly richer over summer. This study identified profound human intrusions, which could potentially impact wildlife communities in the study area. Our findings underscore the conservation efforts to safeguard the threatened species in the study area.

Introduction

Bangladesh is characterized by diverse, intricate ecosystems, including hilly areas, wetlands, plain lands, evergreen forests, deciduous forests (locally known as *Sal* forests), and coastal regions. Notably, Bangladesh is distinguished by abundant plant species, which exhibit exceptional genetic, species, and ecosystem diversity, distributed among forests, village groves, and dwellings (IUCN Bangladesh, 2015). Forests and village groves are integral in providing various services, such as fruit and nuts, fuel and fodder, vegetables, medicinal plants, bamboo, numerous other non-wood forest products, and valuable timber and wood tree species. Forests are invaluable natural resources that serve numerous vital functions in nature. Among the major forest ecosystems, deciduous forests comprising dry-deciduous and moist deciduous forests are prominent landscapes in central and northern Bangladesh (Khan, 2015). Northern Bangladesh is home to only 14% of the *Sal* forest, with the remaining 86% in the central region (Alam et al., 2008).

Based on estimates from the Food and Agriculture Organization (FAO), it is reported that only 10% of *Sal* forest cover was present in 1990, down from an estimated 36% in 1985, indicating a significant reduction in *Sal* forest cover (Haque, 2007). The Sal forest has been identified as one of the most vulnerable ecosystems in Bangladesh (Alam et al., 2008). Various anthropogenic and natural threats, including overuse, deforestation, invasive species, habitat conversion for agriculture, and pollution, are causing critical ecosystems to deteriorate in certain

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forest areas. Consequently, at least 31 wildlife species have been extirpated in Bangladesh (IUCN Bangladesh, 2015). If these conditions persist, wildlife species will likely disappear continuously, leading to ecological imbalance and disaster. As a result, the flora and fauna of *Sal* forests might also be threatened with extinction risks.

Regarding biodiversity, Bangladesh is recognized as having a considerable abundance of wildlife. For example, this country harbors a diverse array of fauna, including approximately 133 mammal species, 711 bird species, 173 reptile species, and 64 amphibian species (IUCN Bangladesh, 2015; Khan, 2015; Khan, 2018; Shome et al., 2021). It is noteworthy that Bangladesh possesses diverse wildlife species due to its geographic location as a continental nation with a variety of habitats shared with neighboring countries (www.bforest.gov.bd). This also instigates the rich biodiversity of northern Bangladesh with various forms of microhabitats. Still, there is a lack of knowledge and research on the wildlife diversity and community structure in the existing *Sal* forests of that particular areas.

Several studies have been conducted on the diversity, status, distribution, threats, and conservation strategies of wildlife in different parts of Bangladesh at different times (Kabir and Ahmed, 2005; Jaman et al., 2015, 2020, 2021, 2022; Shome et al., 2020, 2021, 2022a, 2022b; Barkat et al., 2021; Rabbe et al., 2022a, 2022b, 2022c; Saha et al., 2022). The number of studies on deciduous forests of northern Bangladesh is very limited and done on a preliminary basis. For instance, Rimi et al. (2013) and Ali et al. (2020) assessed the biodiversity, conservation, and management activities in Ramsagar National Park and Singra National Park, respectively. Rabbe et al. (2022a, 2022b) conducted a study on the herpetofaunal diversity, abundance, human perception of the herpetofauna, threats to the herpetofauna, and conservation measures in Greater Dinajpur and Nilphamari districts of Bangladesh.

The present study was designed to address the research gaps in wildlife diversity and community structure in the *Sal* forests of northern Bangladesh. The main objective of this study was to quantify and compare the diversity, composition, and abundance of wildlife in the four deciduous protected areas (i.e., National Parks). In addition, this study aimed to provide baseline information on wildlife and conservation aspects in the study area.

Material and methods

Study areas

This study was conducted in four protected national parks, namely Ramsagar National Park, Birganj National Park, Singra National Park, and Nawabganj National Park, under northern Dinajpur district from July 2021 to August 2022 (Fig. 1, Table 1). These protected areas are dominated by deciduous forests, primarily consisting of *Sal* (*Shorea robusta*) trees. The forests differ in their composition of large and small *Sal* trees, grasslands (with a height of less than or equal to 2 m), bushes and thickets, small canals, roadside areas, and a permanent waterbody (*dighi* only in Ramsagar) (Akter et al., 2023; DoF, 2023).

The microhabitats of the study sites were identified through direct observations and classified into five distinct categories: Agricultural land (AL), which are actively farmed areas for rice, corn, and vegetables; Dense vegetation (DG), consisting of short, small grassy and bushy vegetation with a maximum height of ≤2 m; Homestead area (HA), which includes large and small trees around residential houses near the periphery of the protected area; Trees (T), which include plants with a minimum height of ≥2 m; and Waterbody (W), which encompasses shallow water channels, small and large ponds, and seasonal wetlands.

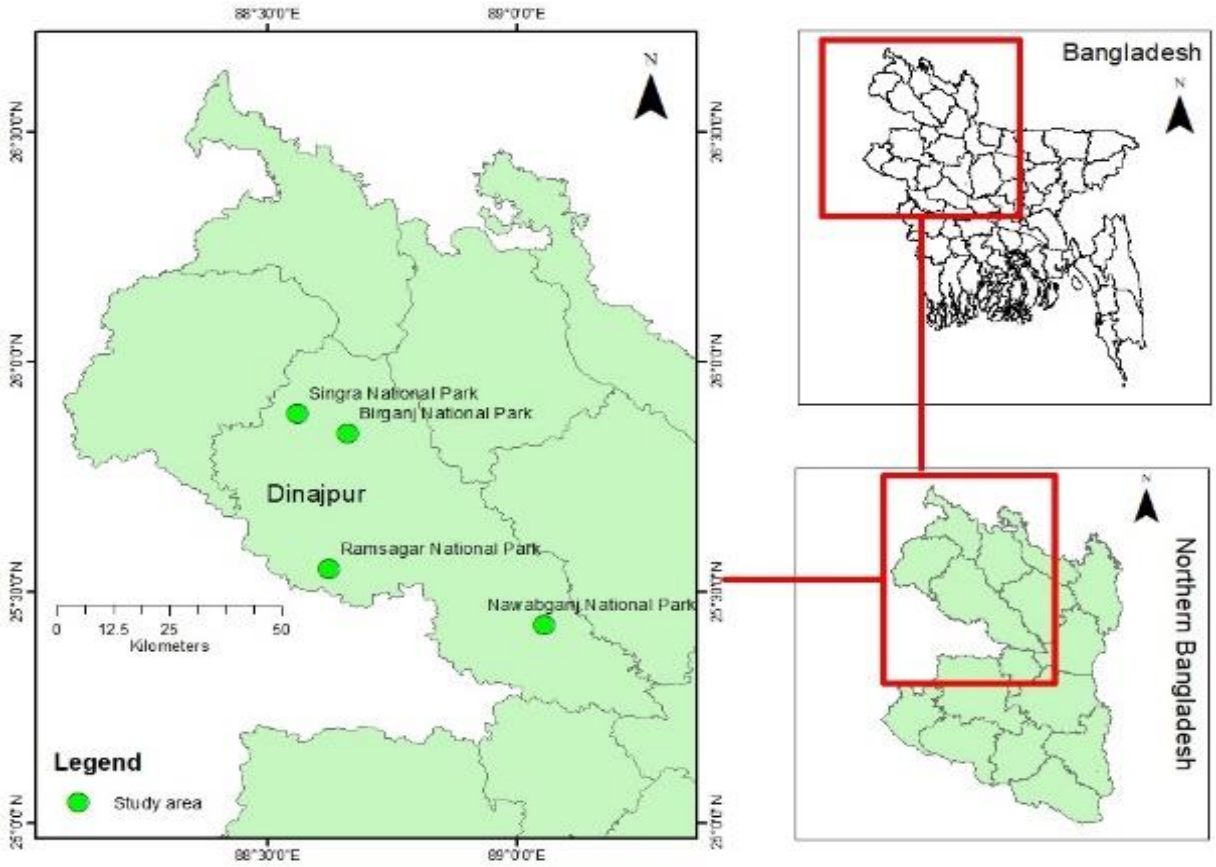

Fig. 1. Map of the study area showing the four national parks of northern Dinajpur district, Bangladesh.

Table 1. Major landscape features and characteristics of habitats in four national parks

Parameters	Ramsagar NP	Birganj NP	Singra NP	Nawabganj NP
Area(ha)	27.75	168.56	305.69	517.61
Latitude and Longitude	25°33′17″N 88°37′24″E	25°51'11"N 88°39'33"E	25°53'31"N 88°33'36"E	25.4517°N 89.0534°E
IUCN category	IV	IV	IV	IV
Declared in	2001	2011	2010	2010
Major tree	–	*Shorea robusta*	*Shorea robusta*	*Shorea robusta*
Waterbody	Permanent and large *dighi*	Permanent ponds & temporary ditches	Temporary canal	*Beel* and temporary ditches
Bushes	Present	Present	Present	Present
Human settlements	Periphery	Inside	Inside	Periphery
Microhabitats	Agricultural land, Dense vegetation, Homestead area, Trees, Waterbody			

Survey protocol

Data were systematically collected through direct field observations using the line transect method following Yallop et al. (2004). Surveys were conducted for a minimum of 10 hours each day. The whole day was divided into morning (06:00 to 10:00), afternoon (15:30 to 19:00), and night (21:30 to 24:00). Each transect had a length of 500 m and a width of 50 m. Each transect had five predetermined intervals, each spaced 100 meters apart, and approximately 20 minutes were allocated at each interval point for amphibians' and reptiles' observation. A pair of binoculars (Bushnell Power view 10x42) was used to facilitate observations of mammals and birds. Upon spotting any species, the individual count and microhabitat usage were recorded. Wildlife species hidden in the bushes, jungles, and branches of trees were detected by hearing their songs and calls, and then identification was confirmed by direct observation. In addition, local people were interviewed, and pictorial guides were shown to confirm the presence and abundance of wild animals, especially turtles and snakes. Species were occasionally photographed using NIKON D5300 with a 55–200 mm lens for identification. To evaluate seasonal changes in wildlife diversity, the entire study period was divided into three seasons: summer (March-June), rainy (July–October), and winter (November–February). The guidelines of IUCN Bangladesh (2015) and Khan (2018) was followed for the taxonomic identification of observed species.

Data analysis

To ensure adequate sampling, we constructed a species accumulation curve following the rarefaction method outlined by Magurran (2013).

We also calculated sampling completeness by following the formula:

$$\text{Sample completeness}=\frac{\text{Observed Number of species (n)}}{\text{Estimated Number of species }(x)}*100$$

To assess the α level of diversity status of wildlife in each site, we measured Margalef Species richness, Pielou's evenness, and the Shannon–Wiener index. The relative abundance (RA) of each species in each site was calculated using the formula RA = (number of individuals of a particular species) / (total number of individuals of all species)×100. We also presented the relative abundance of wildlife observed in different microhabitats as a stacked bar diagram for each study site. To assess β diversity (species turnover) between sites, we performed an Analysis of Similarities (ANOSIM). We used the 'adonis' function from the vegan R package (Oksanen et al., 2019).

A cluster analysis was conducted using the Bray–Curtis index (Everitt et al., 2011) in PAST version 3 (Hammer et al., 2001) to examine similarities among the different microhabitats. A Whittaker rank-abundance diagram was generated by plotting the relative abundance against their rank in each study site (Whittaker, 1965). To identify significant differences among study sites and the seasonal variation of wildlife, we performed one-way ANOVA followed by Dunn's post-hoc comparison test. We checked the normality of the data using Q-Q plots, the Shapiro–Wilk Test, and histograms. All statistical analyses were performed using relevant statistical packages in R 4.0.5 (R Core Team 2020), and the ggplot2 package was used for plotting (Wickham, 2016).

Results and Discussion

Sampling completeness, species diversity, and composition

A total of 159 wildlife species were recorded during the study period, belonging to 64 families under 23 orders. The species accumulation curves indicated that the survey was sufficiently comprehensive and that sampling efforts were adequate (Fig. 2).

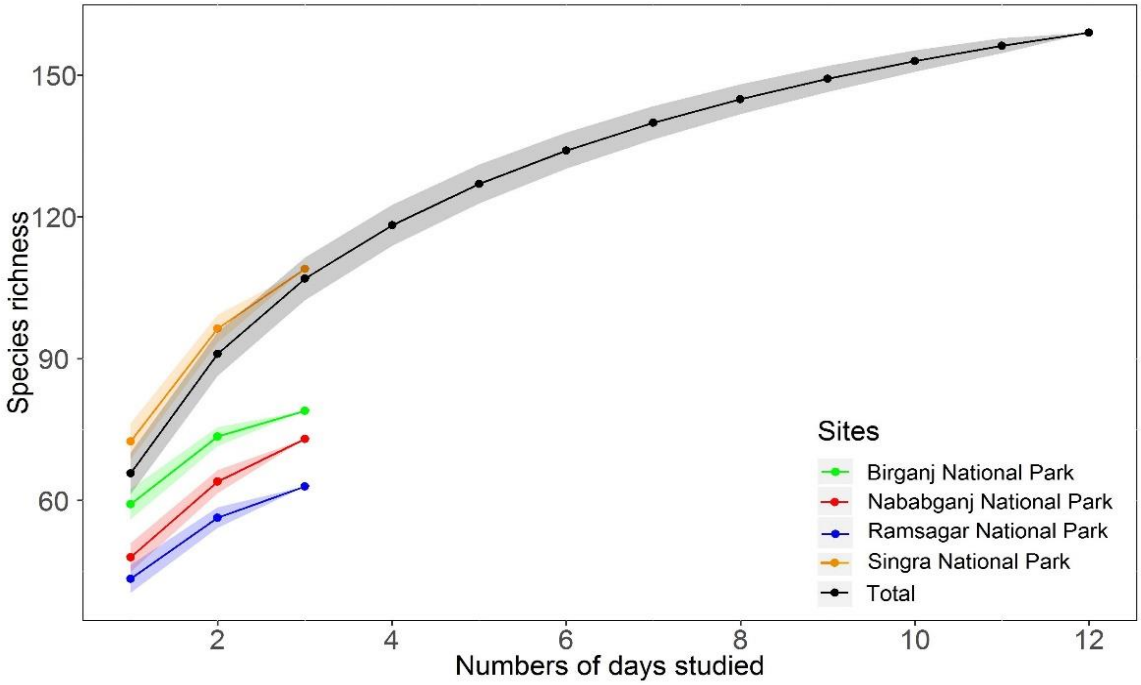

Fig. 2. Species accumulation curve of the study sites. The X-axis has been scaled to show the number of days studied.

Of the 159 wildlife species recorded during the study period, 119 were birds, 12 were amphibians, 10 were mammals, and 18 were reptiles (Table 3). A total of 2966 individuals of these 159 species were observed. Singra National Park had the highest species richness (N=73), followed by Ramsagar National Park (N=71), Nawabganj National Park (N=70), and the lowest in Birganj National Park (N=68). The average number of wildlife species observed per day did not differ significantly among study sites ($F_{3, 8}$=0.11, p = 0.95). Singra National Park had the highest average number of observed wildlife species per day (43±8.71), followed by Ramsagar National Park (40±13), Nawabganj National Park (40±10.44), and Birganj National Park (38.33±7.50) (Fig. 3). However, the relative abundances of wildlife varied among different microhabitats. Agricultural land was the most abundant in Birganj National Park. In contrast, the "Tree" microhabitat was relatively abundant in Nawabganj and Singra National Park. Lastly, wildlife inhabiting waterbodies was the most. abundant in Ramsagar National Park. (Fig. 4).

Shannon-Wiener diversity index (H) showed that Singra National Park had the highest species diversity (H=3.36±0.16), followed by Nawabganj National Park (H=3.25±0.28), Ramsagar National Park (H=2.77±0.86), and the lowest in Birganj National Park (H= 2.73±0.79). However, the average Shannon-Wiener diversity index did not vary significantly among study sites ($F_{3, 8}$=0.846, p=0.50) (Fig. 3). Pielou's Evenness further indicated that species in Singra National Park (J=0.9±0.01) and Nawabganj National Park (J= 0.89±0.08) were more evenly distributed compared to Birganj National Park (J=0.76±0.24) and Ramsagar National Park (J=0.75±0.19). This unevenness of species community was also illustrated in the Whittaker Plot (Fig. 5) and the most dominating species were *Dendrocygna javanica* (RA=40.314%) in Ramsagar National Park, *Euphlyctis cyanophlyctis* (RA=36.506%) in Birganj National Park and *Sturnus contra* in Nawabganj National Park (RA=18.526%) and Singra National Park (RA=8.998%).

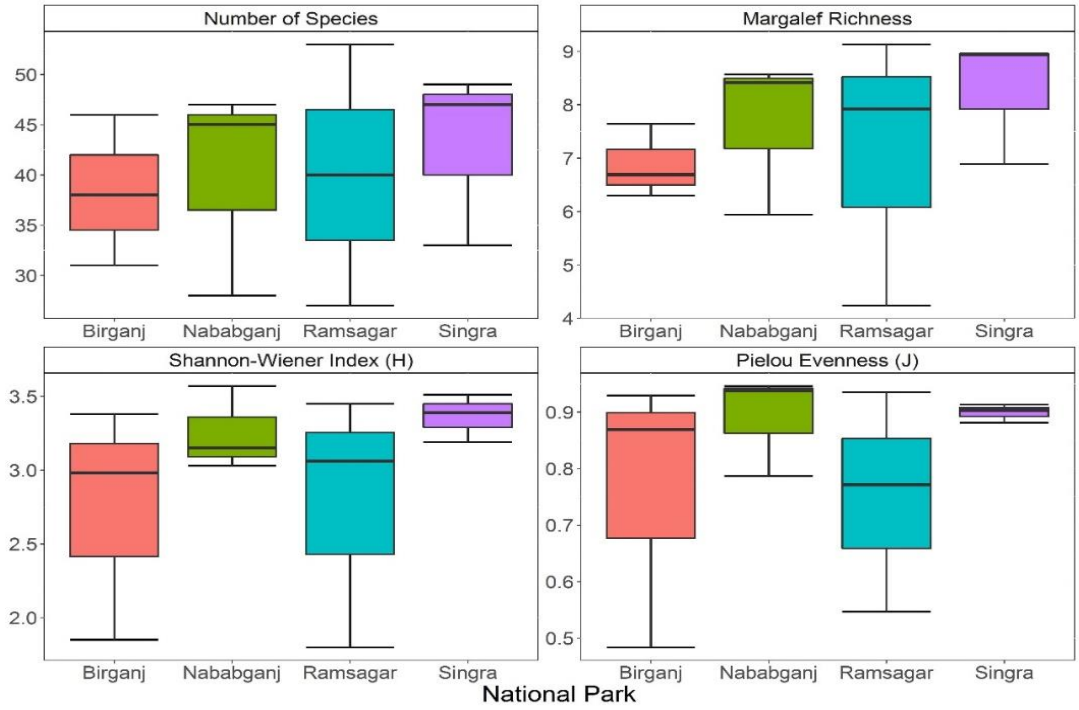

Fig. 3. Boxplot of Alpha-diversity indices, Margalef Richness, and number of observed species in four study sites A, Number of species; B, Margalef Richness C, Shannon-Wiener Index (H) D, Pielou's Evenness (J).

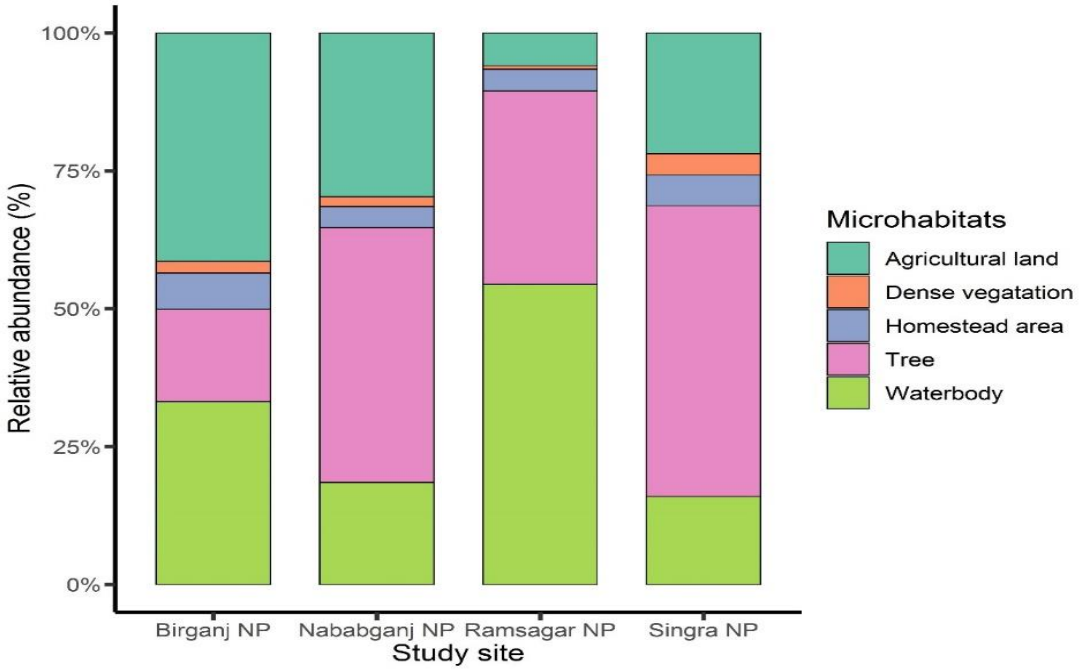

Fig. 4. Histogram of relative abundance of wildlife among study sites. The X-axis represents study sites, and the Y-axis represents the relative abundance of wildlife occupying different microhabitats.

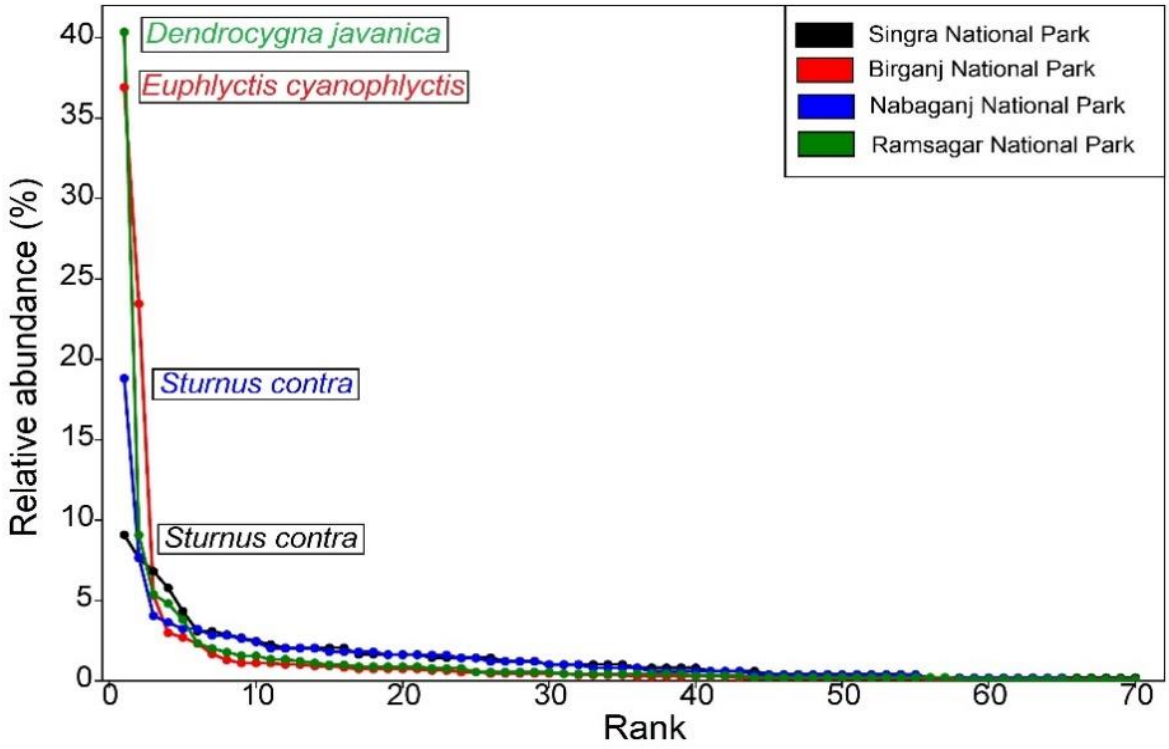

Fig. 5. Whittaker plot representing the abundance rank of wildlife species in the study sites.

The study revealed a seasonal variation in species composition; the winter season had the highest number of recorded wildlife species (115). Still, the number of individuals was highest in the rainy season (1316 individuals). ANOVA indicated a significant difference in wildlife species richness among seasons ($F_{2,9}$=17.8, p=0.0001), and the winter season (46.75±6.34) and the rainy season (44.5±3.10) were significantly richer than the summer season (29.75±2.75) (p<0.05). Similarly, significant variation was seen among seasons for Margalef Richness ($F_{2,9}$=9, p=0.001) and the winter season and summer season were significant over the summer season (p<0.05). Although the Shannon-Wiener index calculated the overall highest diversity in winter (H=3.845), it did not differ significantly ($F_{2, 9}$=0.57, p>0.05) among seasons (Fig. 6).

The beta diversity pattern was analyzed using the Analysis of Similarity (ANOSIM) test, demonstrating a statistically significant difference in wildlife communities across all sites (R=0.5216; p=0.0001). However, no significant differences were observed between sites in pairwise comparisons at p<0.05 (Table 2).

Cluster analysis showed one distinct cluster between "Tree" and "Agricultural land," indicating they shared the most species community. The dendrogram revealed that this group formed a tight cluster with the "Homestead area," which also had considerable similarities in the species community. In addition, the dendrogram demonstrated that the most distinct species communities were observed in "Waterbody" and "Dense vegetation" during the study period (Fig. 7).

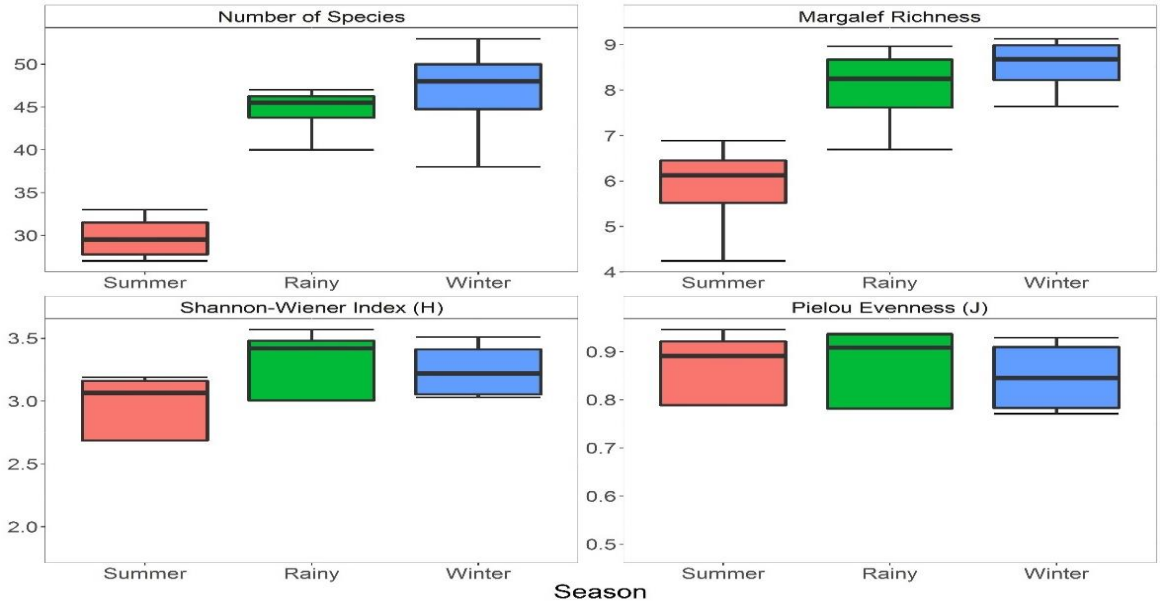

Fig. 6. Seasonal variation in diversity indices- A, Number of Species; B, Margalef species Richness; C, Shannon-Wiener Index; D, Pielou Evenness

Fig. 7. Dendrogram showing species community similarities among microhabitats based on Bray–Curtis Index

Table 2. Pairwise comparison among study sites based on the ANOSIM test. Bonferroni-corrected p values are used.

National parks	Birganj	Nawabganj	Ramsagar
Nawabganj	R=0.44; p=0.09		
Ramsagar	R=0.26; p=0.19	R=0.74; p=0.10	
Singra	R=0.40; p=0.10	R=0.81; p=0.10	R=0.85; p=0.09

Table 3. Class, family, species names, abundance (n), and relative abundance (RA) of observed vertebrate wildlife in four study sites

Family	Scientific name	Common name	n	RA (%)	Site-wise RA (%)			
					BNP	NNP	RNP	SNP
Class: Amphibia								
Bufonidae	*Duttaphrynus melanostictus*	Common Toad	28	0.90	1.30	0.00	0.80	1.40
Dicroglossidae	*Euphlyctis cyanophlyctis*	Skipper Frog	445	15.00	36.50	1.60	0.60	7.60
Dicroglossidae	*Euphlyctis kalasgramensis*	Kalasgram Skipper Frog	281	9.50	23.20	1.40	0.20	4.30
Dicroglossidae	*Fejervarya asmati*	Asmat's Cricket Frog	68	2.30	5.30	1.20	0.20	0.60
Dicroglossidae	*Fejervarya nipalensis*	Nepal Wart Frog	25	0.80	1.10	0.40	0.40	1.40
Dicroglossidae	*Fejervarya pierrei*	Pierre's Cricket Frog	10	0.30	0.50	0.60	0.00	0.40
Dicroglossidae	*Fejervarya teraiensis*	Terai Wart Frog	10	0.30	0.30	0.40	0.00	1.00
Dicroglossidae	*Hoplobatrachus crassus*	Jerdons Bullfrog	2	0.10	0.20	0.00	0.00	0.00
Dicroglossidae	*Hoplobatrachus tigerinus*	Indian Bullfrog	18	0.60	1.00	0.40	0.00	1.00
Microhylidae	*Microhyla sp*	Narrow-mouthed Frog	6	0.20	0.50	0.00	0.00	0.20
Rhacophoridae	*Polypedates maculatus*	Maculated Tree Frog	3	0.10	0.20	0.20	0.00	0.00
Rhacophoridae	*Polypedates leucomystax*	Common Tree Frog	6	0.20	0.20	0.60	0.00	0.20
Class: Reptilia								
Agamidae	*Calotes versicolor*	Common Garden Lizard	6	0.20	0.10	0.60	0.00	0.40
Colubridae	*Ahaetulla nasuta*	Common Vine Snake	2	0.10	0.20	0.00	0.00	0.00
Colubridae	*Dendrelaphis pictus*	Common Bronze-back	1	0.00	0.00	0.00	0.00	0.20
Colubridae	*Enhydris enhydris*	Common Smooth-scaled Water Snake	1	0.00	0.00	0.20	0.00	0.00
Colubridae	*Lycodon aulicus*	Common Wolf Snake	1	0.00	0.10	0.00	0.00	0.00
Colubridae	*Ptyas mucosa*	Indian Rat Snake	2	0.10	0.20	0.00	0.00	0.00
Colubridae	*Xenochrophis cerasogaster*	Painted Keelback	1	0.00	0.10	0.00	0.00	0.00
Colubridae	*Xenochrophis piscator*	Checkered Keelback	2	0.10	0.00	0.00	0.10	0.20
Elapidae	*Naja naja*	Binocellate Cobra	2	0.10	0.20	0.00	0.00	0.00
Gekkonidae	*Gekko gecko*	Tokay Gecko	1	0.00	0.00	0.20	0.00	0.00

Family	Scientific name	Common name	n	RA (%)	Site-wise RA (%)			
					BNP	NNP	RNP	SNP
Gekkonidae	*Hemidactylus brookii*	Brook's House Gecko	2	0.10	0.00	0.40	0.00	0.00
Gekkonidae	*Hemidactylus frenatus*	Common House Gecko	1	0.00	0.00	0.20	0.00	0.00
Scincidae	*Eutropis carinata*	Common Skink	2	0.10	0.00	0.00	0.00	0.40
Scincidae	*Eutropis macularia*	Bronze Grass Sking	1	0.00	0.10	0.00	0.00	0.00
Trionychidae	*Lissemys punctata*	Spotted Flapshell Turtle	1	0.00	0.10	0.00	0.00	0.00
Typhlopidae	*Argyrophis diardii*	Diard's Blindsnake	2	0.10	0.20	0.00	0.00	0.00
Varanidae	*Varanus bengalensis*	Bengal Monitor	1	0.00	0.00	0.00	0.00	0.20
Varanidae	*Varanus flavescens*	Yellow Monitor	1	0.00	0.10	0.00	0.00	0.00
		Class: Aves						
Accipitridae	*Accipiter badius*	Shikra	3	0.10	0.00	0.00	0.00	0.60
Accipitridae	*Buteo rufinus*	Long-legged Buzzard	1	0.00	0.00	0.00	0.10	0.00
Accipitridae	*Circus spilonotus*	Eastern Marsh-harrier	1	0.00	0.00	0.20	0.00	0.00
Accipitridae	*Clanga hastata*	Indian Spotted Eagle	1	0.00	0.00	0.00	0.10	0.00
Accipitridae	*Elanus caeruleus*	Black-winged Kite	1	0.00	0.00	0.00	0.10	0.00
Accipitridae	*Haliastur indus*	Brahminy Kite	2	0.10	0.00	0.00	0.20	0.00
Accipitridae	*Ichthyophaga ichthyaetus*	Grey-headed Fish-eagle	8	0.30	0.00	0.60	0.60	0.00
Accipitridae	*Milvus migrans*	Black Kite	3	0.10	0.00	0.00	0.00	0.60
Accipitridae	*Nisaetus cirrhatus*	Changeable Hawkeagle	1	0.00	0.00	0.00	0.10	0.00
Accipitridae	*Pernis ptilorhyncus*	Oriental Honey Buzzard	8	0.30	0.00	0.00	0.80	0.20
Accipitridae	*Spilornis cheela*	Crested Serpent Eagle	1	0.00	0.00	0.00	0.00	0.20
Aegithinidae	*Aegithina tiphia*	Common Iora	8	0.30	0.00	0.00	0.90	0.00
Alcedinidae	*Alcedo atthis*	Common Kingfisher	26	0.90	0.70	2.00	0.90	0.00
Alcedinidae	*Ceryle rudis*	Pied Kingfisher	2	0.10	0.00	0.40	0.00	0.00
Alcedinidae	*Halcyon smyrnensis*	White-breasted Kingfisher	28	0.90	0.70	1.80	1.20	0.00
Alcedinidae	*Pelargopsis capensis*	Stork-billed Kingfisher	1	0.00	0.00	0.00	0.10	0.00

Family	Scientific name	Common name	n	RA (%)	Site-wise RA (%)			
					BNP	NNP	RNP	SNP
Alcedinidae	*Psilopogon asiaticus*	Blue-throated Barbet	2	0.10	0.00	0.00	0.20	0.00
Anatidae	*Dendrocygna javanica*	Lesser Whistling Duck	360	12.10	0.00	0.00	40.30	0.00
Anatidae	*Nettapus coromandelianus*	Cotton Pygmy-goose	5	0.20	0.00	0.00	0.60	0.00
Anatidae	*Spatula querquedula*	Gargeny	1	0.00	0.00	0.00	0.10	0.00
Apodidea	*Apus nipalensis*	House Swift	2	0.10	0.00	0.40	0.00	0.00
Apodidea	*Cypsiurus balasiensis*	Asian Palm Swift	5	0.20	0.00	0.00	0.60	0.00
Ardidae	*Ardeola grayii*	Indian Pond Heron	62	2.10	1.70	2.80	1.80	2.90
Ardidae	*Bubulcus ibis*	Cattle Egret	8	0.30	0.00	1.60	0.00	0.00
Ardidae	*Egretta garzetta*	Little Egret	14	0.50	0.00	2.80	0.00	0.00
Ardidae	*Nycticorax nycticorax*	Black-crowned Night Heron	4	0.10	0.40	0.00	0.00	0.00
Artamidae	*Artamus fuscus*	Ashy Woodswallow	9	0.30	0.00	1.80	0.00	0.00
Campephagidae	*Coracina macei*	Large Cuckooshrike	8	0.30	0.00	0.00	0.00	1.60
Campephagidae	*Coracina melanoptera*	Black-headed Cuckooshrike	4	0.10	0.20	0.00	0.00	0.40
Campephagidae	*Coracina melaschistos*	Black-winged Cuckooshrike	3	0.10	0.00	0.00	0.30	0.00
Campephagidae	*Pericrocotus cinnamomeus*	Small Minivet	18	0.60	0.00	0.00	2.00	0.00
Campephagidae	*Tephrodornis pondicerianus*	Common Woodshrike	5	0.20	0.00	0.00	0.40	0.20
Caprimulgidae	*Caprimulgus macrurus*	Long-tailed Nightger	2	0.10	0.00	0.00	0.20	0.00
Chardridae	*Charadrius dubius*	Little Ringed Plover	3	0.10	0.00	0.60	0.00	0.00
Chardridae	*Tringa glareola*	Wood Sandpiper	3	0.10	0.00	0.60	0.00	0.00
Chardridae	*Vanellus cinereus*	Grey-headed Lapwing	2	0.10	0.00	0.40	0.00	0.00
Chardridae	*Vanellus indicus*	Red-wattled Lapwing	15	0.50	0.30	0.80	0.30	1.00
Ciconidae	*Anastomus oscitans*	Asian Openbill	15	0.50	0.00	0.00	0.00	3.10
Cicticolidae	*Cisticola juncidis*	Zitting Cisticola	5	0.20	0.30	0.40	0.00	0.00
Cicticolidae	*Prinia gracilis*	Graceful Prinia	4	0.10	0.00	0.00	0.00	0.80
Cicticolidae	*Prinia hodgsonii*	Grey-breasted Prinia	6	0.20	0.00	1.20	0.00	0.00
Cicticolidae	*Prinia inornata*	Plain Prinia	5	0.20	0.00	0.00	0.00	1.00
Columbidae	*Columba livia*	Rock Dove	13	0.40	0.50	0.80	0.40	0.00
Columbidae	*Spilopelia chinensis*	Eastern Spotted Dove	38	1.30	0.00	4.00	0.90	2.00
Columbidae	*Streptopelia decaocto*	Eurasian Collared Dove	17	0.60	0.60	0.00	0.00	2.00
Columbidae	*Streptopelia tranquebarica*	Red Turtle Dove	2	0.10	0.20	0.00	0.00	0.00
Columbidae	*Treron phoenicopterus*	Yellow Footed Green Pigeon	19	0.60	0.00	0.00	0.80	2.50
Coracidae	*Coracias benghalensis*	Indian Roller	3	0.10	0.00	0.20	0.00	0.40
Corvidae	*Corvus splendens*	House Crow	4	0.10	0.00	0.00	0.20	0.40

Family	Scientific name	Common name	n	RA (%)	Site-wise RA (%)			
					BNP	NNP	RNP	SNP
Corvidae	*Corvus levaillantii*	Jungle Crow	13	0.40	0.50	0.00	0.90	0.00
Corvidae	*Dendrocitta vagabunda*	Rufous Treepie	39	1.30	0.90	2.00	1.30	1.40
Cuculidae	*Centropus sinensis*	Greater Coucal	2	0.10	0.00	0.00	0.20	0.00
Cuculidae	*Eudynamys scolopaceus*	Western Koel	4	0.10	0.00	0.00	0.40	0.00
Cuculidae	*Hierococcyx varius*	Common Hawk-Cuckoo	20	0.70	0.00	1.80	0.00	2.20
Cuculidae	*Phaenicophaeus tristis*	Green-billed Malkoha	1	0.00	0.00	0.00	0.00	0.20
Dicaeidae	*Dicaeum erythrorhynchos*	Pale-billed Flowerpecker	9	0.30	0.00	0.80	0.60	0.00
Dicruridiae	*Dicrurus hottentottus*	Hair-crested Drongo	30	1.00	0.50	1.60	0.20	3.10
Dicruridiae	*Dicrurus leucophaeus*	Ashy Drongo	7	0.20	0.30	0.20	0.30	0.00
Dicruridiae	*Dicrurus macrocercus*	Black Drongo	25	0.80	0.00	3.20	1.00	0.00
Dicruridiae	*Dicrurus aeneus*	Bronzed Drongo	11	0.40	0.20	0.60	0.40	0.40
Estrilidae	*Lonchura malabarica*	White-throated Munia	2	0.10	0.00	0.00	0.20	0.00
Estrilidae	*Lonchura punctulata*	Scaly-breasted Munia	6	0.20	0.20	0.00	0.00	0.80
Estrilidae	*Lonchura striata*	White-rumped Munia	6	0.20	0.20	0.80	0.00	0.00
Falconidae	*Falco chicquera*	Red-headed Falcon	1	0.00	0.00	0.20	0.00	0.00
Herundinidae	*Hirundo rustica*	Barn Swallow	2	0.10	0.00	0.40	0.00	0.00
Jacanidae	*Hydrophasianus chirurgus*	Pheasant-tailed Jacana	13	0.40	0.00	2.60	0.00	0.00
Jacanidae	*Metopidius indicus*	Bronze-winged Jacana	5	0.20	0.00	1.00	0.00	0.00
Lanidae	*Lanius cristatus*	Brown Shrike	7	0.20	0.20	0.40	0.10	0.40
Lanidae	*Lanius schach*	Long-tailed Shrike	4	0.10	0.00	0.00	0.00	0.80
Lanidae	*Lanius tephronotus*	Grey-backed Shrike	2	0.10	0.00	0.20	0.10	0.00
Megalaimidae	*Psilopogon haemacephala*	Coppersmith Barbet	10	0.30	0.00	1.20	0.00	0.80
Meropidae	*Merops orientalis*	Asian Green Bee-eater	10	0.30	0.00	0.00	1.10	0.00
Monarchidae	*Terpsiphone paradisi*	Asian Paradise-Flycatcher	2	0.10	0.00	0.00	0.20	0.00
Motacilidae	*Anthus rufulus*	Paddyfield Pipit	2	0.10	0.10	0.00	0.00	0.20
Motacilidae	*Motacilla madaraspatensis*	White-browed Wagtail	4	0.10	0.00	0.00	0.10	0.60
Motacilidae	*Motacilla alba*	White Wagtail	17	0.60	0.00	1.40	0.00	2.00
Motacilidae	*Motacilla citreola*	Citrine Wagtail	2	0.10	0.00	0.20	0.10	0.00
Motacilidae	*Motacilla flava*	Yellow Wagtail	1	0.00	0.00	0.00	0.10	0.00
Muscicapidae	*Copsychus saularis*	Oriental Magpie-robin	45	1.50	1.10	1.60	1.30	2.70
Muscicapidae	*Culicicapa ceylonensi*	Grey-headed Canary-flycatcher	4	0.10	0.40	0.00	0.00	0.00
Muscicapidae	*Eumyias thalassina*	Verditer Flycatcher	2	0.10	0.00	0.00	0.00	0.40
Muscicapidae	*Ficedula albicilla*	Taiga Flycatcher	6	0.20	0.40	0.00	0.20	0.00
Nectarinidae	*Nectarinia asiatica*	Purple Sunbird	10	0.30	0.00	2.00	0.00	0.00
Pandionidae	*Pandion haliaetus*	Osprey	2	0.10	0.00	0.20	0.00	0.20

Family	Scientific name	Common name	n	RA (%)	Site-wise RA (%)			
					BNP	NNP	RNP	SNP
Paridae	*Parus major*	Great Tit	32	1.10	0.70	2.40	0.40	1.60
Passeridae	*Passer domesticus*	House Sparrow	19	0.60	0.70	0.00	0.40	1.40
Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	106	3.60	0.60	1.80	9.10	2.00
Picidae	*Chrysocolaptes guttacristatus*	Greater Flameback	1	0.00	0.00	0.00	0.10	0.00
Picidae	*Dendrocopos macei*	Fulvous-breasted Woodpecker	6	0.20	0.00	0.00	0.00	1.20
Picidae	*Dinopium benghalense*	Black-rumped Flameback	27	0.90	0.70	0.00	1.00	2.00
Picidae	*Picus xanthopygaeus*	Streak-throated Woodpecker	6	0.20	0.00	0.00	0.00	1.20
Ploceidae	*Ploceus philippinus*	Baya Weaver	10	0.30	0.00	1.00	0.00	1.00
Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	71	2.40	0.80	0.00	3.80	5.70
Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	9	0.30	0.40	1.00	0.00	0.00
Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	1	0.00	0.00	0.20	0.00	0.00
Scolopacidae	*Calidris minuta*	Little Stint	2	0.10	0.00	0.40	0.00	0.00
Scolopacidae	*Calidris temminckii*	Temminck's Stint	5	0.20	0.00	0.00	0.60	0.00
Scolopacidae	*Gallinago gallinago*	Common Snipe	2	0.10	0.00	0.40	0.00	0.00
Scolopacidae	*Gallinago stenura*	Pin-tailed Snipe	1	0.00	0.00	0.00	0.10	0.00
Scolopacidae	*Tringa ochropus*	Green Sandpiper	1	0.00	0.00	0.20	0.00	0.00
Sturnidae	*Acridotheres fuscus*	Jungle Myna	9	0.30	0.50	0.00	0.40	0.00
Sturnidae	*Acridotheres tristis*	Common Myna	25	0.80	1.00	0.00	1.60	0.00
Sturnidae	*Acridotheres ginginianus*	Bank Myna	5	0.20	0.20	0.60	0.00	0.00
Sturnidae	*Sturnus malabaricus*	Chestnut-tailed Starling	68	2.30	2.70	3.60	2.40	0.00
Sturnidae	*Sturnus contra*	Asian Pied Starling	210	7.10	2.30	18.50	5.40	8.99
Sylvidae	*Acrocephalus dumetorum*	Blyth's Reed-warbler	1	0.00	0.00	0.00	0.00	0.20
Sylvidae	*Acrocephalus stentoreus*	Clamorous Reedwarbler	1	0.00	0.10	0.00	0.00	0.00
Sylvidae	*Megalurus palustris*	Striated Grassbird	2	0.10	0.00	0.40	0.00	0.00
Sylvidae	*Orthotomus sutorius*	Common Tailorbird	34	1.10	0.90	3.20	0.00	1.60
Sylvidae	*Phylloscopus fuscatus*	Dusky Warbler	4	0.10	0.10	0.00	0.20	0.20
Sylvidae	*Phylloscopus trochiloides*	Greenish Warbler	1	0.00	0.00	0.00	0.00	0.20
Timalidae	*Malacocincla abbotti*	Abbott's Babbler	10	0.30	0.30	0.00	0.00	1.40
Timalidae	*Turdoides striata*	Jungle Babbler	146	4.90	3.00	7.60	4.80	6.70
Turdidae	*Zoothera citrina*	Orange-headed Thrush	6	0.20	0.00	1.20	0.00	0.00
Turdidae	*Zoothera dauma*	Eurasian Scaly Thrush	1	0.00	0.00	0.00	0.00	0.20
Class: Mammalia								
Canidae	*Canis aureus*	Golden Jackal	9	0.30	0.30	0.00	0.40	0.40
Canidae	*Vulpes bengalensis*	Bengal Fox	11	0.40	0.30	0.00	0.00	1.60
Cercopithecidae	*Macaca mulatta*	Rhesus Macaque	4	0.10	0.20	0.00	0.00	0.40
Felidae	*Prionailurus viverrinus*	Fishing Cat	1	0.00	0.00	0.00	0.00	0.20
Megadermatidae	*Megaderma lyra*	Greater False Vampire	2	0.10	0.00	0.00	0.20	0.00
Muridae	*Bandicota bengalensis*	Lesser Bandicoot Rat	1	0.00	0.00	0.00	0.00	0.20
Muridae	*Bandicota indica*	Large Bandicoot Rat	2	0.10	0.00	0.00	0.20	0.00
Muridae	*Mus musculus*	House Mouse	1	0.00	0.00	0.00	0.10	0.00
Pteropodidae	*Pteropus giganteus*	Indian Flying Fox	11	0.40	0.60	0.00	0.00	0.80
Sciuridae	*Funambulus pennantii*	Five-striped Palm Squirrel	8	0.30	0.00	1.60	0.00	0.00

Abbreviations: n = number of individuals; RA = Relative Abundance; BNP = Birganj National Park; NNP = Nawabganj National Park; RNP = Ramsagar National Park; SNP = Singra National Park.

In discussion, wildlife is an essential indicator of ecosystem health and habitat heterogeneity (Pomeroy, 1992; Gonzalez-Gajardo et al., 2009; Lorenzón et al., 2016). It is frequently utilized in conservation planning and monitoring efforts (Kandel et al., 2018; Woldemariam et al., 2018; Priambodo et al., 2019), and serves as a crucial measure of habitat significance as the number of species and individuals present in a given area can provide valuable insights into potential biological hotspots that require conservation efforts (Mengesha and Bekele, 2008). Therefore, effective conservation efforts in biological hotspots and protected areas necessitate continuous monitoring of the wildlife community and identification of potential threats.

The current study provides valuable baseline data on wildlife that can lay the foundation for future monitoring efforts. The study by Rimi et al. (2013) revealed the presence of 38 birds and miscellaneous fauna in Ramsagar National Park, while Ali et al. (2020) documented 28 animal species in Singra National Park. In comparison, the current study recorded 159 species, indicating sampling gaps in prior research. To evaluate patterns of vertebrate diversity at alpha and beta levels, this study examined species richness, composition, and abundance within and between study sites and microhabitats. The results indicate that the highest species diversity was observed in Ramsagar National Park and Singra National Park. Ramsagar National Park, characterized by a large water body and dense vegetation, serves as an essential stopover and wintering ground for numerous migratory waterbird species, including Greylag Goose (*Anser anser*), as previously reported by Rimi et al. (2013). Additionally, we observed another migratory bird, Gargeny (*Spatula querquedula*), from the study site. On the other hand, Singra National Park, with its dense vegetation and forest patches containing various tree species, provides suitable habitat for wildlife species (Ali et al., 2020; Rabbe et al., 2022a). The large water body in Ramsagar National Park is enriched with benthic organisms, mollusks, crustaceans, and freshwater worms (Rimi et al., 2013), which serve as adequate food sources for many waterbird species. As a result, species such as *Dendrocygna javanica* (RA=40.30%, n=360) and *Microcarbo niger* (RA=9.10%, n=106) were found to be the most dominant. These species created an uneven wildlife community in Ramsagar National Park. In Singra National Park, however, there wasn't any single dominant species, and the species community was also evenly distributed according to Pielou's evenness (J=0.9±0.01) and Whittaker's Plot (Fig. 5). The most relatively abundant species in Singra National Park were *Sturnus contra* (RA=8.99%, n=44), *Euphlyctis cyanophlyctis* (RA=7.6%, n=37), and *Turdoides striata* (RA=6.7%, n=33). The Whittaker plot also showed high dominance and low evenness in the other two sites (Fig. 5). In the case of the Birganj National Park, most of the forest areas have been encroached on and turned into agricultural land for farming (Rahman et al., 2022). Thus, most amphibian species were observed near the agricultural fields (RA=41.82%) and nearby waterbodies used specially for breeding during this study. The most dominant species in this site were *Euphlyctis cyanophlyctis* (RA=36.5%, n=395) and *Euphlyctis kalasgramensis* (RA=23.20%, n=251). Finally, Nawabganj National Park, which had a similar habitat heterogeneity to the Singra National Park, didn't support any dominant species except a habitat generalist like *Sturnus contra* (RA=18.50%), and that's why the wildlife community was more evenly distributed compared to Ramsagar National Park and Nawabganj National Park.

Seasonal changes have been found to impact avian diversity significantly (Canepuccia et al., 2007; Neelgund and Kadadevaru, 2020), largely due to seasonal migrations that alter the composition of wildlife communities within a given study area. In addition, the foraging behavior of different avian species is also influenced by seasonal changes; insectivorous birds tend to consume more insects, fruit-eating birds forage for fruit, and nectar-feeding birds seek out nectar from blooming flowers during the winter season (Khan, 2015). Across all four study

sites, the number of observed species and Margalef species richness significantly increased during the winter, largely due to the influx of migratory birds to the study area. This pattern is consistent with findings from other studies conducted in various parts of Bangladesh, where species richness has been shown to increase during the winter months (Jaman et al., 2015; 2022; Saha et al., 2022) due to the presence of migratory birds, from both Central Asian and East Asia/Australasia flyways. Conversely, species richness decreased during the warmer months as migratory waterbirds left the area.

Based on the Analysis of Similarity (ANOSIM) performed on the study sites, significant differences were observed among the wildlife communities of all sites. Differences in habitat heterogeneity, microhabitats, and resource availability typically contribute to variations in wildlife communities (Jaman et al., 2022; Saha et al., 2022). However, since the four studied national parks are closely located and exhibit similar habitat structures and patches, the occupying wildlife communities were found to be not significantly different from one another in pairwise comparison.

The primary factors contributing to the loss of biodiversity are habitat degradation, including changes in land use, the conversion of agricultural lands, the priority of alien invasive species, urbanization, the expansion of road networks, and unplanned development (Khan, 2015). Most ecosystems have been harmed by artificial activities like embankments, overuse of resources, such as unauthorized fishing, illegal logging, encroachment, hunting, indiscriminate removal of non-timber forest products, and environmental pollution (IUCN Bangladesh, 2015). During the study period, some threats were identified in the study areas, like deforestation and anthropogenic developments in Singra National Park, agricultural expansion in Birganj National Park and Nawabganj National Park, and lastly, Sound and Water pollution in Ramsagar National Park. As these study sites harbor one near-threatened (*Hoplobatrachus crassus*), two vulnerable (*Vulpes bengalensis* and *Macaca mulatta*), and one endangered (*Prionailurus viverrinus*) species, it is crucial to implement appropriate conservation measures to minimize these perceived threats and protect these vibrant and diverse protected forests.

Conclusions

The present study provides valuable information on the diversity of vertebrate wildlife in four protected national parks in Bangladesh, which can serve as baseline data for future wildlife conservation efforts. The study examined these species' alpha and beta diversity patterns across different study sites and microhabitats. Human intrusion was identified as a major anthropogenic stressor that might threaten the species community in these protected areas. However, further research is needed to comprehend the full impact of these stressors. The study's results hold significant implications for future biodiversity surveys, monitoring programs, and the development a comprehensive management plan for the conservation of wildlife communities in these four national parks.

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