IMPACTS OF HABITAT VARIATION, SEASONALITY, AND HUMAN THREATS ON AVIFAUNA IN THE GANGES FLOODPLAIN

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ABSTRACT

A study of avifauna in Kaliganj upazila in Jhenaidah district was conducted from July 2020 to June 2021, using direct field observation method. A total of 153 species and 6175 individuals were observed, with the highest diversity of birds (64 species, 41.83%) recorded in the order Passeriformes and 10 species under family Accipitridae. The site with the highest species richness (136 species) and abundance (2308 individuals) was Maliat, characterized by low anthropogenic disturbance, whereas the lowest was at Kaliganj municipality, with high anthropogenic disturbance. Bird communities across the three-study sites showed significant differences in non-metric multidimensional (NMDs) plot analysis. Species richness and abundance varied significantly across the three seasons, with the highest avian species diversity recorded in winter and the most even distribution in the rainy season. Homestead forest was the most frequently used microhabitat, with birds predominantly observed in trees. The most abundant bird species was *Spilopelia chinensis* (264 individuals, 4.27%). Observation status of birds showed that 51 (33.33%) bird species were very common, 22(14.37%) common, 27(17.64%) uncommon, and 53(34.64%) were few. Fifteen species faced anthropogenic threats, particularlly illegal hunting and the use of bird nests in agriculture, which was higher in winter, especially in the Barobazar area. This study on avian diversity and community provides valuable insights for the conservation of avifauna outside protected areas, particularly in human-dominated landscapes of sub-tropical countries like Bangladesh.

KEYWORDS: Community structure, wetlands, urbanization, hunting, agriculture, conservation.

Introduction

Protected areas around the world significantly contribute to preserving biodiversity. However, in sub-tropical countries like Bangladesh, these areas are often not genuinely protected (Chowdhury et al., 2022; Emrose et al., 2024). Despite its rich diversity of wildlife due to its geographical location, only 4.16% of Bangladesh's land is protected, which is alarmingly insufficient (Mukul, 2008; Mandal et al., 2021). The country hosts 690 bird species, which play vital roles in its ecological, economic, and cultural sectors (Khan, 2015). Many bird species in Bangladesh, including threatened species such as *Mycteria leucocephala*, *Ciconia episcopus*, *Platalea leucorodia*, *Calidris pygmaea*, *Rynchops albicollis*, and *Clanga hastata*, face existential threats from human activities like habitat fragmentation, habitat quality deterioration, pesticide and insecticide overuse, rapid urbanization, illegal hunting, poisoning, and trapping (IUCN Bangladesh, 2015; Barkat et al., 2021; Shome and Jaman, 2021).

Bio-ecologically, Bangladesh is divided into 22 regions, among which the Ganges floodplain is significant for various terrestrial and aquatic bird species. However, this area contains only one newly established protected area (IUCN Bangladesh, 2002;

IUCN Bangladesh, 2015). The Ganges floodplain features several wetland habitats, such as baors, beels, ditches, canals, and rivers, which are highly suitable for wetland-specialist bird groups (Rahman, 2005; Shome et al., 2022a; Jaman et al., 2023). Additionally, this region supports diverse habitats, including agricultural land, floodplains, homestead forests, grasslands, and char lands, which host various bird groups (Mostafizur et al., 2017).

The avian community structure in an area reflects environmental quality and ecosystem health. Monitoring avian communities is an effective tool for initiating avifauna conservation efforts (Sethy et al., 2015). Moreover, monitoring birds across seasons and habitats is crucial to understanding dynamic bird movements (Haider et al., 2022).

Kaliganj, an upazila in Jhenaidah district, is situated in the southwestern region of Bangladesh within the Ganges Floodplain. No scientific studies have been conducted on the community structure, habitat use, temporal variation, and conservation status of birds in the human-dominated landscapes of Kaliganj upazila. This study aims to provide baseline data on avian diversity, community structure, ecology, habitat use, and

current conservation status in these non-protected and human-dominated areas.

Materials and Methods

Study area

The study was conducted in the three human dominated landscapes in Kaliganj (23.4139 N, 89.1333 E) upazila (Figure 1) which is situated in the south-western portion as well as the lower Ganges region among 22 bio-ecological zones (IUCN Bangladesh 2002). The total area is covered with 310.16 km² and the major river in this area are Begabati, Chittra and Bhairab. This area is full of natural (River, beel, baor, canal, grassland, etc.) and modified habitats (agricultural land, home state forest, etc.). From the study area three types of macro habitats (terrestrial, arboreal, and aquatic) and six microhabitats (agricultural land, mudflat, grassland, homestead forest,

roadside area, and water body) were surveyed. The study area was mainly divided into three study sites (Figure 1).

Site A (Kaliganj municipality; 23.404877 N, 89.130525 E)

Habitat of this area consists of urban settlements, highway road area, waste disposal site, agricultural land, river, ditches, and homestead forest. Human disturbance and anthropogenic activities are comparatively higher in this area.

Site B (Barobazar Union; 23.305236 N, 89.153332 E)

Homestead forest, beel, baor, ditch, agricultural land, grassland, highway road area, and river are the major habitats of this area. Moderately disturbed than any other study sites.

Site C (Maliat Union; 23.305236 N, 89.153332 E)

River, beel, baor, canal, ditch, homestead forest, agricultural land, and grassland are the major habitat types. Comparatively less disturbed than other study sites.
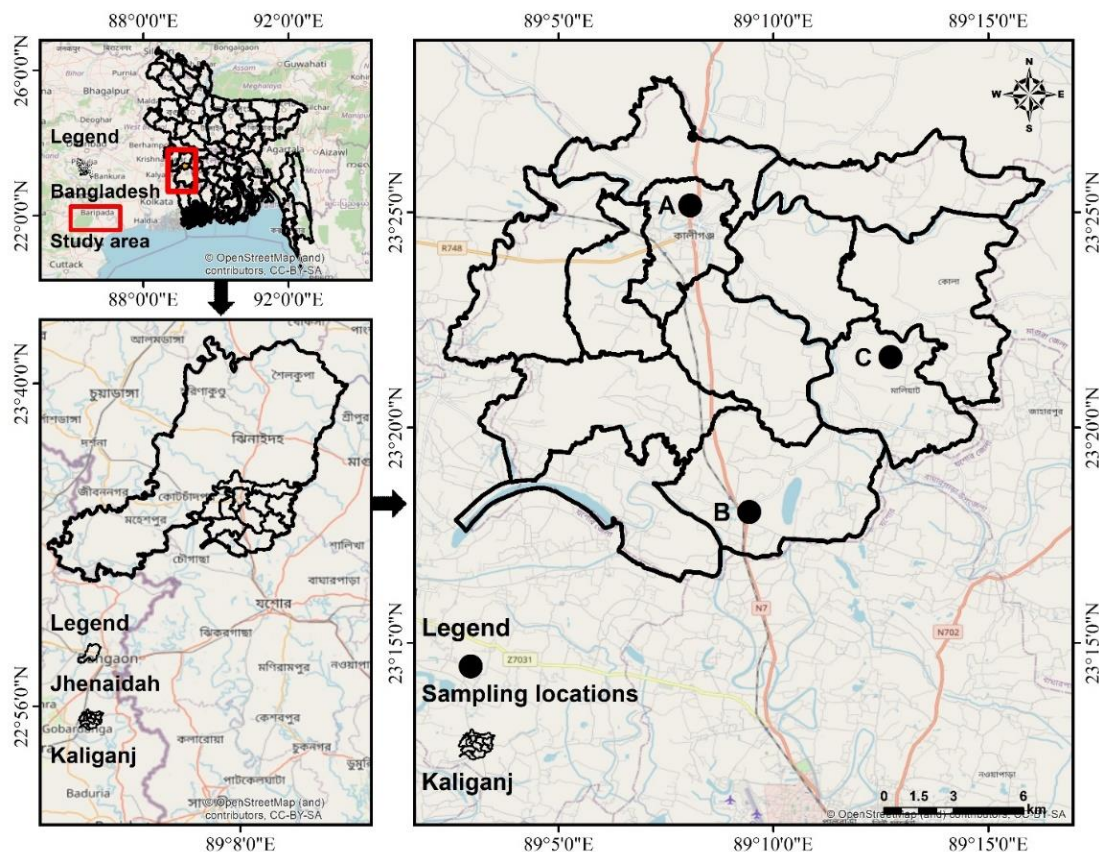

Figure 1. **Map of the study area in Kaliganj Upazila** (Sampling location; A: Kaliganj municipality, B: Barobazar, C: Maliat).

Data collection

The study was carried out for a period of one year, from July 2020 to June 2021, using direct field observation techniques. Transect line (250 m long and 20 m width) and opportunistic survey were conducted for data collection. In each study site, 8 transect lines were surveyed. Data was collected from different ecosystems within the study area. To understand the temporal variation in avifauna, the year was divided into three seasons - summer (March to June), rainy (July to October), and winter (November to February). During the study period, in total 36 days were spent for field surveys which were distributed equally across the season. Observations were made in the

morning and afternoon, and night surveys were conducted to collect data on nocturnal birds using a torchlight and headlamp. A Nikon D500 DSLR camera with a 200-500 mm VR lens was used to take photos of the observed birds, and the relevant field guide (Khan 2018) was used for proper identification. Direct field observations were used to observe and assess existing threats through regular visits to the study area. We categorized the birds affected by different threats and visualized threat intensity based on three sites and seasons.

Data analysis

MS Excel, PAST (version 4.07), and R (version-4.0.5, R Core Team 2020), were used for statistical analyses. First and

second-order Jackknife, Bootstrap, and Chao richness estimators (vegan package's 'specpool' function) were employed to calculate the total number of species in the research area in order to verify sample completeness (Oksanen et al. 2019). Following Fils et al. (2014), the estimated number of species (x) was determined by taking the mean of these four criteria. Sampling completeness was calculated following the formula -

$$Sampling\ completeness = \frac{Observed\ number\ of\ species\ (n)}{Estimated\ number\ of\ species(x)} \times 100$$

The relative abundance of bird species was measured by following the formula -

$$Relative\ abundance = \frac{Number\ of\ individuals\ of\ a\ species}{Total\ number\ of\ individuals\ of\ all\ species} \times 100$$

Khan (2015) was used to evaluate the observation status as very common (VC), 80–100%, common (C), 50–79%, moderately common (FC), 20–49%, and few (F), 10–19% based on the total occurrences per survey effort. Using the Bray-Curtis index (1957), a habitat similarity plot or cluster analysis for microhabitats and non-metric multi-dimensional plot for three research locations were produced. Following Whittaker (1965), a rank abundance plot was created to better illustrate abundance patterns. The diversity indices were calculated using Shannon-Wiener (Shannon and Wiener 1949) and Simpson's indices (Simpson 1949). By dividing the Shannon-Wiener index value by the natural log of species richness, evenness was calculated. Among the six microhabitats, correlation between habitats was performed by taking the species diversity as an independent variable and the habitats as the dependent variable.

Results

In this year-long study, a total of 153 species of birds and 6,175 individuals were observed (Appendix 1). Of them, species diversity (64 Species, 41.83%) and population (n = 3,189, 51.64%) was the highest under the order Passeriformes. Among the non-passerine birds, the highest number of bird species were under the family Accipitridae (10 species) followed by Ardeidae (9 species) and Cuculidae (6 species). Of the recorded birds, 34 (21.79%) species were migratory and the rest were resident. Among the migratory birds, three species (*Merops philippinus, Clamator jacobinus,* and *Cuculus micropterus)* were summer visitors. Richness estimators predicted a range of 158–167 species, which is relatively close to the 153 species observed in the field visit. This seems to be confirmed by the fact that 93.91% of the samples were complete, indicating in the study area, species sampling was adequate.

The species rarefaction curve showed the highest richness (136 species) and abundance (2,308 individuals) in Maliat. The maximum total number of species (136 species) was observed in Maliat site whereas the least was in Kaliganj municipality (Figure 2a). Similar result was found for abundance (n = 2,308 in Maliat) of birds in study sites per habitat shown in figure 2b.
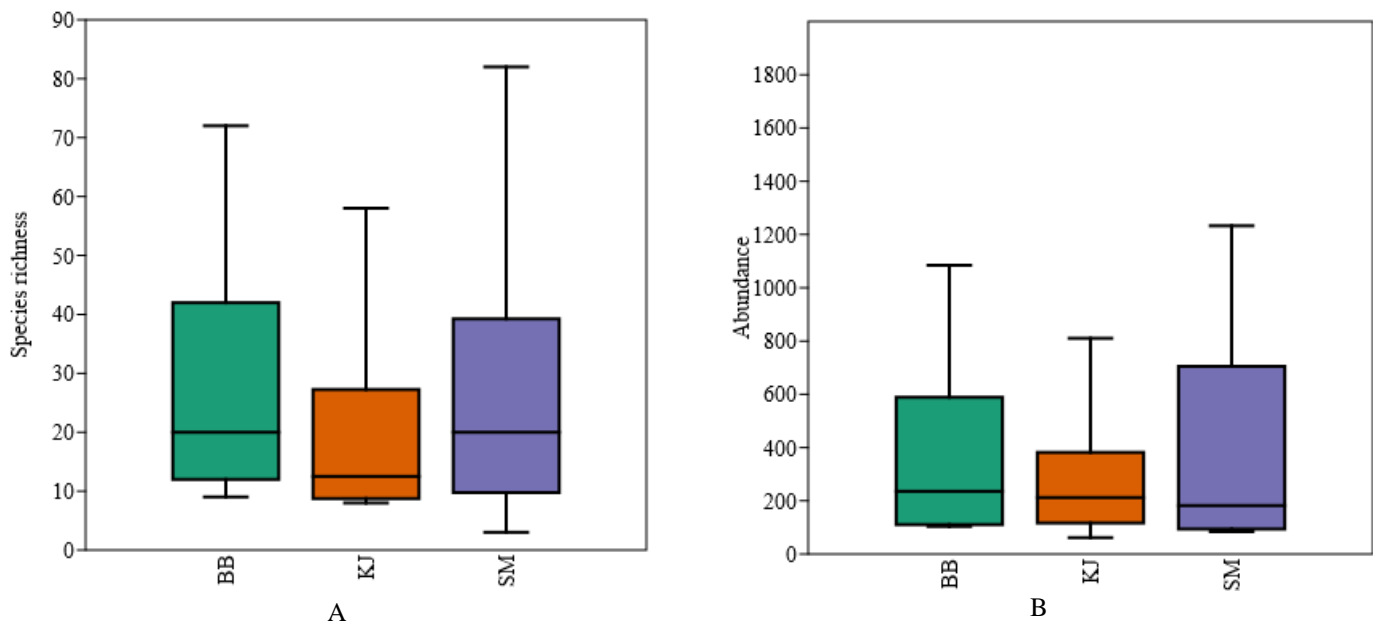

Figure 2. Box plot of species richness **(a)** and bird abundance **(b)** by study sites per habitat (BB- Barobazar, SM- Maliat site, KJ- Kaliganj municipality)

According to the analysis of similarity (ANOSIM) test, significant differences in bird communities was found among the three study sites *(R = 0.374, p >0.0029)*. Birds communities in site Maliat and Barobazar were dominant over the site Kaliganj municipality in the non-metric multidimensional plot (NMDs) with a stress level of 0.116 (<0.2) (Figure 3). In Barobazar site, Shannon and Simpson diversity indices showed the highest diversity *(H= 4.446, D$_s$=0.984)* value. The evenness value was the highest for site Kaliganj (*E= 0.562*) (Table 1).
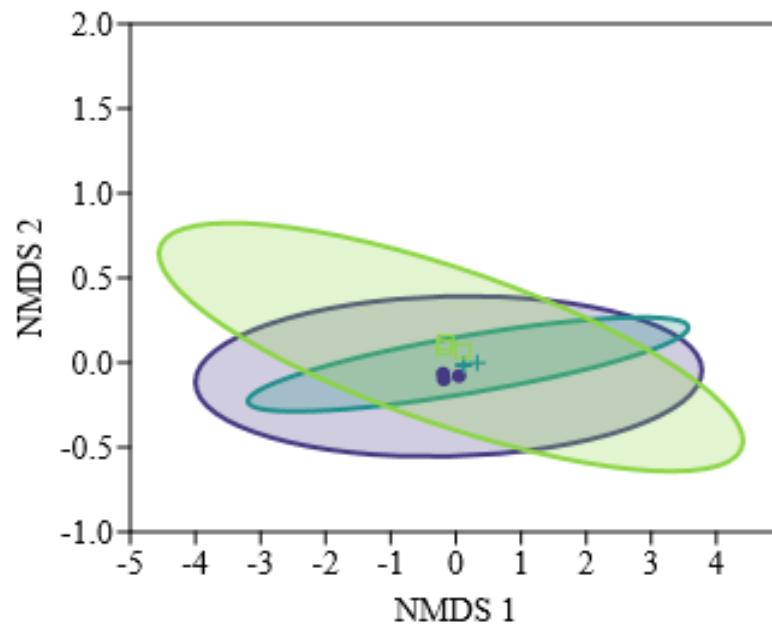
Figure 3. Separation of bird communities among three study sites showing non-metric multidimensional plot (Violet circle and dots indicates the site Barobazar; blue indicates Kaliganj municipality and green indicates Maliat).

The highest number of bird species richness (173 species, 96.11%) and abundance (n = 2,822, 45.70%) were observed during the winter season. In the study area, species richness $(\chi^2 = 19.34, df = 2, p < 0.0001)$ and abundance $(\chi^2 = 429.62, df = 2, p < 0.0001)$ varied significantly among three seasons. The diversity indices also showed the highest value in this season $(H = 4.482, D_s = 0.988)$. In the rainy season, the evenness $(E = 0.697)$ value was the highest (Table 1). Among the three study sites, the highest species richness and abundance were found in site Maliat Union during winter season (Appendix 1).

Table 1. Species richness, abundance, and diversity indices in different study sites considering seasons, months, macro-habitats, and microhabitats.

Category		Richness	Abundance	Simpson's (D_s)	Shannon-Weiner (H)	Evenness (E)
Study Site	BB	134	2196	0.9848	4.469	0.6512
	KJ	87	1671	0.9746	3.972	0.6105
	SM	136	2308	0.9833	4.406	0.6025
Macrohabitats	AQ	46	1331	0.9477	3.281	0.578
	ARB	93	3331	0.9759	3.994	0.5838
	TR	45	1513	0.95	3.257	0.5769
Microhabitats	AG	30	706	0.9213	2.88	0.5939
	GL	30	560	0.917	2.851	0.5768
	HF	88	3127	0.9746	3.948	0.5892
	MF	19	250	0.8992	2.568	0.6863
	RS	14	444	0.842	2.144	0.6092
	WB	36	1088	0.9326	2.995	0.5552
Season	Rainy	87	1606	0.9774	4.106	0.6974
	Summer	97	1747	0.9793	4.172	0.6684
	Winter	148	2822	0.9844	4.482	0.5973

[Note- KJ- Kaliganj, BB- Barobazar, SM- Maliat site; ARB- Arboreal, AQ- Aquatic, TR-Terrestrial; MF- Mudflat, GL-Grassland, RS- Roadside area, WB- Water body, AG- Agricultural land, HF- Homestead Forest]

Homestead forest was used by most of the bird species and population among six types of microhabitats in the study area. The highest number of bird species and population preferred arboreal habitat. Diversity indices also showed the highest value for this type of micro and macro habitat (Table 1).

Among six microhabitats, cluster analysis showed that the species between homestead forest and agricultural land are more similar and formed first cluster. These two types of microhabitats showed similar types of species with roadside area and formed second cluster. The second cluster showed more similar species with grassland habitat and ultimately formed a larger cluster and showed more dissimilar species with

mudflat and water body (Figure 4a). The correlation plot among the communities showed that the avian communities of homestead forest and agricultural land microhabitat were correlated ($r = 0.41$, $p < 0.05$, Figure 4b). Homestead forest was negatively correlated with the water body ($r = - 0.17$, $p < 0.05$) (Figure 4b). The overall comparison of bird richness and abundance for six microhabitats showed significant variation (for richness: $F = 10.86$, $df = 5$, $p = 0.0085$; for abundance: $F = 15.85$, $df = 5$, $p = 0.0052$). The pair-wise test for habitats was significant for the pairs with homestead vs all others microhabitat both in species richness and abundance.
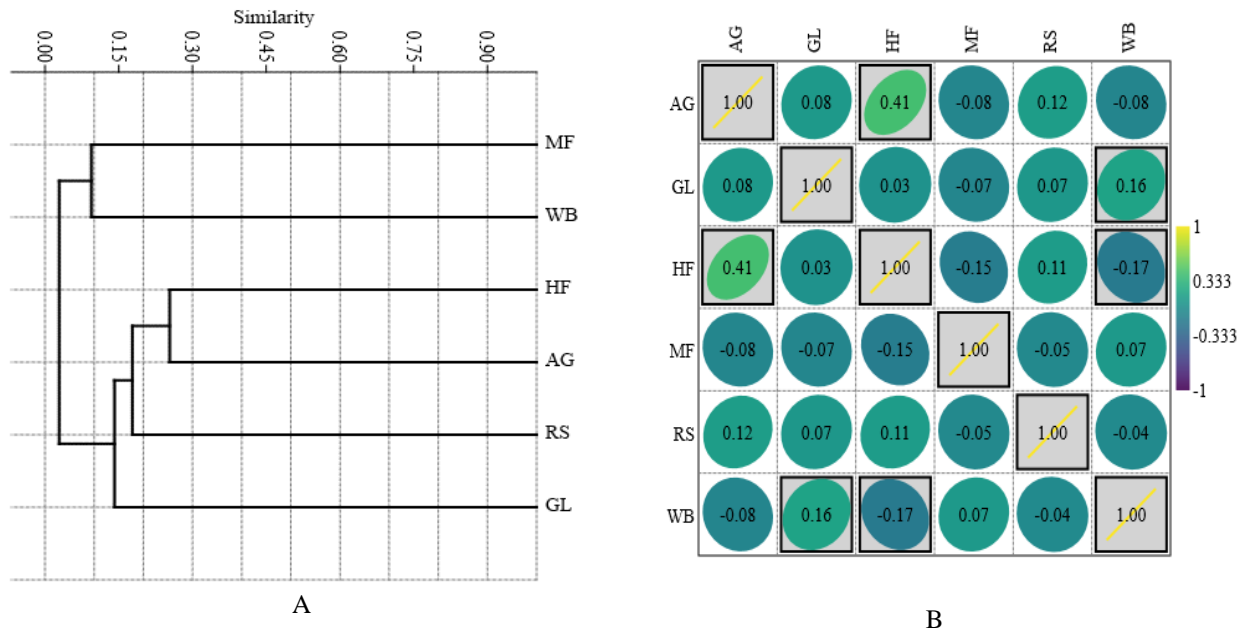

Figure 4. (a) Similarity profile test among microhabitats using Bray-Curtis index. **(b)** Correlation plot showing correlations among microhabitats in the study area. (MF- Mudflat, GL-Grassland, RS- Roadside area, WB- Water body, AG- Agricultural land, HF- Homestead Forest)

Spilopelia chinensis was the most abundant bird species in the study area with the highest relative abundance (264 individuals, 4.27%). *Dicrurus macrocercus* (255 individuals, 4.13%), *Bubulcus ibis* (205 individuals, 3.32%), *Corvus splendens* (189 individuals, 3.06%), *Turdoides striata* (187 individuals, 3.03%), *Acridotheres fuscus* (166 individuals, 2.69%), *Sturnus contra* (162 individuals, 2.62%), *Passer domesticus* (156 individuals, 2.53%), *Pycnonotus cafer* (153 individuals, 2.48%), and *Dendrocygna javanica* (152 individuals, 2.46%) (Figure 5a).

Site Kaliganj municipality had the most uneven distribution of birds in the study area (Figure 5a). Among different types of microhabitats, birds in roadside areas showed the maximum

uneven distribution (Figure 5b). In homestead forest, bird species were more evenly distributed and the highest relative abundance was for the species of *Turdoides striata* (5.98%). Observation status of birds showed that 51 (33.33%) bird species were very common, 22(14.37%) common, 27(17.64%) uncommon, and 53(34.64%) were few (Appendix 1).

In three study sites and among six microhabitats, homestead forest in Maliat union had the highest number of species richness (82 species) and abundance (n = 1233) (Figure 5c,d). Species richness (14 species) and abundance (n=234) in roadside habitat was higher in Kaliganj municipality area (Figure 5c,d).
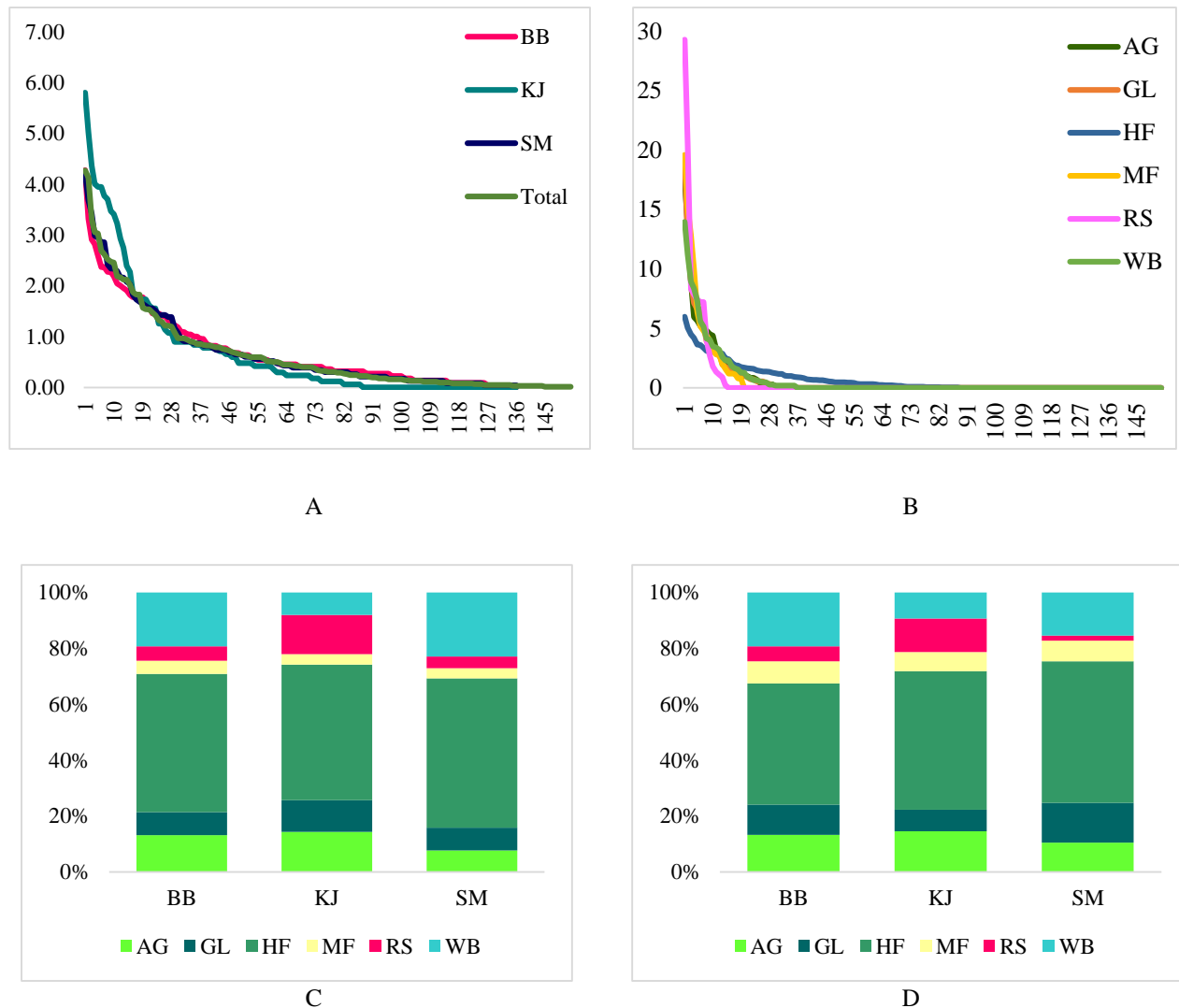
Figure 5. Rank abundance plot for species recorded from the **(a)** study area along with three study sites; **(b)** in six microhabitats (y-axis shows the relative abundance, and the x-axis ranks the species in order of their abundance from highest to lowest); relative abundance of bird **(c)** species richness **(d)** abundance in different microhabitat of three study sites. (Note: BB- Barobazar, KJ- Kaliganj municipality, SM-Maliat site; Microhabitat: MF- Mudflat, GL-Grassland, RS- Roadside area, WB- Water body, AG- Agricultural land, HF-Homestead Forest).

According to IUCN red list assessment of Bangladesh (2015), *Clanga hastata* was categorized as Endangered; *Clanga clanga* as Vulnerable; *Ichthyophaga ichthyaetus* as Near Threatened among the recorded bird species. Different types of anthropogenic threats like illegal hunting, trade of birds, intense agricultural activities specially bird nests exploitation, urbanizations, pollution, disturbance of birds observed. Among them, illegal hunting, trade of birds, threats from agricultural activities were severe and directly observed during field visits. Bird hunting and illegal trade are the major problems found in this study area.

Among those birds, aquatic habitat specialist birds (e.g., wild duck, heron, egret, bittern, coots, moorhen, waterhen) suffer much from different anthropogenic threats (Figure 6a). During field observation, 35 bird species (23%) were found facing threats of which *Spilopelia chinensis* (n = 59), *Dendrocygna javanica* (n = 45), *Bubulcus ibis* (n = 32), *Amaurornis phoenicurus* (n = 28), and *Ardeola grayii* (n = 27) are remarkable. At the Barobazar site, bird species face significant threats, with 26 species and a population of 179 individuals affected. Among the three sites studied, bird hunting emerged as the most prevalent threat (Figure 6b). During winter season, the threats was higher (24 species), especially in Barobazar area (18 species) (Figure 6c).
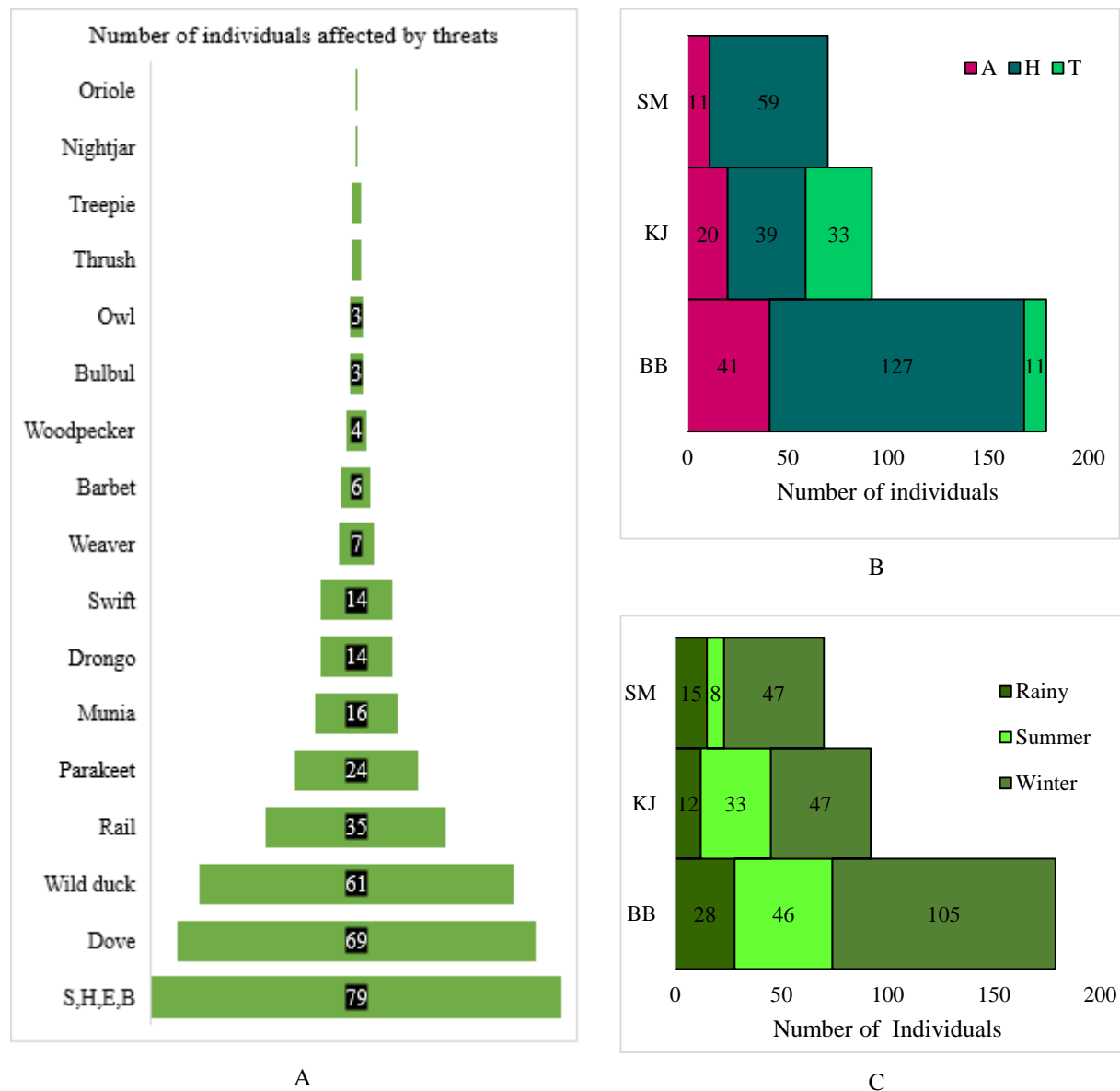
Figure 6. **(a)** Birds group affected by anthropogenic threats (S- Stork, H- Heron, E- Egret, B- Bittern); **(b)** threat types in different area (A- Agricultural practice, H- Illegal Hunting, T- Trade) and **(c)** threats in different seasons (BB- Barobazar, KJ- Kaliganj municipality, SM-Maliat site).

Discussion

The observed bird species in the study area represent 22% of the total bird species found in Bangladesh (Khan, 2018), highlighting the rich avian diversity of the region. The recorded bird diversity is higher than in other studies conducted in areas near the study site, except in Dhaka, Mymensingh, and Faridpur (Figure 7). This result likely reflects the presence of diverse natural and modified habitats, such as grasslands, wetlands, agricultural lands, and homestead forests (Basile et al., 2021). Agriculture is the main occupation in the study area, with most of the landmass used for agricultural activities. This provides ample food opportunities for granivorous and insectivorous birds, possibly explaining the higher population of passerine birds observed (Jayasimhan and Padmanabhan, 2019; Shiferaw and Yazezew, 2020; Menon and Mohanraj, 2022). Additionally, the wetlands in the area, including baors, beels, rivers, canals, and other water bodies, support wetland specialist birds, such as those from the orders Charadriiformes, Pelecaniformes, and Accipitriformes, due to the availability of fish and other aquatic resources (Kumar and Gupta, 2009).

The Maliat union, being a completely rural site, contains diverse natural and manmade habitats suitable for various bird species. In contrast, the Kaliganj municipality site includes urban habitats and busy highways with higher anthropogenic activities that disturb birds, resulting in a lower number of bird species and populations (Figure 2a, b) (Sengupta et al., 2014; Carvajal-Castro et al., 2019; Shome and Jaman, 2021). For instance, 14 bird species, including *Ploceus benghalensis*, *Ketupa zeylonensis*, *Tyto alba*, and *Spilornis cheela*, were exclusive to Maliat, while only one species (*Falco chicquera*) was unique to Kaliganj municipality. This indicates a higher species richness at Maliat (Table 1).

Bird diversity was found to be higher in winter, likely due to the presence of migratory birds during this season (Dar and Dar, 2009; Sonal et al., 2010). These findings also suggest that seasonal variation significantly influences bird communities, consistent with observations from other parts of Bangladesh (Shome et al., 2022a, b).

Microhabitat diversity influences bird community structure across different sites (Brüggeshemke et al., 2022). Among the six identified microhabitats, homestead forest, with their mix of natural and planted trees, support the highest bird species richness and populations (Figure 5b) (Roy et al., 2013; Rosin et al., 2013). Homestead forest in the study area is home to 60 bird species, making them highly suitable habitats for birds (Shome et al., 2021; Shome et al., 2022a, b; Jaman et al., 2023). At Maliat, homestead forest birds showed higher species richness and abundance, whereas in Kaliganj municipality, roadside habitats primarily supported scavenger species like *Corvus*

splendens, *Acridotheres fuscus*, and *Milvus migrans* (Figure 5c, d).

The study area's aquatic habitats, including beels, canals, baors, rivers, ditches, and ponds, provide essential resources for aquatic birds. The proximity of mudflats, water bodies, homestead forests, and agricultural lands facilitates habitat sharing among birds (Figure 4a, b). Agricultural lands, which offer seeds, grains, and insects, support species like *Spilopelia chinensis*, whose primary diet consists of grains and seeds. Consequently, their numbers are higher in the study area.

The study identified ten most abundant species constituting 30.59% of the total individuals, while the least abundant 50 species accounted for only 3.01% (Figure 5a). The Kaliganj municipality site showed uneven bird distribution in the rank abundance plot, with a few abundant species like *Dicrurus macrocercus*, *Sturnus contra*, *Spilopelia chinensis*, *Turdoides striata*, and *Corvus splendens* (Figure 5a).
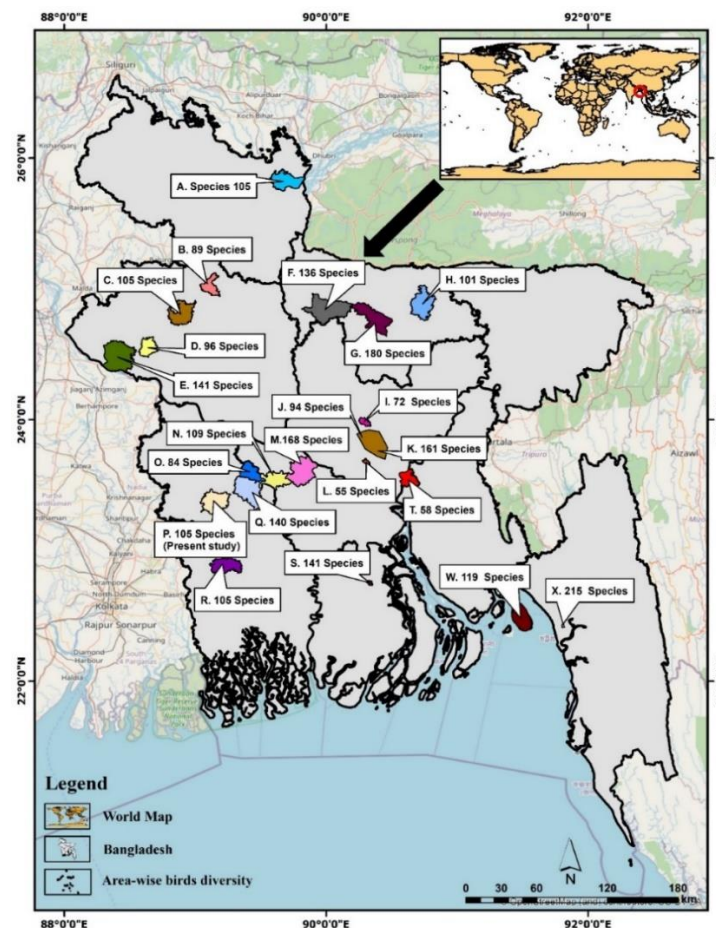

Figure 7. A review on study on bird species diversity in outside protected areas of Bangladesh according to published literature (A-Kurigram, B- Joypurhat, C- Naogaon, D- Mohanpur, Rajshahi, E- Padma River charland, Rajshahi, F- Jamalpur Sadar, G- Mymenshing Megacity, H- Netrokona, I- Kashimpur, J- Gazipur, K- Dhaka megacity, L- Ruhitpur Union, Keraniganj, Dhaka, M- Faridpur Sadar, N-Madhukhali, Faridpur, P- Present study, O-Sreepur, Magura, Q- Keshabpur, Jessore, R- Kashipur, Barishal, S-Magura Sadar, T- Char-kishoreganj, Munshiganj, W- Sandwip, Chattagram, X- Chattagram University Campus (Shome and Jaman 2021; Mandal et al. 2021; Biswas et al. 2022).

Though, the remote areas of Bangladesh are enriched with natural habitat specially wetlands, but unfortunately those are totally unprotected and in rural areas people have a little knowledge on wildlife conservation along with superstitions and misconception (Jaman et al. 2020; Shome and Jaman 2021; Barkat et al. 2021). For these reasons, wetland specialist bird

species (e.g. wild duck, stork, heron egret, bittern, rail) are at risk in the study area for illegal hunting (Figure 6a). Throughout Bangladesh, the same is happening with wetland specialist bird groups especially in rural areas and in the winter season the incidents become higher than any other time (Datta et al. 2021, Shome and Jaman 2021, Shome et al. 2022a) (Figure 6b).

According to the perception of local people during the winter season a number of tourists come from outside the study area to visit different baors and beel and some of them are interested in bird hunting. Moreover, in winter, the abundance of wetland birds was higher which stimulated the people to hunt birds. Some nets and traps were detected from the study area which were used for bird hunting around the wetlands as well as agricultural land (for trapping doves) by local people. In recent times, use of bird nets by farmers is increasing for protecting crops and fruits from birds. Unfortunately, birds live in and around homestead forests and agricultural lands trapped with the nets during flight. Use of bird nets in agricultural land and the fruit plant has become a major problem to bird in the study area. Owl, woodpecker, swift, swallow, tailor bird, tree pie, doves, sparrow, weaver, drongo, oriole, barbet, bulbul, parakeet were observed affected by this net. Pollution and loss of aquatic habitat has increased greatly. The study area is affected by water pollution and the natural status of this aquatic habitat is gradually declining due to human activities. Use of pesticide in the agriculture, plastic pollution, habitat conversion etc. become greater problems for bird species. From the study area deforestation of native plant species, disturbance from roads, highways and rapid urbanization process were also observed.

Conclusion

This study examined the avifauna of Kaliganj upazila, Jhenaidah, providing insights into the community structure, ecological roles, and conservation needs of bird species. Habitat structure, seasonal variations, and human disturbances significantly influenced bird community composition in the area. Bird diversity was the highest in the Maliat site, characterized by minimal human disturbance, and lowest in Kaliganj, where anthropogenic activities were more pronounced. These findings highlight the importance of prioritizing urban bird conservation, as these species inhabit areas outside protected zones. Homestead forests supported the greatest number of bird species and populations, likely due to the availability of diverse habitats, including agricultural lands and home gardens. Migratory birds played a distinct role in the bird community, particularly during winter, when diversity peaked. This study provides essential data on the current status of birds in the region, which can inform conservation strategies. To protect bird populations from illegal hunting, netting, and trade, the enforcement of protective laws and continuous awareness programs are crucial.

Acknowledgement

References

1. Barkat, A.I., Liza, F.T., Akter, S., Shome, A.R. and Rabbe, M.F. (2021), "Wildlife hunting practices of the Santal and Oraon communities in Rajshahi, Bangladesh", *Journal of Threatened Taxa*, Vol. 13, pp. 19484–19491. http://dx.doi.org/10.11609/jott.7260.13.11.19484-19491

2. Basile, M., Storch, I. and Mikusiński, G. (2021), "Abundance, species richness and diversity of forest bird assemblages–The relative importance of habitat structures and landscape context", *Ecological Indicator*, Vol. 133, p. 108402. https://doi.org/10.1016/j.ecolind.2021.108402

3. Biswas, D., Jaman, M.F., Alam, M.M., Rabbe, M.F. and Shome, A.R. (2022), "Community structure, ecology, and conservation issues of avifauna of two human-dominated landscapes in a lower Ganges district, Bangladesh during COVID-19 lockdown situation", *Journal of Asiatic Society, Bangladesh*, Vol. 48, pp. 53–66. https://doi.org/10.3329/jasbs.v48i1-2.64514

4. Bray, J.R. and Curtis, J.T. (1957), "An ordination of the upland forest communities of southern Wisconsin", *Ecological Monograph*, Vol. 27, pp. 326–349. https://doi.org/10.2307/1942268

5. Brüggeshemke, J., Drung, M., Löffler, F. and Fartmann, T. (2022), "Effects of local climate and habitat heterogeneity on breeding-bird assemblages of semi-natural grasslands", *Journal of Ornithology*, Vol. 163, pp. 695–707. https://doi.org/10.1007/s10336-022-01972-7

6. Carvajal-Castro, J.D., Ospina-L, A.M., Toro-Lopez, Y., Pulido-G, A., Cabrera-Casas, L.X., Guerrero-Pelaez, S. ... and Vargas-Salinas, F. (2019), "Birds vs bricks: Patterns of species diversity in response to urbanization in a Neotropical Andean city", *PloS One*, Vol. 14, p. e0218775. https://doi.org/10.1371/journal.pone.0218775

7. Chowdhury, S., Alam, S., Labi, M.M., Khan, N., Rokonuzzaman, M., Biswas, D. and Fuller, R.A. (2022), "Protected areas in South Asia: Status and prospects", *Science of the Total Environment*, Vol. 811, p. 152316. https://doi.org/10.1016/j.scitotenv.2021.152316

8. Dar, I.A. and Dar, M.A. (2009), "Seasonal variations of avifauna of Shallabug wetland, Kashmir", *Journal of Wetland Ecology*, Vol. 2, pp. 20–34. http://dx.doi.org/10.3126/jowe.v2i1.1853

9. Datta, A.K. (2022), "Status of illegal bird hunting in Bangladesh: Online news portal as the source", *Human Dimension of Wildlife*, Vol. 27, pp. 183–192. http://dx.doi.org/10.1080/10871209.2021.1895380

10. Emrose, A., Shome, A.R., Alam, M.M., Rabbe, M.F., Hawladar, N. and Jaman, M.F. (2024), "Northwestern transboundary area of Bangladesh: A key to sustaining a quarter of the country's avian species", *Ornithology Research*, Vol. 32, pp. 23-32. http://dx.doi.org/10.1007/s43388-023-00163-z

11. Fils, E.M.B., Anong, A.G.B.A., Tsala, D.B., Guieké, B.B., Tsala, D.E. and Fotso, A.K. (2014), "Diversity of bats of the Far North Region of Cameroon–with two first records for the country", *Biodiversity*, Vol. 15, pp. 16–22. http://dx.doi.org/10.1080/14888386.2014.889578

12. Haider, M.Z., Ahmed, S., Sial, N., Afzal, G., Riaz, A., Asif, A.R. ... and Ahmad, H.I. (2022), "Avian diversity and abundance of Taunsa Barrage Ramsar site in Punjab, Pakistan", *Journal of Zoological Systematics and Evolutionary Research*, Vol. 2022, pp. 1–14. https://doi.org/10.1155/2022/4736195

13. IUCN Bangladesh. (2002). *Bio-ecological zones of Bangladesh*. International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh: IUCN.

14. IUCN Bangladesh. (2015). *Red List of Bangladesh Volume 3: Birds*. International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh: IUCN.

15. Khan, M.A.R. (2015). *Wildlife of Bangladesh: checklist and guide*. Chyabithi, Dhaka, Bangladesh.

16. Khan, M.M.H. (2018). *Photographic guide to the wildlife of Bangladesh*. Arannayk Foundation, Dhaka, Bangladesh.

17. Rahman, A.K.A. (2005). *Freshwater Fishes of Bangladesh*. Zoological Society of Bangladesh, Department of Zoology, University of Dhaka, Bangladesh.

18. Shannon, C., & Weaver, W. (1963). *The mathematical theory of communication*. University of Illinois Press, Urbana, USA, pp. 117.

19. Simpson, E.H. (1949), "Measurement of diversity", *Nature*, Vol. 163 No. 4148, pp. 688–688. https://doi.org/10.1038/163688a0

20. Jaman, M.F., Alam, M., Shome, A.R., Saha, A., Rabbe, M.F., Rana, M., ... and Rahman, M. (2023), "Diversity and community structure of wild vertebrates in the Sandwip Island of Bangladesh", *Tropical Ecology*, Vol. 64, pp. 224–237. https://doi.org/10.1007/s42965-022-00262-w

21. Jaman, M.F., Rabbe, M.F., Alam, M.M., Shome, A.R., Hossain, M.A., and Sarker, M.A.R. (2020), "Students' perceptions on snake in northwestern Bangladesh", *Asian Journal of Ethnobiology*, Vol. 3, pp. 62–69. http://dx.doi.org/10.13057/asianjethnobiol/y030203

22. Jaman, M.F., Alam, M.M., Rabbe, M.F., and Shome, A.R. (2023), "Temporal variation, habitat heterogeneity and anthropogenic stressors influencing wildlife communities in an oxbow shaped wetland of lower Ganges floodplain, Bangladesh", *Journal of Biodiversity Conservation and Bioresource Management*, Vol. 9, pp. 83–98. https://doi.org/10.3329/jbcbm.v9i2.70092

23. Jayasimhan, C.S. and Padmanabhan, P. (2019), "Diversity and temporal variation of the bird community in paddy fields of Kadhiramangalam, Tamil Nadu, India", *Journal of Threatened Taxa*, Vol. 11, pp. 14279–14291. http://dx.doi.org/10.11609/jott.4241.11.10.14279-14291

24. Kumar, P. and Gupta, S.K. (2013), "Status of wetland birds of Chhilchhila Wildlife Sanctuary, Haryana, India", *Journal of Threatened Taxa*, Vol. 5, pp. 3969–3976. http://dx.doi.org/10.11609/JoTT.o3158.3969-76

25. Mandal, A.K., Jaman, M.F., Alam, M.M., Rabbe, M.F., and Shome, A.R. (2021), "Vertebrate wildlife diversity of Sreepur upazila, Magura, Bangladesh", *Journal of Biodiversity Conservation and Bioresource Management*, Vol. 7, pp. 51–62. http://dx.doi.org/10.3329/jbcbm.v7i1.57123

26. Menon, M. and Mohanraj, R. (2022), "Diversity and community structure of the agroecosystem avifauna in the Cauvery delta region, South India", *Community Ecology*, Vol. 23 No. 3, pp. 365–376. http://dx.doi.org/10.1007/s42974-022-00114-6

27. Mostafizur, A.B.M., Zaman, M.A.U., Shahidullah, M., and Nasim, M. (2017), "Diversity of cropping patterns and land use practices in Faridpur region", *Bangladesh Rice Journal*, Vol. 21 No. 2, pp. 157–172. http://dx.doi.org/10.3329/brj.v21i2.38203

28. Mukul, S.A., Uddin, M.B., Uddin, M.S., Khan, M.A.S.A., and Marzan, B. (2008), "Protected areas of Bangladesh: current status and efficacy for biodiversity conservation", *Proceedings of the Pakistan Academy of Sciences*, Vol. 45 No. 2, pp. 59–68.

29. Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.M., Szoecs, E., and Wagner, H. (2019), "Vegan: Community Ecology Package", R package version 2.5–6.

30. Rosin, Z.M., Skórka, P., Pärt, T., Żmihorski, M., Ekner-Grzyb, A., Kwieciński, Z., and Tryjanowski, P. (2016), "Villages and their old farmsteads are hot spots of bird diversity in agricultural landscapes", *Journal of Applied Ecology*, Vol. 53 No. 5, pp. 1363–1372. https://doi.org/10.1111/1365-2664.12715

31. Roy, B., Rahman, M., and Fardusi, M. (2013), "Status, diversity, and traditional uses of homestead gardens in Northern Bangladesh: A means of sustainable biodiversity conservation", *International Scholarly Research Notices*, 2013, pp. 1–11. https://doi.org/10.1155/2013/124103

32. Sengupta, S., Mondal, M., and Basu, P. (2014), "Bird species assemblages across a rural urban gradient around Kolkata, India", *Urban Ecosystem*, Vol. 17 No. 2, pp. 585–596. http://dx.doi.org/10.1007/s11252-013-0335-y

33. Sethy, J., Samal, D., Sethi, S., Baral, B., Jena, S., Payra, A., ... and Sahu, H.K. (2015), "Species diversity and abundance of birds in and around North Orissa University, Takatpur, Baripada, Mayurbhanj, Odisha", *Species Diversity*, Vol. 4 No. 2, pp. 1–12.

34. Shiferaw, A. and Yazezew, D. (2021), "Diversity, distribution and relative abundance of avifauna at Ansas Dam and surrounding farmland site Debre Berhan Town, Ethiopia", *Avian Biology Research*, Vol. 14 No. 1, pp. 8–17. https://doi.org/10.1177/1758155920963200

35. Shome, A.R. and Jaman, M.F. (2021), "Diversity and seasonal occurrence of vertebrate wildlife at a rural site of Bangladesh: Threats and conservation issue", *Journal of Biodiversity Conservation and Bioresource Management*, Vol. 7 No. 2, pp. 61–72. https://doi.org/10.3329/jbcbm.v7i2.60151

36. Shome, A.R., Alam, M.M., Rabbe, M.F., Mia, T., Munira, S., Ilma, U.H., and Jaman, M.F. (2022a), "Ecology of Avifauna in Green Spaces of a Sub-Tropical Urban Landscape: Community Structure and Habitat Preference", *Journal of Biodiversity Conservation and Bioresource Management*, Vol. 8 No. 2, pp. 37–50. https://doi.org/10.3329/jbcbm.v8i2.63816

37. Shome, A.R., Jaman, M.F., Rabbe, M.F., and Alam, M.M. (2021), "Bird diversity, composition and response during COVID-19 in an urban landscape, Jamalpur, Bangladesh", *Dhaka University Journal of Biological Sciences*, Vol. 30 No. 2, pp. 261–274. https://doi.org/10.3329/dujbs.v30i2.54651

38. Shome, A.R., Rabbe, M.F., Alam, M., Emon, S.F., Islam, M.M., Setu, R.S., Khan, N., Biswas, D., and Jaman, M.F. (2022b), "Avifauna in an urban landscape of a lower Ganges district, Bangladesh: Community structure, seasonality, habitat preference and conservation issues", *Dhaka University Journal of Biological Sciences*, (2), pp. 343–360. https://doi.org/10.3329/dujbs.v31i2.60892

39. Sonal, D., Jagruti, R., and Geeta. (2010), "Avifaunal diversity and water quality analysis of an inland wetland", *Journal of Wetlands Ecology*, Vol. 4, pp. 1–32. https://doi.org/10.3126/jowe.v4i0.4151

40. Whittaker, R.H. (1965), "Dominance and Diversity in Land Plant Communities: Numerical relations of species express the importance of competition in community function and evolution", *Science*, Vol. 147 No. 3655, pp. 250–260. https://doi.org/10.1126/science.147.3655.250