ECOLOGY OF AVIFAUNA IN GREEN SPACES OF A SUB-TROPICAL URBAN LANDSCAPE: COMMUNITY STRUCTURE AND HABITAT PREFERENCE

Shome, A. R., M. M. Alam*, M. F. Rabbe, T. Mia, S. Munira, U. H. Ilma and M. F. Jaman

Department of Zoology, University of Dhaka, Dhaka 1000, Bangladesh
*Corresponding author: mahabub.zoo@du.ac.bd

Abstract

To scrutinize the present status of birds in a sub-tropical urban green space, a research work was conducted in Mymenshing City Corporation from November 2018 to October 2019 by direct field observations. Three green spaces were selected in the study area where in total 180 species of birds with 7,079 individuals were documented. Passeriformes had the highest species richness (76 species, 42.22%) and abundance (n = 4174, 58.96%). Bangladesh Agricultural University Campus Area (Site A) showed the highest diversity index value with the highest species richness (170 species, 94.44%) and abundance (n = 3261, 46.06%). Analysis of similarity (ANOSIM) test showed a significant difference in bird communities among three study sites. Cluster analysis showed that fallow land and agricultural land formed a large cluster which further formed another cluster with grassland, water-body, tree and urban settlements. Species richness and abundance across the seasons and study sites varied significantly. The highest avian diversity and abundance were observed in winter, particularly in January. Species richness and abundance for nine microhabitats showed significant variations where tree was mostly used microhabitat. The avian community of urban settlements and agricultural lands were highly correlated. These urban green spaces support 48 (26.67%) migratory birds in the study area. *Pycnonotus cafér* had the highest relative abundance (4.28%), Maximum observed bird species as the least concern and five species were threatened according to the national conservation status.

Keywords: Urban Avifauna; Relative Abundance; Avian Community; Green Spaces; Conservation.

INTRODUCTION

More than half of the world's population now lives in cities, hastening the rapid urbanization process by altering ecology as a whole. It causes severe challenges to the bird species (UNDES 2019, Rocha and Fellowes 2018, McKinney 2006, Czech *et al.* 2000, Marzluff 2001). To some birds like kite, crow, moyna, sparrow, drongo and starling *etc.*, the urban habitats provide a wide range of benefits. These are increased food accessibility, protection from predators, support for species diversity and abundances better than rural or surrounding habitats (Jessop *et al.* 2012, Gibbs *et al.* 2019). In urban areas some green spaces are to play an important role to protect different types of wildlife species. It enhances the quality of the environment as a whole (WHO 2016, Panda *et al.* 2020). The spaces are home to a diverse group of birds including migratory species. However, in tropical developing countries, they are rapidly declining due to unplanned urbanization. It results in existence for birds population (Karuppannan *et al.* 2014).

Bangladesh has diverse wildlife resources due to its geographical position (i.e., confluence zone of Indo-Himalayan and Indo-China bio-geographical realms) (Khan 2018, Shome and Jaman 2021, Mandal *et al.* 2021). Among the wildlife resources, about 690 species of birds occupy a vital position for their contribution to ecological (e.g., bio-indicator, pollinators, nutrient recyclers, agents of plant gene flow through seed dissemination, population controller), environmental (e.g., controlling pollution,

scavenging), economical (e.g., biological insecticide), and cultural sectors (in history, mythology) (Sekercioglu 2006, Sekercioglu *et al.* 2004, Mistry *et al.* 2008, Gatesire *et al.* 2014). However, in this densely populated tropical country, birds face a variety of man-made hazards, including urbanization (Shome *et al.* 2021a, b). Birds are losing green space and their habitats in the city, and as a result, the number of bird species in the city is rapidly decreasing (Callaghan *et al.* 2018). However, there is limited data on birds in urban areas in Bangladesh as well as birds in green spaces in urban areas with information on their community and ecology (Jaman *et al.* 2021, Shome *et al.* 2020, Sarker *et al.* 2009). Mymenshing City Corporation is one of the oldest urban areas of Bangladesh. Though the expeditious urbanization process transpires here, some urban green spaces still exist. This study deals with the community structure, ecology, habitat utilization and conservation issues of avifauna in the urban green spaces of this area, as well as establishes the baseline information of avifauna which will be helpful for preparing a proper management system and settings conservation priority in the study area on avifauna.

MATERIAL AND METHODS

Study area

Mymenshing City Corporation (24.7538°N, 90.4030°E) is situated in the northern region of Bangladesh with an area of 91.31 km^2 on the bank of the river Brahmaputra, which is one of the oldest urban areas of Bangladesh. Though the northern region is a potential habitat for avifauna, there is a small amount of research work on avifauna in that region of Bangladesh (Shome *et al.* 2021a) and in Mymenshing area there is no recrded previous scientific research work on the bird. In total three urban green spaces were selected in the city corporation area, which were considered for data collection sites (Table 1 and Fig. 1). Different types of the habitats of the three study sites were surveyed during the study period from November 2018 to October 2019. The surveyed habitats were categorized under three macro-habitats (*viz*. arboreal, terrestrial, and aquatic) and nine micro-habitats (*viz*. floating plant, bushy area, fallow land, mudflat, grassland, tree, urban settlement, water body, and agricultural land).

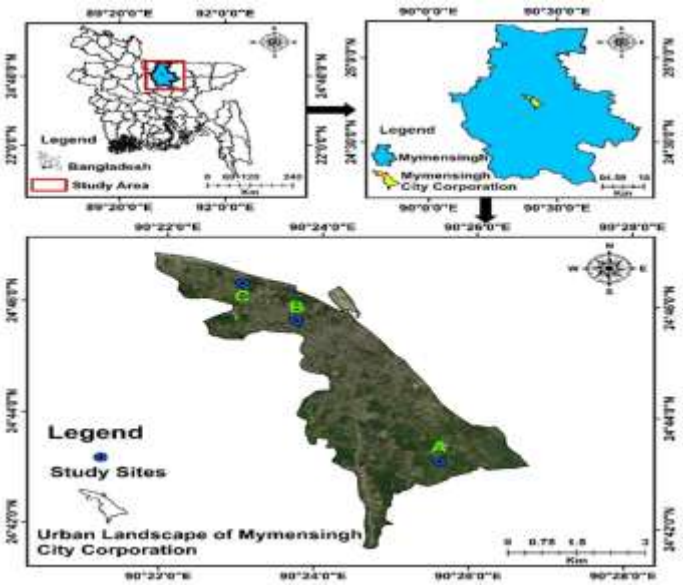


Fig. 1. The maps of the study areas in Mymenshing City Corporation.

Table 1. Surveyed urban green spaces and the habitat structure of the study area with their GPS coordinates.

Study Sites	Latitude	Longitude	Surveyed Habitat Type
Bangladesh Agricultural University Campus Area (A)	24.725	90.428	Urban Settlements, Cultivated Land, Fallow land, Planted Forest, River Bank, Grassland, Water Bodies, Road.
Ananda Mohan College Area including Zainul Abedin Park (B)	24.762	90.395	Urban Settlements, Planted Tree, Water Bodies, River Bank.
Central Jail and Police Lines area (C)	24.772	90.387	Urban Settlements, Cultivated Land, Fallow land, Home state forest, River Bank, Sand Bars, Road.

Data collection

Following the direct field observation method, the study was conducted from November 2018 to October 2019, and the study period was divided into three seasons, i.e. winter (November to February), summer (March to June), and rainy (July to October) following Panda *et al.* (2020). We spent 27 days (9 days in each season) in field surveys throughout the year. Data were collected following the transect line method and opportunistic survey. Each study site was approximately 250×100 = 25,000 square meters, and we surveyed four transects per site. Each site was surveyed at least once in each season. Observation was done early in the morning (from 6:00 am to 10:30 am) and afternoon (from 3:00 pm to 6:30 pm). The birds that were normally hidden in the bushes, grasslands, holes, jungles, and branches of trees were recorded by their songs and calls following Jaman *et al.* (2015). Call records were performed with a Samsung A50 phone, which was later analyzed in the laboratory, and then identified by the experts. For collecting data on nocturnal birds, night surveys were conducted using a torchlight and a headlamp. The photographs of birds were taken using a Nikon D500 DSLR Camera with a 70-300mm VR lens and a relevant field guide (Khan 2018) was used for the proper identification of birds.

Data analysis

The number of species and their individual counts were recorded and computed from each location. The relative abundance of different bird species was calculated by dividing the total individual number of one species by the total individual number of all species and then multiplied by 100. A rank abundance plot was developed after Whittaker (1965) to explain the dominance pattern of the species. A habitat similarity plot or cluster analysis for microhabitats and Non-mteric Multidimentional plot for three study sites were created using the Bray-Curtis index (Bray and Curtis 1957). Khan (2015) was followed to estimate the observation status as very common (VC) 80-100%, common (C) 50-79%, fairly common (FC) 20-49% and few (F) 10-19% which was calculated based on total sighting per survey attempt. The diversity indices were calculated using the Shannon-Wiener index (Shannon and Wiener 1949) and Simpson's index (Simpson 1949). Evenness was assessed by dividing the Shannon-Wiener index value by the natural log of species richness. The Pearson's correlation coefficient was computed to identify the commonness of bird diversity among different urban habitats and a correlation plot was produced. Among the nine micro-habitats, habitat-habitat correlation was done by taking the species diversity as an independent variable and the habitats as the dependent variable. All statistical analyses were carried out using spreadsheets MS Excel, PAST(version 4.03), R 4.0.5 with ggplot2 package which was used for plotting.

RESULTS AND DISCUSSION

Species composition and abundance

A total of 180 species of birds was recorded under 18 orders and 57 families. Non-passerine bird species were higher (104 species, 57.88%) than passerines (76 species, 42.22%) (Table 2). Passeriformes had the highest number of bird species (76 species, 42.22%), followed by Charadriiformes (17 species, 9.44%), Accipitriformes (14 species, 7.77%), Pelecaniformes (11 species, 6.11%), Piciformes (11 species, 6.11%), etc. The species list shows that resident birds were higher (132 species, 73.33%) than migratory birds (48, 26.67%). Among the recorded migratory species, *Clamator jacobinus*, *Cuculus micropterus* and *Merops philippinus* were summer migrants, and *Cuculus canorus* was passage migrants. Among the total counts (7,079 individuals) at all green spaces, Passeriformes birds were the highest in number (n = 4174, 58.96%). The species accumulation curve showed that the number of observed bird species increased progressively as survey efforts increased. Since the curve is close to the equilibrium point, the survey effort was sufficient, and some species may have been missed from the data in the study region (Fig. 2).

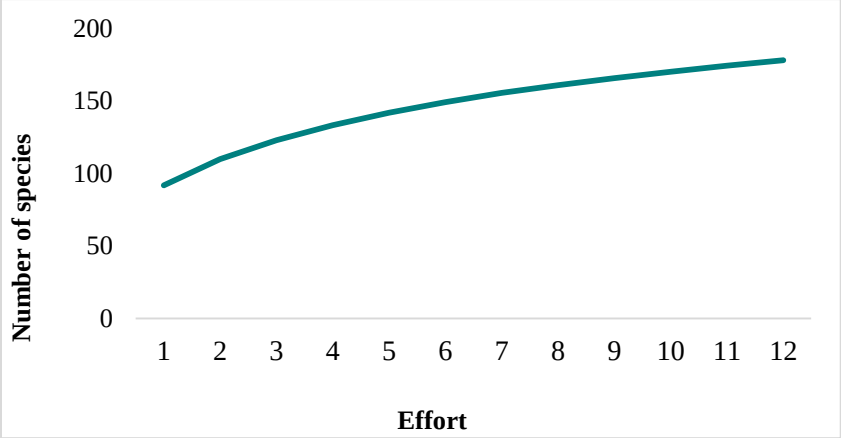


Fig. 2. Species accumulation curve of birds in the study area.

Table 2. List of observed avifauna in the urban green spaces of study area during the study period from November 2018 to October 2019.

Scientific name	Site	MH	Se	RA	OS	Scientific name	Site	MH	Se	RA	OS
Accipiter badius	A, C	T	W	0.07	UC	*Larus ridibundus*	A	WB	W	0.03	F
Acridotheres fuscus	All	T, US	Y	3.19	VC	*Lonchura atricapilla*	A,C	GL	Y	0.52	C
Acridotheres ginginianus	All	T	Y	0.90	VC	*Lonchura malabarica*	All	T, GL,US	Y	0.92	VC
Acridotheres tristis	All	AG,T,US	Y	3.12	VC	*Lonchura malacca*	A,C	GL	R,W	0.08	UC
Acrocephalus aedon	A	BU	W	0.03	F	*Lonchura punctulata*	All	T, GL,US	Y	1.16	VC
Acrocephalus agricola	A	T	W	0.03	F	*Lonchura striata*	All	T, GL	Y	0.62	C
Acrocephalus dumetorum	C	GL	W	0.03	F	*Luscinia svecica*	A,C	GL	W	0.06	UC
Acrocephalus stentoreus	A	GL	W	0.03	F	*Malacocincla abbotti*	A,C	T, BU	R,W	0.14	UC
Actitis hypoleucos	A, C	MF	W	0.07	UC	*Mareca strepera*	A,C	WB	W	0.10	UC
Aegithina tiphia	All	T	Y	1.00	VC	*Megalurus palustris*	A,C	GL	W	0.06	UC
Alcedo atthis	All	T	Y	0.47	VC	*Merops leschenaulti*	A,C	T	W	0.16	UC
Amaurornis phoenicurus	All	T, FP	Y	1.03	C	*Merops orientalis*	All	T, US	Y	1.38	VC
Anastomus oscitans	A, C	T	Y	1.29	C	*Merops philippinus*	A,C	US, AG	S	0.38	UC
Anthus rufulus	A, C	T, GL	Y	0.97	C	*Metopidius indicus*	A,C	FP	Y	0.54	C
Apus nipalensis	All	T, US	Y	1.95	VC	*Microcarbo niger*	All	T, WB	Y	0.85	C
Ardea alba	A,C	WB	Y	0.28	C	*Micropternus brachyurus*	B,C	T	W, S	0.10	UC
Ardea intermedia	A,C	WB	Y	0.34	C	*Milvus migrans*	All	T, US	Y	2.16	VC
Ardeola grayii	All	MF, WB	Y	1.36	VC	*Mirafra assamica*	A,C	T, GL	Y	0.16	UC

Artamus fuscus	All	T, US	Y	0.96	C	*Motacilla alba*	All	MF	W	0.45	UC
Athene brama	All	T	Y	0.47	VC	*Motacilla cinerea*	A,B	MF	W	0.08	UC
Bubulcus ibis	All	GL, WB	Y	2.40	VC	*Motacilla citreola*	All	MF	W	0.10	UC
Butastur teesa	A	T	W	0.01	F	*Motacilla flava*	All	MF	W	0.23	UC
Buteo rufinus	A	T	W	0.03	F	*Motacilla madaraspatensis*	All	MF	W	0.18	C
Butorides striata	A, C	MF	W	0.07	UC	*Nectarinia asiatica*	All	T	Y	1.68	VC
Cacomantis merulinus	A, C	T	Y	0.21	C	*Nectarinia zeylonica*	All	T	Y	1.43	VC
Calandrella raytal	A	GL	W	0.06	F	*Nettapus coromandelianus*	A,C	WB	W, R	0.51	UC
Calidris minuta	A, C	MF	W	0.10	UC	*Ninox scutulata*	All	T	S, W	0.20	C
Calidris temminckii	A, C	MF	W	0.07	UC	*Nisaetus cirrhatus*	A	T	W, R	0.03	UC
Caprimulgus macrurus	A, C	BU	W, S	0.11	UC	*Nycticorax nycticorax*	All	T	Y	0.31	C
Centropus bengalensis	A, C	T	W	0.10	UC	*Oriolus chinensis*	A	T	W	0.03	F
Centropus sinensis	A, C	T, FP	Y	0.30	C	*Oriolus oriolus*	All	T	W	0.08	UC
Ceryle rudis	All	T	Y	0.28	C	*Oriolus xanthornus*	All	T	Y	1.14	VC
Chalcophaps indica	A	T	W, S	0.07	UC	*Orthotomus sutorius*	All	T	Y	0.92	VC
Charadrius alexandrinus	A, C	MF	W	0.18	UC	*Otus lettia*	A	T	S	0.01	F
Charadrius dubius	A, C	MF	W, S	0.49	UC	*Pandion haliaetus*	A	T	W	0.03	F
Chlidonias hybrida	A	WB	W	0.03	F	*Passer domesticus*	All	T, US	Y	2.84	VC
Chrysocolaptes guttacristatus	All	T	W, S	0.18	C	*Passer montanus*	B,C	T	W, R	0.24	UC
Circus spilonotus	A	GL	W	0.01	F	*Pelargopsis capensis*	All	T	Y	0.42	C
Cisticola juncidis	A, C	GL	Y	0.45	C	*Pericrocotus cinnamomeus*	All	T	Y	0.40	C
Clamator jacobinus	A, C	T	S	0.06	UC	*Pericrocotus roseus*	A	T	W	0.06	F
Clanga clanga	A	T	W	0.01	F	*Pernis ptilorhyncus*	A,C	T	W, S	0.04	UC
Clanga hastata	C	T	W	0.01	F	*Phaenicophaeus tristis*	B,C	T	W	0.08	UC
Columba livia	All	T, FL,US	Y	1.79	VC	*Phalacrocorax carbo*	A,C	WB	W	0.16	UC
Copsychus saularis	All	T,GL,US	Y	1.55	VC	*Phylloscopus fuscatus*	All	BU	W	0.31	UC
Coracias affinis	A, C	T	W	0.17	UC	*Picoides canicapillus*	A	T	W	0.04	F
Coracias benghalensis	All	T, US	Y	0.40	VC	*Picus guerini*	C	T	W	0.03	F
Coracina melanoptera	All	T	W	0.18	UC	*Picus xanthopygaeus*	A,C	T	W, S	0.13	UC
Coracina melaschistos	A	T	W	0.04	F	*Ploceus benghalensis*	A	GL	W	0.04	F
Corvus levaillantii	All	T, US	Y	3.19	VC	*Ploceus philippinus*	All	T, US	Y	0.54	C
Corvus splendens	All	T, US	Y	3.19	VC	*Pluvialis fulva*	A	MF	W	0.03	F
Cuculus canorus	A	T	S	0.03	F	*Porphyrio porphyrio*	A	FP	Y	0.40	UC
Cuculus micropterus	All	T	S	0.11	UC	*Prinia gracilis*	A,C	T, GL	Y	0.34	C
Cyornis rubeculoides	A	T	W	0.01	F	*Prinia hodgsonii*	A	GL	Y	0.07	UC
Cypsiurus balasiensis	All	T, US	Y	1.95	VC	*Prinia inornata*	All	T, GL	Y	0.32	C
Dendrocitta vagabunda	All	T	Y	0.90	VC	*Psilopogon asiaticus*	All	T	Y	0.81	VC
Dendrocopos macei	All	T	Y	0.41	VC	*Psilopogon haemacephala*	All	T	Y	0.41	VC
Dendrocygna javanica	A,C	FP, WB	Y	1.26	C	*Psilopogon lineatus*	All	T	Y	0.49	VC
Dicaeum erythrorhynchos	All	T	W, S	0.23	C	*Psittacula alexandri*	A	T	Y	0.14	UC
Dicrurus aeneus	A,C	T, US	W	0.16	UC	*Psittacula eupatria*	C	T	W	0.03	F
Dicrurus leucophaeus	All	T	W	0.13	UC	*Psittacula krameri*	All	T	Y	0.95	VC
Dicrurus macrocercus	All	T, US	Y	1.71	VC	*Pycnonotus cafer*	All	T	Y	4.28	VC
Dicrurus remifer	A	T	W	0.03	F	*Pycnonotus jocosus*	All	T	W	0.69	UC
Dinopium benghalense	All	T	Y	0.71	VC	*Rhipidura albicollis*	All	T, BU	Y	0.52	VC
Egretta garzetta	All	FP, WB	Y	0.79	C	*Saxicola leucurus*	A,C	GL	W	0.06	UC
Elanus caeruleus	A, C	T	Y	0.10	UC	*Saxicola torquatus*	A,C	GL	W	0.07	UC
Eudynamys scolopaceus	All	T, US	Y	0.55	VC	*Spatula querquedula*	A	WB	W	0.03	F
Falco chicquera	A	T	W	0.06	UC	*Spilopelia chinensis*	All	T, US	Y	1.47	VC
Falco tinnunculus	All	T,AG,GL	Y	0.16	C	*Spilornis cheela*	A,C	T	Y	0.08	UC
Ficedula albicilla	All	T, BU	W, R	0.16	UC	*Streptopelia decaocto*	A,C	T, FL, US	W	0.27	UC
Gallicrex cinerea	A	FP	R	0.06	F	*Streptopelia tranquebarica*	A,C	T	Y	0.18	UC
Gallinago gallinago	A	MF	W	0.03	F	*Sturnus contra*	All	T, GL,US	Y	3.36	VC
Gallinago stenura	A	MF	W	0.04	F	*Sturnus malabaricus*	All	T, US	Y	1.13	VC
Gallinula chloropus	A	FP	W	0.06	F	*Tachybaptus ruficollis*	A,C	WB	Y	0.27	C
Halcyon smyrnensis	All	T	Y	0.52	VC	*Tephrodornis gularis*	A	US	W	0.08	F
Haliastur indus	All	T, US	Y	2.83	VC	*Tephrodornis pondicerianus*	All	T	S,W	0.30	UC
Hierococcyx varius	All	T	Y	0.34	VC	*Terpsiphone paradisi*	All	T	Y	1.09	VC
Hirundo daurica	A, C	FP	W	0.08	F	*Threskiornis melanocephalus*	A	WB	W	0.08	F
Hirundo rustica	All	T, FP	W, R	0.88	UC	*Treron bicinctus*	A	T	W	0.04	F
Hydrophasianus chirurgus	A	FP	W, R	0.11	UC	*Treron phoenicopterus*	All	T	Y	0.82	C
Hypothymis azurea	All	T	Y	0.95	VC	*Tringa glareola*	A,C	MF	W	0.10	UC

Ichthyophaga ichthyaetus	A, C	T	W, S	0.04	UC	*Tringa ochropus*	A,C	MF	W	0.08	UC
Ixobrychus cinnamomeus	A,C	FP, WB	Y	0.41	C	*Turdoides earlei*	A,C	GL	W	0.07	UC
Ixobrychus flavicollis	A	WB	R	0.03	F	*Turdoides striata*	All	T, BU	Y	3.74	VC
Ixobrychus sinensis	A,C	FP, WB	Y	0.27	C	*Tyto alba*	C	US	S, W	0.07	UC
Jynx torquilla	A,C	GL	W	0.06	UC	*Upupa epops*	A,C	AG,FL,GL	Y	0.40	C
Ketupa zeylonensis	All	T	Y	0.18	C	*Vanellus cinereus*	A,C	MF	W	0.30	UC
Lanius cristatus	All	T, GL	W	0.16	UC	*Vanellus indicus*	A,C	AG, GL	Y	0.25	C
Lanius schach	All	T, GL	Y	0.83	VC	*Zoothera citrina*	All	BU	Y	0.47	VC
Lanius tephronotus	All	T	W	0.06	UC	*Zoothera dauma*	A,C	BU	W	0.06	UC
Larus brunnicephalus	A,C	WB	W	0.14	UC	*Zosterops palpebrosus*	All	T	Y	2.63	VC

(Note: A- Bangladesh Agricultural University Campus Area, B- Ananda Mohan College Area including Zainul Abedin Park, C- Central Jail and Police Lines area, All- All areas; RA- Relative abundance; OS- Observation Status; VC- Very Common, C- Common, UC- Uncommon, F- Few; MH- Micro-habitat, BU- Bushy area, FL- Fallow land, MF- Mudflat, GL- Grassland, T- Tree, US- Urban settlement, WB- Water-body, AG- Agricultural land, FP- Floating plant; Se- Season W-Winter, S- Summer and R- Rainy, Y- Year-round).

Community structure, relative abundance, and observation status

The site A (Bangladesh Agricultural University Campus Area) had the highest species richness (170 species, 94.44%) and abundance (n=3261, 46.06%), and the lowest were in the site B (Ananda Mohan College Area, including Zainul Abedin Park) (Fig. 3 and Table 3). In the site A, Shannon and Simpson diversity indices showed the highest diversity *(H=4.459, D_s=0.983)* value. Surprisingly, the evenness value was the highest for the site B (*E=0.562*). In total, 83 species of birds were found in all three study sites (Table 3).

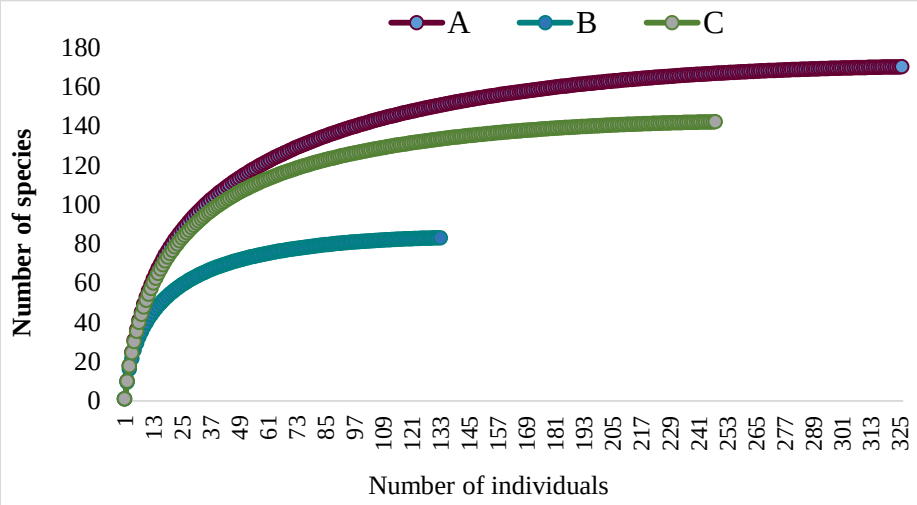


Fig. 3. Rarefaction curves of birds based on three study sites.

Among three study sites, variation in species richness (*χ2=9.959, df=2, p<0.0001*) and abundance (*χ2=793.74, df=2, p<0.0001*) differed significantly. The similarity (ANOSIM) test showed the significant differences in bird communities among three urban green spaces in the study area *(R=0.679, p<0.0029)*. This test also illustrated significant differences among three bird communities. For instance, birds community in the site A was dominant over the site B and site C in the non-metric multidimensional plot (NMDs) with a stress level of 0.089 (<0.2) (Fig. 4).

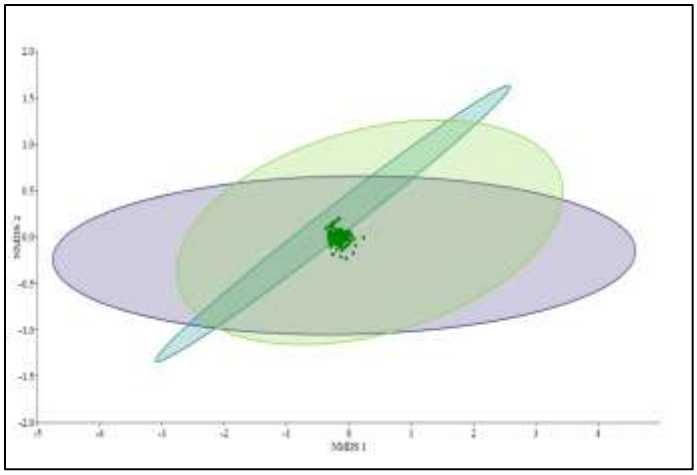


Fig. 4. Non-metric multidimensional plot showing separation of bird communities among three study sites (violet circle and dots indicates the site A; blue indicates B and green indicates C).

Among the recorded species, the relative abundance of red-vented bulbul (303 individuals, 4.28%) was the highest. The other most abundant bird species were *Turdoides striata* (265 individuals), *Sturnus contra* (238 individuals), *Acridotheres fuscus* (226 individuals), *Corvus splendens* (226 individuals), *Corvus levaillantii* (226 individuals), *Acridotheres tristis* (221 individuals), *Passer domesticus* (221 individuals), *Haliastur indus* (200 individuals) and *Zosterops palpebrosus* (186 individuals). The ten most dominant species constituted 32.37% of total individuals, whereas 80 least dominant species held only 5.29%. This signifies an uneven distribution of species in the community, which is explained in the rank abundance plot (Fig. 5 A).

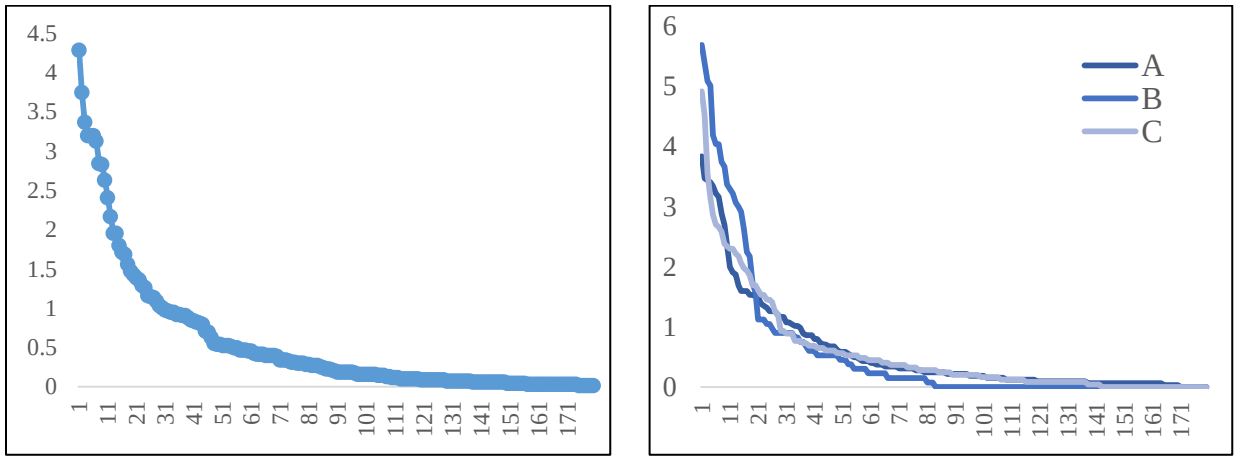


Fig. 5. Rank abundance plot for species recorded from the (A) total study area and (B) in 3 different urban green spaces. The y-axis shows the relative abundance, and the x-axis ranks the species in order of their abundance from highest to lowest. Site: A- Bangladesh Agricultural University Campus Area, B- Ananda Mohan College Area including Zainul Abedin Park, C- Central Jail and Police Lines area.

Among the three study sites, the site B signifies the most uneven distribution of species comparatively to two other study sites. In the site B, the ten most dominant species constituted 44.20% of total individuals, whereas the site A comprised 31.80% and the site B represented 31.64% (Fig. 5 B).

Among the recorded birds, 47(26.11%) very common, 34(18.88%) common, 64(35.55%) uncommon, and 35(19.44%) were few.

Seasonality

Seasonal variation differed significantly in species richness *($\chi 2=29.153$, df=11, p<0.0001)* and abundance *($\chi 2=360$, df=11, p<0.0001)* of birds in the study area. The highest number of bird species richness (173 species, 96.11%) and abundance (n=3086, 43.59%) were observed during the winter season. The diversity indices also showed the highest value in this season *(H=4.573, Ds=0.985)*. In the rainy season, the evenness *(E=0.655)* value was the highest (Table 3). Among the three study sites, the highest species richness and abundance were found in the site A for all seasons (Fig. 6.). The highest number of bird species richness (161 species, 89.44%) and abundance (n=1352, 19.09%) was observed with the highest diversity value *(H=4.596, Ds=0.985)* in January. Evenness was the highest in October (*E=0.718*) (Table 3).

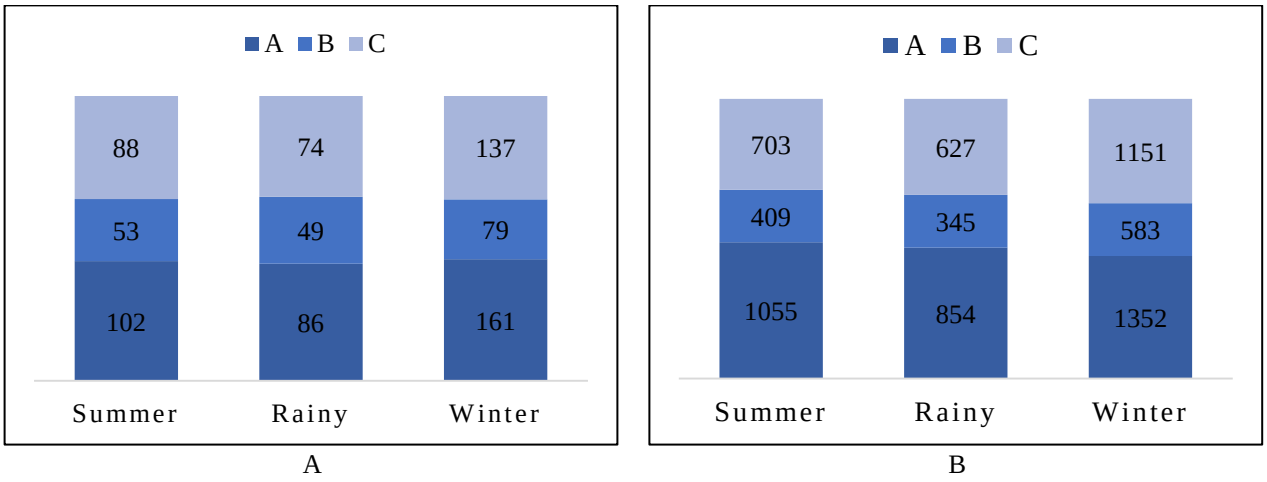


Fig. 6. Species richness and abundance in three seasons in 3 urban green spaces in the study area. Site: A- Bangladesh Agricultural University Campus Area, B- Ananda Mohan College Area including Zainul Abedin Park, C- Central Jail and Police Line areas.

Habitat usage and habitat similarity index

Most of the species were arboreal (114 species, n=4391 indiv, 63.33% of total species). Diversity indices showed the highest value for the arboreal habitats (*H=4.063, D_s=0.975*), and evenness was the highest for aquatic habitat *(E=0.586)* (Table 3). Among nine microhabitats, (303 individuals, 4.28%) the tree was mostly used micro-habitat (114 species, 63.33%); abundance (n=4391, 60.61%), and the highest diversity value (*H=4.063, D_s=0.975*) were calculated for this tree habitat (Table 3).

Cluster analysis among nine microhabitats showed that fallow land and agricultural land, grassland and water-body, and tree and urban settlements shared more similar species and formed large clusters. The species of floating plants, bush areas, and mudflats had more different species than other habitats and showed more distance among them (Fig. 7A). The overall richness and abundance of birds in nine microhabitats showed significant variation (for richness: *$\chi 2= 351.69$, df=8, p<0.0001;* for abundance: *$\chi 2=18633$, df=8, P<0.0001*). The correlation plot among the communities showed that the avian

communities of US and AG micro-habitat were correlated (r = 0.52, p < 0.05, Fig.7B). Tree was highly negatively correlated with the MF (r = - 0.130, p < 0.05). There was also a positive correlation between FL and AG, between US and AG, between US and FL, between US and GL, between Tree and AG, between WB and GL, and between WB and FP (Fig. 7B).

Table 3. Species richness, abundance, and diversity indices in different study sites considering seasons, months, macro-habitats, and microhabitats.

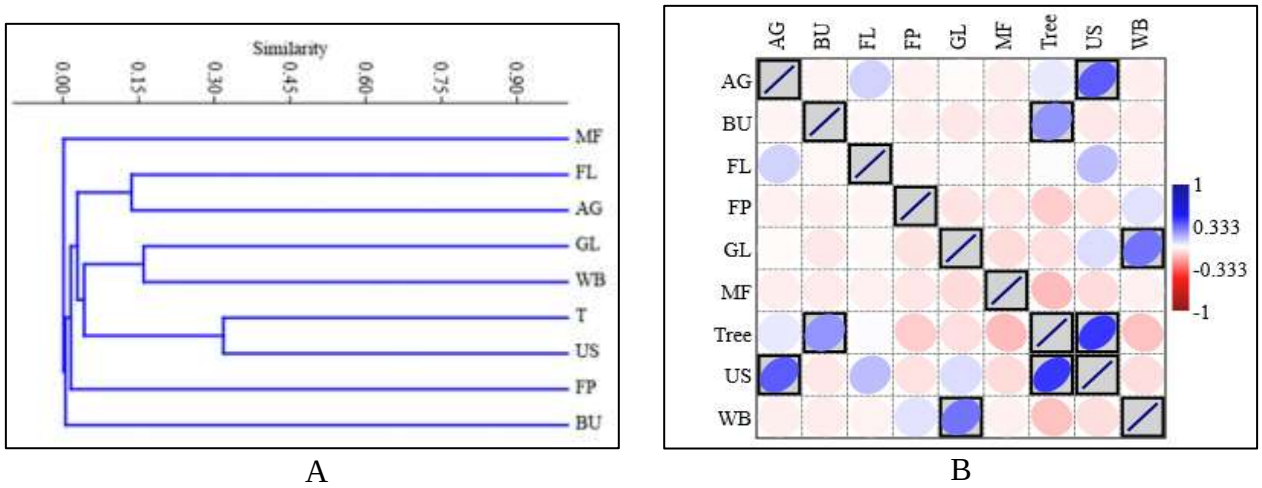
	Category	S	A	D_s	H	E
Study Sites	A	170	3261	0.983	4.459	0.508
	B	83	1337	0.971	3.844	0.563
	C	142	2481	0.982	4.361	0.552
Month	November	137	1151	0.983	4.433	0.615
	January	161	1352	0.986	4.596	0.616
	February	79	583	0.974	3.938	0.650
	March	88	703	0.978	4.079	0.671
	April	102	1055	0.978	4.126	0.607
	June	53	409	0.964	3.566	0.668
	July	74	627	0.974	3.943	0.697
	August	86	854	0.979	4.107	0.707
	October	49	345	0.964	3.562	0.719
Season	Rainy	94	1826	0.979	4.121	0.656
	Summer	106	2167	0.979	4.160	0.605
	Winter	173	3086	0.985	4.573	0.560
Macro-habitat	AQ	45	982	0.949	3.273	0.587
	ARB	114	4291	0.976	4.063	0.510
	TR	62	1806	0.959	3.498	0.533
Micro- habitat	AG	5	41	0.688	1.317	0.747
	BU	9	145	0.770	1.719	0.620
	FL	3	62	0.532	0.908	0.826
	FP	13	276	0.845	2.107	0.633
	GL	30	470	0.921	2.865	0.585
	MF	18	188	0.898	2.544	0.707
	Tree	114	4291	0.976	4.063	0.510
	US	27	1088	0.924	2.798	0.608
	WB	19	518	0.888	2.432	0.599

[Note- Species richness (S), Abundance (A), Simpson's Index (D_s), Shannon-Weiner Index (H), Evenness (E), Site: A- Bangladesh Agricultural University Campus Area, B- Ananda Mohan College Area including Zainul Abedin Park, C- Central Jail and Police Lines area, ARB- Arboreal, AQ- Aquatic, TR-Terrestrial; BU- Bushy area, FL- Fallow land, MF- Mudflat, GL- Grassland, US- Urban settlement, WB- Water body, AG- Agricultural land, FP- Floating plant]

Threatened status and conservation issue

According to IUCN (2015) redlist assessment of Bangladesh, we found only one species (*Clanga hastata)* categorized as Endangered; two species (*Threskiornis melanocephalus* and *Clanga clanga*) as Vulnerable; two species (*Ichthyophaga ichthyaetus* and *Ixobrychus flavicollis*) as Near Threatened among the recorded birds. We found deforestation, alternation of riverbank and rapid urbanization that might be responsible for the destraction of natural habitats in the three study sites. We found illegal hunting for some species, such as dove, wild-duck, wader, myna, parakeet, munia, heron and egret, particularly in the sites A and C.

In discussion we can explain our research findings in the following ways. More than a quarter (26.08 %) of Bangladesh's bird species (Table 2) were reported in urban green spaces, highlighting the importance of the study region for bird species (Khan 2018). This area was once part of a deciduous forest, and three major deciduous forests Bhawal, Madhupur, and Kadigarh national parks remain close to the city today. Aside from that, the city is located on the banks of the Brahmaputra River, which has helped to create a more favorable habitat for birds. We assume that the number of bird species was higher in these three sites in comparison to other cities like Dhaka, Magura, Rajshahi and Joypurhat of Bangladesh (Shome *et al.* 2020, Shome *et al.* 2021b, Jaman *et al.* 2021, Karmakar *et al.* 2011).



A B

Fig. 7. A. Similarity profile test among microhabitats using Bray-Curtis index. B. Correlation-Plot showing correlations among micro-habitats in the study area. (BU- Bushy area, FL- Fallow land, MF- Mudflat, GL- Grassland, US- Urban settlement, WB- Water body, AG- Agricultural land, FP- Floating plant).

Birds under the order Passeriformes are generally insectivores and granivores, and the urban green spaces are suitable habitats for such species of birds. Thus, the passerine birds were mostly found in the study area (Table 2). The Brahmaputra river and its adjacent areas are suitable habitats for waterbirds and fish-eating raptorial birds. So, the number of bird species under those orders was higher in three study sites (Table 3).

The site A (Bangladesh Agricultural University Campus) constituted diverse natural habitats with native plant species; thus, the number of bird species was higher in this area. Besides, this area was comparatively less disturbed, which was another reason for higher bird diversity. Jaman *et al.* (2021) in the megacity Dhaka also showed that the number of birds was higher in the less disturbed area. In the site A, 45 species of winter migratory birds were present, whereas the site B had 10 and the site C had 27 species. The presence of different groups of migratory birds in the winter season as well as resident bird species throughout the year aided in making a significant difference among the three communities (Fig. 3 and Fig. 4).

Among the ten most observed abundant species, six species were mainly scavengers (Table 2). It indicates that pollution is increasing in and around the study sites as the presence of scavengers is a good indicator (Sekercioglu 2006, Sekercioglu *et al.* 2004). While scavengers are getting more opportunities to live in the urban area, the least abundant species are facing an existential crisis due to losing the

quality of habitat. The most abundant bird species *P. cafer* feeds mainly on fruits, grain, nectar, and insects from different plants (Khan 2015). Our observation suggest that the study area harbors diverse plant species although we have not correlated the data with wildlife diversity. However, we assume that *P. cafer* gets more opportunities for its living in the study area because of the presence of a diverse number of plant species providing enough food, shelter, and nesting facilities for them (Fontana *et al.* 2011, Shome *et al.* 2021a, Kaushik *et al.* 2022). Among the birds, *C. splendens, M. migrans, A. tristis, S. contra* and *A. fuscus* were higher in number, which are mainly scavengers and thus got wide arrays of feeding opportunities (Jessop *et al.* 2012, Rebolo-Ifrán *et al.* 2017, Nepali *et al.* 2021). We also found that the relative abundance of *H. indus* is higher in the study area than in any other urban area of Bangladesh (Shome *et al.* 2020, Jaman *et al.* 2021, Shome *et al.* 2021a, b).

Among the three sites, the site B is situated in the central zone of the city which means that it faces numerous disturbances (e.g. sound pollution, light pollution) causing less habitat diversity than the sites A and C. In the sites A and C, the disterbance was less in number and species were evenly distributed comparatively in the site B (Table 3). This signifies an uneven distribution of species in the community, which is explained in the rank abundance plot (Fig. 5).

Seasonal variation influenced the composition of the bird community in the study area. In total, 83 species of birds were observed in all seasons, where 63 species of birds were found particularly in the winter season, contributing to the maximum species richness (Luo *et al.* 2019, Shome *et al.* 2020). The sandbars of the river Brahmaputra around the study sites, water bodies, and forest areas provide more opportunities for feeding and shelter for the migratory bird species. Thus, the species number was higher in the winter season in the study area (Fig. 6).

In the urban areas, the amount of natural habitats for different groups of wildlife is very low compared to the rural areas of Bangladesh (Jaman *et al.* 2021). The aquatic and terrestrial habitats are small as well as fragmented or destroyed. There are some green spaces in the parks, residential, and office areas where different native and exotic plant specie are planted, which become habitats for wildlife species. For this reason, the maximum number of bird species in the study area used arboreal habitat as their macro-habitat and tree as their microhabitat (Fig. 7) (Mardiastuti 2020, Panda *et al.* 2020, Shome *et al.* 2021 b).

Many bird species in urban areas are suffering existential crises as a result of global urbanization. The result from this study showed that more than 40% of bird species have less than 10 individuals (Table 2) in the study area, which indicates an alarming situation of their population status in the area. For example, *S. querquedula, P. haliaetus, P. fulva, T. ochropus, G. stenura, P. fuscatus, G. chloropus, S. decaocto, T. glareola, A. hypoleucos, L. Malacca* and *S. tranquebarica* were less found in this study, but are widely distributed in Bangladesh according to IUCN Bangladesh (2015). Given that, urban green areas are critical for the conservation of bird species in Bangladesh. In an urban park or green space, native plant species must be planted since they provide favourable niche for birds (Burghardt *et al.* 2009). During urbanization, the existing habitats for threatened species should be protected. In the urban area, the homestead forest and rooftop gardens should be expanded since they support the higher richness and abundance of birds (Belcher *et al.* 2018). Although bird diversity in the study area is higher, this city's bird species richness would be gone without an immediate conservation initiatives and

a good management strategy. More research is essential about threats, ecology, and the impact of environmental factors in the study area. The policymakers and urban planners should concentrate on designing eco-friendly urban sites.

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REFERENCES

Belcher, R. N., K. R. Sadanandan, E. R. Goh, J. Y. Chan, S. Menz and T. Schroepfer. 2018. Vegetation on and around large-scale buildings positively influences native tropical bird abundance and bird species richness. *Urban Ecosyst*. **22**(2): 213-225.

Bray, J. R. and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecol. Monogr.* **27**(4): 325-349.

Burghardt, K. T., D. W. Tallamy and W. G. Shriver. 2009. Impact of native plants on bird and butterfly biodiversity in suburban landscapes. *Conserv. Biol.* **23**(1): 219-224.

Callaghan, C. T., R. E. Major, M. B. Lyons, J. M. Martin and R. T. Kingsford. 2018. The effects of local and landscape habitat attributes on bird diversity in urban greenspaces. *Ecosphere.* **9**(7): 1-17.

Czech, B., P. R. Krausman and P. K. Devers. 2000. Economic associations among causes of species endangerment in the United States. *Bio. Sci.* **50**: 593-601.

Fontana, S., T. Sattler, F. Bontadina and M. Moretti. 2011. How to manage the urban green to improve bird diversity and community structure. *Landsc. Urban Plan.* **101**(3): 278-285.

Gatesire, T., D. Nsabimana, A. Nyiramana, J. L. Seburanga and M. O. Mirville. 2014. Bird diversity and distribution in relation to urban landscape types in Northern Rwanda. *Sci. World J.* **2014**(2): 1-12.

Gibbs, J. P., M. F. Buff and B. J. Cosentino. 2019. The Biological System-Urban Wildlife, Adaptation, and Evolution: Urbanization as a Driver of Contemporary Evolution in Gray Squirrels (*Sciurus carolinensis*). In: M. Hall and S. Balogh (eds.). *Understanding Urban Ecology*. Springer, Cham., pp. 269-286.

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

Jaman, M. F., M. A. R. Sarker, M. M. Alam, M. M. Rahman, M. F. Rabbe, A. S. Rana, A. R. Shome and S. Hossain. 2021. Species diversity, distribution and habitat utilization of urban wildlife in a megacity of Bangladesh. *Biodivers. J.* **12**(3): 635-653.

Jaman, M. F., M. Uddin, M. M. Alam, M. M. Rahman, M. T. Khatun and S. M. I. Alam. 2015. Species diversity and population status of wildlife in Keshabpur, Bangladesh. *J. Biodivers. Conserv. Bioresour. Manag.* **1**(2): 9-21.

Jessop, T. S., P. Smissen, F. Scheelings and T. Dempster. 2012. Demographic and phenotypic effects of human mediated trophic subsidy on a large Australian lizard (*Varanus varius*): meal ticket or last supper? *PLOS One*. **7**(4): e34069.

Karmakar, S., S. Parween and A. S. Reza. 2011. Birds of Joypurhat district, Bangladesh. *J. Life Earth Sci.* **6**: 51-57.

Karuppannan, S., Z. M. Baharuddin, A. Sivam and C. B. Daniels. 2014. Urban green space and urban biodiversity: Kuala Lumpur, Malaysia. *J. Sustain. Dev.* **7**(1): 1-16.

Kaushik, M., S. Tiwari and K. Manisha. 2022. Habitat patch size and tree species richness shape the bird community in urban green spaces of rapidly urbanizing Himalayan foothill region of India. *Urban Ecosyst*. **25**(2): 423-436.

Khan, M. A. R. 2015. *Wildlife of Bangladesh-checklist and guide*. Chayabithi, Purana Paltan, Dhaka 1000, Bangladesh. 568 pp.

Khan, M. M. H. 2018. *A Photographic Guide to Wildlife of Bangladesh*. Arannayk Foundation, Dhaka, Bangladesh. 488 pp.

Luo, K., Z. Wu, H. Bai and Z. Wang. 2019. Bird diversity and water bird habitat preferences in relation to wetland restoration at Dianchi Lake, south-west China. *Avian Res.* **10**(1): 1-12.

Mandal, A. K., M. F. Jaman, M. M. Alam, M. F. Rabbe and A. R. Shome. 2021. Vertebrate wildlife diversity of Sreepur upazila, Magura, Bangladesh. *J. Biodivers. Conserv. Bioresour. Manag.* **7**(1): 51-62.

Mardiastuti, A. 2020. Urban park design for bird diversity: Theory and application in landscape and site scales. *IOP Conference Series: Earth and Environmental Science*. **501**(1): 120-126.

Marzluff, J. M., R. Bowman and R. Donnelly. 2001. A historical perspective on urban bird research: trends, terms, and approaches. In: J. M. Marzluff, R. Bowman and R. Donnelly (eds.). *Avian ecology and conservation in an urbanizing world*. Springer, Boston, MA, USA., pp. 1-17.

McKinney, M. L. 2006. Urbanization as a Major Cause of Biotic Homogenization. *Biol. Conserv.* **127**: 247-60.

Mistry, J., A. Berard and M. Simpson. 2008. Birds as indicators of wetland status and change in the North Rupununi, Guyana. *Biodiver. Conserv.* **17**(10): 2383-2409.

Nepali, A., S. Khanal, S. Sapkota and B.S. Nanda. 2021. Seasonal Variation of Bird Diversity in Dhaneshwor Baikiwa Community Forest, Kavrepalanchowk District, Nepal. *J. Biodivers. Manage. Forestry*. **10**(3): 1-6.

Panda, B. P., B. Mahapatra, A. A. Sahoo, S. S. Ray, S. P. Parida and A. Pradhan. 2020. Habitat use of urban and periurban birds in a densely populated city of Eastern India. *Asia J. Conserv. Biol*. **9**: 290-297.

Rebolo-Ifrán, N., J. L. Tella and M. Carrete. 2017. Urban conservation hotspots: predation release allows the grassland-specialist burrowing owl to perform better in the city. *Sci. Rep.* **7**(1): 1-9.

Rocha, E. A. and M. D. E. Fellowes. 2018. Does urbanization explain differences in interactions between an insectherbivore and its natural enemies and mutualists? *Urban Ecosyst.* **21**: 405-417.

Sarker, N. J., D. Sultana, M. F. Jaman and M. K. Rahman. 2009. Diversity and population of avifauna of two urban sites of Dhaka, Bangladesh. *Ecoprint.* **16**: 1-7.

Sekercioglu, C. H. 2006. *Ecological significance of bird populations-Handbook of the Birds of the World*. Birdlife International., pp 15-51.

Şekercioğlu, Ç. H., G. C. Daily and P. R. Ehrlich. 2004. Ecosystem consequences of bird declines. *PNAS*. **101**(52): 18042-18047.

Shannon, C. E. and W. Wiener 1949. *The mathematical theory*. University of Illinois press, Urbana. 117 pp.

Shome, A. R., M. F. Jaman, M. F. Rabbe and M. M. Alam. 2021a. Bird diversity, composition and response during COVID-19 in an urban landscape, Jamalpur, Bangladesh. *Dhaka Univ. J. Biol. Sci.* **30**(2): 261-274.

Shome, A. R., M. F. Rabbe, M. M. Alam, S. F. Emon, M. M. Islam, R. S. Setu, N. Khan and M. F. Jaman. 2020. Avifauna in an urban landscape of a lower Ganges district, Bangladesh: Community structure, seasonality, habitat preference and conservation issue. *Dhaka Univ. J. Biol. Sci.* **31**(2): 343-360.

Shome, A. R., M. M. Alam, M. F. Rabbe, M. M. Rahman and M. F. Jaman. 2021b. Ecology and Diversity of Wildlife of Dhaka University Campus, Bangladesh. *Dhaka Univ. J. Biol. Sci.* **30**(3): 429-442.

Shome, A. R., M. M. Alam, M. F. Rabbe, M. M. Rahman and M. F. Jaman. 2020. Diversity, status and habitat usage of avifauna at Magura Sadar upazila, Bangladesh. *Bangladesh J. Zool.* **48**(2): 441-456.

Shome, A. R. and M. F. Jaman. 2021. Diversity and seasonal occurrence of vertebrate wildlife at a rural site of Bangladesh: Threats and conservation issue. *J. Biodivers. Conserv. Bioresour. manag.* **7**(2): 61-74.

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

UNDES (United Nations, Department of Economic and Social Affairs, Population Division). 2019. World Population Prospects 2019: Highlights (ST/ESA/SER.A/423).

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*. **147**(3655): 250-260.

WHO (World Health Organization). 2016. *Urban green spaces and health*. World Health Organization. Regional Office for Europe. No. WHO/EURO: 2016-3352-43111-60341.