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COMMUNITY STRUCTURE, THREATS AND CONSERVATION ISSUES OF MIGRATORY BIRDS IN THE SOUTH-CENTRAL COASTAL AREA OF BANGLADESH

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Abstract

The coastal areas of Bangladesh are enriched with migratory avian species but the actual status of birds was unknown, particularly in the south-central coastal region of the country. A yearlong (June 2023 to May 2024) direct field observation-based study was conducted to unfold the present status of the migratory avifauna in three protected areas (Kuakata National Park, Tangragiri Wildlife Sanctuary, and Sonarchar Wildlife Sanctuary). In this study, a total of 85 migratory bird species were recorded under 10 orders and 22 families. Individuals of wetland dependent migratory birds were higher than other bird species. Sonarchar Wildlife Sanctuary (SWS) had the highest number of bird species and individuals (70 species; n = 3618 individuals) with the highest diversity index values (H'= 3.135, Ds = 0.9257) compared to two other sites. Significant variations among migratory avian communities were found among the three study sites as indicated by the Analysis of Similarity (ANOSIM) test ($R = 0.168$, $P < 0.001$) in the non-metric multidimensional plot (NMDs). Among the migratory bird species, *Charadrius dubius* (14.75%), *Anas crecca* (14.33%), *Threskiornis melanocephalus* (11.69%), *Actitis hypoleucos* 8.47%), *Vanellus cinereus* (6.75%) were the most abundant. Population abundance was higher for the occurrence of the wetland dependent migratory bird species in the study area. Avian community composition of migratory species showed uneven distribution in the rank abundance curve. Across the three study sites, the majority of the migratory bird species exhibited clumped distribution patterns, followed by regular and random distribution patterns. A total of 37 (45.12%) species of migratory birds were found to use the coastline as their microhabitat. Unplanned fishing, tourism, expansion of agricultural land, hunting, and pollution were identified as major threats to the migratory bird species in the study area. This study suggests community-based conservation measures are essential for the proper conservation of the migratory birds.

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Introduction

Worldwide coastal wetlands are substantially important to the avifauna for breeding, roosting, feeding, and stopping sites for different group of wetlands dependent migratory as well as resident bird species[1]. As a deltaic country in the Ganges, Brahmaputra, and Meghna (GBM) drainage systems, Bangladesh is situated in a region that creates an extremely active estuary which empties into the Bay of Bengal[2]. Except for the Sundarbans, the main landforms along coastal Bangladesh includes *chars* (i.e. deltoid islands with mudflats), sand dunes, and shallow, silt-filled waterways[3]. These significant locations are the important feeding grounds of a wide variety of species. They exhibit distinctive habitat qualities by having a larger portion of endemic and threatened plants and wildlife[4,5] becoming "hotspots" for biodiversity[6]. For instance, the coastal islands of Bangladesh are the habitat of globally threatened species including the critically endangered Spoon-billed Sandpiper, which makes up about 10% of the global population, the vulnerable Indian Skimmer, which makes up about 50% of the global population, and significant numbers of the endangered Spotted Greenshank and Great Knot[7,8]. Wetland dependent birds like wild duck, short and long toed wader, fish-eating raptors, and kingfishers are the most abundant species in this area[9].

The coastline of Bangladesh is 710 km long which is composed of the interface of various ecological and economic systems, including mangroves (the world's largest mangrove forest), and tidal flats. In addition, estuaries, islands, accredited land, beaches, peninsula, rural settlements, urban and industrial areas, and ports are potential habitats of migratory birds[10]. The natural habitats of these coastal areas is becoming vulnerable due to natural and anthropogenic stressors[11,12]. Moreover, excessive fishing pressure, destruction of the mudflat, natural aquatic habitats degradation by cutting down native trees, increasing human settlements, industries and brickfields, domestic and industrial wastes into the water, grazing pressure, expansion of agriculture, lack of awareness among people, unsustainable tourism and fishing pose significant threats to coastal faunal diversity[13-15]. Illegal hunting and illegal trade have also added some pressure, particularly on shorebirds in coastal areas[16-18]. These threats might be responsible for the decline of avifauna in coastal areas, which were not assessed previously.

A detailed study was essential in the south-central coastal areas, including assessment of threats. Previous researches on the coastal birds focused mainly on some particular areas like Sundarbans, Nijhum Dwip, Sonadia Island, Moheshkhali, Teknaf, St. Martin's, and Sandwip[3,16-22]. Also, in the coastal areas, researches are limited to only bird species richness where the bird ecology, community structure, threat assessment, and conservation issues have often been ignored. In comparison to other coastal areas, researches are still scanty in the south-central coastal region of Bangladesh, especially in the Kuakata National Park and Sonarchar Wildlife Sanctuary of Patuakhali and Tangragiri Wildlife Sanctuary of Barguna. Therefore, the objectives of this study was to reveal community structure, identify threats and recommend conservation measures of migratory birds in the study area.

Materials and Methods

Study area and survey period: This survey was conducted through direct field observations from June 2023 to May, 2024 in the three study sites (Sonarchar Wildlife Sanctuary; Tangragiri Wildlife Sanctuary and Kuakata National Park) of the south-central coastal areas of Bangladesh which lie under the Barishal division (Fig. 1, Table 1). The entire study areas were divided into grids by using ArcGIS software following[23,24,25] with a size of 1 km × 1 km (Fig. 1). The particular grids were numbered and later these were identified by using a Garmin etrex 10 Global Positioning System (GPS) and direct observation (Fig. 1).

Table 1. The geographic location of the study areas with the information of the habitat structure

Name of Area	GPS Position	Area (ha.)	Location	No. of Grid	Major Habitats
Kuakata National Park, Patuakhali (KNP)	21.853960°N 90.090764°E	1,613	Kalapara, Patuakhali	21	Mangrove forest, Coastal line, Sandy Beach, Cannels, agricultural landscape.
Tangragiri Wildlife Sanctuary, Barguna (TWS)	21.963479°N 89.964268°E	4,048.58	Taltoli, Barguna	50	Mangrove forest, Cannels, water bodies, Mudflat
Sonarchar Wildlife Sanctuary, Patuakhali (SWS)	21.839952°N 90.503542°E	2,026.48	Rangabali, Patuakhali	34	Island, Mudflat, Forest, Coastline, Agricultural land

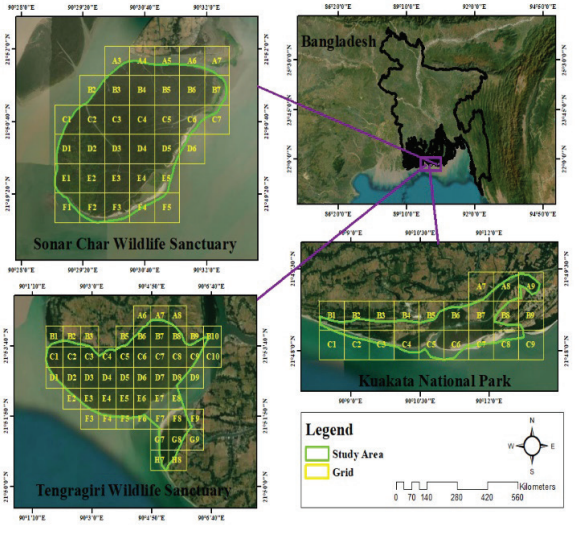


Fig. 1. Maps indicating the location of the study area with grids.

Coastal Mudflat

Coastal Mangrove Forest

Coastal Forest floor

Coastline

Fig. 2. Photos of different types of habitats from the study area.

For seasonal variation the study areas were divided into three major seasons: summer (March to June), winter (November to February), and rainy (July to October). The transect line sampling method was used to survey birds within the marked grid following Yallop et al.[26]. We performed two transects in each grid totaling 210. Each transect was 500 m in length and 50 m in width on both sides. We arranged field trips in three seasons as well as we covered all transects or grids of three sites equally throughout the study period. We printed out the Google earth images of the study area by overlaying the grids. The latitude/longitude values of four corners of each grid were demarcated and identified using a Global Positioning System (GPS) (Model: Garmin etrex 10). Species, individual numbers with their habitat type were recorded. Block counting methods by telescope were applied to observe large flocks of water birds. Surveys were conducted for 8 days per season and spent 8 hours daily (5 hours in the morning + 3 hours in the afternoon) to collect data. The peak active period for birds was also considered during surveys[27,28]. A boat survey was done to count and identify water birds. Visual observation was made by the naked eye, binoculars (Bushnell Power View 10 × 42) in each transect or grid. Some birds were identified by recording their calls. Direct observations were also done to identify threats on migratory birds.

Data analysis: Species richness was estimated using first and second-order Jackknife, Bootstrap, and Chao 2 richness estimators in PAST[22]. The average of the four factors was the predicted richness which was calculated using a 1000 random sample run. The observation status of migratory birds was computed in compliance with Khan[29] classifying 10–19% of all sightings as few (F), 20–49% as uncommon (UC), 50–79% as common (C), and 80–100% as very common (VC) species. Relative abundance (RA) of each taxon was calculated as RA = (Number of individuals of a particular species)/ Total number of individuals of all species multiplied by 100.

Diversity indices (Evenness, Simpson's, and Shannon index) was measured to assess the alpha-level diversity status of migratory birds[30,31]. To assess the beta diversity (species turnover) among sites, Analysis of Similarities (ANOSIM) was carried out following the Similarity Percentages test (SIMPER) to investigate the principal species responsible for community differences amongst study sites. A non-metric multidimensional (NMDs) plot using the Bray-Curtis distance matrix was made to show the divergence and relatedness of taxa in each grid among study sites. We also performed a cluster analysis to observe the similarities among the different microhabitats based on the Bray-Curtis index[32] using PAST version 4.10.

The Whittaker rank-abundance diagram was produced by plotting the overall abundance against their rank in the samples[49]. The coefficient of dispersion was calculated to understand how species were dispersed over the study area[33,34]. All statistical analyses were carried out using relevant statistical packages in the R respective formula of MS (R Core Team 2020).

Results and Discussion

Population status of migratory bird species: A total of 85 species of migratory birds with 7,877 counted individualswere documented from the study period. Two species (i.e., *Cuculus micropterus,* and *Merops philippinus)* were summer migrants, one passage migrants (*Falco amurensis*) and rests were winter visitors (82 species) (Table 2). All the observed migratory bird species belonged to 10 orders and 22 families. The highest number of species and individuals were under the order Charadriformes (32 species, n = 4098) followed by Passeriformes (26 species), Anseriformes (12 species) and Accipitriformes(7 species).

Table 2. Recorded migratory bird species with relative abundance, status and distribution pattern

SN	EN	DP KNP	DP SWS	DP TWS	RA KNP	RA SWS	RA TWS	Total RA	OS
Acrocephalus aedon	Thick-billed Warbler	0	CLU	0	0	0.01	0.01	0.01	F
Acrocephalus agricola	Paddy field Warbler	0	CLU	0	0	0.01	0.02	0.02	F
Acrocephalus dumetorum	Blyth's Reed Warbler	0	CLU	0	0	0.01	0.01	0.01	F
Actitis hypoleucos	Common Sandpiper	CLU	REG	CLU	0.49	2.01	1.67	1.68	F
Anas acuta	Northern Pintail	0	REG	0	0	0.12	0	0.05	F

SN	EN	DP KNP	DP SWS	DP TWS	RA KNP	RA SWS	RA TWS	Total RA	OS
Anas crecca	Common Teal	0	REG	0	0	2.75	3.75	2.84	F
Anas poecilorhyncha	Spot-billed Duck	0	CLU	0	0	0.02	0	0.01	F
Anser anser	Greylag Goose	0	CLU	0	0	0.03	0	0.02	F
Anser indicus	Bar-headed Goose	0	CLU	0	0	0.02	0	0.01	F
Arenaria interpres	Ruddy Turnstone	0	REG	0	0	0.14	0.3	0.19	F
Aythya fuligula	Tufted Duck	0	REG	0	0	0.42	0.3	0.32	F
Butastur teesa	White-eyed Buzzard	CLU	CLU	REG	0.04	0.01	0.01	0.01	F
Buteo rufinus	Long-legged Buzzard	CLU	CLU	REG	0.04	0.01	0.02	0.02	F
Calidris pugnax	Ruff	0	REG	0	0	0.13	0.14	0.12	F
Calidris alpina	Dunlin	0	CLU	0	0	0.01	0	0.01	F
Calidris ferruginea	Curlew Sandpiper	0	0	0	0	0	0.04	0.02	F
Calidris minuta	Little Stint	0	REG	0	0	0.36	0.36	0.31	F
Calidris temminckii	Temminck's Stint	0	CLU	0	0	0.02	0.02	0.02	F
Celeus brachyurus	Rufous Woodpecker	CLU	0	0	0.08	0	0	0.01	F
Charadrius alexandrinus	Kentish Plover	0	REG	0	0	0.47	0.51	0.43	F
Charadrius dubius	Little ringed Plover	REG	REG	0	4.78	2.71	2.63	2.93	F
Charadrius leschenaultii	Greater Sandplover	0	CLU	0	0	0.07	0	0.03	F
Charadrius mongolus	LesserSandplover	0	REG	0	0	0.25	0	0.11	F
Chlidonias hybrida	Whiskered Tern	0	CLU	0	0	0.07	0.02	0.04	F
Circus aeruginosus	Western Marsh Harrier	CLU	0	0	0.04	0	0	0.01	F
Circus cyaneus	Hen Harrier	CLU	0	0	0.04	0	0	0.01	F
Circus spilonotus	Eastern Marsh Harrier	CLU	0	0	0.04	0	0	0.01	F
Coracina melanoptera	Black-headed Cuckooshrike	0	CLU	0	0	0.25	0.21	0.2	UC
Coracina melaschistos	Black-winged Cuckooshrike	0	CLU	0	0	0.25	0.22	0.21	UC
Cuculus micropterus	IndianCuckoo	0	CLU	0	0	0.09	0.07	0.07	F
Dendronanthus indicus	Forest Wagtail	CLU	CLU	REG	0.19	0.01	0.01	0.03	F
Dicrurus leucophaeus	Ashy Drongo	CLU	CLU	REG	0.21	0.01	0.02	0.04	F
Eumyias thalassina	Verditer Flycatcher	CLU	CLU	0	0.17	0.01	0	0.02	F
Falco amurensis	Amur Falcon	CLU	0	0	0.02	0	0	0	F
Ficedula albicilla	Taiga Flycatcher	CLU	0	REG	0.51	0	0.09	0.1	F
Gallinago gallinago	Common Snipe	CLU	CLU	REG	0.19	0.01	0.01	0.03	F
Halcyon pileata	Black-capped Kingfisher	0	CLU	0	0	0.03	0.02	0.02	F

SN	EN	DP KNP	DP SWS	DP TWS	RA KNP	RA SWS	RA TWS	Total RA	OS
Hieraaetus pennatus	Booted Eagle	CLU	0	0	0.04	0	0	0.01	F
Hirundo daurica	Red-rumped Swallow	0	CLU	0	0	0.01	0	0	F
Hirundo rustica	Barn Swallow	CLU	CLU	REG	0.68	0.01	0.13	0.14	F
Jynx torquilla	Eurasian Wryneck	0	0	0	0	0	0.01	0.01	F
Lanius cristatus	Brown Shrike	CLU	CLU	REG	0.04	0.25	0.22	0.21	UC
Lanius tephronotus	Grey-backed Shrike	CLU	CLU	REG	0.04	0.06	0.04	0.05	F
Larus brunnicephalus	Brown-headed Gull	0	REG	0	0	0.3	0.5	0.35	F
Larus fuscus	Lesser black-Backed Gull	0	REG	0	0	0.17	0.18	0.15	F
Larus ichthyaetus	Pallas's gull	CLU	CLU	REG	0.87	0.03	0.02	0.13	F
Larus ridibundus	Black-headed Gull	REG	REG	0	6.24	0.74	0.23	1.18	F
Limosa limosa	Black-tailed Godwit	0	CLU	0	0	0.1	0.03	0.06	F
Luscinia svecica	Bluethroat	0	CLU	0	0	0.01	0	0	F
Mareca penelope	Eurasian Wigeon	0	REG	0	0	0.5	0	0.23	F
Mareca strepera	Gadwall	0	REG	0	0	0.43	0.12	0.25	F
Merops philippinus	Blue-tailed Bee-eater	0	CLU	0	0	0.02	0.01	0.01	F
Monticola solitarius	Blue Rock Thrush	CLU	0	0	0.17	0	0	0.02	F
Motacilla alba	White Wagtail	CLU	CLU	RAN	0.89	0.33	0.44	0.44	UC
Motacilla citreola	Citrine Wagtail	CLU	CLU	REG	0.68	0.3	0.34	0.36	UC
Motacilla flava	Yellow Wagtail	CLU	CLU	0	0.04	0.01	0	0.01	F
Numenius arquata	Eurasian Curlew	CLU	CLU	REG	0.17	0.06	0.06	0.07	F
Numenius phaeopus	Whimbrel	CLU	CLU	REG	0.19	0.09	0.08	0.1	F
Oriolus chinensis	Black-napped Oriole	0	CLU	0	0	0.01	0.01	0.01	F
Pandion haliaetus	Osprey	CLU	CLU	REG	0.04	0.02	0.01	0.02	F
Pericrocotus roseus	Rosy Minivet	0	CLU	0	0	0.01	0	0	F
Phalacrocorax carbo	Great Cormorant	CLU	REG	REG	0.25	0.16	0.07	0.13	F
Phylloscopus fuscatus	Dusky Warbler	0	CLU	0	0	0.01	0.09	0.04	F
Phylloscopus inornatus	Yellow-browed Warbler	0	CLU	0	0	0.01	0.02	0.01	F
Phylloscopus trochiloides	Greenish Warbler	0	CLU	0	0	0.01	0.19	0.08	F
Pluvialis squatarola	Grey Plover	0	CLU	0	0	0.11	0.11	0.1	F
Recurvirostra avosetta	Pied avocet	0	REG	0	0	0.2	0.21	0.18	F
Saxicola torquatus	Common Stonechat	CLU	0	0	0.51	0	0	0.06	F
Spatula clypeata	Northern Shoveler	0	REG	0	0	0.08	0	0.04	F
Spatula querquedula	Garganey	0	CLU	0	0	0.07	0.07	0.06	F

SN	EN	DP KNP	DP SWS	DP TWS	RA KNP	RA SWS	RA TWS	Total RA	OS
Sterna albifrons	Little Tern	0	CLU	0	0	0.06	0.06	0.05	F
Sterna aurantia	River Tern	0	CLU	0	0	0.07	0	0.03	F
Tadorna ferruginea	Ruddy Shelduck	0	REG	0	0	0.67	0	0.3	F
Tadorna tadorna	Common Shelduck	0	REG	0	0	0.56	0.68	0.55	F
Threskiornis melanocephalus	Black-headed Ibis	0	REG	0	4.12	2.76	2.5	2.32	F
Trigna erythropus	Spotted Redshank	0	0	0	0	0	0.01	0.01	F
Trigna glareola	Wood Sandpiper	CLU	REG	REG	0.04	0.22	0.1	0.15	F
Trigna nebularia	Common Greenshank	0	0	0	0	0	0.07	0.03	F
Tringa ochropus	Green Sandpiper	CLU	REG	CLU	0.17	0.13	0.3	0.21	F
Tringa stagnatilis	Marsh Sandpiper	0	REG	0	0	0.16	0	0.07	F
Tringa totanus	Common Redshank	CLU	REG	CLU	0.15	0.22	0.48	0.32	F
Vanellus cinereus	Grey-headed Lapwing	CLU	REG	CLU	0.08	0.94	1.93	1.26	F
Xenus cinereus	Terek Sandpiper	0	REG	0	0	0.12	0	0.05	F
Zoothera dauma	Eurasian Scaly Thrush	CLU	0	REG	0.28	0	0.02	0.04	F

Note: SN – Scientific Name, EN – English Name, DP- Distribution Pattern, RA- Relative Abundance; OS- Observation Status; VC- Very Common; C- Common, UC- Uncommon, Few- F; KNP- Kuakata National Park, TWS- Tangragiri Wildlife Sanctuary, SWS- Sonarchar Wildlife Sanctuary, Total RA- Relative Abundance

Bangladesh is enriched with diverse migratory bird species and globally the number is more than 250[10]. Coastal areas have an exceptional habitat for migratory birds in Bangladesh because these areas have significant mudflats, open water, rivers, mangrove forests, island habitats[14] which supports more than 200 species of migratory bird found across the study area (Table 3). These habitats are also important for globally and nationally threatened bird species like *Mycteria leucocephala*, *Ciconia episcopus*, *Platalea leucorodia*, *Calidris pygmaea*, *Tringa guttifer*, *Rynchops albicollis*, *Sterna acuticauda*, *Gyps bengalensis*, *Heliopais personata*, *Calidris tenuirostris*, *Limnodromus semipalmatus*, *Clanga hastate*, *Haliaeetus leucoryphus*, *Leptoptilos javanicus*, *Ciconia nigra*, *Threskiornis melanocephalus*, *Haematopus ostralegus*, *Clanga clanga*, *Pelargopsis amauroptera*[9].

This study unfolds the details scenario of the migratory birds in the study area that was not documented in the past. According to the prediction of the richness estimators, migratory species diversity ranged from 90-120 which is relatively closer to the observed result confirming 81% sampling. The results indicate that the study area is the home to more than one-third migratory species of birds of Bangladesh[10] and the composition of the diverse type of coastal microhabitats create an ideal habitat for the coastal bird. In comparison to other previous published data across the coastal habitat of Bangladesh,

Sonarchar Wildlife Sanctuary and Tangragiri Wildlife Sanctuary provide important habitats to the migratory birds (Table 3).

Table 3. A review on the migratory avifauna in the coastal areas of Bangladesh

Location	Migratory Bird Species	References
St. Martins, Cox's Bazar	48	35
Teknaf Wildlife Sanctuary and Inani Reserve Forest, Cox's Bazar	56	36
Sonadia, Cox's Bazar	70	37
Sandwip Island, Chittagong	43	3
NijhumDwip, Noakhali	97	38
Hatia, Noakhali	35	39
Sundarbans, Bangladesh Part	139	8
Kashipur, Barishal	28	25
Kuakata National Park, Patuakhali	35	Present Study
Sonarchar Wildlife Sanctuary, Patuakhali	70	Present Study
Tangragiri Wildlife Sanctuary, Barguna	58	Present Study

Spatial variation: The SWS had the highest number of migratory bird species and individuals (70 species; n = 3618 individuals) compared to the two other sites. KNP was found with the lowest number of bird species and individuals (35 species; n = 878 individuals). The highest diversity index values were found at the SWS site (H = 3.135, Ds = 0.9257). In SWS, species were more evenly distributed (E = 0.3283) (Table 4). SWS holds the highest number of unique migratory species among the three study sites (Fig. 3).

Table 4. Diversity indices of migratory bird in three study sites of coastal Bangladesh

Note- Species richness (S), Species abundance (A); Simpson's Index (D_s); Shannon-Weiner Index (H); Evenness (E)

Site	S	A	D_s	H'	E
KNP (Kuakata National Park)	35	878	0.8111	2.328	0.293
SWS (Sonarchar Wildlife Sanctuary)	70	3618	0.9257	3.135	0.3283
TWS (Tangragiri Wildlife Sanctuary)	58	3321	0.9079	2.908	0.3159

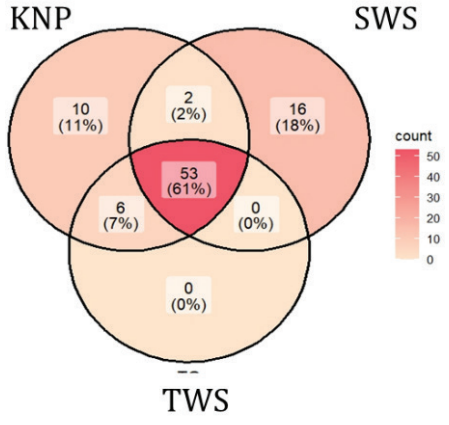


Fig. 3. Number of common species and unique species observed in the three sites.

Avian community structure, species richness and abundance are impacted by various natural and anthropogenic stressors[40,41]. The shape and structure of the habitat, human activities, fishing pressure, movement of water vessels, tourism in the coastal areas might be impacting the community structure of migratory bird in the study area[41,42]. SWS is completely an island habitat and anthropogenic activities like tourism were found to be the lowest here. Furthermore, the study area is enriched with natural habitats such as mangrove forest, canal, river, open water sandy beach, mudflat, coastline thus the number of migratory bird species was higher. On the contrary, in the KNP there is a single small river present and the major portion is basically planted forest. Tourism activities with human settlements were observed to impact in KNP. Thus, the number of migratory avian species richness and abundance is lower in this site.

Significant variations in bird populations were seen among the three study locations, as indicated by the Analysis of Similarity (ANOSIM) test ($R = 0.168$, $P < 0.001$) in the non-metric multidimensional plot (NMDs) with a stress level of 0.121 *(<0.2)* (Fig. 4). In the coastal area, mudflat and coastline habitat play significant role by supporting benthic organisms (e.g. crustaceans, mollusks, marine worms) which are major food source for coastal birds[3,14]. Habitat with a larger area and low anthropogenic stressors attract the wintering migratory birds in the study areas[42]. These habitat structures in SWS utilized bylarge flock of *Threskiornis melanocephalus*, *Anas crecca*, *Charadrius dubius*, *Actitis hypoleucos*, *Vanellus cinereus*, *Larus ridibundus*, *Tadorna ferruginea* which were not observedin other two sites. This also contributed to make a significant variation among the avian communities in the study area (Fig. 4).

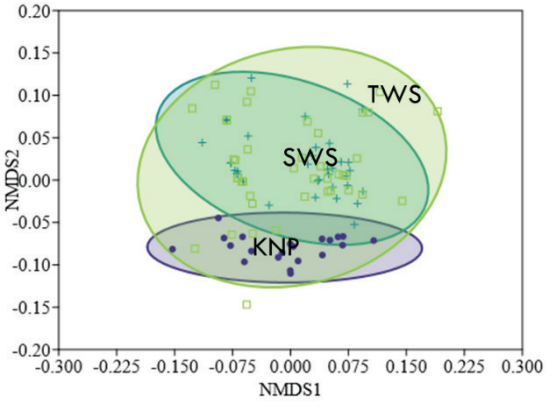
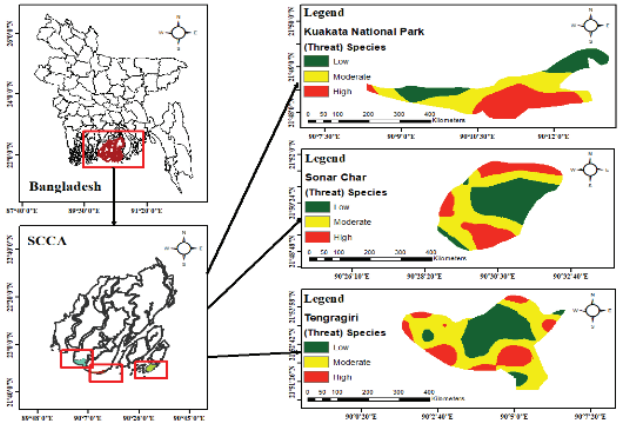


Fig. 4. Non-metric multidimensional plot (based on the Bray-Curtis similarity index) showing the separation of bird communities among sites (KNP- Kuakata National Park, TWS- Tangragiri Wildlife Sanctuary, SWS- Sonarchar Wildlife Sanctuary).

The highest number of the migratory species was recorded in the grids fall into peripheral and transitional zones of the study areas (Fig. 5a and 5b). These areas are actually shoreline/coastline areas where we found low human interferences that provided the ideal habitats for migratory birds.



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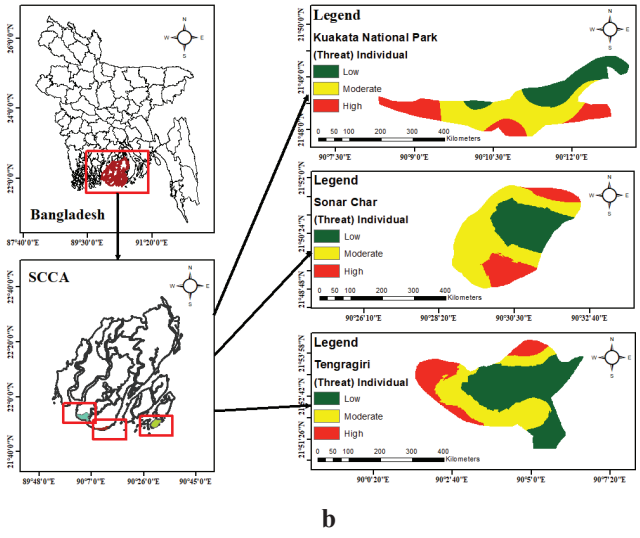

Fig. 5. Distribution of migratory birds according to **a.** species richness and **b.** species abundance.

Relative abundance, observation status and distribution pattern: Among the total bird species, *Charadrius dubius* was the most abundant bird species (n = 1152; 14.45%) in the study area. Other top abundant birds were *Anas crecca* (14.33%), *Threskiornis melanocephalus,* 11.69%), *Actitis hypoleucos* (8.47%), and *Vanellus cinereus* (6.75%). Thefive most abundant species constituted 55.62% of total individuals where 25 least abundant species constitute less than 1% (0.98%) population of the total migratory bird (Fig. 6). Among the top 20 abundant species, all were wetland specialist migratory bird. Due to the high abundance of wetland specialist migratory bird in the study area the avian community composition showed uneven distribution in all sites.

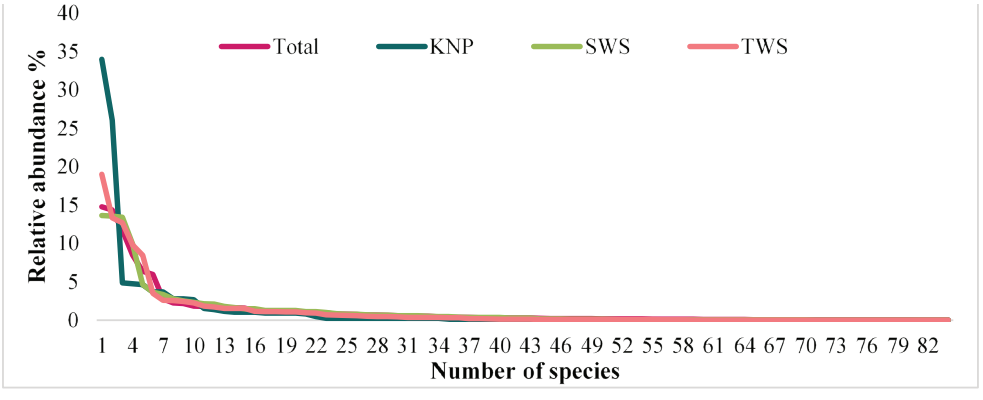

Fig. 6. Rank abundance plot of migratory bird species recorded from the study site (KNP- Kuakata National Park, TWS- Tangragiri Wildlife Sanctuary, SWS- Sonarchar Wildlife Sanctuary).

The majority of migratory bird species exhibited clumped distribution patterns, followed by regular and random distribution patterns across the three sites (Table 2, Fig. 7a). KNP had 32 species with a clumped distribution, 3 species with a regular distribution; SWS with 48 species with a clumped distribution and 28 species with a regular distribution, TWS with 38 species with a clumped distribution, 19 with a regular distribution, and 1 species with a random distribution. This indicates that clumped distribution is the most common pattern across all study sites, regular distribution is also prominent, especially in SWS and TWS, while random distribution is rare, occurring only in TWS.

According to the observation status in all sites, maximum number of bird species were observed relatively few (KNP = 15, SWS = 30, TWS = 31) in number during the field survey. Whereas, the number of relatively common and very common bird species were lower in number (Table 2, Fig. 7b). The observed migratory bird species was mainly winter migratory and observed only in the winter season that contributed some species to be higher in the study area.

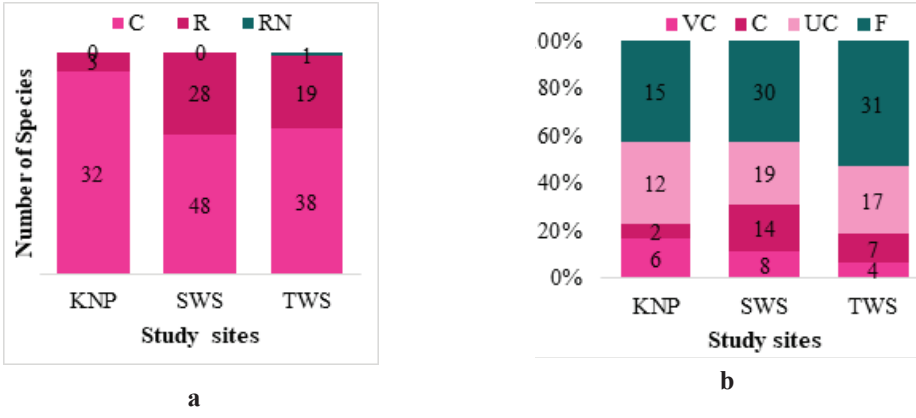

Fig. 7. a. Species distribution pattern and **b.** observation status in study area.

Note- (C-Clumped, R-Regular, RN- Random; VC- Very Common, C- Common, UC- Uncommon, F-Few; KNP- Kuakata National Park, TWS- Tangragiri Wildlife Sanctuary, SWS- Sonarchar Wildlife Sanctuary).

Habitat utilization of migratory bird species: The highest number of migratory bird species (55 species) and the maximum individuals (7202 individuals) were observed using aquatic habitat followed by terrestrial habitat (Table 5). Diversity indices showed the highest diversity value (H = 2.917, Ds = 0.922) for the aquatic habitat with even distribution (E = 0.522) (Table 5).

A total of 37 migratory bird species were found to use coastline as their microhabitat, while only 12 species used open water bodies connected to forests. The highest number of birds (3899 individuals) utilized coastlines followed by open water bodies connected to forests (1840 individuals). For coastline microhabitat diversity indices had the highest value (H = 2.612, Ds = 0.8985). In agricultural land with nearby forest, species distribution was more even (E = 0.0.777) (Table 5). The coastal areas are enriched with diverse type of

aquatic natural habitats like shallow silt-laden waters, extensive intertidal mudflats, deltoid islands, mangroves, small as well as large river channel which supports wetland specialist migratory bird by providing feeding materials and resting sight as well[9,10].

Table 5. Diversity indices in terms of habitat utilization in the study area

Note- Species richness (S), Species abundance (A); Simpson's Index (Ds); Shannon-Weiner Index (H); Evenness (E)

Categories	Sub-Categories	S	A	D_s	H	E
Macro-habitat	Aquatic	55	7202	0.9223	2.917	0.336
Micro-habitat	Terrestrial	35	606	0.9126	2.906	0.5224
	Coastline	**37**	3899	0.8985	2.61	0.3674
	Tree in forest	19	324	0.8482	2.221	0.4851
	Forest associated agricultural land	15	105	0.8732	2.456	0.7773
	Forest floor	16	177	0.7609	2.018	0.4703
	Mudflat	15	1463	0.5786	1.341	0.2548
	Open water body	12	1840	0.6017	1.41	0.3412

Different types of microhabitats were compared using the Bray-Curtis similarity index. Two small cluster were formed in this index. The first smallest cluster, which contained the majority of comparable species, formed by habitats along the coastline and the mudflat. The second small cluster formed between tree species in the forest and the forest floor. Open-water species displayed greater differences from other habitats (Fig. 8).The similarities among the microhabitats, as shown by the Bray-Curtis index, are formed due to the shared environmental conditions and species compositions within each group. Mudflat and coastline microhabitats have high similarity because they all are part of aquatic or semi-aquatic ecosystems. These environments typically share similar species, such as aquatic plants, water-dependent invertebrates, and fish, which thrive in wet conditions. The overlap in physical conditions like water availability, light penetration, and nutrient levels also contribute to their similarity. Forest related habitats such as Forest Associated Agricultural Land (FAG), Tree Species in Forest (DF), and Forest Floor (FF) microhabitats are similar because they are influenced by forest ecosystems. These habitats support similar terrestrial species such as trees, shrubs, and forest-dwelling animals. They also share similar soil types, canopy cover, and microclimatic conditions (like humidity and temperature) typical of forested areas. Within this group, the closer similarity between FF and DF could be due to the presence of tree species common to both settings.

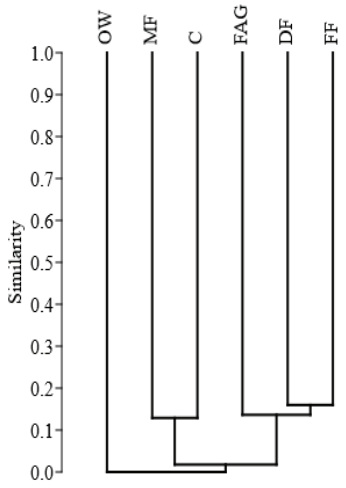

Fig. 8. Similarity profile test among microhabitats using Bray-Curtis index. [Forest associated agricultural land (FAG); Tree species in forest (DF); Forest floor (FF); Floating plant (FP); Mudflat (MF); Open water body (OW)]

Key threat assessment for migratory bird species and conservation issues: Among the recorded bird species, the maximum number was Least Concern according to IUCN Bangladesh (2015) except *Limosa limosa* (Near threatened), *Numenius arquata* (Near threatened), *Threskiornis melanocephalus* (Vulnerable), *Circus cyaneus* (Data Deficient).

In the study area some threats to bird species were observed which might have influenced on the migratory bird species (Table 6). Overall assessment of threats show that threats are higher in the KNP (Table 6). Kuakata area is a popular tourist spot which might cause decreasing migratory bird diversity (Table 6). In contrast, SWS is a remote area and the communication systems are not well developed. So, the tourism as well as the anthropogenic disturbance is lower in this site.

Coastal areas of Bangladesh are becoming increasingly popular as tourist spots. For example, Kuakata in the Patuakhali district is a well-known tourist destination in the south-central coastal area of the country. Unfortunately, eco-friendly tourism is rarely observed due to the expansion of urban areas, an excessive number of tourists, and the rampant movement of local vehicles along the sea beach. The expansion of agricultural land due to the growing human population has posed another threat, as natural habitats have been converted into cropland. Additionally, the transitional areas around forests are gradually being destroyed in the study areas. Tourists are often unaware of the conservation needs of migratory bird species and their habitats, which can be a major cause of disturbance to these birds, along with the degradation of habitat quality[43,44]. Particularly, the large number of tourists and pollution in the shore areas contribute to the destruction of the natural habitat conditions for birds[45]. Some migratory birds from different bird groups,

such as wild ducks, waterfowl, waders, raptors, and kingfishers, are severely affected by these threats in the study area. Passerine migratory birds like wagtails, pipits, flycatchers, thrushes, warblers, larks, drongos, bee-eaters, doves, and cuckoos are also impacted by the expansion of agricultural land. Additionally, human intrusion into the forest for fuel collection further disturbs these birds.

Table 6. Different types of observed threats and scoring of threats in the study area

(Note: KNP- Kuakata National Park, TWS- Tangragiri Wildlife Sanctuary, SWS- Sonarchar Wildlife Sanctuary)

Threats type	KNP	SWS	TWS
Tourism	Very high (4)	No (0)	Moderate (2)
Urban Expansion	Very high (4)	No (0)	Moderate (2)
Vehicle Movement	Very high (4)	No (0)	No (0)
Expansion of Agricultural land	Very high (4)	Moderate (2)	Low (1)
Using of Natural Resources for fuel	High (3)	Moderate (2)	Moderate (2)
Negative impact for fishing	No (0)	Low (1)	Moderate (2)
Hunting	Low (1)	Moderate (2)	Low(1)
Pollution	High (3)	No (0)	Low(1)
Total	23	7	11

We found small scale fishing practice and unconsciousness of the fisherman which is posinga threat to the conservation of aquatic specialist bird species the study area[46]. Especially, in the TWS area, the small canal and coastline inside the forest is full with fisheries resources. The fishing pressure might cause disturbance to migratory bird and their habitats. In particular, winter migratory birds facing disturbance for this activity.

Bird hunting in the coastal wetlandof Bangladesh was found to be a threat available in literature[47,48]. We found some of hunting events done by local people, tourist and ethnic people. Hunting mainly occurs for meat as well as aesthetic purposes. Specially, there is a demand for fowl in the local restaurant supplied by local people in winter. The local people use some traps and gear to catch the birds. Sometimes,poison is also used for hunting that kill entire flock of birds. Some bird such as wild duck, water fowl, waders, heron, egret, bittern and ibis are frequently hunted in the area.

Conclusion

Globally, coastal regions provide suitable habitat to support a wide range of wildlife resources. This study found south-central coastal area of Bangladesh as an important habitat for both migratory and resident birds. Intertidal mudflats, deltoid islands, mangroves, river channel and mangrove habitat are abundant which are substantially important habitats for birds. Unfortunately, some threats such as hunting, tourism, expansion of agricultural land, pollution and unplanned fishing creates existential crisis to them. Lack of eco-friendly tourism, plastic pollution and soil erosion are factors which might impact bird population.

Strong monitoring system, application of existing law, and sustainable eco-tourism are essential to save migratory birds. Awareness program, hand help management systems are essential for fishermen as well as local people. Community-based conservation education program is also needed particularly on the migratory bird. Long term monitoring is recommended to update the species and population status of migratory birds.

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