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Ornis Hungarica 2021. 29(2): 25–45.
DOI: 10.2478/orhu-2021-0017

Assemblage of wetland bird Species in Purbasthali Oxbow Lake, West Bengal, India: Implications for Management

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Received: July 15, 2021 – Revised: October 08, 2021 – Accepted: October 11, 2021

Mandal, M. H., Roy, A., Ghosh, S., Basak, A. & Siddique, G. 2021.Assemblage of wetland bird Species in Purbasthali Oxbow Lake, West Bengal, India: Implications for Management. – Ornis Hungarica 29(2): 25–45. DOI: 10.2478/orhu-2021-0017

Abstract The present study attempts to assess the composition, abundance and diversity of avifauna with respect to their habitat in and around the Purbasthali wetland, based on both primary data collected through the point count method during 2017–2019 and literature data. Among the total 77 species (encompassing 10 orders and 19 families), 39 species are migrants, 18 are rare and 24 species show declining global trend. According to their habitat, they are sub-divided into three categories i.e. *waterfowls* (live in open water, 20 species), *waders* (live in bank areas/water edge area, 45 species) and *wetland associated* (live in nearby trees, 12 species). The Shannon-Wiener Diversity Index (H') and the Evenness Index (E') are used to examine the diversity within and between the habitats. The result reveals higher diversity and evenness of the waders in comparison to others. The maximum diversity (H′=3.02) and evenness (E′=0.79) has been recorded for the waders in 2019, whereas the least values (H′=1.02, E′=0.34) have been found in 2016 for the waterfowls. Relative Diversity Index affirms the dominance of the *Anatidae* family. The birds of the area have now been seriously threatened by human intervention.

Keywords: Shannon-Wiener Diversity Index, Purbasthali wetland, habitat, Relative Diversity Index, migratory birds

Összefoglalás Jelen tanulmány a Purbasthali nevű vizes élőhely és környezete madárfaunájának összetételét, abundanciáját és diverzitását mutatja be a 2017–2019 között pontszámlálással gyűjtött és irodalmi adatok alapján. Az összesen 77 – 10 rendbe és 19 családba sorolható – faj közül 39 vonuló, 18 ritka, 24 faj esetén az egyedszám csökkenő globális trendet mutatott. Élőhelyük szerint e fajok három kategóriába sorolhatók: vízimadarak (nyílt vizet kedvelők, 20 faj), gázlómadarak (partmenti területeket kedvelők, 45 faj) és a vizes élőhelyekhez kötődők (közeli fákat kedvelők, 12 faj). Az élőhelyeken belüli és azok közötti sokféleség vizsgálatára Shannon-Wiener diverzitás indexet (H') és egyenletesség indexet (E') használtunk. Az eredmények alapján a gázlómadarak diverzitása a legmagasabb, és ennek a csoportnak az eloszlása a legegyenletesebb. A maximális diverzitást (H′=3,02) és egyenletességet (E′=0,79) a gázlómadarak esetén regisztráltuk 2019-ben, a legkisebb értékeket (H′=1,02, E′=0,34) pedig a vízimadaraknál 2016-ban. A relatív diverzitás index megerősíti az Anatidae család dominanciáját. A térség madarait jelentősen veszélyezteti a területen végzett emberi beavatkozás.

Kulcsszavak: Shannon-Wiener diverzitás index, Purbasthali vizes élőhely, habitat, relatív diverzitás index, vonuló madarak

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Introduction

Wetlands are considered as home of unique and diverse species of plants and animals especially the water birds (Garg 2015). Freshwater wetlands harbour more than 40% of bird species worldwide (Rajpar & Zakaria 2010). Birds live in wetlands and its surroundings are known as 'wetland birds' which include waterfowl, waders/shorebirds and birds reliant or associated to wetlands (Kumar *et al.* 2005). All species in the first two groups depend on the wetland, live in wetlands or its banks/ water edge for nesting, breeding, feeding and roosting, whereas the last category live in the nearby trees and scrubs.

Congregation of waterfowls in any wetland denotes the rich health of the waterscape and *vice versa* (Gregory 2006). Subsequently, wetland birds play crucial roles in sustaining the natural balance of the aquatic ecosystem (Clout & Hay 1989), possess different trophic levels of a food chain and thus, help supply of energy and maintain species diversity in an ecosystem (Hadley *et al.* 2012), carry out the role of predators, pollinators, herbivores, pest controller, agents of seed dispersal, and vectors of invertebrates and nutrients (Bibi & Ali 2013). Moreover, they are also considered as very sensitive to any sort of alterations in the environment (Koli 2014) and thus, they are often rationally called as effective bio-indicators of the wetland ecosystem (Li *et al.* 2009).

Various authors like Kumar *et al.* (2016), Chatterjee *et al.* (2017), Chen *et al.* (2019), Hamilton *et al.* (2019) and Luo *et al.* (2019) have analysed the distribution, density, diversity, composition and abundance of wetland birds around the world with diverse perspectives and interests. Nowadays, analysing the spatio-temporal dynamism of structure and diversity of avian communities has become essential to assess the impact of anthropogenic activities on the natural systems of wetlands as well as to ascertain the responses of the water birds to such environmental challenges (Cahill *et al.* 2013). Moreover, such studies have been proved to be helpful in explaining the importance of the protection of diverse wetland habitats on the globe for conservation of water birds (Rittiboon & Karntanut 2011).

Endowed with a rich variety of wetland habitats, India provides favourable breeding and wintering grounds for various migratory and vagrant water birds (Hardy *et al.* 1987). About 15% (n=1340) of the bird species of the world are found across the Indian subcontinent (Grimmett *et al.* 2011). Among them, 310 species can be brought under the categories of wetland birds (Grimmett & Inskipp 2007). However, the natural wetlands over the last two centuries have faced tremendous anthropogenic pressure worldwide due to the escalation of human interventions and resultant environmental changes (Turner *et al.* 2000, Kahara *et al.* 2012). More than half of the global wetlands have either been lost or transformed during the past century, and the remaining are experiencing degradation due to reckless human intercession (Fraser & Keddy 2005). Any adverse changes in the function of ecosystem affects the birdlife associated with the wetland (Bhattacharjee & Bargali 2012). Hence, the loss and deterioration of wetlands has not only affected the water birds but also threatened the birds reliant on or associated to wetlands (Ma *et al.* 2010). Studies like Prasad *et al.* (2002) and Reginald *et al.* (2007) have depicted how significant loss of the Indian wetlands has adversely affected the composition of bird community to a significant proportion.

The floodplain wetlands, located over the riparian tract of lower Gangetic plain of West Bengal, are biologically prolific and rich repository of water birds. The Purbasthali wetland is an important repository of various resident and migratory water bird species as it provides favourable space for breeding, foraging, roosting and watering (Mandal & Siddique 2018). Avifaunal diversity of Purbasthali wetland has been studied by Chowdhury (2017), Mandal and Siddique (2018), Mandal *et al.* (2018), Debnath *et al.* (2018) and Chakraborty *et al*. (2021). These works presented a checklist based on both water birds and terrestrial birds living around the wetland. Subsequently, 74 water bird species have been identified by Mandal and Siddique (2018) however; Debnath *et al.* (2018) found 86 species, Chowdhury (2017) reported 89 species while Chakraborty *et al*. (2021) has identified 27 species. Mandal *et al.* (2018) have emphasized how human intervention has reduced the diversity among waders. Thus, it can be stated that its wetland bird assemblages are not properly recorded, evaluated or even documented by the researchers or any proper authority. Therefore, the following objectives have been set up for the present research to address the gaps:

a) to prepare a complete inventory of wetland birds found in Purbasthali Lake based on available secondary data and acquired field-generated primary information;
b) to assess the temporal diversity of avifauna in different habitat niches i.e. open water, water-edge or bank areas and nearby trees/shrubs;
c) to ascertain the existing threats to the avian species of the concerned wetland

Materials and Methods

The Study Site

The Purbasthali oxbow lake (locally known as *Chupi Beel*) is an abandoned channel of the River Bhagirathi on its right bank. The lake extends from 23°25′54″ N to 23° 27′54″ N and 88°19′45″ E to 88°21′54″ E, covering a total water area of 2.19 km^2 (Mandal *et al.* 2018).

The wetland is located along the margin between the districts of Nadia and Purba Barddhaman in the lower Gangetic deltaic region of West Bengal *(Figure 1)*. This water body bears a unique blend of both lacustrine (lentic) and riverine (lotic) ecosystems due to its connectivity with the river at its southern part through a narrow strait (Ganesan & Khan 2008). The crescent-shaped lake was formed during 1989–1991 by the lateral shifting of the river course with simultaneous erosion-deposition processes. Sequential erosion at the left bank with the sediment accretion in its opposite bank has dissociated the meander loop from the prime course of the River (Bandyopadhyay *et al.* 2014).

Data Sources and details of surveying

Both primary and secondary data have been used to fulfil the stated objectives. Due to lack of authentic governmental data, detailed chronological data on avifaunal community encompassing their order, family, species, and population for the years of 2014–2016

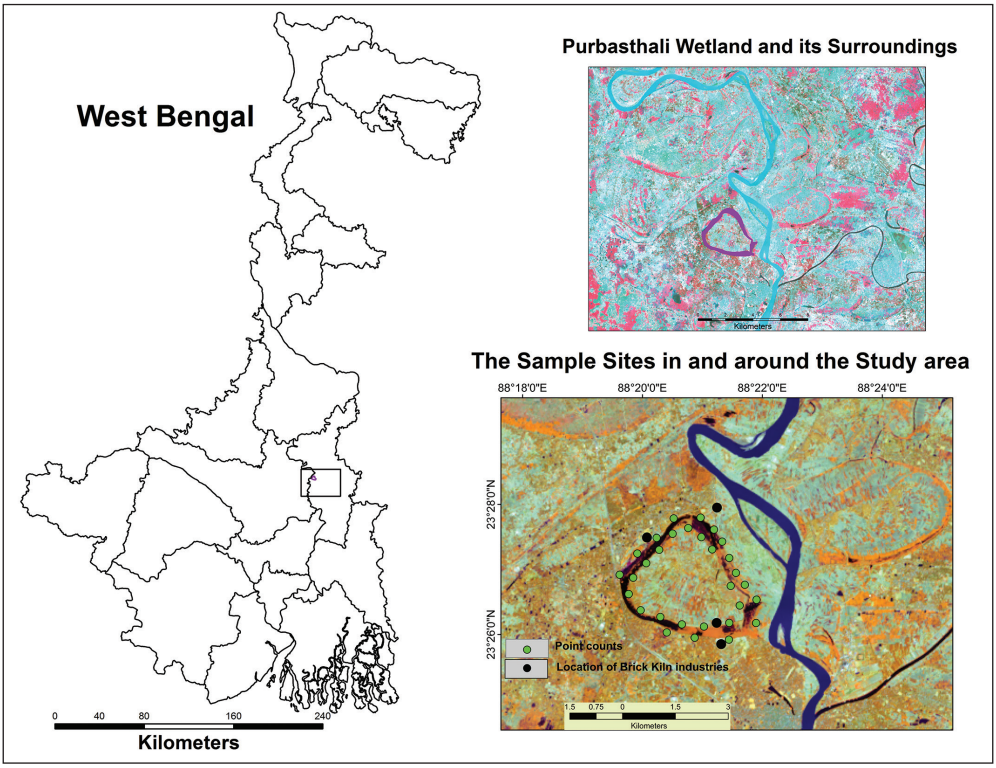

Figure 1. Location of the study area
1. ábra A vizsgálati terület elhelyezkedése

have been accessed from the *Junglees*, a Non-Government Organization (NGO), which professionally collects temporal (annual) data on birds for a long time. The researchers have participated actively in the enumeration processes during 2017–2019 to observe and record the migratory and resident birds found in the wetland. The primary survey has been conducted by following the field guidelines of Ali and Ripley (1987). The bird species in different habitats in and around the wetland have been observed and documented through the point count method. Three types of habitats has been identified from the wetland area i.e. open water, water edge area/transitional zone between land and water, and adjacent trees / shrubs, and bird's data have been collected according to these categories. Point count method, one of the most suitable methods of enumeration of the highly visible bird species across different habitats, has been operated from a fixed location for a definite period at any season of the year (Issa 2019). For the present study, the sighted bird species have been identified, counted and enlisted during the most active day period (i.e. 6 am – 10 am and 4 pm – 6 pm) (Kumar & Gupta 2013) from 30 fixed points *(Figure 1)* with a circle of 50 m radius for 10 minutes interval at every point. The lake has been monitored twice in every month during the aforesaid period to examine the monthly variation in species richness. The actual population under each species has been counted with eye-estimation in January in each year due to greatest abundance of the birds during winter.

A comprehensive inventory including their common (local) name, scientific name, taxonomic position (orders, families, and species), dispersal status, habitat, IUCN status (2017), food habit, and global trends of the population has been prepared after identification, enumeration, and documentation of the avifaunal community of the Purbasthali lake. Works of Mazumdar (2017), Chowdhury (2017), Mandal and Siddique (2018), Debnath *et al.* (2018) and Kumar and Sharma (2018) have intensively studied to frame the checklist. The identified birds have been classified into three categories according to their habitat preference/ location i.e. 'wetland-dependent' or 'waterfowls, 'water edge' or 'waders' and 'wetland associated' or 'terrestrial'. Further, they are also sub-divided into four groups based on the frequency of observation (Khan & Nahar 2009), which are 'Very common' (Vc) (sighted nearly 80–100% during field visit), 'Common' (Co) (50–79.9%), 'Fairly common' (Fc) (20–49.9%) and 'Rare' (Ra) (<19.9%).

Methods of analysis

Species richness refers to the total number of species in a particular habitat. **Relative Diversity Index** (***RDI***) has been used to assess the relative abundance of bird species by using the succeeding formula (Mandal & Siddique 2018):

$$RDI = \frac{n}{N} X\ 100$$

Where, n = Total number of birds in a species, and N = Total number of birds across all species

To determine the habitat wise diversity of birds, **Shannon-Wiener's Diversity Index** (***H′***) has been employed, by following the equation below (Kumar & Sharma 2018):

$$H' = -\sum_{i=1}^{s} pi\ ln(pi)$$

Where, S=Total number of species in the community; pi = Proportion of the total sample fit in to the i^{th} species, and $ln(pi)$ = Natural logarithm of this proportion.

In this study, the diversity of bird communities was assessed within habitat (**α** diversity) and compared between habitats (**β** diversity). Subsequently, the Evenness index (***E′***) was computed to reveal the diversity within and between the selected habitats of the birds by using the following equations (Kumar & Sharma 2018):

$$E' = H'/\ ln\ S$$

Where, ***H′***=Shannon-Wiener's Diversity Index and ***S***=number of species in selected wetland, and natural algorithm.The value of the index ranges from zero and one, where higher values (closer to one) represents higher evenness (Smith & Wilson 1996).

Result and Discussion

Composition and assemblage of avifauna

The ecological suitability of the lake attracts various native as well as migratory bird species (of different orders and families) to settle here or to choose it as a winter destination for feeding, breeding, grazing and swimming. A total of 77 bird species that belong to 10 orders and 19 families directly depended upon or associated with the concerned wetland, have been recorded during the study period. *Table 1* represents the detailed inventory of the identified bird species of the site studied.

The order Charadriiformes has hadthe highest number of families (6) and species (26), whereas the order Anseriformes has represented by only one family i.e. Anatidae, with 14 species. Naturally, the Anatidae family has shown the highest RDI value (18.18) followed by the Charadriidae (14.29), Ardeidae (11.69) and Scolopacidae family (11.69). On contrary, the lowest RDI value (1.30) has been represented by nearly six avian families like Podicipedidae, Rostratulidae, Burhinidae, Hirundinidae, Pandionidae and Apodidae *(Table 2)*.

It should be noted that spatial variations within a natural habitat effectively determine the abundance and occurrence of bird species (Pennington & Blair 2011). In order to understand the impact of habitat structure on the communities, the observed birds species of the area are classified into three groups based on their habitat preferences. The three distinctive habitats, chosen for further analysis, are A. **open water** (**waterfowls**), B. **water edge** or **bank areas** (**waders or shorebirds**), and C. **adjacent trees** and **shrubs** (**wetland associated**). Preference of habitat varies with families according to their feeding habit, availability of nesting materials, and behaviour (Malik & Joshi 2013). Several birds (like herons, egrets) are generally found in the bank areas or in the surrounding agriculture fields, whereas some others (like jacanas) prefer to take shelter in the dense, floating water hyacinth or other hydrophytes. The waterfowls used to dive in open water. Nearby trees and shrubs also provide shelters to some other arboreal birds like kingfishers, Shikra *(Accipiter badius)*, Osprey *(Pandion haliaetus)*. A large part of the wetland is still deep enough to hold a significant volume of freshwater. Moreover, this part of the water body is devoid of any type of hydrophytes, especially water hyacinths. The presence of such a vast open water surface provides a suitable arena for the members of the Anatidae family as they mostly prefer such type of environment (Benoit & Askins 1999). Naturally, the relative diversity of the Anatidae family has reported the maximum. On contrary, a notable proportion of the bank areas or water edge areas are used for cropping purposes. Even a larger segment of the shallow submerged water edge areas has been reclaimed and utilized as seedbeds. The abundance of waders (shorebirds) is getting influentially controlled by the availability of food (mainly small invertebrates) in the agricultural fields as invertebrates are less available in deep water (Murkin & Kadlec 1986). Increasing areas of cropland offer the ecological niche of several bird families like Charadriidae, Ardeidae, and Scolopacidae. Though, they are confined to the bank areas and adjacent agricultural fields, their relative diversity are significant.

Among the recorded species, 50.56% are migratory birds, who visit the wetland during the winter days, whereas 49.44% are resident birds *(Figure 2)*. The most common resident birds

Table 1. Checklist of wetland birds found in and around of the Purbasthali Wetland
Dispersal Status: R resident, M migratory;
Habitat Location: OW open water, WE water edge, T trees and Shrubs;
Abundance: ++++ very common, +++ common, ++ fairly common, + rare;
IUCN Status: LC least concern, NT near threatened, VU vulnerable;
Trend: ? unknown, ↑ increasing, ↓ decreasing, → stable

1. táblázat A Purbasthali vizes élőhelyen előforduló madárfajok

Order	Family	Common name	Scientific name	Dispersal Status	Habitat location	Abundance	IUCN status	Trend	Feeding Habits
Podicipediformes	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	R	OW	++++	LC	↓	Carnivorous
Pelecaniformes	Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	R	OW	++	LC	↑	Carnivorous
		Indian Shag	*Phalacrocorax fuscicollis*	R	OW	+++	LC	?	Carnivorous
		Little Cormorant	*Microcabro niger*	R	OW	+++	LC	?	Carnivorous
	Ardeidae	Grey Heron	*Ardea cinerea*	R	WE	+++	LC	?	Carnivorous
		Purple Heron	*Ardea purpurea*	R	WE	+++	LC	↓	Carnivorous
		Indian Pond Heron	*Ardeola grayii*	R	WE	++++	LC	?	Carnivorous
		Night Heron	*Nycticorax nycticorax*	R	WE	+++	LC	↓	Carnivorous
		Cattle Egret	*Bubulcus ibis*	R	WE	++++	LC	↑	Carnivorous
		Intermediate Egret	*Ardea intermedia*	R	WE	++++	LC	↓	Carnivorous
		Great Egret	*Ardea alba*	R	WE	+++	LC	?	Carnivorous
		Little Egret	*Egretta garzetta*	R	WE	++++	LC	↑	Carnivorous
		Yellow Bittern	*Ixobrychus sinensis*	R	WE	++	LC	?	Carnivorous
	Threskiornithidae	Glossy Ibis	*Plegadis falcinellus*	R	WE	+	LC	↓	Carnivorous
		Black Ibis	*Pseudibis papillosa*	R	WE	+	LC	↓	Carnivorous
		Spoon Bill	*Platalea leucorodia*	R	WE	+++	LC	?	Carnivorous
		Black-headed Ibis	*Threskiornis melanocephalus*	R	WE	++	NT	↓	Carnivorous

Order	Family	Common name	Scientific name	Dispersal Status	Habitat location	Abundance	IUCN status	Trend	Feeding Habits
Ciconiiformes	Ciconiidae	Asian Openbill Stork	*Anastomus oscitans*	M	WE	++++	LC	?	Carnivorous
		Lesser Adjutant Stork	*Leptoptilos javanicus*	R	WE	+	VU	↓	Carnivorous
Anseriformes	Anatidae	Greylag Goose	*Anser anser*	M	OW	+	LC	?	Omnivorous
		Ruddy Shelduck	*Tadorna ferruginea*	M	OW	+++	LC	?	Omnivorous
		Northern Pintail	*Anas acuta*	M	OW	+++	LC	↓	Omnivorous
		Common Teal	*Anas crecca*	M	OW	+++	LC	?	Omnivorous
		Cotton Pygmy-goose	*Nettapus coromandelianus*	M	OW	++++	LC	→	Omnivorous
		Gadwall	*Marecas trepera*	M	OW	+++	LC	↑	Omnivorous
		Eurasian Pigeon	*Mareca penelope*	M	OW	++	LC	↓	Omnivorous
		Garganey	*Spatula querquedula*	M	OW	+++	LC	↓	Omnivorous
		Northern Shoveller	*Spatula clypeata*	M	OW	+++	LC	↓	Omnivorous
		Common Pochard	*Aythya ferina*	M	OW	++	VU	↓	Omnivorous
		Tufted Duck	*Aythya fuligula*	M	OW	++	LC	→	Omnivorous
		Red-crested Pochard	*Netta rufina*	M	OW	++++	LC	?	Omnivorous
		Lesser Whistling Duck	*Dendrocygna javanica*	R	OW	++++	LC	↓	Omnivorous
		Ferruginous Pochard	*Aythya nyroca*	M	OW	+	NT	↓	Omnivorous
Gruiformes	Rallidae	Bailon'sCrake	*Zapornia pusilla*	M	WE	+	LC	?	Omnivorous
		Water Cock	*Gallicrex cinerea*	R	WE	+++	LC	?	Omnivorous
		Purple Swamp Hen	*Porphyrio porphyrio*	R	WE	+++	LC	?	Omnivorous
		White-breasted Waterhen	*Amaurornis phoenicurus*	R	WE	+++	LC	?	Omnivorous
		Indian Moorhen	*Gallinula chloropus*	R	WE	+++	LC	→	Omnivorous
		Common Coot	*Fulica atra*	R	WE	+++	LC	↑	Omnivorous

Order	Family	Common name	Scientific name	Dispersal Status	Habitat location	Abundance	IUCN status	Trend	Feeding Habits
Charadriifofmes	Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	R	WE	+++	LC	?	Omnivorous
		Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	R	WE	+	LC	↓	Omnivorous
	Charadriidae	River Lapwing	*Vanellus duvaucelii*	M	WE	+	NT	↓	Omnivorous
		Grey-headed Lapwing	*Vanellus cinereus*	M	WE	++	LC	?	Omnivorous
		Red-wattled Lapwing	*Vanellus indicus*	R	WE	++++	LC	?	Omnivorous
		Yellow-wattled Lapwing	*Vanellus malabaricus*	R	WE	++	LC	?	Omnivorous
		Pacific Golden Plover	*Pluvialis fulva*	M	WE	++	LC	?	Carnivorous
		Little Ringed Plover	*Charadrius dubius*	M	WE	++	LC	?	Carnivorous
		Little Stint	*Calidris minuta*	M	WE	++	LC	?	Insectivorous
		Marsh Sandpiper	*Tringa stagnatilis*	M	WE	++	LC	?	Insectivorous
		Ruff	*Philomachus pugnax*	M	WE	+	LC	↓	Insectivorous
		Lesser Sand Plover	*Charadrius mongolus*	M	WE	++	LC	?	Carnivorous
		Black-Winged Stilt	*Himantopus himantopus*	M	WE	+++	LC	↑	Insectivorous
	Scolopacidae	Common Snipe	*Gallinago gallinago*	M	WE	+	LC	↓	Insectivorous
		Common Red Shank	*Tringa tetanus*	M	WE	++	LC	?	Insectivorous
		Green Shank	*Tringa nebularia*	M	WE	+	LC	↑	Insectivorous
		Spotted Redshank	*Tringa erythropus*	M	WE	++	LC	?	Insectivorous
		Common Sandpiper	*Actitis hypoleucos*	M	WE	++++	LC	↓	Insectivorous
		Wood Sandpiper	*Tringa glareola*	M	WE	+	LC	→	Insectivorous
		Green Sandpiper	*Tringa ochropus*	M	WE	+	LC	?	Insectivorous
		Pin-Tailed Snipe	*Gallinago stenura*	M	WE	++++	LC	?	Insectivorous
		Temminck's Stint	*Calidris temmincki*	M	WE	+	LC	?	Insectivorous
	Rostratulidae	Painted Snipe	*Rostratula benghalensis*	R	WE	++	LC	?	Omnivorous
	Burhinidae	Great Stone Plover	*Esacusre curvirostris*	R	WE	+	NT	?	Carnivorous
	Laridae	Whiskered Tern	*Chlidonias hybrid*	M	OW	+++	LC	→	Omnivorous
		River Tern	*Sterna aurantia*	R	OW	++++	NT	↓	Omnivorous

Order	Family	Common name	Scientific name	Dispersal Status	Habitat location	Abundance	IUCN status	Trend	Feeding Habits
Passeriformes	Hirundinidae	Barn Swallow	*Hirundo rustica*	R	T	++++	LC	↓	Insectivorous
	Motacillidae	White Wagtail	*Motacilla alba*	M	T	+	LC	→	Insectivorous
		Yellow Wagtail	*Motacilla flava*	M	T	++	LC	↓	Insectivorous
		CitrineWagtail	*Motacilla citreola*	M	T	+	LC	↑	Insectivorous
Coraciiformes	Alcedinidae	Pied Kingfisher	*Ceryle rudis*	R	T	+++	LC	?	Carnivorous
		Common Kingfisher	*Alcedo atthis*	R	T	+++	LC	?	Carnivorous
		Stork-billed Kingfisher	*Pelargopsis capensis*	R	T	+++	LC	↓	Carnivorous
		White-breasted Kingfisher	*Halcyon smyrnensis*	R	T	+++	LC	↑	Carnivorous
Accipitriformes	Accipitridae	Marsh Harrier	*Circus spilonotus*	M	T	+	LC	↑	Carnivorous
		Indian Shikra	*Accipiter badius*	R	T	+++	LC	→	Carnivorous
	Pandionidae	Osprey	*Pandion haliaetus*	R	T	++	LC	?	Carnivorous
Apodiformes	Apodidae	Asian Palm Swift	*Cypsiurus balasiensis*	R	T	++	LC	?	Insectivorous

Table 2. Relative diversity of avian families
2. táblázat A madár családok relatív diverzitása

Name of the Families	No of Species	RDI	Name of the Families	No of Species	RDI
Podicipedidae	1	1.30	Rostratulidae	1	1.30
Phalacrocoracidae	3	3.90	Burhinidae	1	1.30
Ardeidae	9	11.69	Laridae	2	2.60
Threskiornithidae	4	5.19	Hirundinidae	1	1.30
Ciconidae	2	2.60	Motacillidae	3	3.90
Anatidae	14	18.18	Alcedinidae	4	5.19
Rallidae	5	6.49	Accipitridae	3	3.90
Jacanidae	2	2.60	Pandionidae	1	1.30
Charadriidae	11	14.29	Apodidae	1	1.30
Scolopacidae	9	11.69	Total (N)	77	100

found in the area are Lesser Whistling Duck *(Dendrocygna javanica)*, Pond Heron *(Ardeola grayii)*, Cattle Egret *(Bubulcus ibis)*, while, Red-crested Pochard *(Netta rufina)*, Ruddy Shelduck *(Tadorna ferruginea)*, Gadwall *(Mareca strepera)* are the few most abundant migrants. Nearly 18.18% of the species have been observed very frequently, hence are termed as 'very common'. Another 33.77% of birds are common and have been sighted frequently. Nearly 24.68% of birds are fairly common and the rest 23.38% of birds are rare *(Figure 2)*. Two vulnerable species i.e. Common Pochard *(Aythya ferina)* (Order: Anseriformes, Family: Anatidae) and Lesser Adjutant Stork *(Leptoptilos javanicus)* (Order: Ciconiiformes, Family:

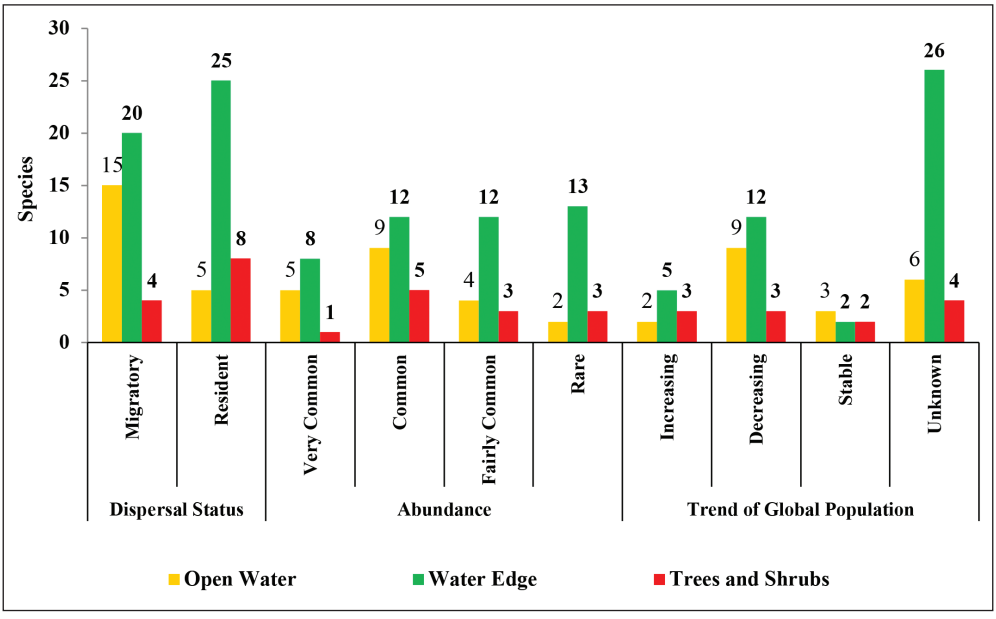

Figure 2. Status of the wetland birds, Purbasthali oxbow lake
2. ábra A vízimadarak jellemzői a Purbasthali holtág területén

Ciconidae) as per IUCN's Red Data Book has been found during the survey. Furthermore, five near-threatened species namely Black-headed Ibis *(Threskiornis melanocephalus)* (Order: Pelecaniformes, Family: Threskiornithidae), Ferruginous Pochard *(Aythya nyroca)* (Order: Anseriformes, Family: Anatidae), and three members of Charadriiformes, i.e. River Lapwing *(Vanellus duvaucelii)* (Family: Charadriidae), Great Stone Plover (curlew) *(Esacus recurvirostris)* (Family: Burhinidae) and River Tern *(Sterna aurantia)* (Family: Laridae) have been observed in the area during enumeration. *Figure 2* shows the dispersal status, abundance and global trend of bird species classified according to habitat.

The observed bird community of the wetland has been sub-divided into three groups according to their habitat associations. Nearly ¼ (25.97%) of the identified bird species have been found in the deep and clean open water area. All the 14 species of Anatidae family (Order: Anseriformes), one species of Podicipedidae family (Order: Podicipediformes), three species of Phalacrocoracidae (Order: Pelecaniformes) and two species of Laridae family (Order: Charadriiformes) have been recorded in the area fall in this category. On contrary, the maximum share of bird species (58.44%) has been observed at the water edge areas of the wetland. Families like Ardeidae, Charadriidae, Scolopacidae, Jacanidae prefer to live in those transitional zones and nearby crop fields due to the easy availability of food and shelters. Besides, several other bird species like kingfishers, Asian Palm Swift *(Cypsiurus balasiensis)*, Osprey, Shikra, and wagtails have been recorded at nearby trees and shrubs of the wetland, which constitutes 15.58% of the avian community.

It should be further mentioned that nearly 32.43% of the recorded species observed in the area show a declining trend in their global population, whereas 13.51% have reported growth at the global level. Only 9.46% bird species reveal a stable condition, whereas the global population status of nearly half of the observed species is unidentified to date. Moreover 37.66% of birds observed in the site are omnivores, 38.96% are carnivores and the rest 23.38% are insectivores. The concerned water body provides all kind of food and prey for the birds found here.

Temporal Variation of Species Richness and abundance

The time series analysis exhibits that all of these three categories of wetland birds found in the area show a positive trend of population growth over the observation period of 2014–2019 *(Figure 3)*, which is conclusively a promising fact. The birds live in open water and bank areas/ water edge show quite fluctuations in their abundance. On contrary, the birds sheltered in the nearby trees exhibit a slow but steady growth, though their share in the total population is very low (3.1% in 2019) *(Table 3)*.

Species richness of the waders is much higher than the other two categories, while the birds dependent on wetlands exhibit the lowest species richness. Maximum 20 species of waterfowls were observed during 2017–2019, while their lowest richness (17) was found in 2014. In case of the waders, the lowest richness (31) were recorded in 2014 and the maximum (44) in 2019 *(Figure 4)*.The temporal fluctuation in the richness of bird species preferring trees/shrubs is insignificant. It should be specified that, despite less species diversity, the population size of the waterfowls are notably higher than the birds of other habitats. They comprise the lion's share of the total bird population of the area over the years. For example,

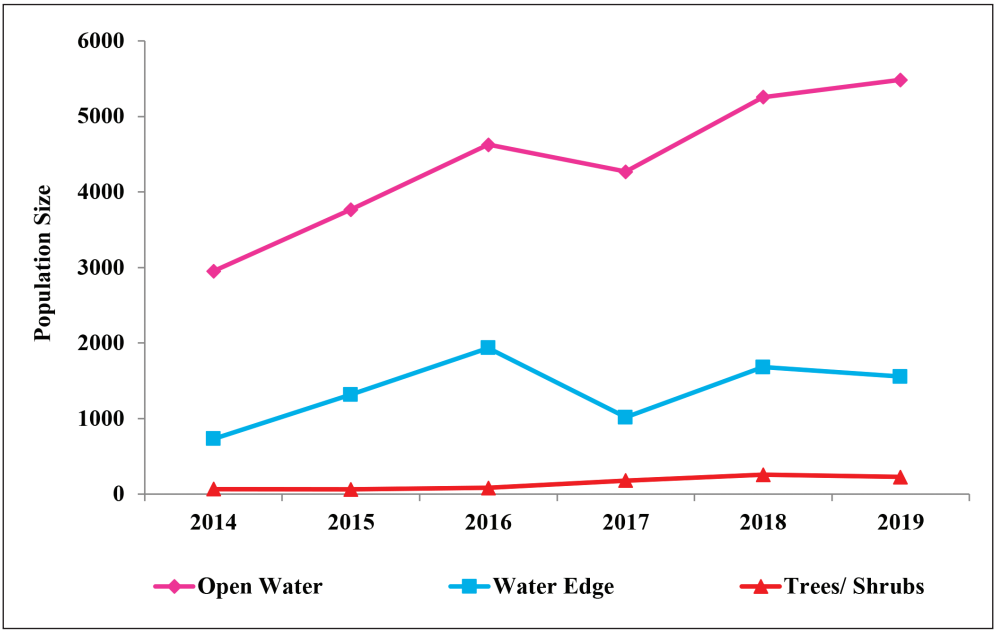

Figure 3. Temporal variation in bird population, 2014–2019
3. ábra A madárpopulációk nagyságának változása 2014–2019 között

in 2019 the recorded number of the waterfowls was 5,485, which accounts for 75.50% of the bird population *(Table 3)*. On the contrary the number of waders and wetland associates was only 1,555 (21.40%) and 225 (3.10%) respectively. More specifically, the greater number of the Lesser Whistling Duck is solely responsible for the dominance of waterfowls in the birds' flock. For example, the number of Lesser Whistling Ducks was 4,008 in 2019, which comprises73.07% of the waterfowls and 55.17% of the total bird population of the area. Since 2014 the Lesser Whistling Duck has constantly occupied the dominant position in the birds' colony and shown an increasing trend over time. From 2014 to 2018, this specific bird species accounts for nearly 38.72%, 48.60%, 53.46%, 53.47% and 51.99% of the total bird population of the area respectively. Hence, they have been intentionally excluded

Table 3. Year-wise birds population, 2014–2019
3. táblázat A különböző madárpopulációk egyedszáma 2014–2019 között

Year	Waterfowls		Waders		Wetland Associated		Total
	Number	%	Number	%	Number	%	
2014	2,952	78.72	730	19.47	68	1.81	**3,750**
2015	3,766	73.18	1,317	25.59	63	1.22	**5,146**
2016	4,626	69.66	1,933	29.11	82	1.23	**6,641**
2017	4,268	78.13	1,016	18.60	179	3.28	**5,463**
2018	5,255	73.06	1,681	23.37	257	3.57	**7,193**
2019	5,485	75.50	1,555	21.40	225	3.10	**7,265**

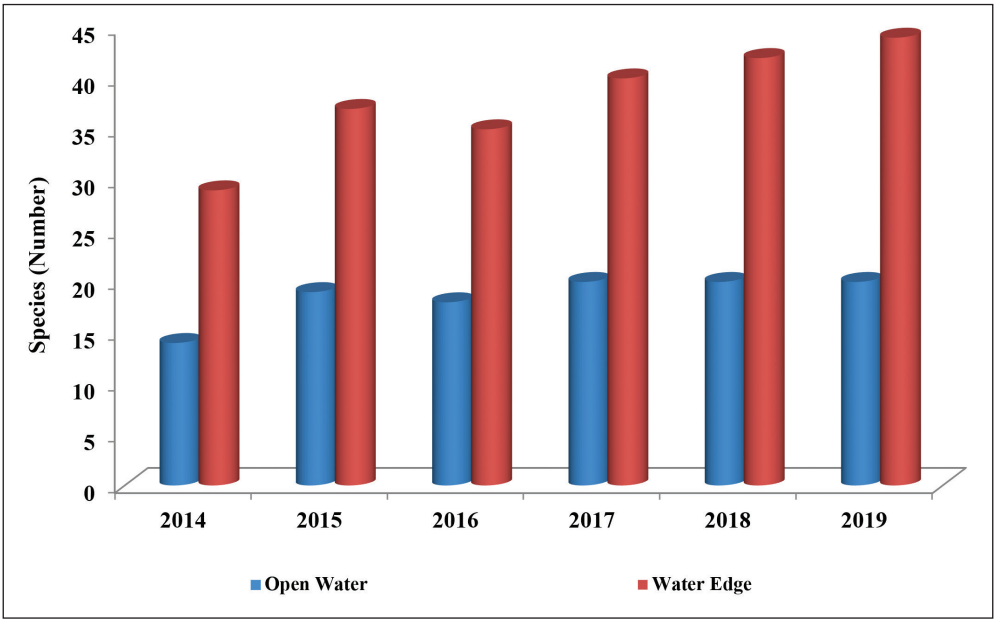

Figure 4. Temporal variation in species richness, 2014–2019
4. ábra A fajgazdagság változása 2014–2015-ben

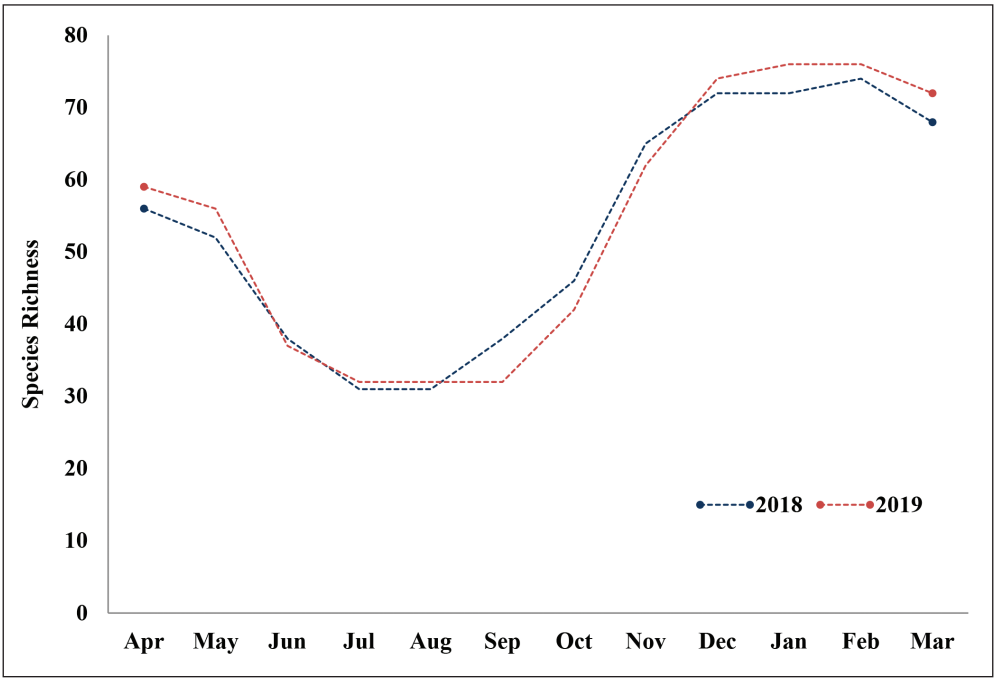

Figure 5. Monthly variationin species richness, 2018–2019
5. ábra A fajgazdagság havonkénti változása 2018–2019-ben

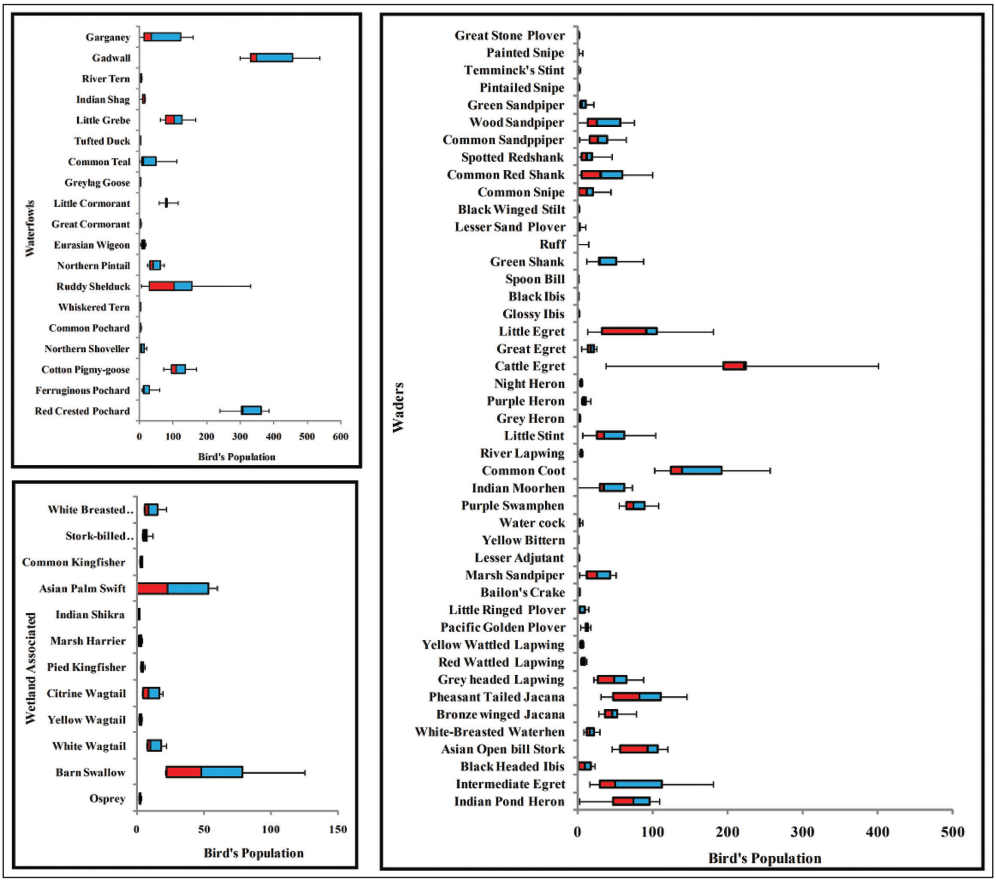

Figure 6. Temporal variation of population of bird species
6. ábra A madárpopulációk időbeli változása

while creating box plots, as their huge fleet distorts the diagrammatic representation of the temporal variation of species *(Figure 6)*.

The species richness has achieved its maximum level during the winter season due to the inflow of a considerable number of migratory birds, while it was reduced during the monsoon *(Figure 5)*. The primary survey has identified 39 winter migrants in the study site, which normally arrive at the beginning of November and stay till the mid of March. Thus, the wetland turns into bliss of migratory birds and a popular winter destination for the bird-watchers and nature-lovers. The monthly variation of species richness in 2018 and 2019 showed an almost similar trend *(Figure 5)*. During the rainy days, adjacent lowlands, floodplains, ponds or any other surface depressions, even the nearby paddy fields get inundated. As a consequence, the extent of the natural habitat as well as the ecological niche of the resident birds gets expanded. This phenomenon helps the birds to spread over a vast area, which reduces species richness in the specific wetland. On the contrary, in summer the wetland becomes the only source of food and shelter for the water birds as other water storages of the area become dried up. Naturally, the species richness lies at

a higher level. Additionally, the arrival of a few summer migrants (like Lesser Whistling Duck) and residents (like Pheasant-tailed Jacana or *Hydrophasianus chirurgus*, Pond Heron, and egrets) has enhanced the species richness during those days.

The temporal data also reveals that most of the waterfowl and shorebird species show remarkable variability in their numbers within the stipulated period *(Figure 6)*. In contrast, the wetland associated birds exhibit striking consistency in number, except one species, of Barn Swallow *(Hirundo rustica)* (Order: Passeriformes, Family: Hirundinidae). Primarily, the members of the Ardeidae family alike various types of egret (Cattle Egret, Little Egret, Intermediate Egret) and heron (Indian Pond Heron) have shown wide fluctuations in their population. Similarly, the flocks of a few open water bird species like Ruddy Shelduck, Garganey *(Spatula querquedula)*, Gadwall *(Mareca strepera)* and Common (Eurasian) Teal *(Anas crecca)* have shown oscillating nature over the stipulated period.

Habitat wise Species Diversity, Richness, and Distribution

The Shannon-Wiener Diversity Index (H′) and Evenness index (E′) is computed for every year separately based on the habitat-wise gathered data *(Table 4)*. Both the H′ and E′ values are found to be less for the open water bird species compared to the other species lived in the water edge area and nearby trees/shrubs during the stipulated period of study. On an average, the birds in water edge areas record the highest H′ value (2.90), whereas, species that live in the trees show the maximum evenness value (0.78). The highest H′ value (3.02) is possessed by the water edge birds during 2019, and maximum E′ value (0.94) is reported by the birds of trees/shrubs in 2014. Similarly, the lowest H′ (1.02) and E′ value (0.34) were recorded for the open water birds in 2016. It has also been observed that the diversity values for the bird species of water edge areas show insignificant fluctuation, whereas birds of the other two categories confirm distinctive variation over the observation periods.

The birds settled in nearby trees / scrubs have shown the lowest species richness, though their H′ and E′ values are higher than open water birds. Maximum species richness but low population figure has been recorded for the water edge birds, where population under various species is not much different from each other and no species can claim its dominance. Hence,

Table 4. Habitat-wise Species Diversity (H′) and Evenness Index (E′)
4. táblázat Fajdiverzitás és kiegyenlítettség a különböző élőhelyeken

Year	Open Water		Water Edge		Trees and Shrubs	
	H′	E	H′	E	H′	E
2014	1.70	0.59	2.83	0.74	2.33	0.94
2015	1.34	0.45	2.95	0.77	2.14	0.86
2016	1.02	0.34	2.83	0.74	2.01	0.81
2017	1.19	0.40	2.82	0.74	1.76	0.71
2018	1.19	0.40	2.97	0.78	1.57	0.63
2019	1.14	0.38	3.02	0.79	1.83	0.73
Average	1.26	0.43	2.90	0.76	1.94	0.78

the diversity of waders and wetland associated birds has become high alike the evenness. On the contrary, low H′ and E′ values of open water birds reveal the remarkable inter-species difference in abundance of the birds and relative dominance of one or two species. The massive dominance of Lesser Whistling Duck in the open water certainly leads to the lowest species diversity and evenness in the studied wetland.

Present threats to the wetland birds

Purbasthali Wetland has been the source of different services to the native rural folks and thus they have utilized the water body in nearly twelve ways such as the collection of material goods (like food, fodder, fuel, clay, humus, etc.), fishing, cattle bathing, bird watching, boating, wetland agriculture (Mandal *et al.* 2020). Indiscriminate extraction of resources and higher degree of utilization nowadays has imposed serious threats upon the physico-chemical as well as biological health of the concerned wetland (Mandal *et al.* 2018). Worldwide anthropogenic interference has extensively damaged the natural habitat of birds through isolation and fragmentation, which have crucially impacted upon the existence and variety of birds (Westphal *et al.* 2006). Human-induced alterations in land use/cover mosaic in different parts of the globe have driven out a significant number of bird species from their original habitats (Burgess *et al.* 2002).

Discharge of effluent, infilling, conversion of bank areas or water edge areas for agriculture, aquaculture, over extraction and utilization of wetland resources are few most common forms of threats, in which reclamation has been pointed out as the most important cause for endangering the birds' species in the Asian region (Kumar *et al.* 2005). The present study site is not an exception. The authors have identified four such distinct human operations, which have become bane to the biodiversity of the lake. These are agricultural expansion and shrinkage of the wetlands area, pollution, establishment of brick kilns *(Figure 1)* and hunting/ trapping of birds. In addition, the use of pesticides and insecticides in the crop fields reduces the food availability for the birds. The use of the sub-marshal pumps for irrigation purposes creates noises which affect the bird abundance in the bank areas. Moreover, farmers often use firecrackers to repel the waders from their fields along the banks of the wetland. The agricultural activities at the bank areas date back to the origin of the water loop, which has expanded gradually and at present a sizable portion of the banks has been transformed into permanent or semi-permanent crop fields through the reclamation of the wetland area. Such human activities have turned the ecotone (transitional areas) into the zone of human-bird conflict, which has directly destroyed the habitat as well as the ecological niche of the waders and affecting their abundance. As the response of birds to changes in habitat differs according to their strategies, few species have successfully adopted the change, while few others get tremendously affected due to their incapability to do so.

The Land Use and Land Cover (LULC) analysis *(Table 5)* of the studied region has been prepared by Maximum Likelihood technique in Arc-GIS. Landsat Satellite Images of 30 meter resolution of 1990, 2000, 2010 and 2020 have been used for the analysis. The LULC is extracted on the basis of 3 km radius from centre of the wetland that exhibits the transformation of land use/cover mosaic over the time. With the help of LULC exact transformation of certain

Table 5. Conversion of water area into other land use categories, 1990–2020
5. táblázat A vízterület átalakítása más földhasználati kategóriákba 1990–2020 között

Land use land cover class/Year	1990	2000	2010	2020	Total
Water bodies	4.0797	3.492	2.2419	1.4598	11.2734
Agriculture land	11.5128	13.6836	14.7096	15.192	55.098
Vegetation	6.6438	5.346	4.7448	1.9557	18.6903
Built up area	2.007	4.5441	6.2307	9.405	22.1868
Other	4.0419	1.2195	0.3582	0.2727	5.8923

land categories are found. *Table 5* disclose rapid shrinkage of the water body from 4.08 km^2 in 1990 to 1.45 km^2 in 2020 with significant increment of cropland and built-up space. Expansion of agricultural land and incessant urban growth are the two prime responsible factors of such conversion. The agricultural area has been increased from 11.51 km^2 in 1990 to 15.19 km^2 in 2020, while the urban area has also been increased from 2 km^2 to 9.41 km^2 in 2020 within the stipulated period. Such swift depletion of open water space of the wetland will become the most potential threat to wetland birds of the area in near future. The works of Mandal and Siddique (2018) and Mandal *et al.* (2018) have already stated that agricultural expansion in the Purbasthali wetland has lessen the abundance of the waders.

In spite of higher degree of human intervention, the water edge areas provide the richest habitat for the birds in terms of species assemblage. *Figure 2* shows 45 species are found in those areas, out of which 20 are migratory and 25 are resident. Nearly 20 species are common to very common, whereas another 13 species are rarely seen. Besides, 12 birds species, observed in the banks, have shown a declining trend in numbers at the global level. One vulnerable species i.e. Lesser Adjutant Stork and two near threatened species namely Great Stone Plover (Order: Charadriiformes, Family: Burhinidae) and Black-headed Ibis (Order: Pelecaniformes, Family: Threskiornithidae) are also found in this zone. Thus, the water edge areas need attention for conservation because further degradation and interruption may cause reduction in the population size or extinction of species. In comparison to the other two types, the waders have shown very less increment in their fleet over the past six years. Apart from them, the waterfowls and the wetland associated birds also need protection. For example, the problem of eutrophication, algal bloom and other invasive species have thwarted the diving and grazing habits of open water birds in many parts of the lake. Over extraction of resources and exhaustive uses of the water body by human groups, trim down the appositeness of the wetland as the habitat of birds. Preventive and curative measures are immediate needs to resolve those problems.

Some precautionary measures were taken through community participation to restrain the negative impact of human interference as well as to make Purbasthali attractive to migratory birds. The local people have also started to get benefits from the promotion of seasonal tourism based on the migratory birds in winter. As a result, the stakeholders have become interested to protect the migratory birds, whereas clear negligence for the resident species has been witnessed. Based on its avifaunal diversity, the lake possesses an immense possibility to be developed as an ecotourism site.

To make the wetland a healthy habitat for birds, the Purbasthali Lake, particularly its bank areas should be protected from human interventions. Use of chemical pesticides/ fertilizers in crop fields should be restricted. Some stringent prohibition should be imposed on unrestrained picnic activities, especially the high decibel sound boxes. The ecotourism guidelines should be strictly imposed to control tourist activities. Plastic material and food packets should be banned while boating and bird-watching. The more scientific method should be adopted for fishing, which will not disturb the assembly of the birds. Above all, mass awareness is imperative to sustain the health of the wetland and its ecological pulse.

Conclusion

Although the value of ecosystem services extended by the Purbasthali wetland is immense in nearby rural life and livelihood, its role as a habitat of birds is equally great, rather more imperative. The *beel* hosts an excellent avifaunal diversity. Thus, its appraisal as mere human common pool resource indeed seems prejudiced and unjust. Now, it has become crucial to assess the ecological value of the concerned wetland in regulating the nature and conserving the biodiversity. Thus, it is essential to gather detailed knowledge and database about its floral and faunal communities. The study represents a comprehensive and informative account of the wetland birds of Purbasthali Lake, which may help the researchers in further studies or the administration in future planning. It is promising that despite conspicuous human intervention, the lake still provides food and shelter to 77 bird species, resident and migratory. This phenomenon signifies that the state of the health of the lake is good enough, though at present the avifauna of the area faces a high degree of human disturbances, which may prove disadvantageous to the abundance of few bird species. Specifically, the waders are facing serious threats due to human encroachment in the bank areas. The entire ecological set up of the Purbasthali Lake has been vulnerable by anthropogenic interference. In such a context, community participation in management of the wetland may become a solution for sustaining the biological resources, especially the birds. Proper management of the *beel* will not only improve the environmental condition for its resident species, but will also attract more migratory and vagrant species in near the future. Awareness among the stakeholders along with the efforts of the local authorities in a participatory manner regarding the conservation of the wetland will help to retain the ecological propriety of this habitat (wetland) of avifauna. Furthermore, the preservation efforts will be equally auspicious to the local human groups too.

Acknowledgements

The authors gratefully acknowledge the help and cooperation extended by the stakeholders, participated during the field survey. They are also indebted to the members of *Junglees* for contributing valuable secondary data. The authors also acknowledge to the guidance and valuable suggestion of Dr. Tibor Csörgő, the Editor-in-Chief of the Ornis Hungarica and two anonymous reviewers.

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