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# Wintering waterbird assemblage in an emerging wetland of West Bengal, India: characterization for conservation management

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**Abstract** Waterbirds constitute a prominent biota and reflect the ecosystem health and functionality of the freshwater wetlands. Documentation of the bird species assemblages of wetlands is therefore carried out as a part of monitoring of wetlands from a sustainability viewpoint. Using the emerging wetland of Purbasthali, West Bengal, India, as a model study area, the diversity of the associated bird species was estimated to supplement necessary information for conservation management of birds and ecosystems. The point count method was applied to count the waterbirds from each sighting location with a 25 m radius covering 360° arc and the counting period lasted 10 min for each site, and counts were made in the winter of 2016/2017. The data on the waterbirds encountered were recorded and subjected to diversity analysis, including the residential status, global population trend and feeding guilds. Apparently, the wetland was considered as suitable habitat for 27 waterbird species, which could be grouped under 24 genera, 10 families and 5 orders. Among these, the family Anatidae with maximum relative density and abundance dominated in the wetland. Out of the 27 recorded species, 5 species were widespread winter visitors, 3 species widespread resident, as well as, widespread winter visitors and 2 species were sparse local winter visitors. A globally near threatened species, the Black-headed Ibis *(Threskiornis melanocephalus)* was very common in the sampling sites. The waterbird assemblage in the wetland was dominated by carnivores followed by omnivores and herbivores. The abundance of the waterbirds with considerable variations in the foraging guild reflects availability and exploitation of multiple resources of the Purbasthali wetlands. Prominence in the differences in relative abundance of the different waterbirds could be linked with the heterogeneity in the habitat quality. The present information on waterbird assemblage calls for appropriate measures for conservation of the species and appropriate management of Purbasthali wetlands.

Keywords: emerging wetland, waterbird, habitat suitability, conservation

**Összefoglalás** A vízimadarak többnyire feltűnő együtteseket alkotnak, és jól tükrözik az édesvízi élőhelyek ökoszisztémájának állapotát és működését. A vizes élőhelyek madárfaj-együtteseinek dokumentálását ezért ezen élőhelyek fenntarthatósági szempontú monitorozásának részeként végzik. Az indiai Nyugat-Bengáliában található Purbasthali nevű vizes élőhely, mint mintaterület vizsgálata az ott előforduló madárfajok sokféleségére vonatkozó becslések szerint olyan kiegészítő információkat szolgáltat, amelyek szükségesek a madarak és az ökoszisztémák megfelelő természetvédelmi kezeléséhez. A vízimadarak számlálására minden egyes megfigyelési helyen pontszámlálási módszert alkalmaztak egy 25 m sugarú körben, 360°-os ívet lefedve, egyenként 10 perces időtartamban. A vizsgálat 2016/2017 telén zajlott. A megszámlált vízimadarak adatait rögzítették és diverzitás elemzésnek vetették alá, beleértve az élőhelyi státuszt, a globális populációs trendet és a táplálkozási guildeket is. Ez a vizes élőhely 27 vízimadárfaj számára bizonyult megfelelőnek, amelyek 24 nemzetségbe, 10 családba és 5 rendbe sorolhatók. A területen az Anatidae család dominált, maximális relatív denzitással és abundanciával. A 27 megfigyelt faj közül 5 gyakori téli vendég, 3 gyakori állandó faj, valamint gyakori téli vendég, 2 faj pedig ritka helyi téli vendég volt. Egy globális léptékben mérve mérsékelten veszélyeztetett faj, a feketefejű íbisz *(Threskiornis* *melanocephalus)* nagy gyakorisággal fordult elő a mintavételi területeken. A vizes élőhelyen megfigyelt vízimadarak együttesében, sorrendben, a ragadozók, majd a mindenevők és a növényevők domináltak. A vízimadarak gyakorisága és a táplálkozási guildek jelentős eltérései jól mutatják a Purbasthali vizes élőhely rendelkezésre álló erőforrásainak gazdagságát és kiaknázhatóságát. Az egyes vízimadárfajok relatív abundanciájában mutatkozó különbségek összekapcsolhatók az élőhely minőségének heterogenitásával. A vízimadarak együtteseiről jelenleg rendelkezésre álló információk megfelelő intézkedéseket tesznek lehetővé és szükségessé a faj megőrzése és a Purbasthali vizes élőhelyek kezelése érdekében.

Kulcsszavak: megújuló vizes élőhely, vízimadár, élőhelyek alkalmassága, megőrzés

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## Introduction

Wetland ecosystems are the most productive and diversified aquatic ecosystems with higher economic, as well as, ecological values representing a balance between the environment and the life in it (Aynalem & Bekele 2008, Khan 2010). They provide an array of precious services for the environment and civilization (Zedler & Kercher 2005, Biggs *et al.* 2017). Occupying about 6% of the Earth's surface, they are able to maintain ecological sustainability and by providing suitable habitat for a large number of species established as assets of biodiversity (Gopal & Sah 1995, Zedler & Kercher 2005). However, huge resource availability and habitat suitability makes the wetland favourable place for many of the species; among them, waterbirds are the most important component of that ecosystem (Collar & Andrew 1988, Adhurya *et al.* 2020). Waterbirds absolutely depend on wetland habitat for their existence. They use certain wetlands as a microhabitat for their reproduction, nesting and feeding activities (Weller 1999, Hazra *et al.* 2012). Many of these waterbirds spend a certain period of time in one wetland and the rest of the time to another showing seasonal migratory behaviour (Gatto *et al.* 2005). Owing to their insightful response to sudden changes in habitat quality, vegetation composition and resource availability of the wetland, the species composition, diversity and abundance in waterbird populations are strongly affected, thus, they are considered to be an excellent bio-indicator in favour of the health of the ecosystem (Gregory *et al.* 2003, Bhat & Hosetti 2009). Due to the lack of proper knowledge on functioning wetlands, numerous threats arise because of anthropogenic activities that could lead to habitat destruction, pollution and overexploitation of the resource in wetlands. According to some estimates over 50% of the wetland habitats of the world are lost in the last century (Fraser & Keddy 2005, Datta 2011, Davidson 2016). Thus, to protect the wetlands from serious threats spreading of awareness, making conservation policies and their proper implementation is necessary (Islam & Rahmani 2008, Céréghino *et al.* 2014). India is blessed with a large number of wetlands varied from larger to smaller in size occupying about 15.26 million ha of the area (Panigrahy *et al.* 2012, Kumar *et al.* 2016). In addition to 37 wetlands with international importance under Ramsar convention, India has more than five hundred thousand other natural or artificial wetlands containing inland deltas, freshwater ponds, permanent or intermittent freshwater or brackish lakes extended in an area of 2.25 ha (Panigrahy *et al.* 2012). All of these wetlands providing a suitable habitat, which ensures the existence of more than 310 bird species, out of them, 107 winter migrants are known to depend completely on wetland habitat (Manakadan & Pittie 2001, Kumar *et al.* 2005). All of these birds are known to gather in wetlands of different parts of India and their diversity become highest during the winter season (Khan *et al.* 2016, Mazumdar 2019). Diversity of waterbirds is one of the most essential features explaining of the status, productivity and the health of wetlands (Muñoz-Pedreros & Merino 2014). That is the way it is more preferable to observe the community structure of waterbirds to get adequate information about the impact of environmental changes and anthropogenic activities on sustainability of wetland ecosystems (Islam & Rahmani 2008, Mukhopadhyay & Mazumdar 2017). Therefore, in the course of the survey of waterbirds, and estimating the species assemblage pattern, a prediction on the functional integrity of the ecosystem, as well as, planning for proper protection of water bodies can be made.

The wetland of Purbasthali, physiographically an oxbow lake of Gangetic Alluvial Plains (Mandal & Siddique 2018), has long been familiar as it provides suitable habitat for a large number of bird species. However, few works have been accomplished (Jha 2013, Debnath *et al.* 2018) on the diversity and distribution of various bird species that reside in this wetland. This is the first time when a survey was focused mainly on diversity of all kinds of waterbird considering their foraging guilds during midwinter, when they are known to show maximum abundance (Khan *et al.* 2016). Thus, the present study aims to represent the species diversity through field observation and count of the waterbird population during winter, to characterize the species assemblage of waterbirds and to identify the waterbirds with global importance. The study explores the primary observations made on the waterbird species (Mandal & Siddique 2018) emphasizing the trophic guilds, relative abundance and diversity indices. The monitoring of the waterbirds is promoted as a basis for conservation management and sustenance of the ecosystem services derived from the freshwater wetlands. The resultant information of the present study will facilitate planning strategies for conservation of the waterbirds, as well as the emergent freshwater lake of Purbasthali, West Bengal, India.

## Material and Methods

### Study area

The present study was conducted in Purbasthali Oxbow Lake (regionally named as Chupi char), is actually categorized as a wetland of Gangetic Alluvial Plain (Mandal & Siddique 2018). This wetland is formed naturally by the meandering of Bhagirathi River on its right bank. Geographically, it is situated at the boundary of Burdwan and Nadia districts of West Bengal, extending in between the coordinates of 23°25′55″N to 23°27′52″ N and 88°19′45″ E to 88°21′55″ E *(Figure 1)*. The spatial coverage of water in this wetland area was 3.2 km$^2$ during the study period. The maximum depth and width of wetland range from 2.5–6.0 m and 450–550 m, respectively. The cold season starts in the beginning of November and lasts for four months, to the end of February. The average temperature was 20 °C during the study period. Throughout its entire area, the wetland possesses a large number of macrophytes like common water hyacinth *(Eichhornia crassipes)*, duckweed *(Lemna minor)*, water lettuce (*Pistia* sp.), water nymph (*Najas* spp.), floating heart (*Nymphoides* spp.), ditch grasses (*Ruppia* spp.), pondweed (*Potamogeton* spp.), etc. Several snail species including *Lymnaea acuminata, Indoplanorbis exustus, Gabbia orcula* and *Gyraulus convexiusculus*

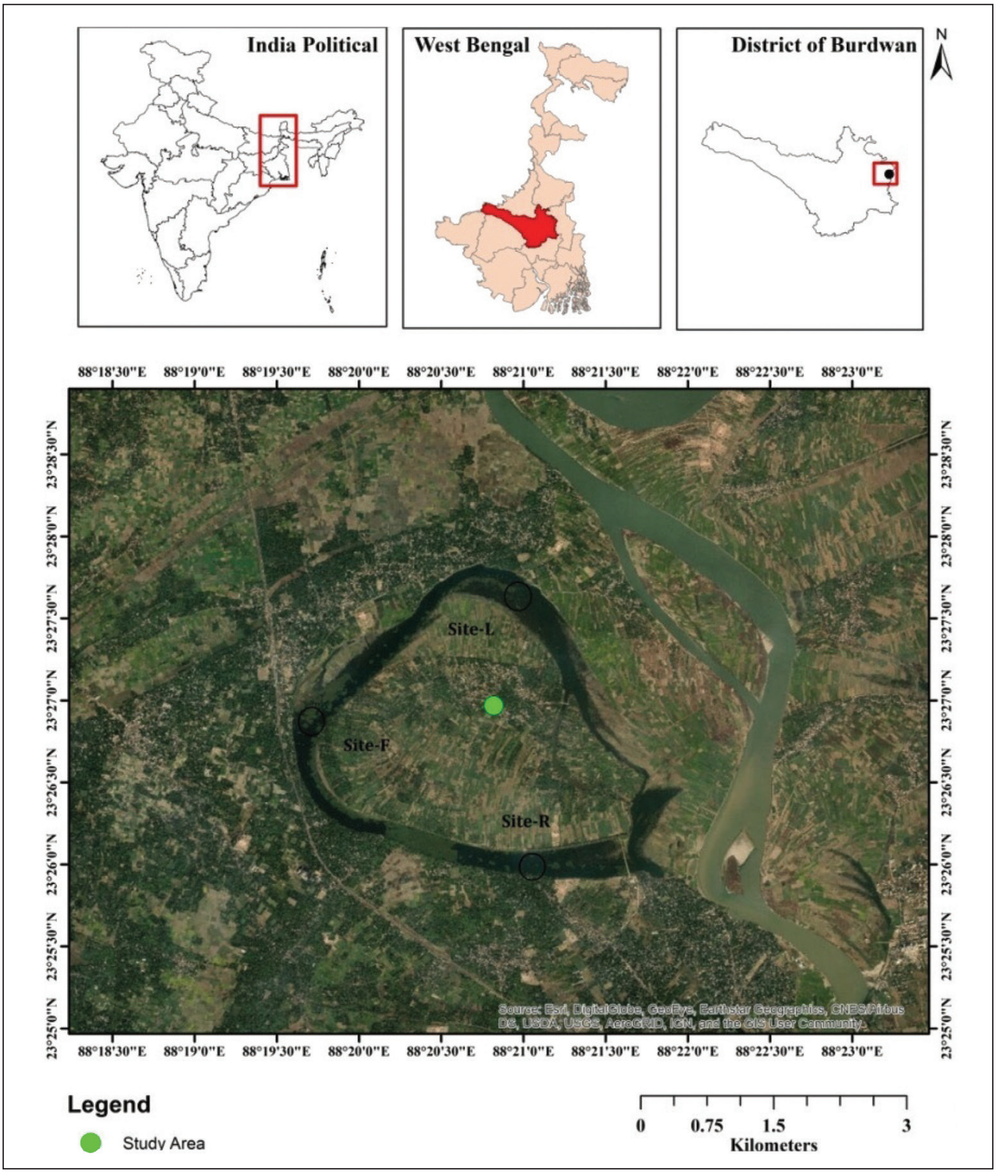


*Figure 1.* Location of the study area and the sampling sites along the Purbasthali wetland, West Bengal, India

*1. ábra* A vizsgálati terület és a mintavételi helyek elhelyezkedése a Purbasthali melletti vizes élőhelyen (Nyugat-Bengália, India) were observed attached with the leaves of the macrophytes. Moreover, it also supports a rich diversity of insects, crustaceans and fish. In course of the observations on the wetland waterbirds, selected physicochemical parameters of the wetland water were estimated and the values were (represented as Mean±SE); pH: 7.2±0.27, Total Dissolved Solids: 148±13.8 ppm, Dissolved Oxygen: 7.11±0.19 ppm, $NH_4^+$-N 0.31±0.04 mg/L, $PO_4^{3-}$-P: 0.04±0.009 mg/L and $NO_3^-$-N: 0.12±0.02 mg/L.

## Census methods

The present study was carried out between November 2016 to February 2017 to have the comprehensive idea about the diversity and abundance of waterbirds at Purbasthali wetland. The waterbird counts were made by employing boat and following the same methods suggested by Wetlands International (2006) and Sinha *et al.* (2011). Each time of the survey, the waterbird counts were started at 8:00 AM and continued until the counts on entire area could be completed, approximately till 6:00 PM in the evening. In this study, the point count method was applied (Bibby *et al.* 1993) to count the waterbirds. In each day, the wetland was entirely surveyed by moving slowly on the boat following the same route and stopping at each preselected vintage point to count the waterbirds. The positions and numbers of vintage points were placed randomly in view of the size of the wetland. Waterbirds counts from all points were repeated at a regular interval of 7days and for each site, counting period lasted for 10 min to minimize the counting errors (Sarkar *et al.* 2014, Muñoz-Pedreros *et al.* 2018, Issa 2019). Birds were counted from each sighting point with a 25 m radius covering 360° arc (Hutto *et al.* 1986, Issa 2019). The intensity of sampling was evaluated through previous censuses following the rarefaction, as well as species accumulation methods (Willson *et al.* 1994). To count the waterbirds, a binocular (Olympus 7×21 PS III) was used and the photographs of waterbirds were taken by Nikon P900 for further identification. The birds were identified observing the photography (Grimmett *et al.* 1998, Kazmierczak & van Perlo 2000, Ali 2002) and recorded for analysis. The data on the relative abundance of each bird species was made with reference to the day surveyed and the data were used for the diversity analysis and estimation of the assemblage characteristics.

## Data analysis

The relative diversity ($RD_i$) of each bird family was estimated following the equation (Torre-Cuadros *et al.* 2007):

$$RD_i = \frac{\text{Number of species in the family}}{\text{Total number of species}} \times 100$$

Relative abundance of each species was measured, from the count of the birds in each day. On this basis, they were categorized into very common (VC) species, where they were found in 75–100% of total visits; common (CO) species observed 50–74% of visits; uncommon (UC) 25–49% of field visits and less common (LC) recorded less than 25% of total visits (Manakadan & Pittie 2001, Tak *et al.* 2010). They were also categorized on the basis of their seasonal dispersal pattern into widespread resident (R), widespread winter visitor (W), widespread resident as well as widespread winter visitors (RW) and sparse local winter visitors (rW) (Kazmierczak 2000). The status of global population trends was collected from the IUCN Red List (del Hoyo *et al.* 1996) and by following IUCN website (https://www.iucnredlist.org/).To obtain the diversity indices of waterbird abundance, the data taken from each study site were analysed separately using Biodiversity Pro software (McAleece *et al.* 1997 Biodiversity Professional; Scottish Association for Marine Science and the Natural History Museum, London, UK). Species richness (S) was calculated by totalling the number of different species present in that area (Mukherjee *et al.* 2015, Issa 2019). Diversity of waterbird species was represented by calculating Shannon diversity index [$H' = -\sum (P_i \ln P_i)$], Simpson index [$D = 1 - (\sum n(n-1))/N(N-1)$] and Shannon $H_{max}$ [$H_{max} = \log_{10}(S)$]. To compare the similarity of population size of each waterbird species the evenness [$J = H'/H_{max}$] was calculated, where $P_i$ is the proportion of total samples belonging to i$^{th}$species, n is the total number of waterbirds belongs to a particular species and N includes the total number of waterbirds of all species (Magurran 1988). The relationship among species richness (S), information (H), and evenness (J) in the samples was made by SHE analysis (Buzas & Hayek 1998). Foraging guilds were determined by examining their feeding habitat. In our observation, we found waterbirds species belonging to three feeding guilds, i.e. carnivore (CARV), herbivore (HERV) and omnivore (OMNV) (Ali & Ripley 1980, Hutto 1986). A non-parametric Kruskal-Wallis test followed by multiple pair-wise comparisons (Dunn method with Bonferroni correction) was carried out to analysis the differences between foraging guilds considering their species composition. The statistical analyses were performed following Zar (1999) using the XLSTAT software (Addinsoft 2010).

In order to highlight the indicator value of the waterbird species, the observations were classified into three clusters for application of the IndVal method (Dufrêne & Legendre 1997). The estimation was initiated with the assumption that for each species *i*, in each cluster *j*, $A_{ij}$ is the mean abundance of species *i* in the clusters *j,* and $B_{ij}$ is considered as the relative frequency of occurrence of species *i* in the clusters *j* (Dufrêne & Legendre 1997). The cluster *j* in the present instance includes discrete observations of certain days representing the term sites in the original definition (Dufrêne & Legendre 1997). The measure $A_{ij}$ represents the specificity that relies on the abundance values while the term $B_{ij}$ represents fidelity, depending on the presence data of the $i^{th}$ species in the clusters. In this estimation, the mean number of individuals in each cluster is used to sum the total individuals in all the observations under a cluster, thereby removing the effect of variations owing to the discrete observation under the various clusters. Similarly the representation of $B_{ij}$ is indicative of the presence of $i^{th}$ species in *j* clusters among the *N* number of sites, in $N_j$ number of sites in $N_j$+ number of sites. Following the calculation of the specificity and fidelity, the indicator value of the species was calculated as the indicator value, IndVal for cluster *j*, species $i = 100 \times A_{i,j} \times B_{i,j}$; where, $A_{i,j}$ represents specificity and B*i,j* represents fidelity defined in accordance with the IndVal proponents (Dufrêne & Legendre 1997). The IndVal for a species is deduced as: $IndVal_{speciesi} = \max[IndVal_{i,j}]$. The significance of the IndVal for a species is judged through a permutation test, carried out in R software (‘indicspecies’ package) (De Cáceres & Legendre 2009). In order to deduce the indicator value of the waterbirds, the observations were broken into three clusters consisting of 5, 5 and 4 days followed by the application of the data in R software (De Cáceres 2020).

## Results

### Sampling adequacy and waterbird species records

Sampling efficiency was measured based on the number of waterbird species encountered during the study period (sampling days) which reached in more or less stable form on or after 10th sampling day *(Figure 2)*. During the course of this study, it was recorded that this emerging wetland providing a habitat of 27 waterbird species belongs to 24 genera, 10 families and 5 orders *(Table 1)*. The maximum numbers of waterbird species were recorded under family Anatidae with 7 species (25.93%) followed by Ardeidae with 5 species (18.52%), Rallidae with 4 species (14.81%), Phalacrocoracidae with 3 (11.11%), Jacanidae and Charadriidae each with 2 species (7.41% each), and Podicipedidae, Ciconiidae, Threskiornithidae and Scolopacidae each with 1 species (3.7% each).

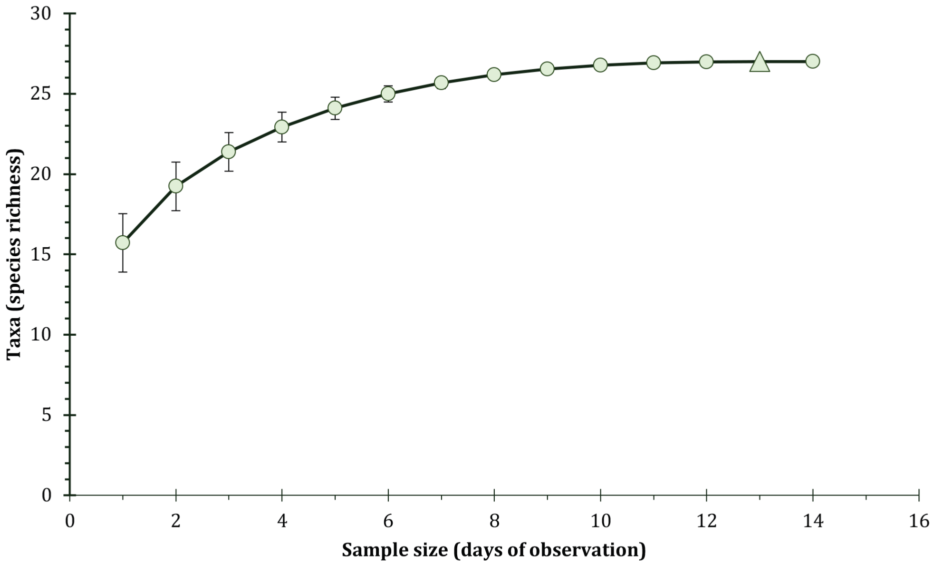


*Figure 2.* Sample-based rarefaction curve (species accumulation curve) representing the relationship of sampling effort (days) and number of species encountered in the study area. The species saturation (27 species) was observed on the 13th sample (13th day) and is marked with a triangle. The standard error values are provided for each point (sample)

*2. ábra* Minta-alapú ritkítási görbe (fajtelítődési görbe), amely a mintavételi ráfordítás (napok) és a vizsgálati területen megfigyelt fajok számának összefüggését mutatja. A fajtelítettséget (27 faj) a 13. mintán (13. nap) figyelték meg, ezt háromszög jelöli. Az egyes pontokhoz (mintákhoz) kapcsolódó függőleges vonalak a standard hibaértékeket jelölik

*Table 1.* List of waterbirds recorded in Purbasthali wetland together with their feeding guild (HERB=herbivore, OMNV=omnivore and CARV=carnivore), residential status (R= widespread resident, W=widespread winter visitor, RW=widespread resident as well as widespread winter visitors and rW=sparse local winter visitor), relative abundance (VC=very common, CO=common, LC=less common, UC=uncommon) andglobal population trend (ST= stable, IN=increasing, DE=decreasing and UN= unknown). *IUCN near threatened species

*1. táblázat* A Purbasthali vizes élőhelyen megfigyelt vízimadarak táplálkozási guildjeikkel együtt (HERB=növényevő, OMNV=mindenevő és CARV=ragadozó), helyi státuszuk (R=széles körben előforduló állandó faj, W=széles körben előforduló téli vendég, RW=széles körben előforduló állandó, valamint széles körben előforduló téli vendégek és rW=ritka, helyi téli vendég), relatív abundanciájuk (VC=nagyon gyakori, CO=-gyakori, LC=ritkább, UC=nem gyakori) és globális populációs trendjük (ST=stabil, IN=növekvő, DE= csökkenő és UN=ismeretlen). * IUCN mérsékelten veszélyeztetett fajok

| Order | Family | Common Name | Scientific Name | Acronym used | Feeding guild | Residential status | Relative abundance |
|---|---|---|---|---|---|---|---|
| **Anseriformes** | Anatidae | Cotton Pygmy Goose | *Nettapus coromandelianus* (Gmelin, 1789) | NCO | HERB | R | VC |
| | | Gadwall | *Mareca strepera* (Linnaeus, 1758) | MST | HERB | W | CO |
| | | Lesser Whistling-duck | *Dendrocygna javanica* (Horsfield, 1821) | DJA | OMNV | R | VC |
| | | Red Crested Pochard | *Rhodonessa rufina* (Pallas, 1773) | RRU | HERB | W | CO |
| | | Ruddy Shelduck | *Tadorna ferruginea* (Pallas, 1764) | TFE | OMNV | rW | LC |
| | | Ferruginous Pochard | *Aythya nyroca* (Güldenstädt, 1770) | ANY | OMNV | rW | LC |
| | | Northern Pintail | *Anas acuta* (Linnaeus, 1758) | AAC | OMNV | W | LC |
| **Charadriiformes** | Jacanidae | Bronze-winged Jacana | *Metopidius indicus* (Latham, 1790) | MIN | OMNV | R | VC |
| | | Pheasant-tailed Jacana | *Hydrophasianus chirurgus* (Scopoli, 1786) | HCH | OMNV | R | LC |
| | Charadriidae | Grey-headed Lapwing | *Vanellus cinereus* (Blyth, 1842) | VCI | CARV | W | CO |
| | | Red-wattled Lapwing | *Vanellus indicus* (Boddaert, 1783) | VIN | CARV | R | UC |
| | Scolopacidae | Wood Sandpiper | *Tringa glareola* (Linnaeus, 1758) | TGL | CARV | W | CO |
| **Gruiformes** | Rallidae | Common Coot | *Fulica atra* (Linnaeus, 1758) | FAT | OMNV | RW | VC |

| Order | Family | Common Name | Scientific Name | Acronym used | Feeding guild | Residential status | Relative abundance |
|---|---|---|---|---|---|---|---|
| | | Purple Swamphen | *Porphyrio porphyrio* (Linnaeus, 1758) | PPO | OMNV | R | LC |
| | | Common Moorhen | *Gallinula chloropus* (Linnaeus, 1758) | GCH | OMNV | R | LC |
| | | White-breasted Waterhen | *Amaurornis phoenicurus* (Pennant, 1769) | APH | OMNV | R | LC |
| Pelecaniformes | Ciconiidae | Asian Openbill | *Anastomus oscitans* (Boddaert, 1783) | AOS | CARV | R | VC |
| | Threskiornithidae | *Black-headed Ibis | *Threskiornis melanocephalus* (Latham, 1790) | TME | CARV | R | VC |
| **Pelecaniformes** | Ardeidae | Cattle Egret | *Bubulcus ibis* (Linnaeus, 1758) | BIB | CARV | R | VC |
| | | Intermediate Egret | *Ardea intermedia* (Wagler, 1829) | AIN | CARV | R | LC |
| | | Indian Pond-Heron | *Ardeola grayii* (Sykes, 1832) | AGR | CARV | R | VC |
| | | Little Egret | *Egretta garzetta* (Linnaeus, 1766) | EGA | CARV | R | VC |
| | | Purple Heron | *Ardea purpurea* (Linnaeus, 1766) | APU | CARV | RW | LC |
| | Phalacrocoracidae | Indian Cormorant | *Phalacrocorax fuscicollis* (Stephens, 1826) | PFU | CARV | R | LC |
| | | Little Cormorant | *Microcarbo niger* (Vieillot, 1817) | MNI | CARV | R | LC |
| | | Great Cormorant | *Phalacrocorax carbo* (Linnaeus, 1758) | PCA | CARV | RW | LC |
| **Podicipediformes** | Podicipedidae | Little Grebe | *Tachybaptus ruficollis*(Pallas, 1764) | TRU | CARV | R | VC |

### Residential status, global population trends and relative abundance of recorded species

Out of 27 recorded waterbird species, 17 species (62.96%) were widespread residents (R), 5 species (18.52%) widespread winter visitors (W), 3 species (11.1%) widespread resident as well as widespread winter visitors (RW) and 2 species (7.41%) were sparse local winter visitors (rW) (Kazmierczak 2000). Among all reported waterbirds varieties, only one species, the Black-headed Ibis, was near threatened according to the IUCN, very common to the studied area and rest are the least concerned species. Considering the global population trend, it was noticed that the surveyed area holds 3 waterbird species known to follow the stable population trend (ST), 5 increasing (IN), 10 with unknown (UN) and noticeably,9 species known to follow the decreasing (DE) population trend. We observed that among these nine species three were very common (VC), one species was common (CO) and five species were less common (LC) to the area *(Figure 3)*. Three species (Lesser Whistling Duck, Black-headed Ibis and Little Grebe) following globally declining population (DE) trend were found very common (VC) to the studied area while one species (Grey Headed Lapwing) of the global DE category was common (CO) and the other five species (Ferruginous Pochard, Northern Pintail, Pheasant Tailed Jacana, Intermediate Egret and Purple Heron) of the same category were less common to the area. Mean±SE of the total number of species of Lesser Whistling Duck and Little Grebe were 34.14±5.95 and

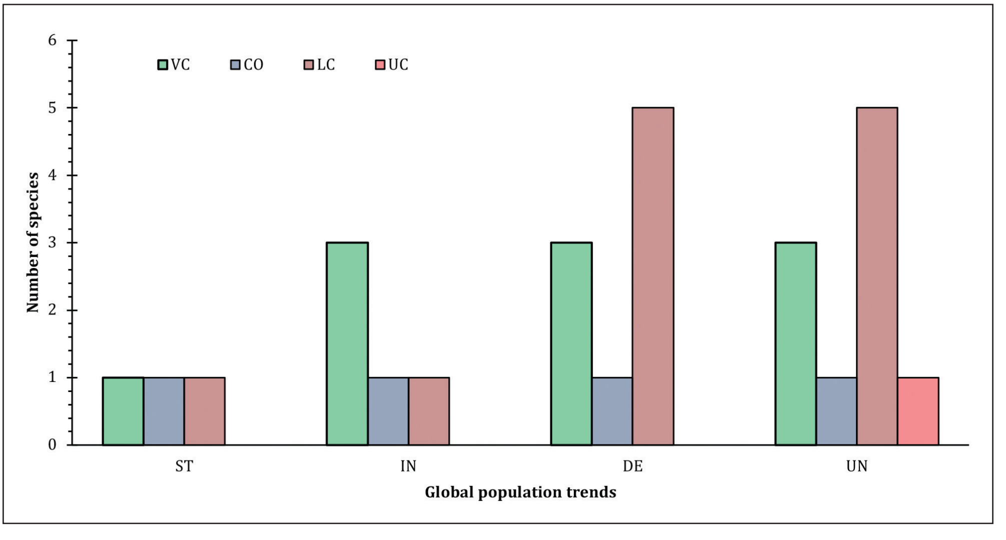


*Figure 3.* Comparison of relative abundance (VC, CO, LC and UC) and global population trend (ST, IN, DE and UN) of bird species observed from Purbasthali, West Bengal, India (VC=very common, CO=common, LC=less common, UC=uncommon, ST=stable, IN=increasing, DE=decreasing and UN=unknown)

*3. ábra* Az indiai Purbasthaliban (Nyugat-Bengália) megfigyelt madárfajok relatív abundanciájának (VC, CO, LC és UC) és globális populációs trendjének (ST, IN, DE és ENSZ) összehasonlítása (VC=nagyon gyakori, CO=gyakori, LC=kevésbé gyakori, UC=ritka, ST=stabil, IN=növekszik, DE=csökken és UN=ismeretlen)

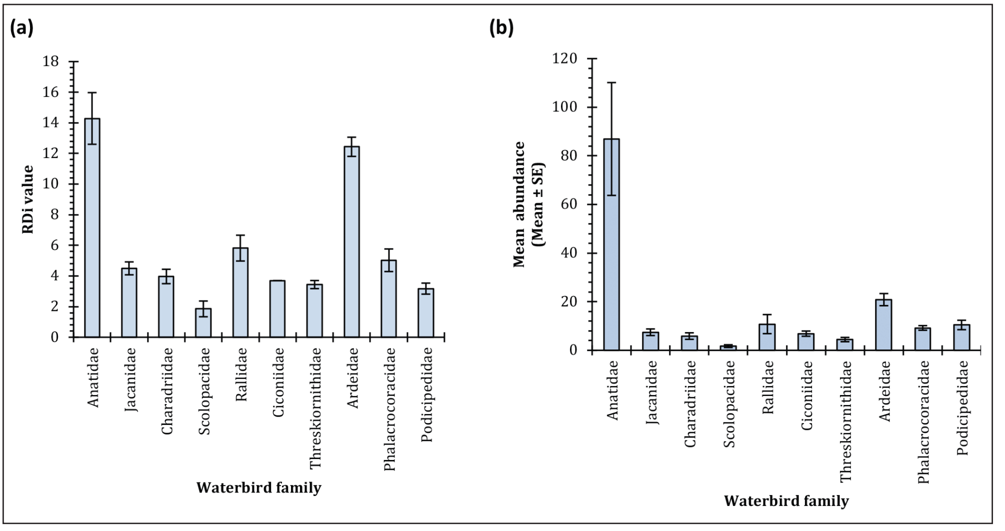


*Figure 4.* a – Relative diversity ($RD_i$) and b – mean abundance of various waterbird families recorded from Purbasthali wetland, West Bengal, India

*4. ábra* a – Relatív diverzitás (RDi) és b – átlagos abundancia az indiai nyugat-bengáli Purbasthali vizes élőhelyről feljegyzett vízimadár családok esetén

10.42±1.94, respectively. Observing the relative abundance of all waterbird species, it was reported that ten species (37.04%) were very common (VC), four species were common (14.81%), while another twelve species (44.4%) were less common (LC) and the remaining one species were uncommon (CO). The relative abundance was the highest for Red Crested Pochard (38.57±22.38) and the lowest for Purple Heron and Little Cormorant (0.21±0.11 for each). Throughout the sampling period, a total of 540 Red-crested Pochard was counted, which was the maximum in number compared to the other species.

## Relative diversity ($RD_i$) and mean abundance of various waterbird families

Comparing the relative diversity ($RD_i$), as well as mean abundance values among the recorded avian families *(Figure 4a, b)* revealed that Anatidae having maximum relative diversity (7 species, $RD_i$=14.29±1.69) and mean abundance value, followed by Ardeidae (5 species, $RD_i$=12.43±0.62) represented dominant group, while Scolopacidae with a single species ($RD_i$=1.85±0.51) poorly represented in the study area.

## Analysis of diversity indices

Along the wetland habitat, the values of diversity indices were recorded for waterbirds as species richness (S=15.71±0.94), Shannon-Weiner diversity index (H'=2.24±0.08), Simpson's Diversity (D=0.84±0.02), Shannon evenness (J=0.82±0.03) and maximum diversity value ($H_{max}$=2.73±0.05).As revealed through the output of SHE analysis *(Figure 5)*, the association among S (species richness), H (information), and E (evenness) in the

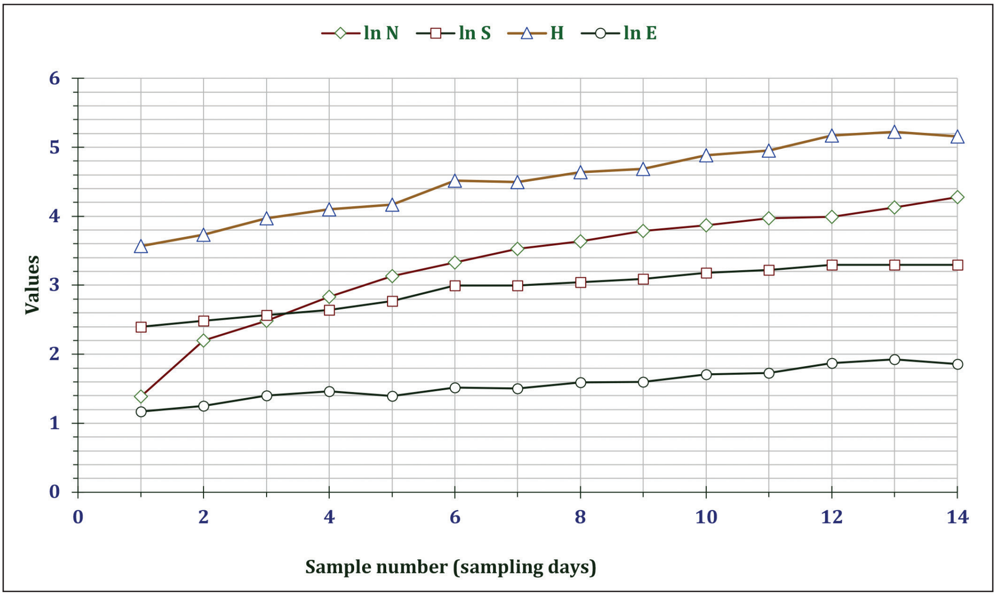


*Figure 5.* Plot of SHE analysis calculated on four months data of relative abundance of 27 waterbird species reported in Purbasthali wetland, West Bengal, India. Each point in x-axis represents a sampling day consisting of multiple observations

*5. ábra* Az SHE-analízis görbéje 27 vízimadárfaj relatív abundanciájának négy hónapos adatai alapján számolva, amelyeket a Purbasthali vizes élőhelyen figyeltek meg Nyugat-Bengáliában (India). Az x tengely minden pontja egy mintavételi napot jelent, amely több megfigyelésből áll

samples can be interpreted properly. For this multispecies community as the number of individuals (N) accumulated with each sampling effort, the species richness (S) usually increases. In the meantime, it was very prominent in the studied community that H increases as InS increases and InE decreases with the accumulation, while the ratio InE/lnS remain constant. Kind of departures from the linear trends specified a diversified community.

## Feeding guilds of waterbirds

The recorded waterbird species were divided into three feeding guilds observing their habitat use and foraging behaviour during the survey. The results revealed that the waterbird species in that habitat were dominated by carnivore group (51.85%) followed by omnivore (37.04%) and herbivore (11.11%) *(Figure 6)*. Comparing the relative abundance of the species among the foraging guilds it was observed that they varied significantly (Kruskal-Wallis test: K=35.03, df=2, P<0.05). For a more specific comparison of single variable between feeding guilds a pair wise post-hoc comparisons using Dunn's test with the Bonferroni correction was carried out (between carnivore and herbivore: 27.179, P<0.0001; between carnivore and omnivore: 13.321; P<0.0037, and between herbivore and omnivore: 13.857, P<0.0025; with the critical value for two tailed Dunn's comparison being 10.994; Bonferroni corrected significance level: 0.0167). Thus the significant differences between

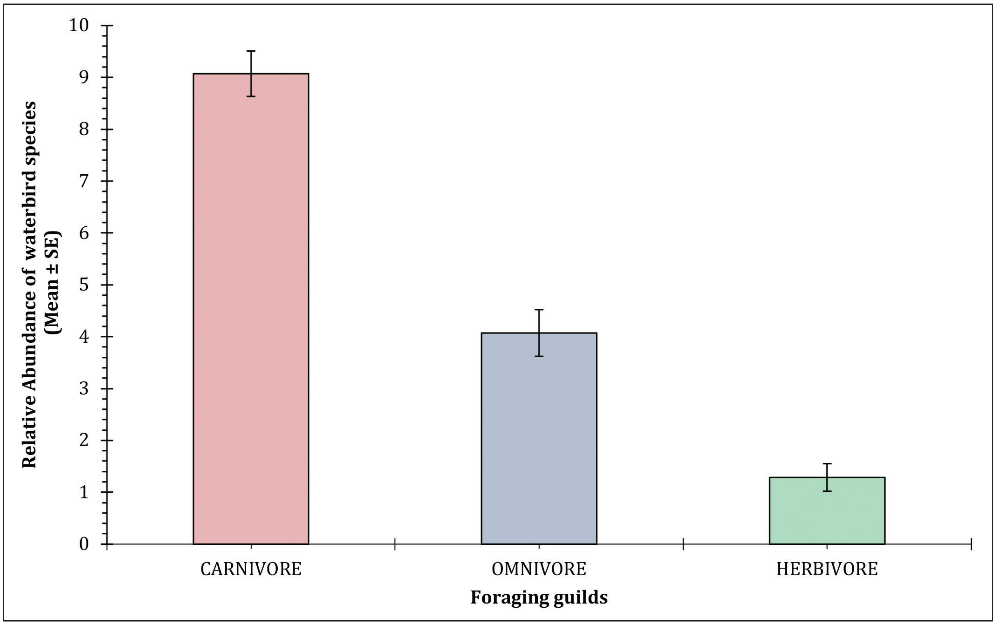


*Figure 6.* Relative abundance of waterbird species belonging to three foraging guilds recorded in the study area

*6. ábra* A vizsgálati területen megfigyelt vízimadárfajok relatív abundanciája három különböző táplálkozási guild szerinti megoszlásban (carnivore – ragadozó, omnivore – mindenevő, herbivore – növényevő)

each pair of foraging guilds in the study area (Bonferroni Dunn; $P<0.05$) are indicative of diverse species assemblages of waterbirds in the Purbasthali wetlands.

### Indicator value for waterbird species

The indicator values of waterbird species observed in the samples are shown in *Table 2* along with the relative abundance in the samples. Following preliminary assessment the IndVal differed for the species and between the clustered samples. However, on the basis of the results of the permutation tests, the IndVal values of the four bird species, RRU, PPO, APU, and MST bear significance at $P<0.001$ level as shown in *Table 2*. In addition, the IndVal of TRU was also significant when values from two groups (clusters) were taken together. Thus, out of 27 species recorded, five species remained significant in terms of their IndVal score based on the relative abundance in the samples.

## Discussion

The study site Purbasthali oxbow lake, situated in Burdwan, India is a natural emerging wetland, which features a range of waterbird species during the winter season (November

*Table 2.* The relative abundance of the representative waterbirds and the contribution to the IndVal in the three clusters deduced from the samples. A randomization test (multilevel pattern analysis, indicspecies package of R) for the IndVal was carried out to conclude about the significant values of the respective species. A and B corresponds to the specificity and fidelity respectively as described in the IndVal equation

*2. táblázat* A vízimadarak relatív abundaciája és IndVal értékei. A randomizációs teszt (többszintes mintázat elemzés az indicspecies R csomagban) megadja a fajok IndVal értékeihez tartozó szignifikancia értékeit. A és B az IndVal egyenlet megfelelő paramétereit mutatja

| **Acronym** | **Range, Mean±SE** | **IndVal,** | **Acronym** | **Range, Mean±SE** | **IndVal,** |
|---|---|---|---|---|---|
| NCO | 2–16<br>7.21±1.02 | **8.1188** | GCH | 0–3<br>0.43±0.25 | 6.67 |
| MST | 0–25<br>6.07±1.95 | 17.941 | APH | 0–2<br>0.29±0.16 | 9.38 |
| DJA | 12–80<br>34.14±5.95 | **8.9958** | AOS | 4–18<br>6.86±1.07 | 10.42 |
| RRU | 0–300<br>38.57±22.37 | **21.481** | TME | 0–11<br>4.43±0.88 | **11.935** |
| TFE | 0–2<br>0.36±0.2 | **7.5** | BIB | 3–14<br>6.14±0.84 | **8.8372** |
| ANY | 0–2<br>0.29±0.19 | **12.5** | AIN | 0–2<br>0.29±0.16 | 3.125 |
| AAC | 0–2<br>0.29±0.16 | **6.25** | AGR | 5–25<br>11.07±1.47 | **9.9355** |
| MIN | 2–21<br>7.07±1.32 | **9.3434** | EGA | 0–7<br>3.14±0.53 | 10 |
| HCH | 0–2<br>0.38±0.2 | 2.5 | APU | 0–1<br>0.21±0.11 | 18.75 |
| VCI | 0–17<br>4.29±1.42 | 8.8 | PFU | 3–15<br>8.57 ± 0.96 | **8.3333** |
| VIN | 0–8<br>1.57±0.66 | 6.82 | MNI | 0–2<br>0.21±0.15 | 8 |
| TGL | 0–6<br>1.71±0.57 | **3.67** | PCA | 0–3<br>0.43±0.25 | 6.67 |
| FAT | 0–44<br>8.43±3.03 | 15.89 | TRU | 0–24<br>10.43±1.94 | 11.47 |
| PPO | 0–12<br>1.64±0.97 | **18.75** | | | |

Multilevel pattern analysis; Total number of species: 27; Selected number of species: 5; Number of species associated to 1 group: 4; Number of species associated to 2 groups: 1 Group 2, species 4, Group 2+3=1 species (STAT–represents the values obtained through random permutation in R)

| Group 2 only | A | B | STAT | P value |
|---|---|---|---|---|
| RRU | 0.9297 | 1 | **0.964** | 0.024 |
| PPO | 0.9014 | 1 | **0.949** | 0.021 |
| APU | 0.8889 | 1 | **0.943** | 0.026 |
| MST | 0.7593 | 1 | **0.871** | 0.050 |
| Group 2+3 | | | | |
| TRU | 0.8887 | 1 | **0.942** | 0.016 |

to February). Information on the characteristic species assemblage of waterbirds can be deduced through the present check list. A total of 27 waterbird species were recorded during the survey period from November 2016 to February 2017. Among the waterbird species, 17 were residents, 5 species were widespread winter visitors, 3 species were widespread resident as well as widespread winter visitors and 2 species were sparse winter visitors, which were prominent in the census within this microgeographic habitat. The bird species assemblages in a similar wetland bearing significance for the migratory birds, the Santragachi *jheel*, Howrah, West Bengal, India, 22 bird species were observed (Singha Roy *et al.* 2011). In the Santragachi *jheel*, the water quality parameter and the growth of the weeds were directly influenced by the abundance of the birds, which provides a reflection of the multifunctional role of the birds in sustaining the wetland ecosystems (Singha Roy *et al.* 2011, Adhurya *et al.* 2020). Among the 22 species, 15 species of birds were migratory (Khan 2010) and were observed through continuous monitoring over several years. Similarly, in the wetlands of Alipurduar and Coochbehar, West Bengal, 27 water bird species were recorded with 13 being migratory (Chatterjee *et al.* 2020), with various feeding techniques and foraging habitats. Coexistence of the birds in these wetlands can possibly be a reflection of the habitat and niche segregation (Chatterjee *et al.* 2020), as well as temporary exploitation of the habitat, particularly during the winter season, by the winter visitors (Khan 2010, Singha Roy *et al.* 2011). Similar observations are also available for three different wetlands spread across West Bengal, where consistent presence of 19 species and additional 5species as vagrants were observed over a long period (Khan *et al.* 2016). While our observations on the number of the bird species remain comparable to the Santragachi *jheel*, and other regions of West Bengal, the earlier observations from Purbasthali appear to be considerably higher (74 species reported by Mandal & Siddique 2018, 86 species reported by Debnath *et al.* 2018), particularly because of the inclusion of several nonaquatic bird species. Similarly, in two other wetlands in Jalpaiguri, West Bengal, 42 and 80 species of birds were observed (Datta 2011), of which 63 were waterbirds, mostly migratory. On a comparative scale, the species composition observed in the present instance, the variations appear to be similar to those observed in the wetlands in similar geographical conditions (Khan 2010, Hazra *et al.* 2012, Khan *et al.* 2016, Mukhopadhyay & Mazumdar 2017, Mazumdar 2019, Chatterjee *et al.* 2020). The incidence of winter migratory waterbirds in the area indicates that the wetland provides suitable habitat not only for resident species but also for migratory birds (Hazra *et al.* 2012, Menon *et al.* 2015, Mazumdar 2019). A globally near threatened species, the Black-headed Ibis, was very common in the wetland of Purbasthali. During the survey, nine waterbird species were encountered with globally declining population trend. Among them, three were very common, one species was common and five species were less common in the habitat. Higher values of diversity indices revealed significant species richness comparing to the size of the wetland. It may be due to the availability as well as the variety of alternative food resources for birds over the favourable habitat for nesting and breeding (Hossain & Aditya 2016). Considering the vegetation of the studied wetland, it was noticed that various macrophytes like *Eichhornia*, *Lemna*, *Nymphoides*, *Najas*, *Typha*, *Phragmites* distributed the entire area. Though high vegetation in a wetland may negatively influence the waterbird community, but for some other number of birds like Common Moorhen, White-breasted Waterhen and Purple Swamphen, it could provide a perfect breeding ground (Kosiński 1999, Khan *et al.* 2016). In addition to that, due to the close association of various macroinvertebrates and fishes with hydrophytes, it could favour the diving waterbirds unlike the dabblers as the closed water surface reduced their feeding area (Khan 2010). However, in this study, we found relatively higher abundance of carnivores than omnivores followed by herbivores. Migratory waterbirds being an opportunist and having higher adaptability during winter season to the wetland when reducing water level exposed some new emergent areas, which provided appropriate feeding habitat for all waterbirds belonging from every feeding guild. For this unmanaged wetland, the similarities in habitat quality are supposed to sustain greater diversity (Kaminski *et al.* 2006). Starting from November, the species richness began to rise in this wetland and continued to increase up to the February. Continuous increase in migratory waterbirds during winter in this site may be due to its favourable climatic condition as well as availability of resource and habitat. An association of hydrophytes with perennial wetlands acting as a microhabitat for macroinvertebrates and fish assemblages, which serve as a feeding ground for many waterbirds as well as supporting various breeding population to that area. During the study, the estimation and monitoring of different physicochemical characteristics of wetland like quality and depth of water, size of the wetland, abundance of food resource (molluscs and fishes), suitability of roosting sites and observing higher species diversity with the available existence of some species whose population are now declining globally, suggest that the wetland of Purbasthali is now qualified as a perfect habitat for waterbirds, therefore, the effective management is required. From sustained monitoring (Panigrahy *et al.* 2012) of the bird assemblages from protected waterbodies like Santragachi, West Bengal (Khan 2010, Singha Roy *et al.* 2011), and other wetlands in West Bengal (Hazra *et al.* 2012, Khan *et al.* 2016) Okhla, India (Mazumdar 2019) and the present study, it can be revealed that this wetland provides an essential wintering habitat for varieties of waterbird species. However, further observations to that place are also required during other seasons and over the year to figure out the values of the wetland ecosystem for waterbird sustainability.

In the emerging wetland Purbasthali, 27 waterbird species, categorized under 24 genera, 10 families and 5 orders were observed with varying relative density. Among all, the three types of foraging guilds (herbivore, carnivore and omnivore) were recorded, the representations were the highest for the carnivores, probably due to the adequacy of macroinvertebrates and fishes as food sources. Earlier observations (Mukherjee *et al.* 2002, Hossain & Aditya 2016) indicated that waterbirds frequently forage outside wetland to the adjacent agricultural lands and sometime a few of them were known to inhabit in artificial lands like adjoining paddy fields or another crop fields, which usually provide an alternative habitat for them in degraded landscape. Increasing agricultural practices with the indiscriminate use of chemical pesticides can cause a severe impact on the waterbird population of the Purbasthali wetland. Pollution of water by anthropogenic activities, uncontrolled fishing habits and most recently sprouting of a number of brick kilns at the edge of wetland area were spotted as significant threats of the wetland. Instead of the existence of threats, interference of proper management like environment friendly agricultural practices, controlling fishing activities, restraining constructions adjacent to the wetland area may help to conserve waterbird species in several ways (Rahmani *et al.* 2016). However, the studied wetland of Pubasthali has already exposed its potentiality as a suitable habitat for both resident and migratory waterbirds, now it is our turn to protect its habitat by leaving it undisturbed and allow it to stay with its own identity by implementing an enduring conservation programme.

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