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Diversity and population trends of waterbirds at Lake-2, the Ballavpur Wildlife Sanctuary, West Bengal State, India

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Abstract

The focus of the present study was (i) to develop a complete checklist, (ii) to find the seasonal variation of waterbird diversity, and (iii) to assess the population trends of different waterbirds at Lake-2 of the Ballavpur Wildlife Sanctuary (BWLS), Birbhum District, West Bengal, India. The study was carried out from January 2018 to November 2019. All waterbirds spanning in the freshwater lake were counted with field binoculars and digital cameras. The bird count data were used to calculate different biodiversity indices (such as Shannon-Weiner diversity index, Simpson's Diversity Index etc.). Further, we assessed the population trends of different waterbirds with the data available from eBird. A total of 32 waterbird species belonging to 27 genera, 9 families and 8 orders were recorded during the present study. *Dendrocygna javanica* (Horsfield) was found to be the most dominant species throughout the year. Maximum richness and abundance were recorded during the winter months (December to February), whereas the highest species diversity was recorded during the monsoon months (March to June). The present study further establishes that both the richness and abundance of the waterbirds at BWLS have increased as compared to the past data. However, various species of wading waterbirds that were recorded previously were not observed during the present study. Moreover, the population trend analysis revealed a strong decline in the population of *Mareca strepera* (Linnaeus) and a moderate increase in the population of *Ardeola grayii* (Sykes). Thus, the present study concludes that BWLS supports high waterbird diversity irrespective of its small area.

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Key words: Aquatic avifaunal diversity, diversity indices, wetland-dependent birds

Introduction

Freshwater lakes only constitute 0.003% of the water resources of the world (Gleick, 1993) but support a great variety of biodiversity. Many waterbirds are known to congregate in large numbers in freshwater lakes during the winter months throughout the globe. They have always fascinated humankind with their soothing beauty, delightful chorus, and amazing mass migration ability year after year (Kear, 2010). The different ecosystem services provided by the waterbirds can be found in the existing literature (Green and Elmberg, 2014). But regardless of their immense importance, waterbirds were used as game and every year they were hunted in large numbers for meat consumption by humans (Madsen and Fox, 1995; Ramachandran et al., 2017). Besides, their population is also negatively impacted by degrading

water quality and ever-decreasing freshwater patches (Wang et al., 2018; Zhang and Ouyang, 2019).

Yet, the recent global bloom of the number of bird-watchers and their empathetic attitude towards the habitat loss and hunting of waterbirds has led to the conservation of many waterbird habitats. Furthermore, the fascinating beauty of the wintering flocks made waterbirds a flagship for wetland conservation and so the number of waterbirds is largely used as an indicator to evaluate the importance of a waterbody (Green and Elmberg, 2014). The ever-increasing concern regarding waterbirds led to different initiatives such as the Ramsar Convention (Conventions on Wetlands) in 1971 and the formation of many organizations such as Wetlands International in 1937, Wildfowl and Wetlands Trust in 1946, and the Waterbird Society in 1999.

The most popular approach to the study of waterbirds is simply to take a species-specific count. Bird count data provides baseline information for any studied ecosystem and helps to understand long-term ecological changes. It also helps the understanding of the diversity and relative abundance of different waterbirds, which again is very important from a conservation aspect (Ontoy and Padua, 2014).

Birbhum is one of the most important districts in the state of West Bengal in terms of the abundance of waterbirds, especially those belonging to the family Anatidae (ducks and geese). Lakes and reservoirs of the Birbhum district provide refuge to a large number of wintering waterfowls during the winter months, of which the Ballavpur Wildlife Sanctuary (BWLS), Tilpara Barrage, Bakreswar Reservoir (also known as the Nil Nirjone Dam) and Hinglow Reservoir deserves special mention. Interestingly, all of these are man-made water bodies.

Historical evidence of high waterbird congregations at different water bodies of the Birbhum district can be found in Bengal District Gazetteers published during British rule (O'malley, 1910). After independence, the first article regarding the birds of this district was published in 'Visva-Bharati News', titled 'Birds around Santiniketan' between 1954–1958 in ten installments. Later, those articles were compiled and published in the form of a book in 2019 (Sen Gupta, 2020). Not many waterbirds were reported in those publications except some waders, herons, storks, and only a single species of duck because of the absence of a large water body at Santiniketan (a neighborhood of Bolpur city in the Bolpur subdivision of Birbhum) during that time. In later years, 10 waterbodies of the Birbhum district were surveyed during 1993–94 and as a result, 36 waterbird species were reported (Nandi et al., 2001).

Winter waterbird counts from BWLS, Tilpara Barrage, and Bakreswar Reservoir between 1999–2010 (except 2000–2002) can be found in Ganguly (2015). Diversity and population trends of waterbirds at the Bakreswar Reservoir between 1998–2011 were assessed by Sinha et al. (2012) who found increasing population trends of most of the waterbirds during the study period. Further, Sinha et al. (2011) studied the overall population trends, community structure, indicator species, and population shift between the waterbodies of Birbhum (Bakreswar Reservoir, Tilpara Barrage, and lakes of BWLS) with the data collected between 1998–2010. They found that the population of waterbirds declined to 38% between the study periods from these reservoirs. A population shift of waterbirds from the Tilpara Barrage to the Bakreswar Reservoir was also observed (Sinha et al., 2011). They also emphasized the global importance of the Birbhum district as a winter waterfowl refuge because these waterbodies met Criterion 5 (the wetland regularly supports 20,000 or more waterbirds) and 6 (the wetland regularly supports 1% of the individuals in a population of one species or subspecies of waterbird) of the Ramsar Convention (Sinha et al., 2011).

The communities of waterbirds of BWLS lakes were found to be very different from each other and also different from the communities of the Bakreswar Reservoir and Tilpara Barrage. In another study, eight waterbodies in southern Bengal were surveyed during 2006 and high waterbird abundance was observed in Birbhum, especially at the lakes of BWLS (Mazumdar et al., 2007). A checklist of different aquatic plants and waterbirds was prepared by Maity et al. (2010) for the three BWLS lakes (separately) observed between 2004–2007.

The present work is a part of a broad study to understand the effect of waterbirds on the nutrient dynamics of a freshwater ecosystem with a process-based modeling approach. So, there was a need for data collection of different physicochemical and biological variables to serve as the baseline data of the modeling study. The modeling study has recently been published elsewhere (Adhurya et al., 2021a). Due to the need for a large amount of data collection, the Lake-2 of Ballavpur Wildlife Sanctuary was selected as the study site. Another reason behind selecting this site was the presence of one of the largest congregations of *Anser anser* (Linnaeus) in West Bengal during the winter months.

Furthermore, the previous studies were focused only on the diversity of wintering waterbirds and very little is known about the seasonal diversity supported by these water bodies. So, the present study was aimed to observe the seasonal pattern of diversity and abundance of the waterbirds of Lake-2 of BWLS. In addition to this, a comparison has also been drawn with previous research to understand the change in the water avifaunal composition of this lake over the period. Attempts were also made to develop a comprehensive checklist of this lake and population trends for all waterbirds were analyzed. Finally, the problems associated with the lake and its wildlife is also highlighted in this study.

Material and Methods

The present study was carried out at Lake 2, BWLS, Birbhum District, West Bengal, India. The lake is located between 23°41′24.5″N to 23°41′16.7″N and 87°39′55.9″E to 87°40′05.8″E (Fig. 1). The study site is located at an elevation of 51 m from the mean sea level as per Google Earth data. The average span of the lake is 2.1 ha whereas the maximum and minimum depth is 2.4 m and 0.7 m, respectively (Adhurya et al., 2021b). This shallow lake is mainly dominated by aquatic weeds and due to the macrophyte domination, the chlorophyll-a concentration never exceeds the oligotrophic range (mean chlorophyll-a concentration 0.007 ± 0.003 mg/l) (Adhurya et al., 2021b). The different species of aquatic microvegetation can also be found in the previous literature from the present study site (Maity et al., 2010).

The three man-made lakes of BWLS (Lake-1 at east, Lake-2 at middle, and Lake-3 at west) were created by the overflowed water from the Binuria canal around 60 years ago during the early phase of the Mayurakshi Reservoir Project (Sen Gupta, 2020). Presently, the lakes are mainly rainfed and water enters/exits to and from the lake only during the monsoon via the adjoining Binuria canal at the northern side. Waterbirds congregate in high numbers at the lakes of BWLS. As per the recent collaborative waterbird survey conducted by the State Forest Department, BWLS supports the highest number of waterbirds in the state of West Bengal (PTI, 2021).

Bimonthly surveys were performed between January 2018 and November 2019. Surveys were conducted between the 15th to 25th of every month. All wetland-dependent birds including waders, waterfowls, kingfishers, and wetland-dependent raptors were considered as waterbirds. The feeding habit of many waterbirds is nocturnal. These waterbirds were found to return and subsequently settle down at the lake (roosting site) between 7–8 am. Mostly these waterbirds roost at the lake throughout the day and start to return to their feeding ground from evening. Sometimes they also visit the feeding ground during midday, but it depends on the climatic conditions. Thus, the waterbirds were counted between 8 am to 10 am during each survey. Counts were attempted for all waterbirds in the lake using a total count (or census) method with the help of binoculars and digital camera (Sutherland et al., 2004). In the case of large congregations, as are generally observed in winter, all waterbird spanning the lake were first photographed. Then, each photograph was divided into several grids. Species-specific counts were then taken from each grid and each photograph. The sum of all counts over all photographs was considered as the total number of waterbirds present at the lake during that particular survey. The waterbirds were observed using field binoculars (Olympus 8x40 DPSI and Zeiss 10x42 Terra ED) and photographed with digital cameras (Nikon D7500 DSLR camera with Tamron 100-400 f/4.5-6.3 Di VC lens and Canon SX60 HS advanced point and shoot camera). Birds were identified using standard field guides (Grimmett et al., 2011; del Hoyo et al., 2017).

Waterbird density was estimated by dividing the total lake waterbird count by the average area of the lake. The average lake area was estimated from multiple historical maps from Google Earth. Seasonality (bimonthly) was plotted using the MS Excel column sparkline tool. The feeding habits are taken from del Hoyo et al. (2017). The IUCN Red List of Threatened Species (IUCN, 2021) and State of Indian Birds (SoIB, 2020) were used to indicate waterbird conservation statuses. To understand the relative waterbird abundance, the monthly average of all waterbird counts was taken. Then, the Pareto plot was plotted with the annual averaged waterbird count. To understand the seasonal diversity, the total study period was divided into four major seasons as observed in India: winter (December to February), pre-monsoon (March to June), monsoon (July to September), and post-monsoon (October to November). Four diversity indices were estimated using PAST 4.05: Richness (S), Shannon diversity index (H) (Shannon, 1948), Pielou's evenness index (J) (Pielou, 1966), and Berger-Parker dominance (d) index (Berger and Parker, 1970). Where,

$$Richness, S = Total\ number\ of\ species$$

$$Shannon's\ Diversity\ Index, H = -\sum_{i=1}^{s} \frac{ni}{N} \ln \frac{ni}{N}$$

Here, *ni* is the number of individuals of a particular species and N is the total number of individuals covering all species.

$$Pielou's\ Evenness\ Index, J = H/\ln S$$

$$Berger\text{-}Parker's\ dominance,\ d = \frac{N_{max}}{N}$$

Here, N_{max} is the number of individuals of a species having maximum count.

To understand the change in diversity between 2018 and 2019, an independent 2-sample t-test has been performed in PAST software for richness, individual count, and Shannon Diversity Index. Population trends of different waterbirds were analyzed with the help of winter bird data available from eBird https://www.ebird.org (a popular citizen science platform where birders can upload their bird observations and the data can be used by scientists and researcher to understand occurrence, distribution and abundances of birds) and the present study.

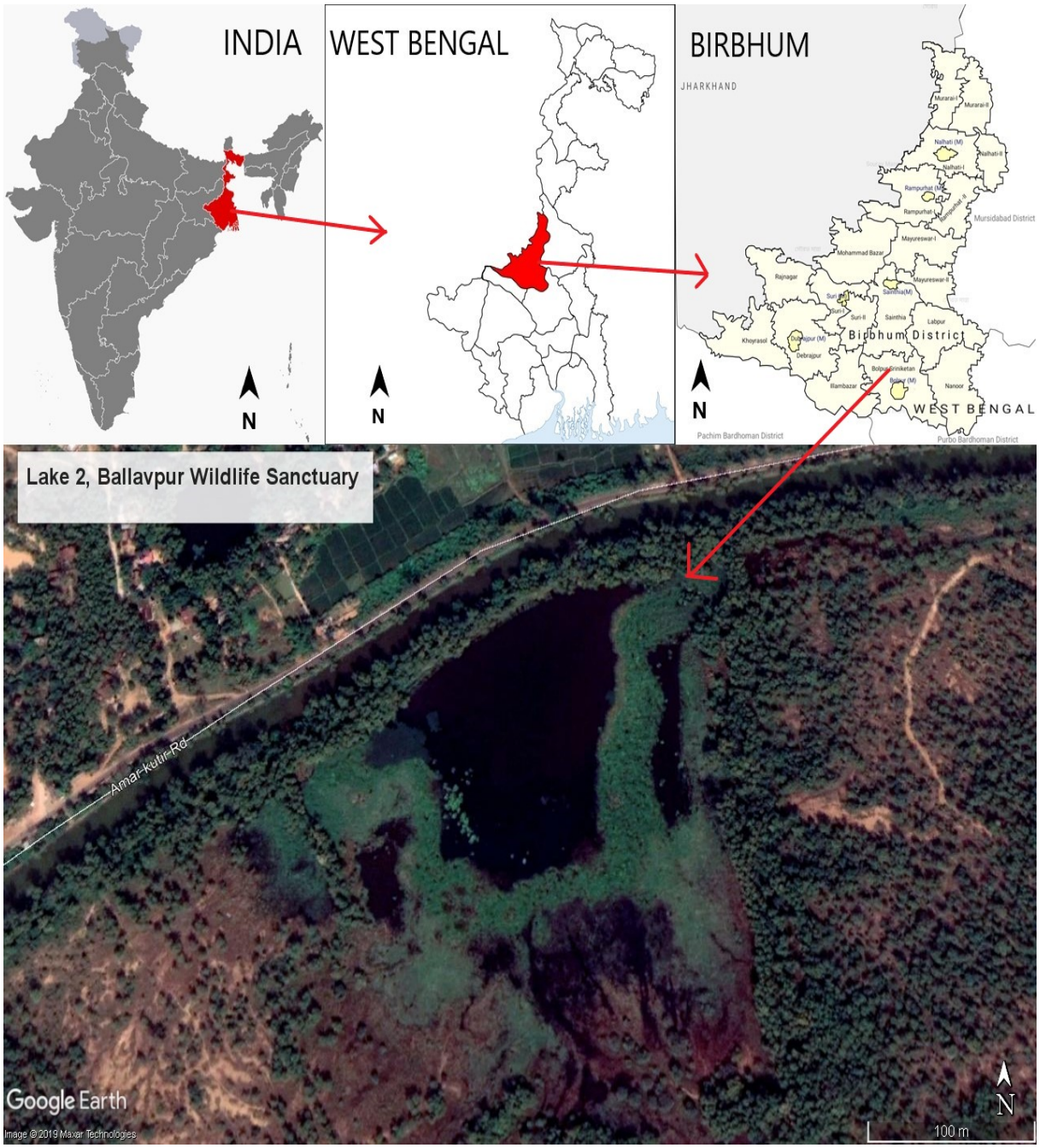

Figure 1: Satellite image of the study site at Lake 2 of BWLS, India, and its relative position to the map.

Only the winter months are considered for the population trend study because data of other seasons are not usually available. The eBird data is available from 2015 to 2021. The population trend was analyzed with R (R Core Team, 2021) with the help of *'rtrim'* package and *r-TRIM shell version 1.3* (Bogaart et al., 2020). Trends and Indices for Monitoring Data (TRIM) has remained a standard tool for population trend estimation of birds in Europe and approved by the Birdlife International https://www.birdlife.org and it generally uses the Poisson-based log-linear modeling for population trend estimation. It also analyses the time-series count from yearly data and produces indices and trends. These indices are further justified with the Wald's χ^2 test (Wald, 1943) for its significance.

Results and Discussion

A total of 32 species belonging to nine families and eight orders were recorded in the present study (Table 1, Fig. 2) of which 20 species were residents and 12 species were winter migrants. As per the IUCN Red list of Threatened Species, one Vulnerable species, the Greater Spotted Eagle *Clanga clanga* (Pallas, 1811) (assessment year 2017) and two Near Threatened species, the Ferruginous Pochard *Aythya nyroca* (Güldenstädt, 1770) (assessment year 2019) and Oriental Darter *Anhinga*

melanogaster Pennant, 1769 (assessment year 2016) were observed during the study period from the present study location. The Cotton Pygmy Goose *Nettapus coromandelianus* (J.F. Gmelin, 1789), a common waterbird of the lake, showed a nationwide strong long-term decline in terms of its population (SoIB, 2020).

As per feeding habit, 14 species were chiefly herbivorous (species belongs to the family Anatidae and Rallidae except *Amaurornis phoenicurus* (Pennant, 1769)) and 18 species were chiefly carnivorous in feeding habit (species belongs to all other families except *Metopidius indicus* (Latham, 1790)). As per the annual averaged waterbird count, the Lesser Whistling Duck *Dendrocygna javanica* (Horsfield, 1821) was found to be the most abundant species (70.24%) followed by the Greylag Goose *Anser anser* (Linnaeus, 1758) (10.5%) and Northern Pintail *Anas acuta* Linnaeus, 1758 (7.14%) (Fig. 3). Although seasonally this dominance pattern varied (as can be found in Table 2) due to the influx of a large number of wintering waterbirds to the lake, *D. javanica* remained the dominant species throughout the season, but its number increased in winter due to the large immigration of wintering flocks.

The results of different diversity indices along with their seasonal pattern are been given in Figure 4. The individual count was found to be higher during winter and this was largely due to the winter influx of migratory waterbirds. It is interesting to note that the abundance of most of the waterbirds (except *A. phoenicurus*, *Ciconia episcopus* (Boddaert, 1783) and *Bubulcus ibis* (Linnaeus, 1758)) was found to increase in presence of the migratory waterbirds. Similarly, richness was also found to be higher during winter. The maximum diversity was recorded during monsoon or when individual count remained low. Despite high richness and abundance, diversity remained low during the winter months. Because H depends on both richness and evenness (Shannon, 1948), the higher dominance of *D. javanica* in winter resulted in both low H and J values. Evenness showed higher values during summer and monsoon in absence of the dominant species. Maximum diversity was observed in November 2019 due to the high richness and evenness of that month. Although individual count remained low for that month as compared to the previous year. The possible reason behind this low count was the ongoing human activities inside the lake due to the regular clearing of aquatic weeds for lake management. No significant difference ($p< 0.05$) was found between both richness, individual count, and H between the years 2018 and 2019 with 2-sample independent t-tests.

A checklist of the various waterbirds that were previously observed at the study site but were not observed during our study period is provided in Table 3. The checklist contains a total of 21 species belongs to eight families and seven orders. As compared to the previous study on wintering waterbirds by Ganguly and Mukhopadhay (2014), both the number of species (from 14 in 1999 to 30 in 2018–19) and the number of individuals (from 673 in 1999 to 4239 in 2018–19) has increased considerably. Maity et al. (2010) only documented the diversity of waterbirds from the three lakes of BWLS during 2004–2007 and found 19 waterbird species during that period from Lake-2. It is clear from both of the previous studies conducted during 1999 (Ganguly and Mukhopadhay, 2014) and 2004–2007 (Maity et al., 2010) that the number of species is continuously increasing at Lake 2, BWLS.

The Knob-billed Duck *Sarkidiornis melanotos* (Pennant, 1769), Eurasian Wigeon *Mareca penelope* (Linnaeus, 1758), Common Teal *Anas crecca* Linnaeus, 1758, Red-crested Pochard *Netta rufina* (Pallas, 1773), Little Grebe *Tachybaptus ruficollis* (Pallas, 1764), Great Egret *Ardea alba* Linnaeus, 1758, Indian Pond Heron *A. grayii*, Greater Spotted Eagle *C. clanga*, Western Marsh Harrier *Circus aeruginosus* (Linnaeus, 1758) and Stork-billed Kingfisher *Pelargopsis capensis* (Linnaeus, 1766) were not recorded previously from this lake but were recorded during our study. Many waders belonging to the family Charadriidae and Scolopacidae were recorded previously by both the previous studies, were not found during the present study period.

Additionally, the Indian Cormorant *Phalacrocorax fuscicollis* Stephens, 1826 recorded by Maity et al. (2010) was not observed in the present study. Interestingly, it had been recorded in Lake 2 during the winter bird survey conducted in January 2021 by us. Brown-winged Kingfisher *Pelargopsis amauroptera* (J.T. Pearson, 1841), as recorded by Maity et al. (2010), might be a misidentification of the Stork-billed Kingfisher *P. capensis*, as this species is only reported from coastal and mangrove regions (Grimmett et al., 2011). Other studies (Nandi et al., 2001; Mazumdar et al., 2007; Sinha et al., 2011) conducted at BWLS, did not document avian assemblages of three lakes separately and because of that fact, no comparison could be made with those studies.

Additional records of some species at the lake were also available from eBird such as the Osprey *Pandion haliaetus* (Linnaeus, 1758), Common Pochard *Aythya ferina* (Linnaeus, 1758), Tufted Duck *Aythya fuligula* (Linnaeus, 1758), Fulvous Whistling Duck *Dendrocygna bicolor* (Vieillot, 1816), Falcated Duck *Mareca falcata* (Georgi, 1775), Baikal Teal *Sibirionetta formosa* (Georgi, 1775), Northern Shoveler *Spatula clypeata* (Linnaeus, 1758), Garganey *Spatula querquedula* (Linnaeus, 1758), Ruddy Shelduck *Tadorna ferruginea* (Pallas, 1764), Common Snipe *Gallinago gallinago* (Linnaeus, 1758), Black Crowned Night Heron *Nycticorax nycticorax* (Linnaeus, 1758), and Indian Cormorant *P. fuscicollis*. Most of the species reported in eBird were observed after 2019 and many of these species were recorded by the authors themselves during subsequent winter bird surveys after the present study. As per the information obtained from experienced birders (e.g. Prakriti Samsad, an organization member who surveyed the lakes of BWLS between 1990–2005), waterbirds started to arrive at Lake-2 gradually from 2001. The previously stated literature also reflects the same. Images of the counted waterbirds are given in Figure 5.

Table 1: Checklist of the bird species found during the study period at Lake 2 of BWLS, India. Here LC= Least Concerned, VU= Vulnerable, NT= Near Threatened, FH= Feeding habit, H= chiefly herbivorous feeding habit, C= chiefly carnivorous feeding habit. The six-bar in seasonality plot represents six months of data collection (January, March, May, July, September, and November).

Sl No.	Scientific name	Common name	FH	Seasonality	IUCN status	Monthly averaged bird density (count ha^{-1})	
						2018	2019
A	**Order**	**Accipitriformes**					
I	**Family**	**Accipitridae**					
1	*Circus aeruginosus* (Linnaeus, 1758)	Western Marsh Harrier	C		LC	0.16	0.16
2	*Clanga clanga* (Pallas, 1811)	Greater Spotted Eagle	C		VU	0.00	0.08
B	**Order**	**Anseriformes**					
II	**Family**	**Anatidae**					
3	*Anas acuta* Linnaeus, 1758	Northern Pintail	H		LC	33.57	30.40
4	*Anas crecca* Linnaeus, 1758	Common Teal	H		LC	0.40	2.38
5	*Anser anser* (Linnaeus, 1758)	Greylag Goose	H		LC	51.82	42.22
6	*Aythya nyroca* (Güldenstädt, 1770)	Ferruginous Duck	H		NT	1.43	3.73
7	*Dendrocygna javanica* (Horsfield, 1821)	Lesser Whistling Duck	H		LC	356.67	272.62
8	*Mareca penelope* (Linnaeus, 1758)	Eurasian Wigeon	H		LC	0.48	0.00
9	*Mareca strepera* (Linnaeus, 1758)	Gadwall	H		LC	4.52	4.76
10	*Netta rufina* (Pallas, 1773)	Red-crested Pochard	H		LC	2.38	2.22
11	*Nettapus coromandelianus* (J.F. Gmelin, 1789)	Cotton Teal	H		LC	15.40	12.78
12	*Sarkidiornis melanotos* (Pennant, 1769)	Knob-billed Duck	H		LC	0.16	0.08
C	**Order**	**Charadriiformes**					
III	**Family**	**Jacanidae**					
13	*Hydrophasianus chirurgus* (Scopoli, 1786)	Pheasant-tailed Jacana	C		LC	0.16	0.48
14	*Metopidius indicus* (Latham, 1790)	Bronze-winged Jacana	H		LC	3.65	4.37
D	**Order**	**Coraciiformes**					
IV	**Family**	**Alcedinidae**					
15	*Alcedo atthis* (Linnaeus, 1758)	Common Kingfisher	C		LC	0.40	0.32
16	*Halcyon smyrnensis* (Linnaeus, 1758)	White-throated Kingfisher	C		LC	0.56	0.63
17	*Pelargopsis capensis* (Linnaeus, 1766)	Stork-billed Kingfisher	C		LC	0.40	0.40
E	**Order**	**Gruiformes**					
V	**Family**	**Rallidae**					
18	*Amaurornis phoenicurus* (Pennant, 1769)	White-breasted Waterhen	C		LC	0.95	1.03
19	*Fulica atra* Linnaeus, 1758	Common Coot	H		LC	1.27	1.75
20	*Gallinula chloropus* (Linnaeus, 1758)	Common Moorhen	H		LC	3.25	3.33
21	*Porphyrio poliocephalus* (Latham, 1801)	Grey-headed Swamphen	H		LC	2.78	4.37
F	**Order**	**Pelecaniformes**					
VI	**Family**	**Ardeidae**					
22	*Ardea alba* Linnaeus, 1758	Great Egret	C		LC	0.08	0.08
23	*Ardea cinerea* Linnaeus, 1758	Grey Heron	C		LC	0.56	0.56
24	*Ardea intermedia* Wagler, 1829	Intermediate Egret	C		LC	0.56	0.32
25	*Ardea purpurea* Linnaeus, 1766	Purple Heron	C		LC	0.63	0.56
26	*Ardeola grayii* (Sykes, 1832)	Indian Pond Heron	C		LC	1.67	2.14
27	*Bubulcus ibis* (Linnaeus, 1758)	Cattle Egret	C		LC	2.46	4.13
28	*Egretta garzetta* (Linnaeus, 1766)	Little Egret	C		LC	1.11	1.03
G	**Order**	**Podicipediformes**					
VII	**Family**	**Podicipedidae**					
29	*Tachybaptus ruficollis* (Pallas, 1764)	Little Grebe	C		LC	1.67	1.99
H	**Order**	**Suliformes**					
VIII	**Family**	**Anhingidae**					
30	*Anhinga melanogaster* Pennant, 1769	Oriental Darter	C		NT	0.32	0.40
IX	**Family**	**Phalacrocoracidae**					
31	*Microcarbo niger* (Vieillot, 1817)	Little Cormorant	C		LC	2.38	3.73
32	*Phalacrocorax carbo* (Linnaeus, 1758)	Great Cormorant	C		LC	0.00	0.08

Table 2: The seasonal relative abundance (%) of different waterbirds found at the Lake 2 of BWLS, India.

Pre-monsoon	Monsoon	Post-monsoon	Winter
Dendrocygna javanica (34.02%)	*Dendrocygna javanica* (33.88%)	*Dendrocygna javanica* (78.92%)	*Dendrocygna javanica* (72.69%)
Nettapus coromandelianus (30.93%)	*Nettapus coromandelianus* (19.63 %)	*Anser anser* (3.30%)	*Anser anser* (13.2%)
Bubulcus ibis (4.9%)	*Metopidius indicus* (8.41%)	*Nettapus coromandelianus* (3.19%)	*Anas acuta* (9.16%)
Porphyrio poliocephalus (4.38%)	*Porphyrio poliocephalus* (6.31%)	*Mareca strepera* (2.7%)	*Mareca strepera* (0.8%)
Anas acuta (3.87%)	*Gallinula chloropus* (5.37%)	*Gallinula chloropus* (1.76%)	*Nettapus coromandelianus* (0.69%)

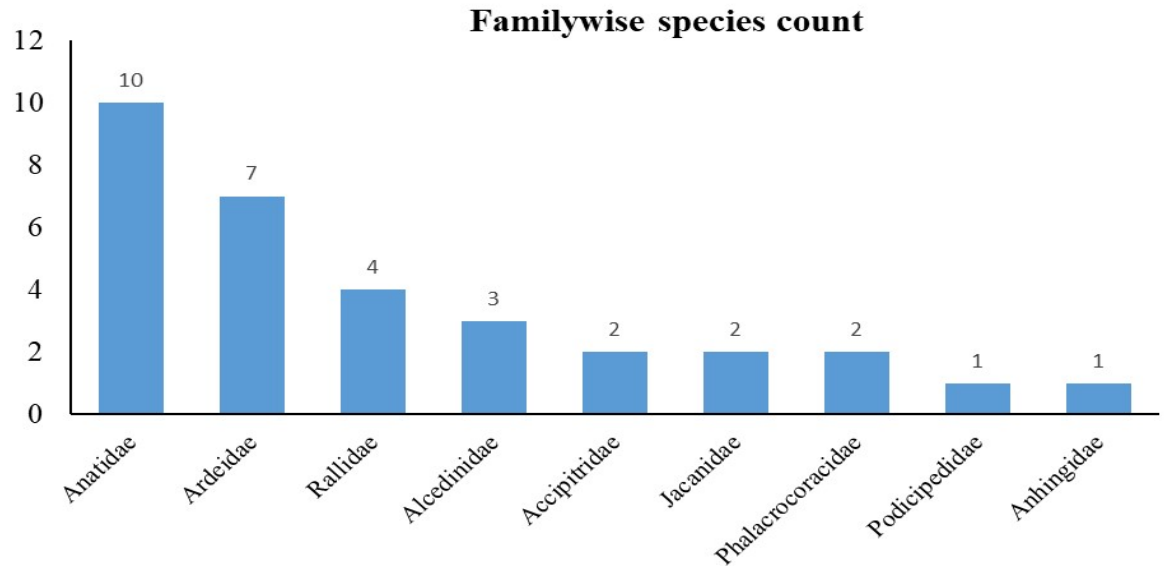

Figure 2: Family-wise species count of the waterbirds found at the Lake 2 of BWLS, India during the study period.

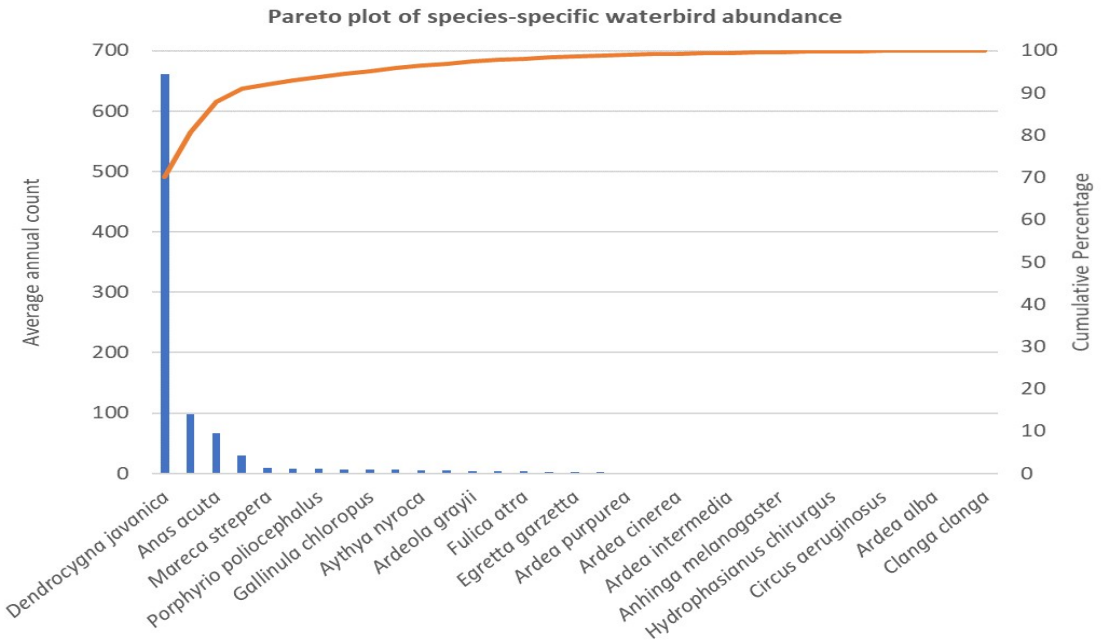

Figure 3: Pareto plot representing the relative abundances of different waterbird species found at the Lake 2 of BWLS, India, during the study period. Here the bar represents the annual average bird count and the line represents the cumulative percentage of abundances.

Table 3: Checklist of the waterbirds which were recorded previously at the study site (Lake 2 of BWLS, India), but not during the present study.

Sl No	Scientific name	Common name	IUCN Status	Max. Count	Reference
A		**Order Accipitriformes**			
I		**Family Pandionidae**			
1	*Pandion haliaetus* (Linnaeus, 1758)	Osprey	LC	1	(Das, 2018)
B		**Order Anseriformes**			
II		**Family Anatidae**			
2	*Anser indicus* (Latham, 1790)	Bar-headed Goose	LC	1	(Maiti, 2018)
3	*Aythya ferina* (Linnaeus, 1758)	Common Pochard	VU	1	(Adhurya, 2019)
4	*Aythya fuligula* (Linnaeus, 1758)	Tufted Duck	LC	3	(Adhurya et al., 2021c)
5	*Dendrocygna bicolor* (Vieillot, 1816)	Fulvous Whistling Duck	LC	1	(Adhurya et al., 2021c)
6	*Mareca falcata* (Georgi, 1775)	Falcated Duck	NT	1	(Adhurya et al., 2021c)
7	*Sibirionetta formosa* (Georgi, 1775)	Baikal Teal	LC	1	(Sengupta, 2016)
8	*Spatula clypeata* (Linnaeus, 1758)	Northern Shoveler	LC	2	(Adhurya and Mandal, 2016)
9	*Spatula querquedula* (Linnaeus, 1758)	Garganey	LC	54	(Chatterjee et al., 2021)
10	*Tadorna ferruginea* (Pallas, 1764)	Ruddy Shelduck	LC	2	(Majumdar, 2019)
C		**Order Charadriiformes**			
III		**Family Charadriidae**			
11	*Vanellus cinereus* (Blyth, 1842)	Grey-headed Lapwing	LC	7	(Ganguly and Mukhopadhay, 2014)
12	*Vanellus indicus* (Boddaert, 1783)	Red-wattled Lapwing	LC	-	(Maity et al., 2010)
IV		**Family Scolopacidae**			
13	*Actitis hypoleucos* (Linnaeus, 1758)	Common Sandpiper	LC	-	(Maity et al., 2010)
14	*Gallinago gallinago* (Linnaeus, 1758)	Common Snipe	LC	1	(Karmakar, 2019)
15	*Tringa glareola* Linnaeus, 1758	Wood Sandpiper	LC	4	(Maity et al., 2010; Karmakar, 2019)
16	*Tringa nebularia* (Gunnerus, 1767)	Common Greenshank	LC	-	(Maity et al., 2010)
17	*Tringa ochropus* Linnaeus, 1758	Green Sandpiper	LC	-	(Maity et al., 2010; Adhurya et al., 2021c)
D		**Order Coraciiformes**			
V		**Family Alcedinidae**			
18	*Pelargopsis amauroptera* (J.T. Pearson, 1841)	Brown-winged Kingfisher	NT	-	(Maity et al., 2010)
E		**Order Gruiformes**			
VI		**Family Rallidae**			
19	*Gallicrex cinerea* (J.F. Gmelin, 1789)	Watercock	LC	2	(Maiti, 2018)
F		**Order Pelecaniformes**			
VII		**Family Ardeidae**			
20	*Nycticorax nycticorax* (Linnaeus, 1758)	Black-crowned Night Heron	LC	2	(Karmakar, 2019)
G		**Order Suliformes**			
VIII		**Family Phalacrocoracidae**			
21	*Phalacrocorax fuscicollis* Stephens, 1826	Indian Cormorant	LC	-	(Maity et al., 2010)

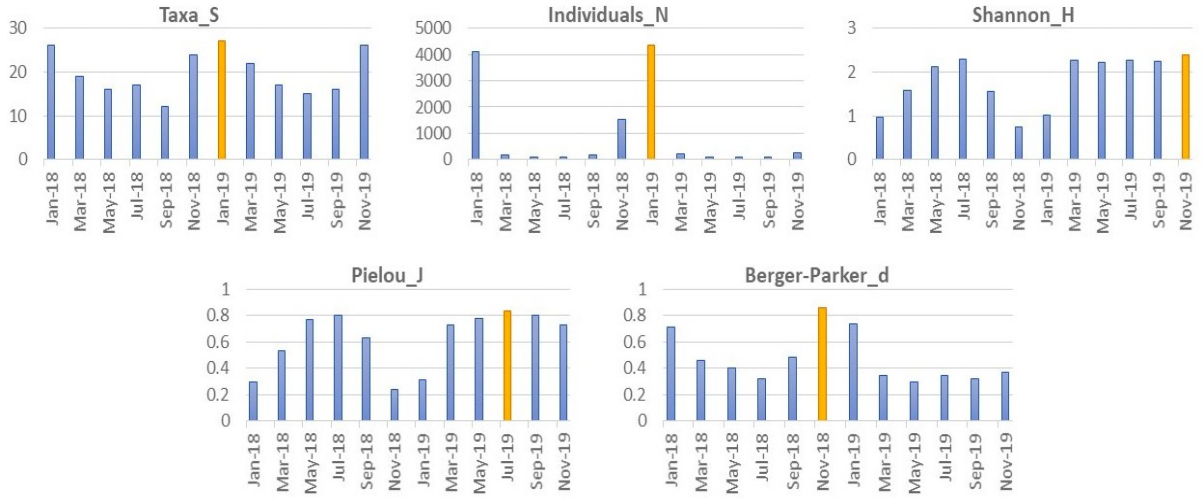

Figure 4: The seasonal variation of different diversity indices of waterbirds at the Lake 2 of BWLS, India. On the top of each chart the diversity index for which it is plotted and its abbreviation are indicated. The left axis indicates the respective value of the same. The golden-yellow color indicates the highest value.

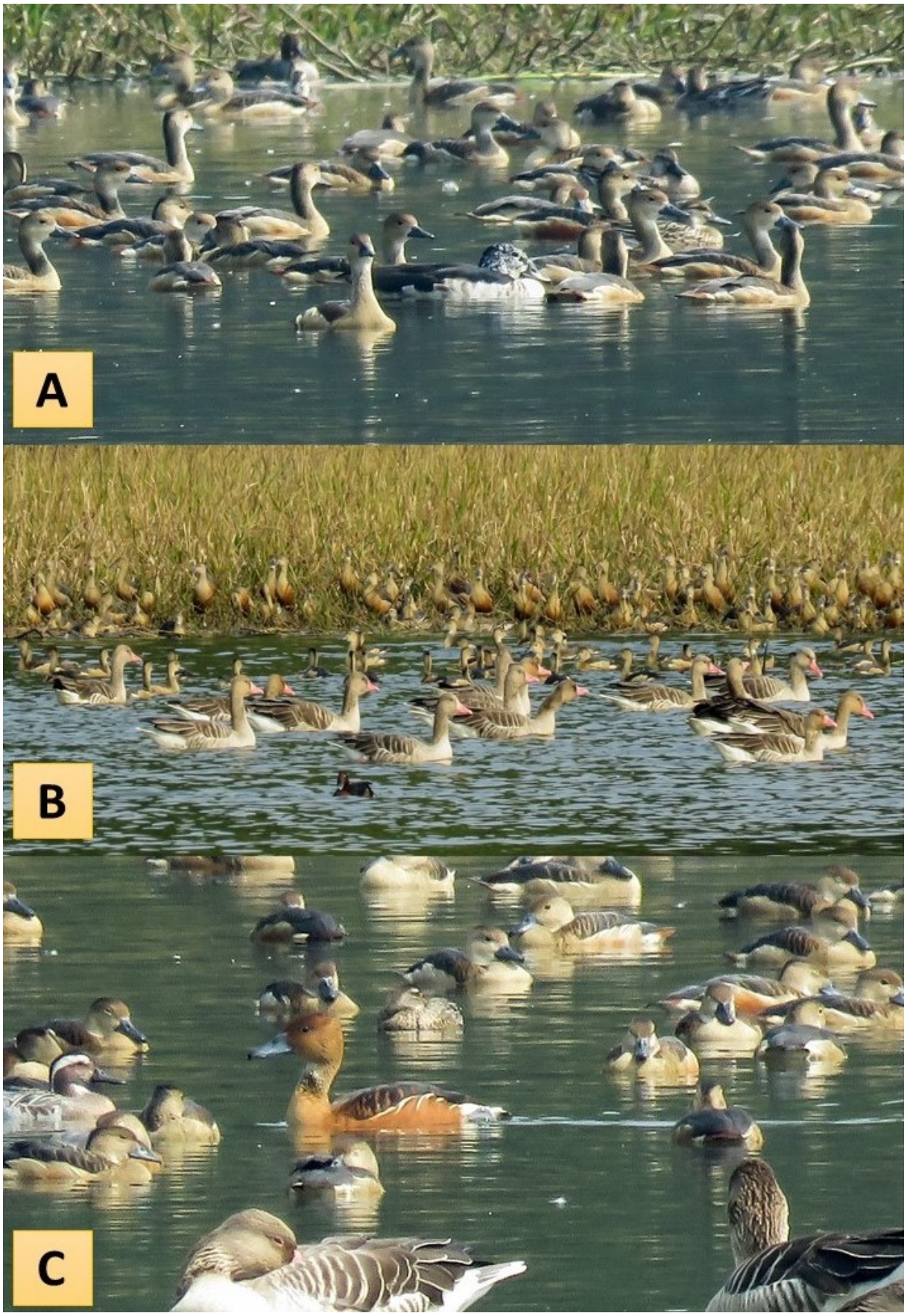

Figure 5: Images of some waterbirds taken at the Lake 2, BWLS. (Photo Credit- Debayan Gayen): Knob-billed Duck, Garganey, and Lesser Whistling ducks (A); Flock of Greylag Goose (B); Fulvous Whistling-Duck and Garganey amongst the Flocks of Greylag Goose and Lesser Whistling Duck (C).

In the population trend study, a strong decline in population was observed for Gadwall *M. strepera* ($p< 0.05$), and a moderate increase was observed for Indian Pond Heron *A. grayii* ($p< 0.05$). For the other species, the population trend result was uncertain. It might be because eBird data is available for Lake 2, BWLS since 2015 and during this short period, the population of most species showed very high fluctuation. Some species were also recorded only once between 2015 and 2021. So, it is very difficult to draw a statistical conclusion and needs prolonged study and long-term data to comment on that aspect. The reason behind this irregularity of the occurrence of waterbirds can be movement of waterbirds between different lakes to find more suitable and habitat and food (Sinha et al., 2011).

All lakes of BWLS are situated in a protected area and face minimal anthropogenic disturbance. However, some human disturbances to the lake should be noted. People from the nearby village defecate around the lake and open defecation increases during summer months when the surrounding waterbody gradually dries up. During the summer months, anthropogenic intervention increases in the lake as the villagers also use this place for bathing and other purposes. One direct threat observed during the study is the hunting of waterbirds by villagers despite strong vigilance by the forest guards. Apart from these threats, the lakes are prone to periodic collapse by nuisance aquatic macrophyte growth. The Forest Department regularly cleans the macrophytes and performs periodic dredging to keep the lake habitable for waterbirds.

Conclusion

The present study found high avian richness and abundance of waterbirds in a small lake of Birbhum District. The diversity of waterbirds in this man-made lake has been found to be continuously increasing over the last few years. Uncertainty in the population trends of most of the species indicates the need for long-term data collection to gain an understanding of the population trends of different waterbirds in this lake. Furthermore, threats to waterbirds (as discussed in the previous section) need responsible management practices by concerned authorities to further improve the waterbird diversity of this lake.

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Conflict of interest

All the authors declare that there are no conflicting issues related to this research article.

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