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Original Article

Impact of Limnological Variables on Waterbird Assemblage in a Tropical Lentic Ecosystem of Southern West Bengal, India

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Abstract

Birds are well-known *bio-indicators,* because of their high sensitivity to even slight changes in their surroundings. Therefore, documentation of waterbird assemblage in a water body can be a part of wetland monitoring from a sustainability perspective. The present study was carried out in Hansadanga beel (an ox-bow lake of Gangetic alluvial plain) of southern West Bengal (India) from January 2023 to December 2023 to assess the impact of limnological variables on waterbird assemblage. 35 different waterbird species from 11 families were identified from the study area, out of which 16 species (45.71%) were winter-migrants, 15 species (42.86%) were resident and 4 species (11.43%) were local-migrants. Ardeidae was the dominant family with highest Relative Diversity Index (RD_i=20) followed by Anatidae (RD_i=17.14). The maximum values of different diversity indices were observed in post-monsoon months due to the assemblage of winter-migrants and its lower values were recorded from summer months. Canonical correspondence analysis revealed that among the eight limnological variables, pH, total alkalinity, and nutrient levels best explained the variance in waterbird assemblages. Even though the study area has been impacted by a number of anthropogenic activities, it is still preferred by a variety of waterbird species, including winter-migrants. Hence, regular monitoring of avifauna and the environmental health by local or state authorities, through integrated management programs, will be beneficial for sustaining habitat growth.

Keywords: Diversity indices, Hansadanga beel, Limnological variables, Southern West Bengal, Waterbird.

Introduction

In India, the meandering nature of river Bhagirathi (The Ganga) with its tributaries and distributaries have created a significant number of floodplain wetlands (primarily oxbow lakes) in its lower course in Southern part of West Bengal. These wetlands are locally known as *beel* or *bnour*and support significant number of biodiversity (Ganesan & Khan, 2007). Wetlands, which make up around 6% of the Earth's surface, are able to preserve ecological sustainability and provide a home for many species and also for aquatic birds that have been recognized as biodiversity assets (Zedler & Kercher, 2005, Mcparland& Paszkowski, 2007).Some wetlands serve as microhabitats for waterbirds, which they use for feeding, nesting, and breeding grounds (Hazra *et al.,* 2012). Birds can be used as "*bio-indicators*" because of their high sensitivity to environmental changes (Koli, 2014). 84 of the 1375 bird species that are considered to be at risk of extinction worldwide are found in the Indian subcontinent (Bird life International, 2015). The major reason behind this population depletion is loss of habitat and breeding grounds. Over 50% of the world's wetland habitats have reportedly disappeared in the past century (Datta, 2011).

Hansadanga beel, a closed type ox-bow lake of Gangetic alluvial plains, has long been well-known for its variety of waterbird species. Nevertheless, a few research works have been carried out on the water quality, macro-invertebrate community, fish and zooplankton diversity of the wetland (Das & Chakrabarty, 2007 & 2008, Debnath *et al.,* 2021) and also on geographical observation (Das & Das,

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2015). This is the first approach to enlist and assess the diversity and assemblage of waterbirds of this water area. Hence, the current study was conducted to evaluate the biodiversity and distinctive species assemblage of the study area, with special reference to the diversity of waterbirds (both migratory and non-migratory). The resultant information of this study will not only help to predict the functional integrity of the ecosystem but also develop conservation efforts for both the waterbird population and the emerging freshwater ox-bow lake, Hansadanga beel in West Bengal, India.

Material and Methods

Study Site:

The study was conducted in a closed type ox-bow lake named Hansadanga beel (HB) of river Jalangi, which is a tributary of Holy River Ganga (Bhagirathi). HB (23° 27' N; 88° 27' E; elevation: 12m) is situated at Krishnanagar-II block of Nadia district of the state West Bengal, India and in close proximity to the "Tropic of Cancer" (Figure 1). Total area of this lake is 41.94 ha with 1.98 m depth and 830363.94 m^3 capacity (Das & Das, 2015). The study area experiences temperature range between 17°C to 40°C with an annual rainfall >1500 mm (District Environment Plan, 2024-25). Three sampling sites (Figure 1) were considered for the data collection on the basis of accessibility and variation of habitat. The location map and sampling points were made through QGIS software *ver.* 3.40.2.

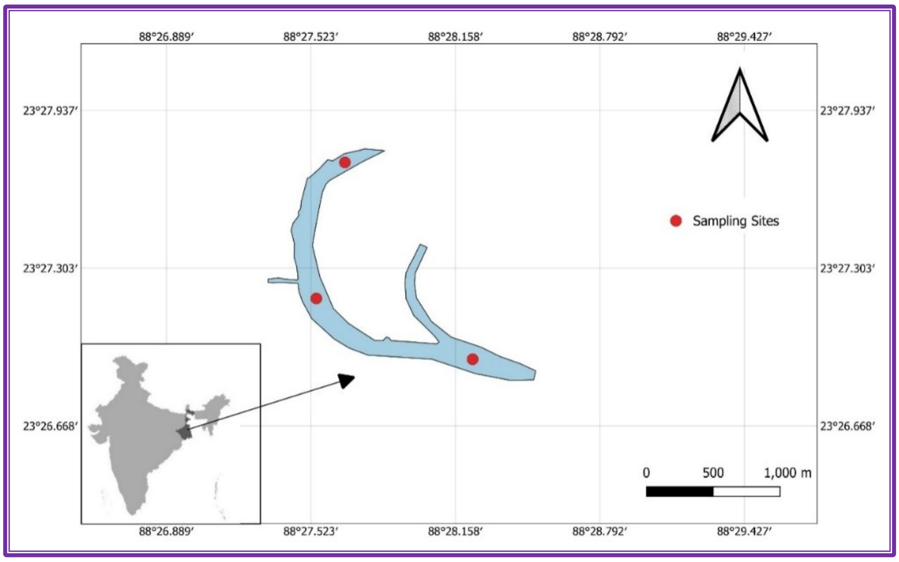

Figure 1: *Location and outline map of study area-HB with sampling sites*

Data Collection & Identification:

Monthly water samples were collected in the morning hrs. (7-10 am) for the period of one year (January 2023 to December 2023) to analyse the limnological variables of HB. During the study, some of the samples were immediately analysed, while the others were preserved properly and carried to the research laboratory of Departmental Zoology of Brahmananda Keshab Chandra College for further analysis. Additionally, three replicates of the water samples were taken from the bottom, column, and surface of each sampling site; the mean value of these was then taken into account. Surface and subsurface water samples (5-10 cm water depth) were collected with handheld high-density polythene or glass containers. Whereas column (50-80 cm water depth) and bottom (160-180 cm water depth) samples were collected in a glass bottle (without cap) with the help of a metal bottle holder and a calibrated vertical rope to avoid drift. Samples were collected by lowering the bottle slowly to the target depth and allow it to remain at that depth for 10–20 seconds to replace the water; Then pull the rope up steadily to avoid turbulence and remove the bottle and cap immediately to avoid atmospheric mixing.

Monthly collection of waterbirds data was carried out for the period of one year (January 2023 to December 2023). The most effective way to estimate bird density is by point count method (Sutherland *et al.,* 2005). With this approach, samplings were carried out during morning (6:00 AM – 10:00 AM) and evening time (3:00 PM – 6:00 PM) at each sampling stations. Each sampling station had four randomly chosen spots for bird observation that were at least 100 meters away. Sampling was done 4 times in a month and the mean values were taken into account (Urfi et al., 2005). Observations were made with the help of Olympus 8-16×40 zoom DPS I Binocular and Laser Rangefinder (600 m; model: MiLESEEY-PF210) and photographed by Nikon D7000 DSLR camera and Nikon AF-S Nikkor 200-500 mm F/5.6E ED VR lens.

Identification of various waterbird species were carried out with the help of following literatures (Ali & Ripley, 1987, Grimmett *et al.,* 1999 & Sangha, 2021). A few inconspicuous waterbird species were identified through their calls (Aynalem & Bekele, 2009).

Data Analysis:

A total of eight limnological variables of water such as water temperature (WT), pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total alkalinity (TA), nitrate nitrogen (NO_3-N), phosphate phosphorus (PO_4-P) were analysed following the standard method of APHA (1998).

IUCN status of the waterbird species recorded from study area were recognised as per IUCN (2025). The Residential status, such as Resident (R), Local-Migrant (LM), and Winter-Migrant (WM) was determined bytheiravailability and observations during the study period (Singh & Laura, 2013). Relative diversity (RD_i) of waterbird families was calculated using the following formula (Torre-Cuadros *et al.,* 2007):

$$\text{Relative diversity } (RD_i) = \frac{\text{Number of waterbird species in a family}}{\text{Total number of species}} \times 100$$

Relative abundance (RA) was calculated as - Very common (VC)(occurring 75–100% of visits), Common (C) (occurring 50–74% of visits), Uncommon (UC) (occurring 25–49% of visits), and Rare (R) (occurring <25% of visits) on the basis of sighting frequency (Khan, 2005).Shannon-Wiener diversity index, Simpson's dominance index, Margalef's richness index and Pielou's evenness index of waterbird population were calculated with the help of PAST statistical software *ver.* 4.03 and graphical representations were carried out with the help of Origin 2025 (*ver.* 10.2).Canonical correspondence analysis (CCA) were made through R statistical programme *ver.* 4.1.3.

Results

Limnological Variables

In the present study, total eight limnological variables were analysed for the water quality examination of HB. The results are tabulated as the minimum (min), maximum (max), mean, and standard deviation (SD) (Table 1).

Table 1: *Overall trend of limnological variables in HB during study period.*

Parameter	Min	Max	Mean ± SD*
Water Temperature (WT) (°C)	16.83	31.23	24.74±4.94
pH	7.80	8.33	8.13±0.16
Dissolved Oxygen (DO) (mg/L)	4.98	7.91	6.53±0.99
Biochemical Oxygen Demand (BOD_5) (mg/L)	8.30	12.49	9.59±1.83
Total Alkalinity (TA) (mg/L)	69.90	129.82	94.52±20.77
Chemical Oxygen Demand (COD) (mg/L)	30.26	80.91	48.08±18.29
Nitrate-Nitrogen (NO_3-N) (mg/L)	0.27	1.21	0.75±0.32
Phosphate (PO_4-P) (mg/L)	0.20	1.40	0.70±0.46

*The Mean ± SD is the observation of 12 values.

The minimum WT was recorded 16.83°C, in the month of January, where the maximum, 31.23°C, was found in May. The average WT from the study site was recorded 24.74±4.94 (°C). In this study the lowest pH was recorded 7.8, in the month of July and the highest, 8.33, in the month of February. The average pH of the study area was recorded as 8.13±0.16. DO content is a crucial physico-chemical variable for evaluating water quality, organic contamination, productivity, ecological status and the overall health of water resources (Lone *et al.,* 2021). In this study, the lowest DO value (4.98 mg/L) was observed in April whereas the highest value (7.91 mg/L) was found in the month of August with an average of 6.53±0.99 (mg/L). The BOD of water is a measurement of the quantity of oxygen needed by microorganisms to break down organic matter in a sample of water under particular conditions (Boyd, 2020). The minimum BOD value, 8.30 mg/L, was observed in August and the peak value, 12.49 mg/L, was found in May, with average BOD value 9.59±1.83 (mg/L) during study period. In this study, the minimum and maximum TA values were recorded as 69.9 mg/L in September and 129.82 mg/L in April respectively. The average TA value was 94.52±20.77 (mg/L). The minimum COD value, 30.26 mg/L, was observed in December and the peak value, 80.91 mg/L, was found in May, with average COD value 48.08±18.29 (mg/L) during study period. The nitrate level in this wetland was found to be moderate. The lowest value was observed in the month of December (0.27 mg/L) whereas the highest value was found in the August (1.21 mg/L) with the average value of 0.75±0.32 (mg/L). Phosphorus is the primary nutrient influencing the rate of eutrophication in freshwater (Lee, 1973). In this study, the minimum value of PO_4-P was observed in the month of December (0.20 mg/L) whereas the maximum value was found in the July (1.40 mg/L) with the mean value of 0.70±0.46 (mg/L).

Waterbird diversity

According to the current study, 35 species of waterbirds from 11 families were recorded from Hansadanga beel throughout the study period (Table 2). The highest number of waterbird species were observed under the family Ardeidae with 7 species (20%), followed by Anatidae with 6 species (17.14%), Scolopacidae with 5 species (14.29%), Alcedinidae with 4 species (11.43%), Charadriidae, Motacillidae and Rallidae with 3 species each (8.57% each) and Ciconiidae, Phalacrocoracidae, Podicipedidae and Recurvirostridae each with single species (2.86% each). Muralikrishnan et al., (2017), Debnath *et al.,* (2018) &Chakraborty *et al.,* (2021b) have also found Ardeidae as the dominant family in similar type of wetlands.

Among the observed waterbird species, 15 species (42.86%) were residents (R), 4 species (11.43%) local-migrants (LM) and 16 species (45.71%) were winter migratory (WM) (Table 2). In the present study, residential status of waterbird species showed some variations in their relative abundance (Figure 2). Out of 35 waterbird species, 8 species each (22.86% each) were reported as Very common (VC) and common (C), 13 species (37.14%) as Uncommon (UC) and 6 species (17.14%) were reported as rare (RA).

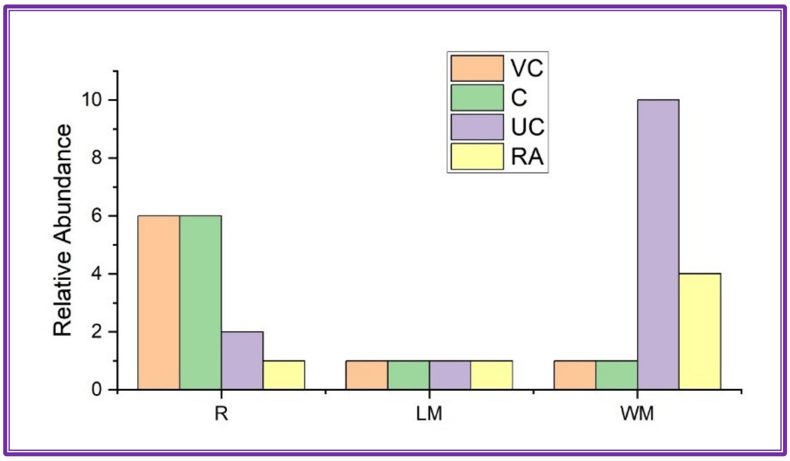

Figure 2**:** Residential status (R: Resident; LM: Local-Migrant; WM: Winter-Migrant) and Relative abundance (VC: Very common; C: Common; UC: Uncommon; RA: Rare) of waterbirds of HB

Table 2: *Systematic list and status of waterbirds recorded from HB during study period*

Code	Family / Common English Name	Scientific Name	IUCN Status*	Residential Status**	Relative Abundance ǂ
	Ardeidae				
S1	Little egret	*Egretta garzetta*	LC	R	VC
S2	Intermediate egret	*Ardea intermedia*	LC	R	C
S3	Great egret	*Ardea alba*	LC	LM	UC
S4	Cattle egret	*Bubulcus ibis*	LC	R	VC
S5	Indian pond heron	*Ardeola grayii*	LC	R	C
S6	Black-crowned night heron	*Nycticorax nycticorax*	LC	R	RA
S7	Purple heron	*Ardea purpurea*	LC	LM	RA
	Anatidae				
S8	Lesser whistling-duck	*Dendrocygna javanica*	LC	WM	VC
S9	Common teal	*Anas crecca*	LC	WM	RA
S10	Gadwall	*Anas strepera*	LC	WM	RA
S11	Ruddy shelduck	*Tadorna ferruginea*	LC	WM	UC
S12	Red-crested pochard	*Netta rufina*	LC	WM	UC
S13	Cotton pygmy-goose	*Nettapus coromandelianus*	LC	WM	UC
	Phalacrocoracidae				
S14	Little cormorant	*Phalacrocorax niger*	LC	R	VC
	Podicipedidae				
S15	Little grebe	*Podiceps ruficollis*	LC	R	VC
	Alcedinidae				
S16	Common kingfisher	*Alcedo atthis*	LC	R	C
S17	White-throated kingfisher	*Halcyon smyrnensis*	LC	R	VC
S18	Pied kingfisher	*Ceryle rudis*	LC	R	C
S19	Stork-billed kingfisher	*Pelargopsis capensis*	LC	R	UC
	Charadriidae				
S20	Red-wattled lapwing	*Vanellus indicus*	LC	R	C
S21	Lesser sand-plover	*Charadrius mongolus*	LC	WM	UC
S22	Little ringed plover	*Charadrius dubius*	LC	WM	UC
	Ciconiidae				
S23	Asian openbill-stork	*Anastomus oscitans*	LC	LM	VC
	Motacillidae				
S24	Eastern yellow wagtail	*Motacilla tschutschensis*	LC	WM	UC
S25	White wagtail	*Motacilla alba*	LC	WM	UC
S26	White-browed wagtail	*Motacilla maderaspatensis*	LC	R	C
	Rallidae				
S27	Common coot	*Fulica atra*	LC	WM	UC
S28	Grey-headed swamphen	*Porphyrio poliocephalus*	LC	R	UC
S29	White-breasted waterhen	*Amaurornis phoenicurus*	LC	R	VC
	Recurvirostridae				
S30	Black-winged stilt	*Himantopus himantopus*	LC	WM	RA
	Scolopacidae				
S31	Wood sandpiper	*Tringa glareola*	LC	WM	RA
S32	Common redshank	*Tringa totanus*	LC	WM	UC
S33	Common sandpiper	*Tringa hypoleucos*	LC	LM	C
S34	Common snipe	*Gallinago gallinago*	LC	WM	C
S35	Common greenshank	*Tringa nebularia*	LC	WM	UC

* LC: Least concern; ** R: Resident; LM: Local-Migrant; WM: Winter-Migrant; ǂ VC: Very common; C: Common; UC: Uncommon; RA: Rare.

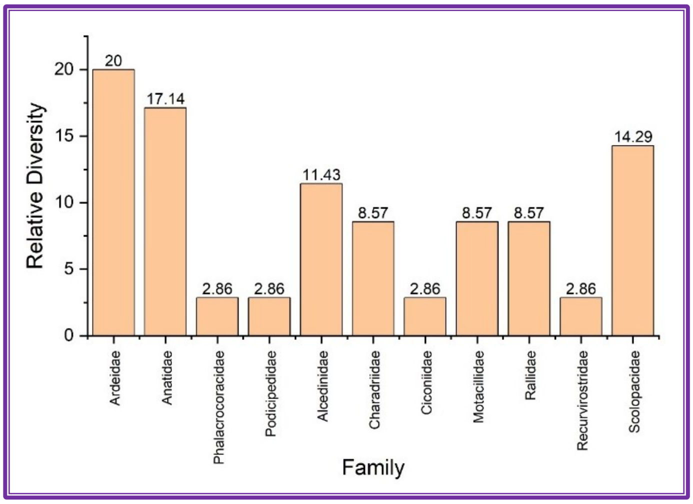

Figure 3: *Relative Diversity of different waterbird families of HB*

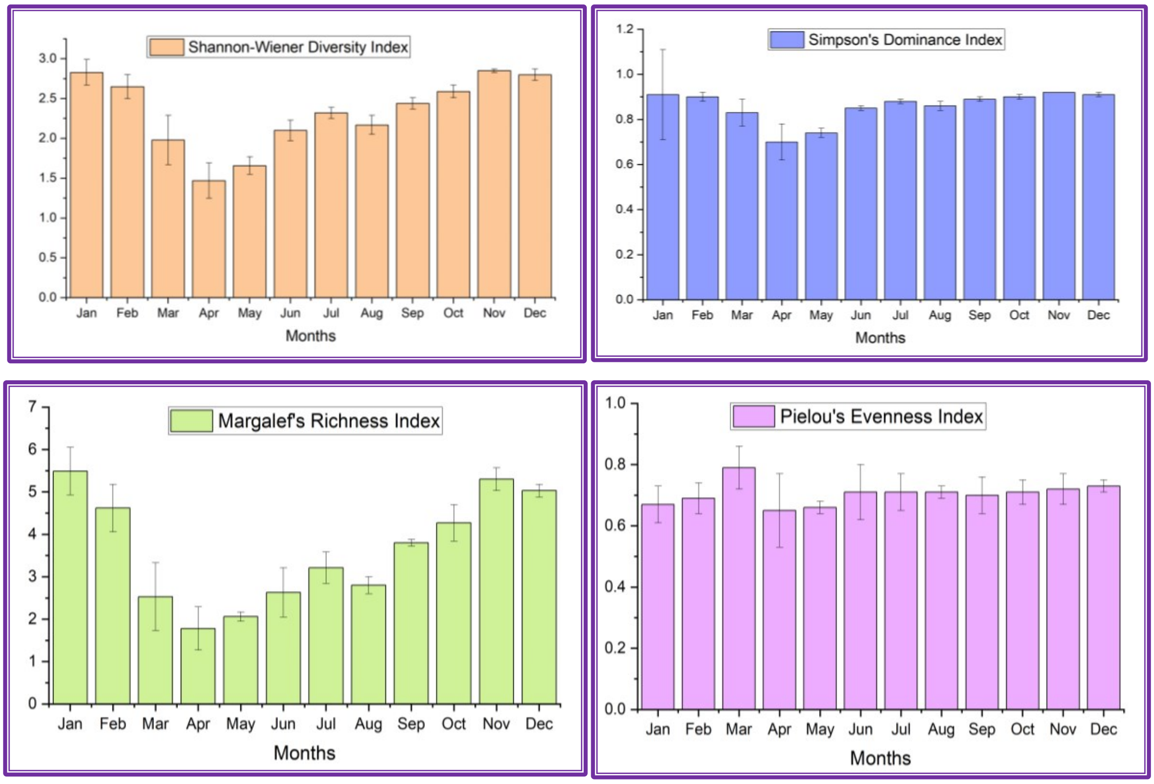

Figure 4: *Diversity indices of waterbirds from HB under present investigation*

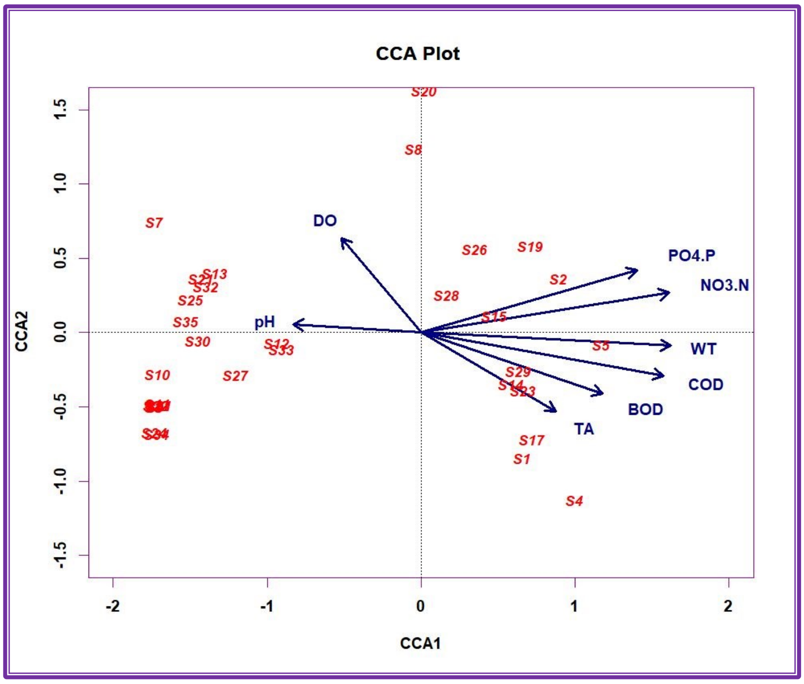

Figure 5: *Canonical Correspondence Analysis (CCA) Plot showing the impact of different limnological variables on waterbird assemblage in HB*

Ardeidae showed the highest relative diversity (RD_i) value (7 species, RD_i = 20.00) among waterbird families, followed by Anatidae (6 species, RD_i = 17.14), whereas Ciconiidae, Phalacrocoracidae, Podicipedidae and Recurvirostridae have the lowest RD_i value (1 species each, RD_i = 1.163) (Figure 3). Total waterbird species (n=35) recorded from the study area were listed under Least Concern (LC) category by IUCN, *Ver. 2024-2* (IUCN, 2025) (Table 2).

Different waterbird diversity indices recorded from the study site were shown in the Figure 4. In the recent study, highest Shannon-Wiener diversity index, 2.85±0.02, was recorded in November whereas its lowest value, 1.47±0.22, was recorded in the month of April. Maximum Simpson's dominance index, 0.92±0.00, was recorded in November whereas its minimum value, 0.70±0.08, was recorded in the month of April. The highest Pielou's Evenness index, 0.79±0.07, was recorded in March whereas its lowest value, 0.65±0.12, was recorded in the month of April and the maximum Margalef's richness index, 5.49±0.56, was observed in January whereas its minimum value, 1.78±0.51, was recorded in the month of April.

CCA was employed to evaluate the relationship between waterbird community structure and limnological variables across the sampling sites over one year of study period (Figure 5). First two CCA axes explained 43.26% of the total variation in the waterbird community structure and overall model was statistically significant ($p<0.01$).

Discussion

WT has a significant effect on aquatic animals' metabolic rates, reproductive processes, and oxygen solubility in water (Boyd, 2019). The WT values of Hansadanga beel exhibited the tropical nature of the waterbody. Similar trend of water temperature (WT) was found in the previous study by Das & Chakrabarty (2008). The onset of heavy rain may be the reason for low pH in monsoon months (June-August). The significant anthropogenic load and human settlements may be the main causes of the observed alkaline pH levels and similar investigations have been conducted by several authors yielding same results (Das & Chakrabarty 2007 & 2008, Debnath & Panigrahi, 2018 & Ahmed *et al.,* 2024). The use of oxygen for the breakdown of organic matters at high temperatures may be the cause of the lower DO readings in summer months. Such condition in pre-monsoon enhances the growth of blue-green algae (Chakraborty *et al.,* 2021a). Das & Chakrabarty (2007), Patra *et al.,* (2010) & Chakraborty *et al.,*

(2024) have also reported similar observations. The current study exhibited monthly BOD fluctuations and it was mainly due to the different bacterial activities and inputs through surface runoff (Das, 2011). The low values of BOD during monsoon months were probably due to the precipitation and high values of dissolved oxygen in the water body. Biswasroy *et al.,* (2010) & Chakraborty (2022) have also reported similar findings. The abundance of nutrients in the lake water caused the TA value to rise throughout the summer and rainy season, while the slow decomposition of organic matter and lower CO_2 production during the winter months kept the values low (Patra *et al.,* 2010). The results of the present study are consistent with those of many previous studies (Chennakrishnan *et al.,* 2008 &Panigrahi *et al.,* 2014). The higher COD values in summer months can be the result of the breakdown of suspended organic matter, which were released in the water (Das, 2000 & Rout *et al.,* 2003). The lower COD in winter might be because of the low WT at that time, which slows down the organic material break down (Das, 2011). Chakraborty (2022) & Chakraborty *et al.,* (2024) have found quite similar results. However, the amount of nitrate was found to be slightly higher during the monsoon season due to the effects of surface drainage and microbiological activity (Kaur & Sinha, 2019). Chakraborty (2022) & Chakraborty *et al.,* (2024) have also found similar type of observations from the wetlands of southern West Bengal. The high values of phosphate during monsoon were probably due to the surface run-off from adjacent agricultural fields. A significant amount of phosphorus can be absorbed and stored by the macrophytes (Boyd, 1971). The abundance of macrophytes in winter months, not only provide the nesting grounds for a huge number of migratory waterbirds, but it also absorbs and stores a lot of phosphorus, which in turn lowers the phosphorus content of the ambient water.

In a calendar year the WM usually arrived in the wetlands of West Bengal, usually in November, and remained until the end of February. In the months of December and January, the number of WM peaked. Similar to the current study, Anatidae and Ardeidae have been identified as the major families in various wetlands in West Bengal by Patra *et al.,* (2010), Chakraborty *et al.,* (2021b), and Chowdhury (2023). Datta (2011), Debnath *et al.,* (2018) have reported a comparatively high avian species diversity, mainly due to the inclusion of several non-aquatic avian species in their studies. From the present study, Shannon-Wiener diversity, Simpson's dominance, Margalef's richness and Pielou's evenness index values revealed a quite stable and balanced population. The post-monsoon months of the study period showed significantly greater diversity index values. It might be because a wide range of WM species have gathered in the lake in search of food and forage. On the other hand, pre-monsoon months showed lower values. High temperatures, lack of nutrients and shelter, and migration of LM species to neighbouring agricultural areas in search of food could all be contributing factors (Maheswaran & Rahmani, 2001). Usually Shannon-Wiener diversity index values fall between 0 and 4 (Thapa & Saund, 2012). The values above 3.0 indicate that habitat structure is very much balanced and stable, whereas values below 1.0 indicate the presence of pollution and degradation of habitat structure (Derso *et al.,* 2015). The value of Simpson's dominance index ranges from 0 to 1. A value of 1 indicates limitless diversity, while a value of 0 indicates no diversity. A high Margalef index indicates that the population is quite diverse. CCA-plot analysis revealed that, among different limnological variables pH, TA, PO_4-P and NO_3-N were best explained the variance in waterbird species assemblage observed. It showed that S12, S33, S27, S30, S35, S25, S32, S21 and S13 tend to be more influenced by pH level of ambient water. Whereas S2, S19, S26 and S15 were remain associated with nutrients (PO_4-P and NO_3-N) level of water. S5 and S29 remained associated with ambient WT and BOD level respectively. S14, S23 and S17 showed its association with TA. Some study revealed that the waterbird diversity was significantly influenced by water quality (FU *et al.,* 2025). Similar findings to this present study have been made by Patra *et al.,* (2010), Balapure *et al.,* (2013) & Haileselasie (2023).

Conclusion

According to the current study, it is evident that the Hansadanga beel is an important ox-bow lake in the wetland network of the Bhagirathi–Jalangi floodplain system within the lower Gangetic basin. The wetland is a significant habitat for various waterbird species, including winter migrants, especially the species of the Anatidae family, which generally favour open water habitats. The avian diversity of this area is most likely a result of its geographical location, water quality, depth and size of the water body, and intricate vegetation structure, which provide shelter, microhabitats and appropriate foraging grounds to various water and land bird species. Moreover, this lake also plays a pivotal role in providing various ecosystem services to the local people through regulating floods and supporting local fisheries and livelihoods. As this study is the first ever approach to estimate the diversity of the waterbird population, more observations to that area are also needed to evaluate the overall avifaunal diversity of the wetland. Although the waterbird population of the wetland may suffer greatly as a result of expanding agricultural practices and the careless application of chemical pesticides in adjacent areas. Instead of these threats, the overall species diversity of the wetlands in this comparable geographic region can be conserved through sustainable and holistic management practice by engaging local fishers in co-management-community involvement and restraining the construction next to the wetland region.

Conflict of Interest

The authors declare they have no conflict of interest.

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