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Seasonal variation in water bird community structure in Shekha wetland an IBA site and their association with physico-chemical parameters

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Abstract
Wetlands are the key habitats for water birds and its wealth is influenced by various environmental factors, hydrological condition and anthropogenic pressure and birds are the most important component to understand the health of wetland. This study was conducted at Shekha, an IBA site of Aligarh district, for abundance assessment and factors affecting the population characteristics of water birds. there were 91 species recorded and found significant variations in the waterbird composition among the seasons (One way ANOVA). The density of Ducks & Geese was found maximum whereas richness of large waders was maximum. Cluster analysis used to grouping the months based on birds abundance, and rarefaction curve revealed that January was the richest month. Physicochemical parameters of water showed significant variations with water bird density, diversity, richness, and evenness. It play as a vital role to regulate the bird community structure in the wetland ecosystem.

Keywords: Waterbird population characteristics, physico-chemical parameters, cluster analysis, rarefaction curve

1. Introduction
Wetlands are key protected areas because of their biodiversity and their ecological services [1, 2, 3]. Since then, it has a great nutritive value and productivity that helps maintain wilderness habitat and facilitates the congregation of many migratory and resident bird species [4] including a stopover site for the migratory bird [5, 6]. Waterbirds, in particular, have different ecological roles such as nutrient cycling, propagules dispersal, habitat engineering, and biological regulation [7]. In many aquatic environments, it thought to be top-level consumers who eat mostly fish and macro invertebrates [8] so they are helpful to control the populations of organisms such as fish [9, 10], invertebrates [11, 12], and aquatic plants [13]. They are highly mobile and thus quickly respond to changes in habitat [14, 15, 16], thereby providing knowledge about the health of wetland and regarded as good bio-indicators of habitat quality [17-20]. Studies of bird community structure and function are helpful to know the ecological theory and conservation practice [21-22]. Waterbird communities provide a valuable approach for examining the functional diversity of wetlands since they are simple to observe and bird count is the validated way of measuring wetland conditions for their long term environmental effects as conducted in many Ramsar sites or other wetlands around the world [23].
Diverse factors such as food access, wetland size [4], and abiotic parameters, and water quality in wetlands are influencing the bird distribution [24, 25]. The quality of water is vital for the evaluation of waterbird habitat, as numerous physical and chemical factors interacting can influence the primary productivity of the aquatic environment and thus affect overall biomass across the water food web [26] and a major influence on waterbird population through its direct and indirect effect on the availability and abundance of the birds' prey [27]. Several studies have already shown a link between water quality and waterbirds [28-32].
Present work was carried out at Shekha wetland (shekha jheel) in Aligarh district which an IBA site and identified under National Wetland Conservation Programme (NWCP) as per Ministry of Environment and Forests, Government of India in 2009. A significant number of birds inhabited this geographical area along with a substantial number of winter visitors. However, only few studies have been conducted in this wetland for waterbirds community structure. Here we provide baseline information on waterbird assemblage in the shekha

wetland. The main aim of the present study on the population of the aquatic avifauna was to find out their density, diversity, richness, and evenness in different seasons and months and as well as to find out the relationship between population abundance with the physico-chemical parameters of water.

2. Material and Method

2.1 Study Area

Shekha lake is a perennial wetland that falls between the latitude 27° 51' 21" North and longitude 78° 13' 05" East, in the upper Gangetic Plain of northern India (Fig 1). It is situated at about 17 km away from Aligarh in the dhanipur block of Koil tehseel on the Aligarh Jalali road. The metal road and upper Ganga canal made two boundaries i.e. eastern and northern respectively of the lake while the other two sides are surrounded by agricultural fields that separated through a thick tree line. It represents a mosaic of habitats that support a wide variety of aquatic and terrestrial flora and fauna, especially for the wintering waterbirds.

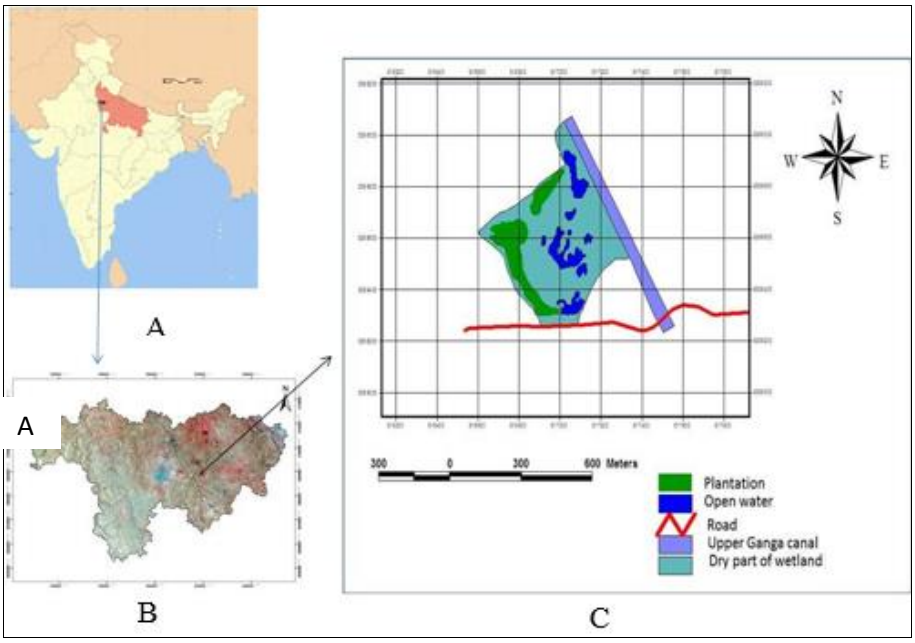

Fig 1: Map of study area (A) India with Uttar Pradesh (B) Aligarh district and (C) Shekha wetland

2.2 Waterbird sampling

We used the total count method [33] to record the bird species abundance with an attempt to cover all the birds in the wetland. The wetland was visited twice in the month from Sept 2017 to April 2018 and Sept 2018 to April 2019. The birds were identified based on standard field guide of Birds of Indian subcontinent [34]. All the recorded waterbirds were categorized into five ecological groups based on their foraging activities *viz*., Group I: Ducks & Geese, Group II: Diving birds, Group III: Large waders, Group IV: Small waders, and Group V: Aerial foragers.

2.3 Sampling and estimation of physicochemical parameters of wetland

Water samples were collected from four cardinal stations of the wetland. The temperature, ph, Electrical conductivity, Salinity, Total dissolved solids, and Dissolved oxygen was recorded using the microprocessor water analysis kit whereas Total Acidicity, Total alkalinity and total hardness was estimated using the titration method described by APHA [35].

2.4 Data Analysis

Density (birds/hectare) was calculated in excel Microsoft office whereas diversity, richness, and evenness were calculated for the waterbirds on a monthly and seasonally basis in the PAST software. One way Anova was used to know the significant differences among the seasons and monthly abundance of waterbirds. Cluster Analysis was used to grouping similar months based on the waterbird abundance in the wetland using the average linkage method. Spearman correlation coefficient was calculated for investigating the relationship between physico-chemical variables and waterbird populations characteristics *viz*., density, richness, diversity, and evenness. These analyses were performed by using Windows-based statistical package SPSS [36].

3. Results and Discussion

3.1 Waterbird structure and Composition at Shekha Wetland

A total of 91 species was recorded that belong to 32 families of 13 orders, these birds comprises 61 waterbirds and wetland-dependent birds and 30 terrestrial birds. The percentile distribution of migratory birds was 38.5% and 61.5% for resident birds. Globally threatened species such as 1 Endangered (Egyptian Vulture), 6 Near Threatened (Ferruginous Pochard, Black necked stork, Black headed ibis, Painted stork, Black tailed Gotwit and Darter) and 4 Vulnerable species (Greater spotted Eagle, Common Pochard, Woolly necked stork and Sarus crane) were recorded from the study site. However, this number was in contrast with other researchers such as Yahya *et al.* (1990) [37] described 188 species from the environs of Aligarh, Rahmani & Sharma (1997) [38] reported 161 species and Abbasi F (2004) [39] reported 165 species. This shift might be attributed to the changes in environmental factors and anthropogenic actions that degrade habitat to affect the structural composition of birds.

3.2 Seasonal density, diversity, richness and evenness of waterbirds at Shekha wetland The overall annually mean density of total birds in Shekha wetland was (48.18±7.31) indi/ha. Out of this, the mean density of waterbirds and terrestrial birds was (45.89±7.09) indi/ha and (2.30±0.37) indi/ha respectively (Fig 2A) (Table 1). Seasonally, the mean density of total waterbirds was found maximum in the winter season (78.56±5.46) indi/ha followed by post-monsoon (34.23±8.72) indi/ha and minimum in summer (23.54±6.55) indi/ha (Table 1). The result was found to be highly significant (One way ANOVA, $F_{2\ 29}$= 15.46, p=0.001). It might be attributed to the arrival of more migratory species during the winter season.

As far as the species diversity and richness is concerned, the total waterbirds were found higher in winter (2.88±0.11), (5.30±0.16) followed by summer (2.86±0.03), (4.32±0.44) and lower in post-monsoon (2.82±0.10), (4.31+0.43) respectively whereas waterbirds were more evenly distributed in summer (0.63±0.04) followed by post-monsoon (0.58±0.03) and less in winter (0.42±0.01) (Fig 3), the result was found to be highly significant only for evenness (One-way Anova, $F_{2\ 29}$=15.30; $p< 0.05$). Because in summer and post monsoon, waterbird's population is less than they have more space to their activities and more resources to fulfill their requirments. The result of higher density, diversity, richness during winter season is similar with many studies such as (Deshkar *et al.* (2010), Jha *et al.* (2015), Kumar *et al.* (2016) Mazumdar (2017), Rajashekara & Venkatesha (2017)) [30, 40-43].

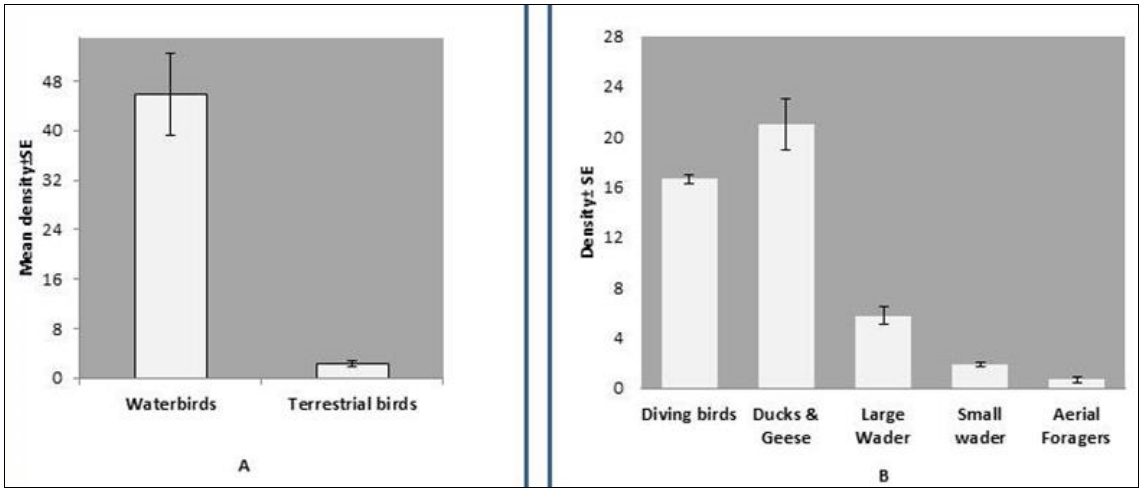

Fig 2: Mean density (Indi/ha±SE) of (A) total birds and (B) groups of waterbirds at Shekha wetland

Table 1: Seasonal mean density (Indi/ha) of waterbirds in shekha wetland

	Post monsoon	Winter	Summer	Overall
Terrestrial birds	1.90±0.32	3.37±0.75	1.31±0.19	2.30±0.37
Waterbirds	32.33±8.4	75.19±4.71	16.99±6.36	45.89±7.09
Total birds	34.23±8.72	78.56±5.46	23.54±6.55	48.18±7.31

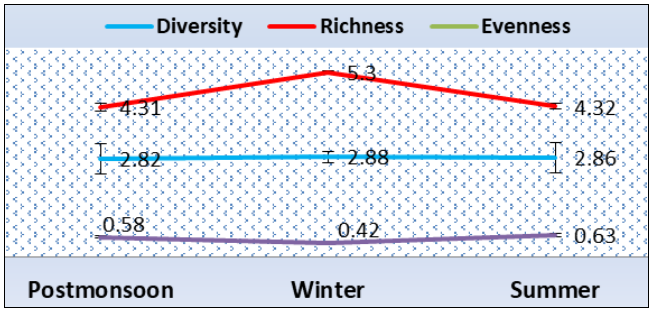

Fig 3: Species diversity, richness, and evenness of waterbirds in Shekha wetland across the different seasons

3.3 Seasonal density, diversity, richness and evenness of different ecological groups of waterbirds at Shekha wetland

Among the ecological groups of waterbirds, the overall maximum abundance was found in the ducks & Geese group > diving birds > large waders > small waders > aerial foragers (Fig 2B) (Table 2). Seasonally, the mean density of each group i.e. ducks & geese (40.78±5.61) indi/ha, diving birds (10.74±2.44) indi/ha, large waders (3.59±0.41) indi/ha, small waders (2.13±0.35) indi/ha, aerial foragers (0.88±0.69) indi/ha and terrestrial birds (3.37±0.75) indi/ha was found maximum in winter season whereas the group of ducks & geese (5.90±3.33) indi/ha, large waders (3.59±0.41) indi/ha, diving birds (10.74±2.44) indi/ha, aerial foragers (0.30±0.20) indi/ha and terrestrial birds (1.31±0.19) indi/ha was found minimum in the summer except small waders (1.60±0.14) indi/ha that found minimum in post-monsoon (Table 2). The results were found to be highly significant only for ducks & geese (One way ANOVA; $F_{2\ 29}$=13.78; p=0.001), and diving birds (One way ANOVA; $F_{2\ 29}$=13.57; p=0.001). However, the diversity and richness of large waders was higher among all seasons whereas aerial foragers were evenly distributed in all the seasons (Fig 4)

Ducks & geese was found the most dominant group in winter because it belong to group Anatidae family that reported to the largest family of waterbird community [44-46] and comprising 85% of the winter migrant bird population [47, 48], in the present study, more than 50% migratory species belongs to this group that utilizes this wetland with different feeding habits i.e. the dabbling ducks, diving ducks and Marsh ducks [34] occupy different microhabitats of the wetlands which are sufficiently powerful in sustaining the load of a broad population of ducks. This lessens the competitiveness for food resources known as the restrictive factor in the distribution of ducks [49]. Moreover, the abundance of diving birds was found dominated in the summer and post-monsoon season. While the group of large waders was dominated in terms of their diversity and richness

throughout all the seasons. This result was supported by the Deshkar *et al.* (2010) [30]. The reason behind this all the species of diving group and more than 70% species of large waders was resident and common to the study area such as cormorants, darter, Eurasian coot, purple swamphen, common moorhen, herons, egrets and storks. During post monsoon and summer, some species were busy with their nesting and breeding activities. Further the study area is distant from urban impact and partly shielded against vehicular traffic with thick layer of tree line that provide shelter to many species in all seasons. However, In general, according to Hattori and Mae (2001) [50], shrubs, trees and crop fields surrounding wetlands offer ideal shelters for waterbirds particularly herons, egrets and cormorants that often use the trees and shrubs as places for roosting and crop fields as foraging place.

Table 2: Overall and seasonal mean density (Indi/ha) of different ecological groups of waterbirds in shekha wetland

	Post monsoon	Winter	Summer	Overall
Diving birds	13.03±2.30	24.13±1.06	10.74±2.44	16.62±1.84
Ducks and Geese	11.30±4.92	40.78±5.61	5.90±3.33	21.01±4.84
Large Waders	5.72±1.36	7.27±0.91	3.59±0.41	5.77±0.69
Small waders	1.60±0.14	2.13±0.35	1.71±0.50	1.83±0.18
Aerial Foragers	0.67±0.30	0.88±0.69	0.30±0.20	0.66±0.28

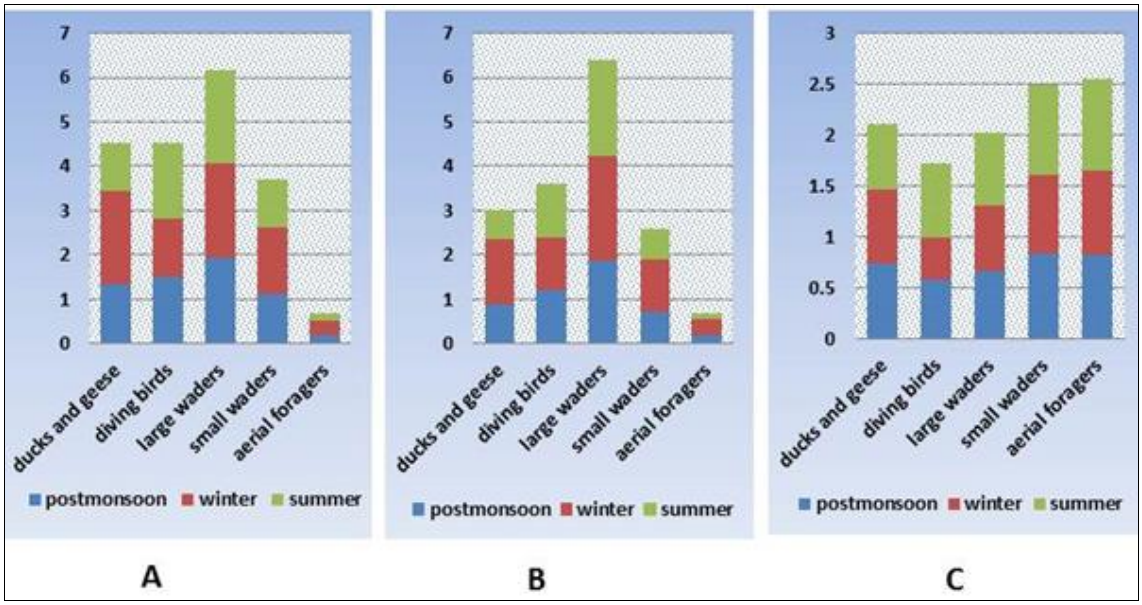

Fig 4: Species diversity (A), richness (B), and evenness (C) of different ecological groups of waterbirds across the different seasons

3.4 Monthly distribution of waterbird population structure at Shekha wetland

In the present study, the rarefaction curve of birds revealed that the richness of birds maximum in January followed by December and February than November, March and minimum in October, September, and then April (Fig 5).Moreover, hierarchical cluster analysis depicted in dendrogram depending on the month-wise abundance of birds revealed that eight studied months formed three main clusters (Fig 6). Sept, Apr, Oct, and March were very closely related months in terms of the abundance of birds that were dominated by the diving group of birds (Fig 7). The second cluster of related months was November, December, and February that dominated by diving birds and ducks & geese groups of waterbirds (Figure 7), and the month of January was the single distinct cluster due to the highest abundance of waterbirds, dominated by ducks & geese group (Fig 7).

The congregation of waterbirds was at a peak in January and lowest in April, this result was supported by Saxena (1975), Bhat *et al*. (2009), and Sharma (2018) [51, 17, 52]. The result shows a distinct pattern of species composition and frequency of wetland birds in various seasons and months of the year because the fundamental necessities such as food, refuge, adequate roosting, and nesting spots for birds are not uniformly accessible during various seasons [53, 54, 40].

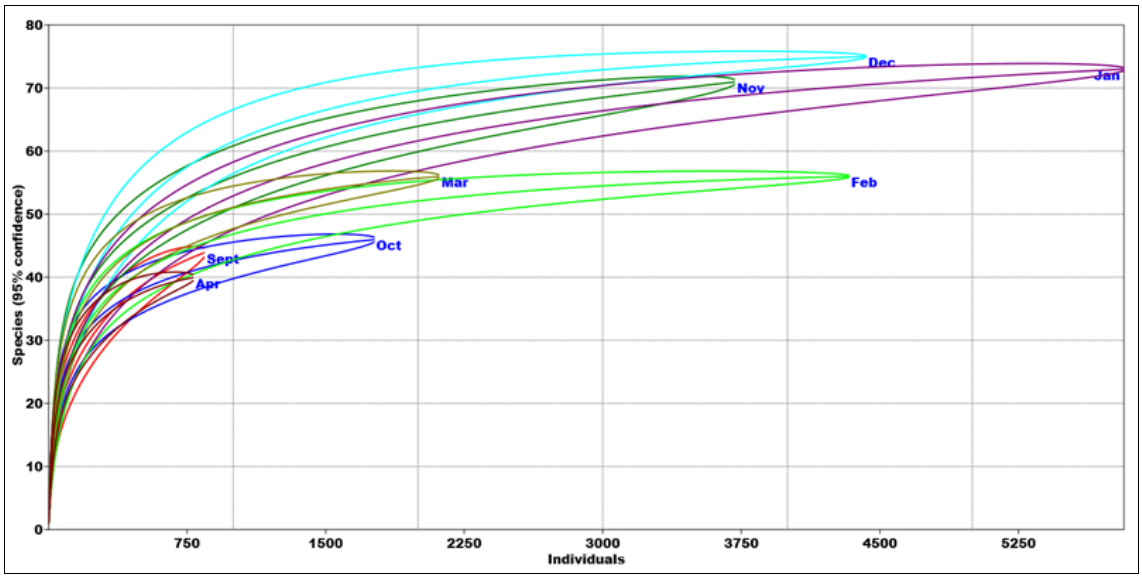

Fig 5: Rarefaction curve for the monthly richness of birds

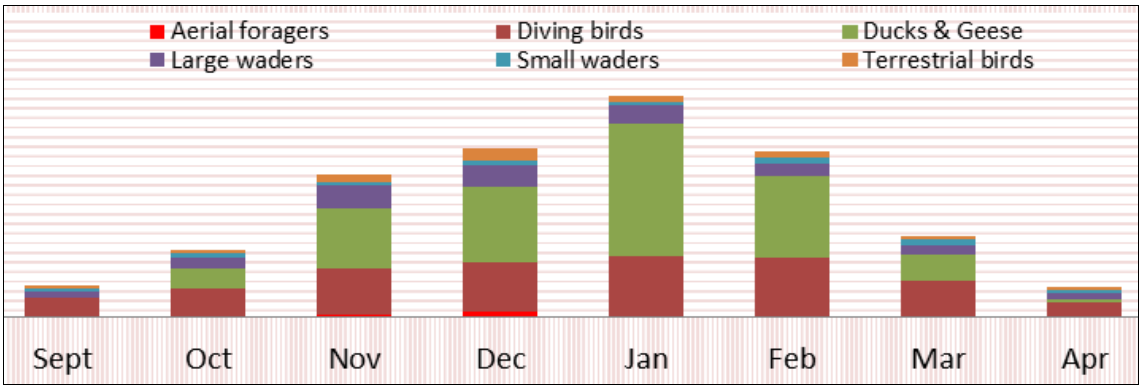

Fig 6: Monthly abundance of waterbirds at shekha wetland

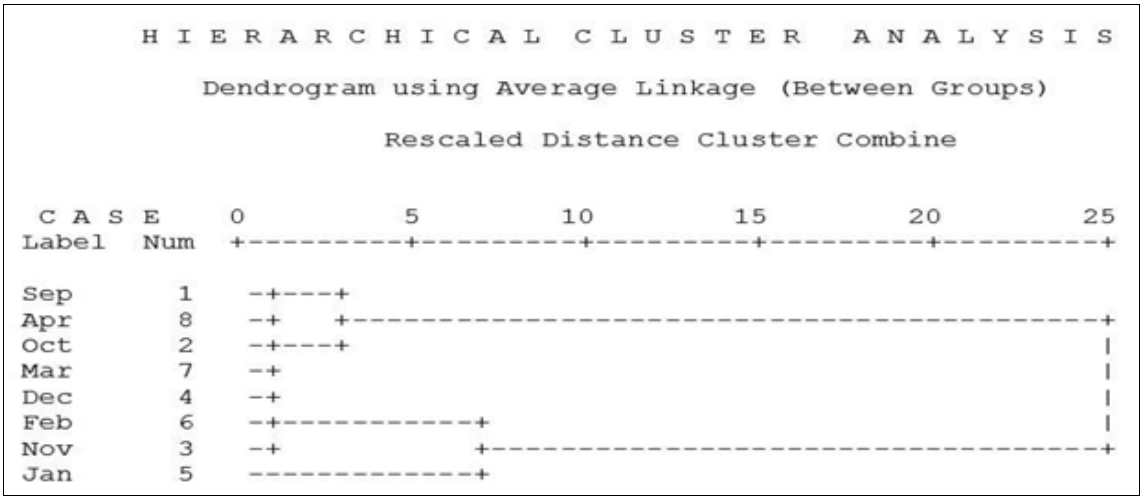

Fig 7: Hierarchical cluster analysis to show the similarity of months in terms of their abundance

3.5 Relationship between the waterbirds and physicochemical parameters

The assemblage of waterbirds and their distribution are influenced by several variables such as morphological structure, vegetational features, open water, food availability, surrounding wetland habitats, wetland depth and area etc. In the present study, physico-chemical characteristics were investigated as it is chiefly determined the waterbird community of wetland habitats, primarily by their direct and indirect influence on the availability and abundance of the birds' prey [27] and regulate the abundance of waterfowl [28].

The overall correlation between the waterbirds and physico-chemical parameters was shown in table 3. At Shekha wetland, waterbird density was significantly positively correlated with dissolved oxygen (r=0.783; p<0.05) and negative with temperature (r=-0.862; p<0.01), hardness (r=-0.778; p<0.05), and total acidicity (r=-0.795; p<0.05).Waterbird diversity was significantly positive

correlated with dissolved oxygen (r=0.711; $p<0.05$) and negative with salinity (r=0.810; $p<0.05$), while bird richness was negative with temperature (r=0.790; $p<0.05$),electrical conductivity (r=-0.790; $p<0.05$), total dissolved oxygen (r=-0.738; $p<0.05$), hardness (r=-0.898; $p<0.01$), and total acidicity (-0.747; $p<0.05$) and positive with dissolved oxygen (r=0.819; $p<0.05$). However, bird species evenness was negatively correlated with dissolved oxygen and hardness. Temperature being a key factor for seasonal waterbird migration and primary productivity of wetlands that influence the invertebrate physiology and the waterbird composition in the wetland system [55]. Infect many ecological processes are impacted through temperature in wetlands [56]. Among all the abiotic factors, the most significant aspect in freshwater life is dissolved oxygen since it provides vital information about the biological and biochemical reactions in waterbody [57] and governs the metabolism of aquatic organisms and the water body condition [56]. The oxygen content governs the distribution of invertebrates, which impacts the population and distribution of waterfowl as these birds mainly feed on a broad range of invertebrates and small fish [58]. Hardness and total acidicity also important parameter for the distribution of waterbirds. Hence our study indicate that the changes in the bird composition and their structure related to the seasonal variation, migratory pattern, habitat structure and hydrological structure of wetland.

Table 3: Relationship of waterbird population with the water parameters

	Bird Diversity	Bird Richness	Bird Evenness	Bird Density
Temperature	-0.611	-.790*	0.707	-.862**
pH	0.455	0.599	-0.192	0.575
Electrical Conductivity	-0.659	-.790*	0.695	-0.635
Salinity	-.810*	-0.643	0.476	-0.595
Total dissolved solids	-0.643	-.738*	0.595	-0.548
Dissolved Oxygen	0.711*	0.819*	-0.771*	0.783*
Total Alkalinity	-0.357	-0.143	0.191	-0.31
Total Acidicity	-0.386	-.747*	0.699	-.795*
Hardness	-0.611	-.898**	.826*	-.778*

**Correlation is significant at 0.01 level
*Correlation is significant at 0.05 level

4. Conclusion

The result of this study highlighted the importance of Shekha Lake that situated in the Gangetic plain of northern India as a potential habitat for birds and other flora and fauna also. As 91 bird species belonging to 32 families of 13 orders were observed throughout the research sufficiently reflected the importance of this wetland since it is a mosaic of habitats such as wetland, grassland, forest, and agricultural field that provide nesting, roosting, feeding, and foraging place for the waterbirds and some terrestrial birds. Winter visitors constitute 38.5% of all species recorded suggested the attractive quality of wetland. The results indicate that waterbird populations in wetlands and related landscapes need to be conserved due to the presence of globally threatened species. This study also indicates the effect of limnological characteristics on waterbird's congregation especially temperature and dissolved oxygen.

The management recommendation comprises good water quality maintenance, minimization of water pollution, controlling weed infestation, cattle grazing, maintaining habitat heterogeneity, and adequate water level that are decisive to maintain the ecological integrity and conserve overall biodiversity, as well as, enduring the wetland bird community of this protected wetland. Education and environmental awareness activities should be accessible to local people. Therefore, Long-term monitoring and management of avifaunal musters over time and analyzing physiochemical parameters, and other wetland features is an effective tool to determining the ecological health of wetland and thus could help instill the sustainability.

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