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SEASONAL SURVEILLANCE OF LIMNOLOGICAL PARAMETERS WITH RELATION TO ICHTHYOFAUNAL DIVERSITY IN A FLOODPLAIN LAKE OF WEST BENGAL, INDIA USING PRINCIPAL COMPONENT ANALYSIS AND COMPREHENSIVE POLLUTION INDEX

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ABSTRACT

The health status of any aquatic body is directly dependent on its physicochemical properties. This present seasonal assessment was carried out to evaluate the correlation between limnological parameters and fish diversity, as well as Comprehensive Pollution Index of Nandannagar jheel, North 24 Parganas, West Bengal, during the tenure of March 2019 to February 2021. Water samples were collected on monthly basis at 4 stations of this jheel and limnological characteristic like pH, dissolve oxygen, carbon dioxide, turbidity, water temperature, total alkalinity, total hardness, phosphate, nitrate and biochemical oxygen demand are measured. The principal component analyses (PCA) result showed that pH (-0.864), total alkalinity (-0.799), dissolve oxygen (-0.900), and carbon dioxide (0.853) were the main factors. Significant ($p < .05$) negative correlations were recorded between water temperatures and dissolve oxygen, carbon dioxide and dissolve oxygen, while significant ($p < .05$) positive correlations were found between pH and biochemical oxygen demand, pH and dissolve oxygen. In respect of fish faunal diversity, a total of 28 species belonging to 6 orders and 15 families were identified. Maximum representatives belong to order Cypriniformes having 6 species with 38% catch composition, whereas Perciformes with 12 species with 28.55% catch composition. Both the Shannon Weiner diversity index (2.871-2.998) and comprehensive pollution index (0.53-0.61) indicate the water body of this jheel is moderately polluted. The study recommends constant monitoring is needed to minimize the anthropogenic activities surrounding this jheel.

KEY WORDS : Limnological parameters, PCA, Shannon-Weiner index, Nandannagar jheel, CPI.

INTRODUCTION

Wetland is one of the important habitats for a huge number of aquatic flora and fauna stretching from plankton-like microorganisms to various micro and macro hydrophytes, invertebrate, and vertebrate species. Those aquatic biota are the main factors for maintaining the food chain of the wetland ecosystem. Wetlands are the most productive ecosystem and continuous monitoring is required for the proper management of these water bodies (Ramachandra *et al.*, 2006). The hydrology of wetland in relation to its physicochemical property is one of the important parameters to assess during the study of its health status (Bera *et al.*, 2014). The physicochemical parameters play an important role to study any aquatic environment (Jagadeeshapp and Kumara, 2014). In the present scenario due to unplanned urbanization, rapid industrialization, and indiscriminate use of chemical pesticides in agricultural land, these water bodies are getting damaged both qualitatively and quantitatively in terms of water quality as well as depleting species diversity (Sati and Paliwal, 2008). Alteration of the Hydrological state of wetland affects the aquaculture activities, decreases in fish productivity, change in species composition, and overall loss of biodiversity that resulted in degradation of wetland ecosystem (Patra *et al*., 2010).

Multiple works have been done regarding physicochemical status, plankton density diversity, fish diversity, etc by several workers (Ara *et al*., 2003; Korai *et al*., 2008; Mondal *et al.,* 2010; Kumar, 2011; Vincent *et al*., 2012; Koli and Muley, 2012; Bhatnagar and Devi, 2013; Azmi *et al*., 2015; Dey *et al*., 2015; Iqbal *et al*., 2015; Das Gupta *et al*., 2016; Ansari, 2017) in various wetlands throughout the world. But very little is known about Nandan Nagar Jheel regarding its physicochemical properties of water and fish diversity. Correlation between physicochemical parameters and fish diversity was measured during the pre-monsoon, monsoon, and post-monsoon season from March 2019 to February 2021. A comprehensive pollution index of this jheel was also carried out.

MATERIALS AND METHODS

The present study was carried out in Nandan Nagar Jheel (22°40'8.37''NL; 88°24'23.8''EL) (Figure 1) falls under North 24 Parganas districts of West Bengal, India, at an altitude of 6 meters above sea level. Nandan Nagar Jheel spreads over an area of 7 hectares.

A total of four representative sampling sites (Site 1, Site 2, Site 3, and Site 4) were selected. The most changeable and sensitive water quality parameters such as water temperature (WT), pH, turbidity (TUR), dissolve oxygen (DO) and free carbon dioxide (CO_2) were measured in-situ (Panigrahi and Pattanayak, 2020), while rest parameters like biochemical oxygen demand (BOD), total hardness (TH), total alkalinity (TA), phosphate (PO_4^-) and nitrate (NO_3^{2-}) were examined in the laboratory. The collection procedure was followed for sample preservation and assessment of various water quality indices (APHA, 2005; APHA, 2012). The wild fishes were captured at four stations with local nets and their identification was confirmed by the method used by Armantrout *et al*. (1994). The diversity indices were calculated by the references of Shannon *et al* (1950). Comprehensive Pollution Index (CPI) was carried out to find out the water quality (Zhao *et al*., 2012).

Comprehensive Pollution Index (CPI)

$$\text{CPI} = \frac{1}{n}\sum_{i=1}^{n}\frac{Ci}{Si}$$

Where CPI is comprehensive pollution index, Ci is

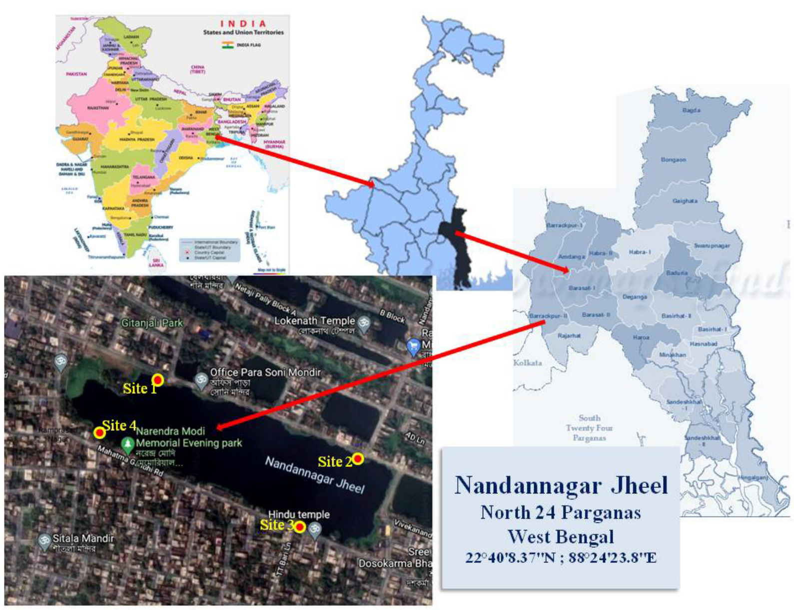

Fig. 1. Map (source: Google) of the study area with the site name.

the measured concentration of the pollutant (mgl^{-1}), Si represents the limits allowed by the CPCB (2011), BIS (2012), and WHO (2011) for water quality, and 'n' is the number of selected pollutants.

CPI ranges from 0 to 2 which classify water quality as: ≤ 0.20 is clean; 0.21-0.40 is sub-clean; 0.41-1.00 is slightly polluted; 1.01-2.0 is moderately polluted and ≥ 2.0 is severely polluted.

RESULTS

Seasonal variation of the physicochemical parameters of water (water temperature, pH, turbidity, dissolved oxygen, biochemical oxygen demand, total alkalinity, free carbon dioxide, total hardness, nitrate, and phosphate) of Nandan Nagar Jheel in pre-monsoon, monsoon, and post-monsoon season are showed in Table 1. In the present study the range of the physicochemical parameters viz., water temperature 18.9-32.2 ^{0}C, turbidity 17.3 - 27.4 cm, pH 6.2-9.2, carbon dioxide 0.1 - 9.9 mgl^{-1}, dissolved oxygen 3.4 - 9 mgl^{-1}, biochemical oxygen demand 1.2 - 6.7 mgl^{-1}, total alkalinity 140 - 203 mgl^{-1}, total hardness 100 - 165 mgl^{-1}, phosphate 0.11 - 0.4

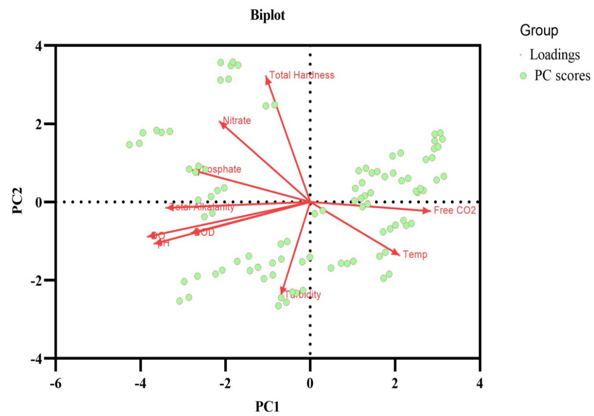

Fig. 3. Biplot of different water physicochemical parameters of water of Nandan Nagar Jheel from March 2019 to February 2021 via PCA.

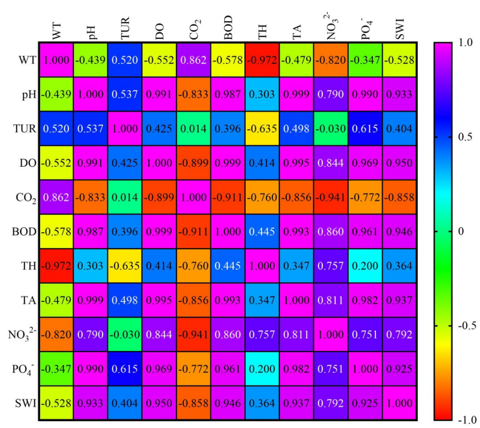

Fig. 2. Pearson correlation matrix heat map among the physicochemical parameters and Shannon-Wiener diversity Index of Nandan Nagar Jheel from March'2019 to February'2021 using PCA.

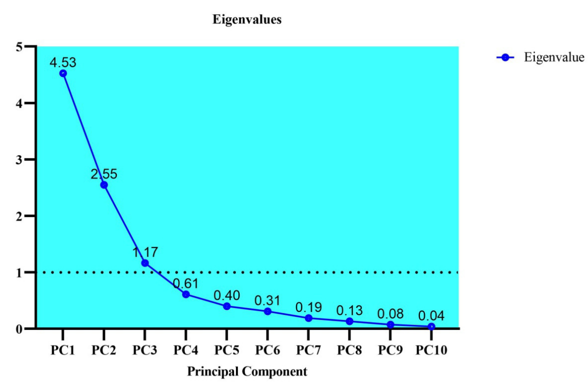

Fig. 4. Scree plot showing the eigenvalues and principal components derived from PCA regarding the different water physicochemical parameters of water of Nandan Nagar Jheel from March 2019 to February 2021.

Table 1. Different letters (a-b) indicates a significant difference ($p<0.05$) within the same row (One way ANOVA followed by Tukey test) of Nandan Nagar jheel during the study period.

	March 2019 - Feb 2020			March 2020 - Feb 2021		
	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon
W. T. (^{0}C)	27.82 ± 2.54^a	30.04 ± 1.31^a	21.41 ± 2.47^b	27.35 ± 2.51^a	29.54 ± 1.28^a	21.05 ± 2.43^b
pH	6.56 ± 0.24^a	7.72 ± 0.79^b	8.01 ± 0.38^b	6.45 ± 0.24^a	7.59 ± 0.77^b	7.88 ± 0.37^b
TUR (cm)	20.48 ± 1.92^a	25.97 ± 0.91^b	21.78 ± 2.95^a	20.12 ± 1.9^a	25.53 ± 0.9^b	21.42 ± 2.91^a
DO (mgl^{-1})	4.7 ± 0.96^a	6.75 ± 1.36^b	7.71 ± 0.59^b	4.62 ± 0.95^a	6.64 ± 1.34^b	7.58 ± 0.57^b
CO_2 (mgl^{-1})	7.56 ± 2.03^a	6.18 ± 2.06^a	2.74 ± 1.6^b	7.43 ± 1.99^a	6.08 ± 2.03^a	2.69 ± 1.57^b
BOD (mgl^{-1})	3.35 ± 1.13^a	4.32 ± 0.94^a	4.84 ± 0.99^a	3.29 ± 1.12^a	4.25 ± 0.92^a	4.76 ± 0.98^a
TH (mgl^{-1})	130 ± 6^a	122 ± 7^a	141 ± 24^a	127 ± 6^a	120 ± 6^a	138 ± 23^a
TA (mgl^{-1})	154 ± 8^a	174 ± 13^a	181 ± 15^a	152 ± 8^a	172 ± 12^a	178 ± 14^a
NO_3 (mgl^{-1})	0.04 ± 0.01^a	0.04 ± 0.01^a	0.05 ± 0.02^a	0.04 ± 0.01^a	0.04 ± 0.01^a	0.05 ± 0.02^a
PO_4- (mgl^{-1})	0.18 ± 0.03^a	0.23 ± 0.09^a	0.23 ± 0.08^a	0.18 ± 0.03^a	0.22 ± 0.09^a	0.23 ± 0.08^a

mgl^{-1} and nitrate 0.03 - 0.08 mgl^{-1} of was found. To evaluate the significance of water quality, ten water quality parameters were selected.

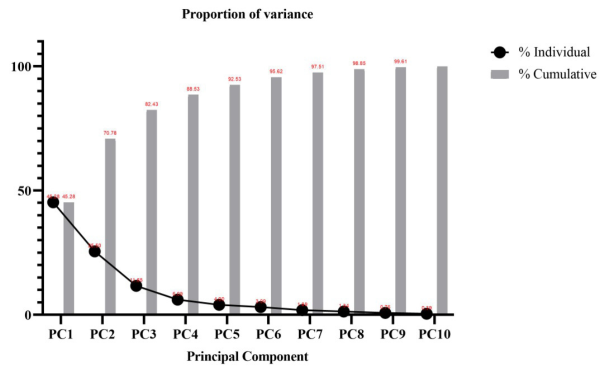

Fig. 5. Proportion of variance of principal components showing different water physicochemical parameters of water of Nandan Nagar Jheel derived from PCA of 19 –21.

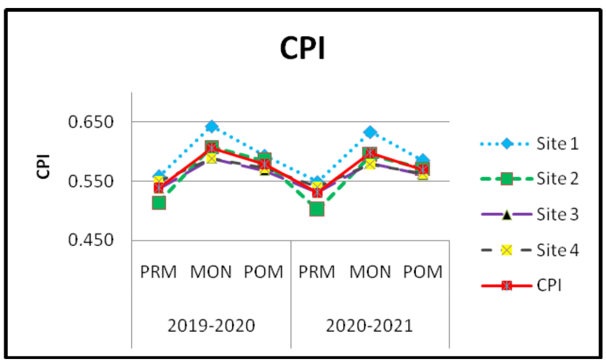

Fig. 6. Site-wise comprehensive pollution index (CPI) in three different seasons from March'2019 to February'2021.

DISCUSSION

The higher pH was recorded in post-monsoon due to the low level of water, higher nutrient content. The pH of the lake fluctuating allying 6.2 to 9.2 depicted the low trophic status of the water body which is again in consonance with the oligotrophic water bodies. However, there is a slight increase in pH values from the earlier reports of Golam Ziauddin *et al.* (2013). The range of pH showed sub-alkaline in nature (6.5 to 8.5) that was within the permissible limit as prescribed by WHO (2011) and CPCB (2011). The highest mean turbidity values (25.97 cm) were found in 2019-2020 during monsoon season because of surface runoff and the lowest average value (20.12cm) of turbidity was recorded in 2020-2021 during pre-monsoon season. Higher values were recorded during the rainy season as compared to the dry season which shows similarities to the earlier work of Eliku and Leta (2018). Dissolved oxygen attributes are inversely related to the temperature cycle, differing from post-monsoon upside to pre-monsoon lowest point. The DO was higher in the post-monsoon season than in the pre-monsoon season in Nandan Nagar jheel. Low DO values in pre-monsoon seasons were most likely caused by increased microorganism activity, which needed a considerable amount of oxygen attributable to metabolism and organic matter breakdown. The highest mean values (7.71 mgl^{-1}) of DO were observed in 2019-2020 during the post-monsoon season. The lowest concentration of DO (4.62 mgl^{-1}) was discovered in 2020-2021, during the pre-monsoon season, along the jheel, which accumulates agricultural runoff. In natural surface water systems, dissolved oxygen is perhaps the most essential criterion for evaluating the water quality of an ecosystem (Yang *et al.,* 2007). Eliku and Leta (2018), also reported similar observations in Awash River, Ethiopia. Free carbon dioxide was relatively high during the summer season which can be due to the faster decomposition of organic matter and high temperature. Lacking free carbon dioxide in other seasons could be due to its utilization by phytoplankton and other aquatic plants via photosynthesis and retain by calcium in form of the calcium bicarbonate. The amount of carbon dioxide in water showed a negative correlation (r= -0.858)

Table 2. Species diversity indices and CPI in three different seasons during the study period.

		SWI	CPI	Evenness Index	Dominance Index
Mar19 - Feb 20	Pre-monsoon	2.871	0.54	0.862	0.079
	Monsoon	2.961	0.61	0.889	0.071
	Post-monsoon	2.998	0.58	0.900	0.066
Mar 20 - Feb 21	Pre-monsoon	2.914	0.53	0.875	0.070
	Monsoon	2.961	0.60	0.889	0.070
	Post-monsoon	2.986	0.57	0.896	0.065

with the Shannon Weiner index which confirms the findings of Dutta and Patra (2013). The findings of BOD varied from 1.18 mgl^{-1} to 4.95 mgl^{-1} in the pre-monsoon season and between 3.35 mgl^{-1} to 6.65 mgl^{-1} in the post-monsoon season. In post-monsoon of the year 2019-2020, showed higher mean values (4.84 mgl^{-1}) of BOD during the post-monsoon season while the lowest mean BOD value (3.29 mgl^{-1}) was found in 20-21 in the pre-monsoon season (Tables 1). Based on the result of the present study, the mean BOD value (6.65 mgl^{-1}) was significantly higher than the mean value of BOD (1.66 mgl^{-1}) from natural water bodies in West Bengal (Dey *et al.*, 2015) but lower than the mean value of BOD (34.33 mgl^{-1}) from Rapti River, India (Chaurasia and Tiwari, 2011). The maximum value (141 mgl^{-1}) of total hardness was obtained in post-monsoon due to some construction activity. Ansari (2017) also reported similar observations in the Surajpur wetland. The results of total alkalinity obtained from the present study were in close conformity with the findings of Mishra *et al.* (2014) and Arya (2011). The amount of nitrate in all three sites of this jheel was found very low. During the monsoon period, however, the level of nitrate was found a bit high due to the surface runoff and some microbial activity. In monsoon, the activities of these microbes go down (Kaur *et al.,* 1996) resulting in a higher value of nitrate. Phosphorus in water commonly exists as phosphate. The phosphate concentration in water above 0.5 mgl^{-1} indicates pollution (Jain *et al.,* 1996). Maximum phosphate was observed in Nandannagar jheel during the post-monsoon (0.23mgl^{-1}) and minimum during the pre-monsoon (0.18mgl^{-1}). The concentration of phosphate which was moderate throughout the year indicates that this jheel is mesotrophic. The phosphorus levels in a mesotrophic aquatic system are generally found to be low to medium, making it ideal for the growth of aquatic plants and fishes (Das Gupta *et al.,* 2016).

The seasonal CPI values (Table 2) of Nandan Nagar jheel vary within the range of 0.53-0.61, throughout the study period. According to the rating sale of CPI, the observed pollution index values for all the seasons were reported lower than 1 which indicated that the jheel water quality is slightly polluted (Zhao *et al.*, 2012).

Principal component analysis of the study revealed that pH (-0.864), total alkalinity (-0.799), dissolve oxygen (-0.900), and carbon dioxide (0.853) were with strong loadings in the first principal component, this indicated that these five variables were the basic environmental factors in the Nandannagar jheel. The eigenvalues of the PCA are greater than 1.0 are considered significant (Shrestha and Kazama, 2007). The eigenvalues (Figure 4) of the first three main components are larger than 1.0 and contribute to 82.43 percent of the variance (Figure 5) in the data. The first principal component found high positive loadings of carbon dioxide (0.853) and high negative loadings of pH (-0.864), total alkalinity (-0.799), and dissolve oxygen (-0.900). The second principal component found high positive loadings of total hardness (0.869) and negative loadings of turbidity (-0.897). In summary, the results showed that the very first principal component expressed pollution level of water whereas the second principal component expressed regularly changing common parameters.

The results described above indicate that the physicochemical parameters studies are within acceptable limits and the water quality of this jheel is good enough to support rich high species diversity and suitable for fish culture. This was also relevant to the findings of Bhatnagar and Devi (2013), where they found most of the physicochemical parameters were within the target range.

A total of 28 species of fishes belonging to 6 orders, 15 families, and 21 genera were obtained from the Nandan Nagar Jheel wetland. Out of those fishes, Cypriniformes was the most dominating order having 6 species with 38% Relative Abundance, followed by Perciformes with 12 species and 28.55% Relative Abundance, Siluriformes with 6 species and 19.83% Relative Abundance, Clupeiformes with 2 species and 8.67% Relative Abundance, Synbranchiformes with 1 species and 4.47% Relative Abundance and Osteoglossiformes with 1 species and 0.48% Relative Abundance.

The Shannon-Wiener diversity index ($\overline{H}$) shows a negative correlation (Figure 2) with water temperature and carbon dioxide while positive relation with the other parameters. Natural as well as anthropogenic activities directly impact the relative abundance of species until it becomes an endangered species (De Roy *et al.,* 2013). All the seasons showed values ranging from 2.871-2.998 representing moderate to light pollution and suggested a healthy environment with little alterations (Iqbal *et al.*, 2015).

CONCLUSION

The findings of this assessment suggest this jheel is suitable for domestic uses and aquaculture. Limnological status of this jheel is mostly within the target range of water quality guidelines of CPCB and WHO. Fish diversity varies significantly with seasonal fluctuation. Various anthropogenic activities, seepage of drain water are primary contaminants which are the major concern to alter the health status of this jheel in near future. A constant surveillance is required for the sustainability of Nandannagar jheel.

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Conflict of Interest

The authors declare no conflict of interest.

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