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Interrelationship between limnological parameters of a floodplain lake in Dwarkeshwar river basin and their impact on fish biodiversity

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Abstract
Present study was designed to figure out the correlation between the physicochemical amplitude of the tropical lake Ray Pukur with its ichthyofaunal diversity in the region of the Dwarkeshwar River Basin. Water samples were collected on monthly basis over two years (March 2019 to February 2021) and selected physical and chemical variables including water temperature, transparency, pH, total alkalinity, total hardness, dissolved oxygen, carbon dioxide, biological oxygen demand, nitrates and phosphates were measured every month at four selected sites in this wetland. Results of principal component analysis revealed that water temperature (-0.878), dissolved oxygen (-0.803), and pH (0.747) were the key parameters and were considered the main ecological health determinants of this wetland. Altogether 22 self-recruiting fish species, representing 7 orders and 14 families were recorded. Order Cypriniformes was most dominating, with 5 species accounting for 52.84 percent of the catch composition, while Perciformes has 8 species accounting for 28.69 percent of the catch composition. Shannon Weiner diversity index of this wetland (2.36–2.47) indicates that the water quality of this lake is moderate. This study concludes that this wetland is perfect for aquaculture. Proper management is required in this wetland to maintain its sustainability in near future.

Keywords: Diversity index, Dwarkeshwar river basin, fish diversity, indigenous fish, limnological parameters, ray pukur.

Introduction

Wetland has been described as a ‘kidney of landscape’ (Sun, 2018) [1]. Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life (Guesmi, 2021) [59]. The wetlands are the most productive ecosystems on the Earth (Ghermandi *et al*., 2008) [2] and they provide many beneficial services to human society (Brink *et al*., 2011). The total wetland area estimated in India is 15.260 Mha (SAC, 2011) [4] which is about 4.7% of the total geographical area of the country (Bassi & Kumar, 2012) [5]. The state of West Bengal is rich in wetlands and has a significant share of the overall wetland biodiversity of the country (SAC 2011) [4]. West Bengal has more than 150 floodplain lakes encompassing a segment of 42,000 ha, accounting for around 22% of the entire state’s freshwater habitat (ICAR, 2006) [6]. Limnology is the prime factor to determine the health status of any aquatic body (Reddy *et al*., 2018) [8]. Seasonal fluctuations on limnology have a great impact on the hydrological status of aquatic body (Alaez *et al*., 2006) [9]. The interrelationship between limnological quality and fish diversity has gained increasing attention now a day (Vieira & Tejerina-Garro, 2020) [19]. Alterations in hydrochemical factors of wetland ecosystems cause a threat (Malekmohammadi *et al*., 2023) [20] to the fish community because of their high susceptibility (van Treeck *et al*., 2020) [21]. Any alteration in hydrological parameters can cause a series of physiological stress on the aquatic organism (Carbajal-Hernández *et al*., 2012; Chang *et al*., 2017) [15, 7]. The hydro-logical parameters of wetlands are gradually deteriorating day by day due to various natural and manmade activities (Sarkar & Saha, 2018) [16]. This in turn can kill fish, crabs, oysters and other aquatic animals and deteriorate the water quality (Herath & Satoh, 2015) [17]. Pollution caused by various anthropogenic activities disrupts the biotic community structure and food web of the lake (Rhind, 2009) [18]. Diversity in the fish community has supreme importance (Shahnawaz & Venkateshwarlu, 2010) [14] within the food chain (Beisner *et al*., 2006) [22] for a stable aquatic ecosystem (Irfan & Alatawi, 2019) [23]. In West Bengal, multiple freshwater bodies like ponds, lakes and beels are seen in the basins of various river like Ganga, Damodar, Dwarkeshwar, Subarnarekha, etc. Several studies have been carried out to investigate the limnological status, and floral and faunal diversity of these water bodies by several workers (Maiti and Maiti, 2011; Bhatnagar and Devi, 2013; Dey *et al*., 2015; Das Gupta *et al*., 2016; Ansari, 2017) [24, 25, 26, 28, 27]. But very little is known about the wetlands in the Dwarkeshwar river basin regarding the physicochemical properties of water and fish diversity. In the present study, an attempt has been carried out to evaluate the physicochemical parameters of Ray Pukur and to explore their impact on small wild fish diversity, species richness, and species evenness by implementing multiple commonly used diversity indices.

Materials and Methods

Sampling Sites

The present study was carried out in Ray Pukur (22°51'42.4"NL; 87°49'5.19"EL) spreads over an area of 25 ha, falls under Dihibayara village of Arambagh Block in the Hooghly districts of West Bengal, India at an altitude of 6 meters above sea level. For the study of water quality parameters, four representative sampling sites (Site1, Site2, Site3, and Site4) were selected.

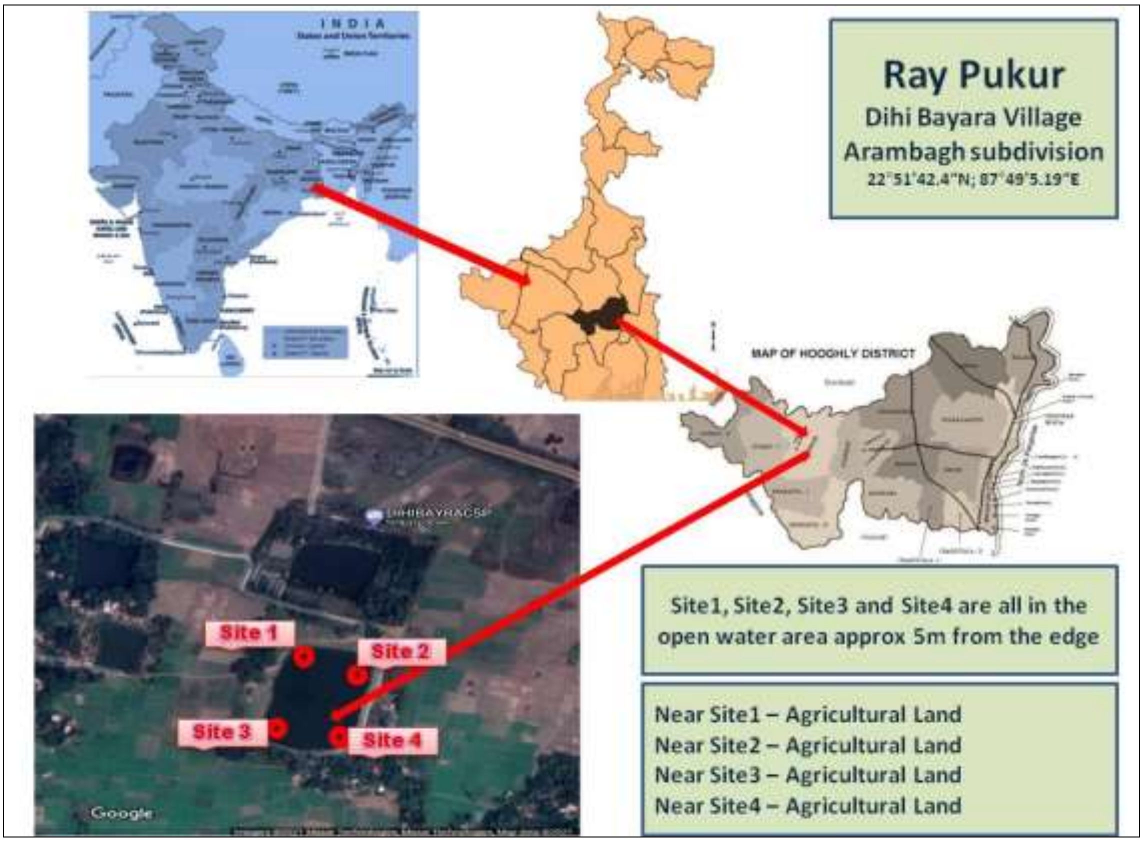

Fig 1: Map of Ray Pukur wetland in Dwarkeshwar river basin, West Bengal, India.

Data Collection

Sampling was made once per month and data were presented seasonally viz., pre-monsoon (March-June), monsoon (July-October), and post-monsoon (November-February) between March 2019 and February 2021. The collection procedure was followed for sample preservation and assessment of various water quality indices (APHA, 2012) [29]. A total of 10 physicochemical parameters (water temperature, transparency, pH, dissolved oxygen, free carbon dioxide, biochemical oxygen demand, total hardness, total alkalinity, nitrate, and phosphate) were determined at all sites on the same day of fish collection. Water samples were collected monthly using a clean air-tight bottle at four sample stations over two years. Wild fish were retrieved from the wetland with the assistance of local fishermen using a variety of nets, including gill nets, cast nets (Khepla Jal), and drag nets (Behundi Jal) with various mesh sizes (0.5cm to 2.5cm). For diversity studies, one kilogram of wild fishes from each site has been considered as the sample for the present calculation and fish species identities was validated using a procedure developed by earlier researchers (Talwar and Jhingran, 1991; Jayaram, 2010) [34, 33]. The Shannon-Weiner diversity index was calculated with the references of Shannon & Weaver (1963) [31]. The mean values with standard deviation (SD) and standard errors (SE) of physicochemical parameters were measured and compared between each sampling site using a one-way analysis of variance (ANOVA) for various parameters for three seasons. A P-value at<0.05 was used to indicate statistical significance. PCA was conducted amongst these several hydrological indicators to find key elements and analyze variations in water quality (Howladar *et al*., 2018) [30].

Statistical analysis

Statistical analysis was performed using standard software. To identify the significant differences between several physicochemical parameters during the study period, one-way ANOVA was done followed by Tukey's test (Lee & Lee, 2018) [35]. PCA was conducted amongst these several hydrological indicators to find out key elements which are the controlling factor of the ecological health of this wetland (Howladar *et al*., 2018) [30]. Pearson correlation matrix between different physicochemical parameters and Shannon-

Wiener diversity Index (H') was conducted to find the relationship among themselves (Mukaka, 2012) [36].

Results

Seasonal variation of the physicochemical parameters of water (water temperature, pH, transparency, dissolved oxygen, biochemical oxygen demand, total alkalinity, free carbon dioxide, total hardness, nitrate, and phosphate) of Ray Pukur in pre-monsoon, monsoon, and post-monsoon seasons are showed in table1. In the present study, the range of the physicochemical parameters like, water temperature 17.9 to 32.6 ^{0}C, transparency 46.1 to 58.9 cm, pH 7.1 to 8.1, carbon dioxide 0.05 to 6.9 mg/l, dissolved oxygen 1.69 to 5.78 mg/l, biochemical oxygen demand 1.85 to 5.1 mg/l, total alkalinity 138 to 200 mg/l, total hardness 103 to 166 mg/l, phosphate 0.58 to 1.01 mg/l and nitrate 0.4 to 1.1 mg/l of were found.

Table 1: Seasonal variation of physicochemical parameters of water in Ray Pukur (different letters indicate a significant difference ($p<0.05$) within the same row) during the study period.

March 2019 - February 2021			
	Pre-Monsoon	**Monsoon**	**Post-Monsoon**
	Mean± SE	**Mean± SE**	**Mean± SE**
Water Temp. (WT) (^{0}C)	29.01±0.6^{a}	26.76±0.53^{a}	19.59±0.23^{a}
pH	7.5±0.04^{a}	7.62±0.07^{ab}	7.82±0.04^{b}
Transparency (Trans) (cm)	50.87±0.65^{a}	55.61±0.52^{a}	52.23±0.08^{a}
Dissolve Oxygen (DO) (mg/l)	3.66±0.25^{b}	4.43±0.02^{ab}	5.06±0.14^{a}
Carbon dioxide (CO_2) (mg/l)	3.12±0.41^{a}	3.24±0.52^{a}	2.49±0.35^{a}
Biochemical Oxygen Demand (BOD) (mg/l)	3.73±0.18^{a}	3.51±0.27^{ab}	2.69±0.16^{ab}
Total Hardness (TH) (mg/l)	129±1.76^{b}	121±1.64^{ab}	140±5.75^{a}
Total Alkalinity (TA) (mg/l)	152±1.82^{a}	171±3.05^{ab}	178±3.52^{ab}
Nitrate (NO_3^-)(mg/l)	0.52±0.02^{a}	0.75±0.06^{ab}	0.65±0.06^{ab}
Phosphate (PO_4^-)(mg/l)	0.75±0.02^{a}	0.85±0.02^{a}	0.67±0.02^{a}

Table 2: In Ray Pukur, fish species were documented during the study period.

Order	Family	Species	Local Name	IUCN Status
1. Beloniformes	1. Adrianichthyidae	1. *Oryzias dancena*	Indian ricefish	LC
2. Clupeiformes	2. Clupeidae	2. *Gudusia chapra*	Khaira	LC
3. Cypriniformes	3. Cyprinidae	3. *Amblypharyngodon mola*	Mourola	LC
		4. *Labeo bata*	Bata	LC
		5. *Pethia ticto*	Titpunti	LC
		6. *Puntius sophore*	Punti	LC
		7. *Systomus sarana*	Swarna Punti	LC
4. Osteoglossiformes	4. Notopteridae	8. *Notopterus notopterus*	Pholui	LC
5. Perciformes	5. Ambassidae	9. *Chanda nama*	Chanda	LC
	6. Anabantidae	10. *Anabas testudineus*	Koi	LC
	7. Channidae	11. *Channa gachua*	Cheng	LC
		12. *Channa punctata*	Lata	LC
		13. *Channa striata*	Sol	LC
	8. Chichlidae	14. *Oreochromis mossambicus*	Tilapia	Vul
	9. Gobiidae	15. *Pseudapocryptes elongatus*	Gule	LC
	10. Osphronemidae	16. *Trichogaster fasciata*	Kholse	LC
6. Siluriformes	11. Bagridae	17. *Mystus bleekeri*	Tengra	LC
		18. *Mystus cavasius*	Tengra	LC
		19. *Mystus vittatus*	Tangra	LC
	12. Clariidae	20. *Clarias batrachus*	Magur	LC
	13. Heteropneustidae	21. *Heteropneustes fossilis*	Singi	LC
7. Synbranchiformes	14. Mastacembelidae	22. *Macrognathus pancalus*	Pankal	LC

Table 3: Fish diversity index, richness and evenness index in Ray Pukur at pre-monsoon, monsoon and post-monsoon during the study period (March 2019 - February 2021).

March 2019 - February 2021		Pre-monsoon	Monsoon	Post-monsoon
Shannon-Weiner diversity index (H')	2019 –2020	2.360	2.395	2.471
	2020 –2021	2.412	2.367	2.416
Pielou's evenness index (J')	2019 –2020	0.788	0.829	0.825
	2020 –2021	0.805	0.804	0.806
Margalef's richness index (d)	2019 –2020	6.47	5.74	6.45
	2020 –2021	6.43	6.09	6.50

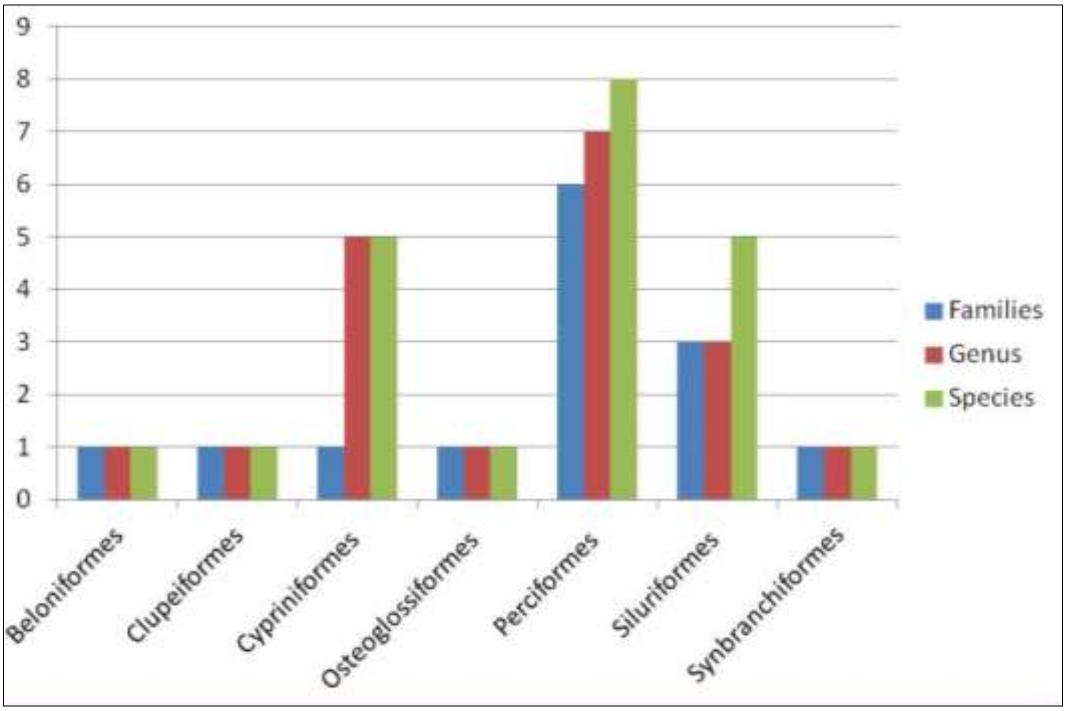

Fig 2: Families, Genera and Species belonging to different orders of fish found in Ray Pukur during the study period.

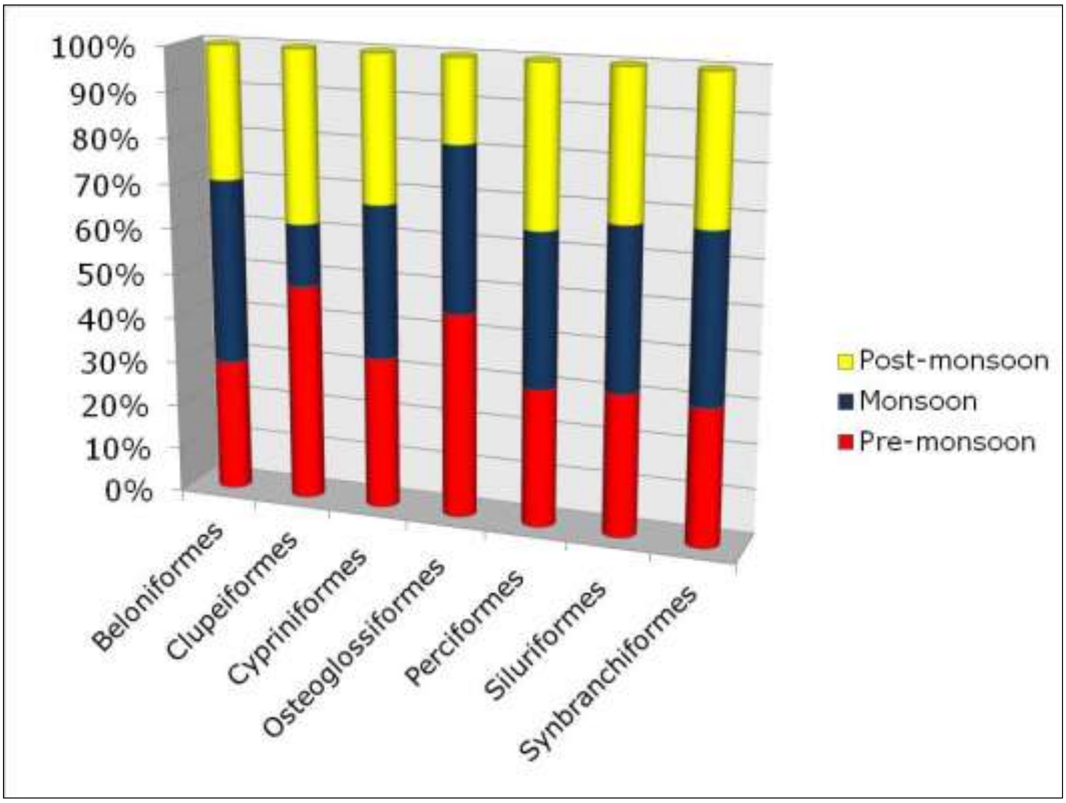

Fig 3: Fish species under 7 orders in Ray Pukur during the study period in 100% stacked cylindrical figure.

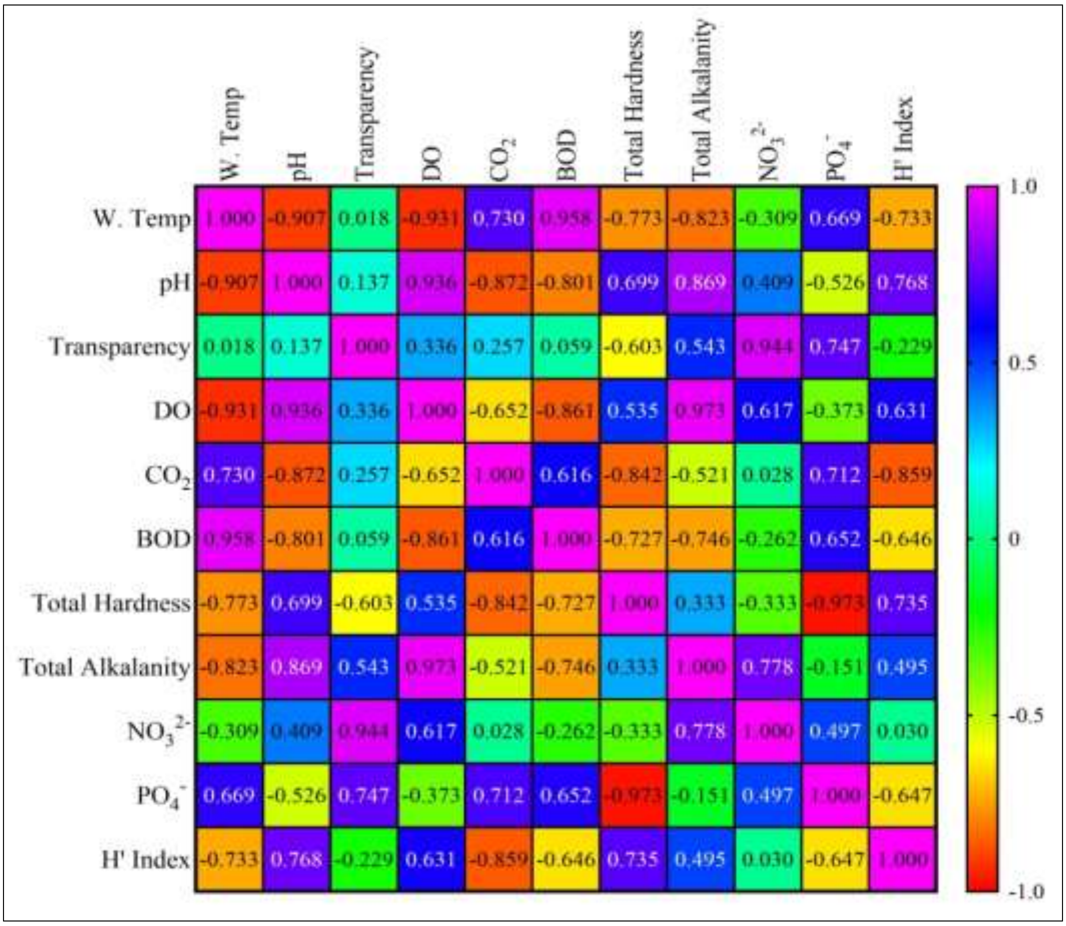

Fig 4: Pearson correlation matrix among the physicochemical parameters and H Index of Ray Pukur during the study period.

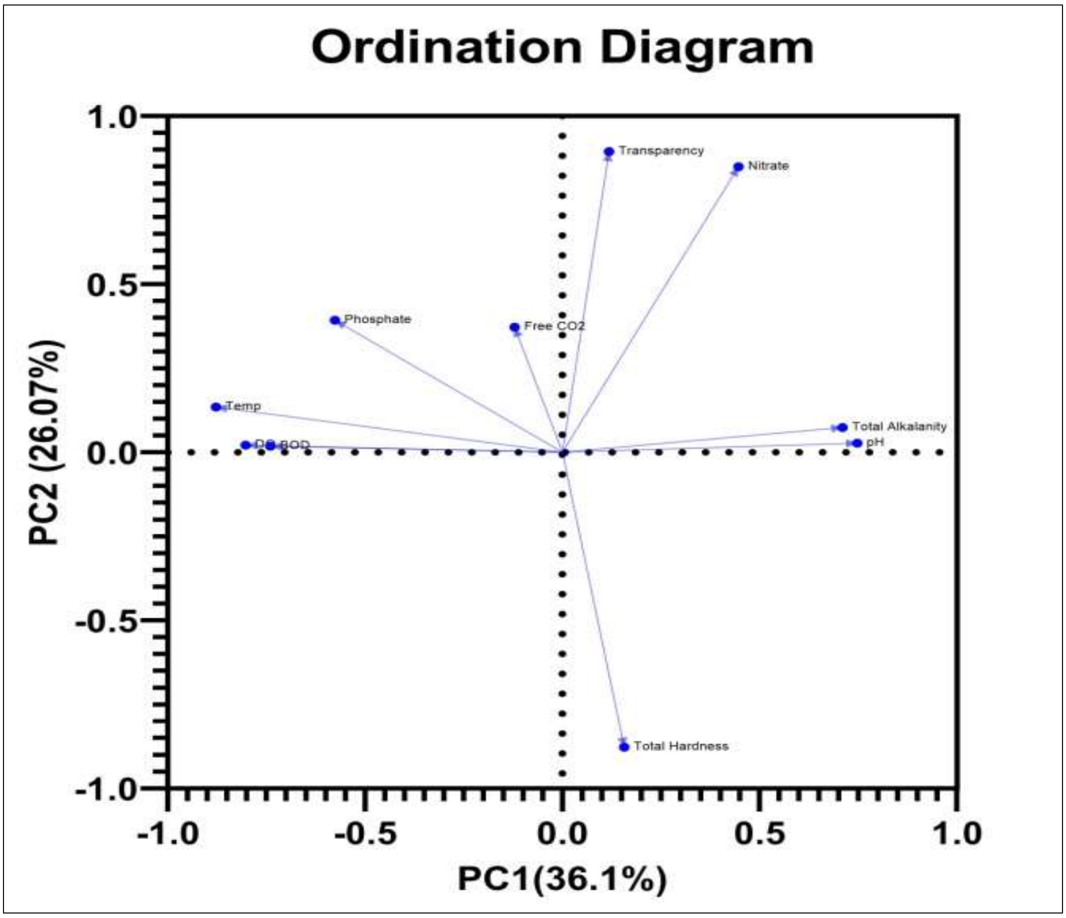

Fig 5: Loading of different physicochemical parameters of Ray Pukur during the study period.

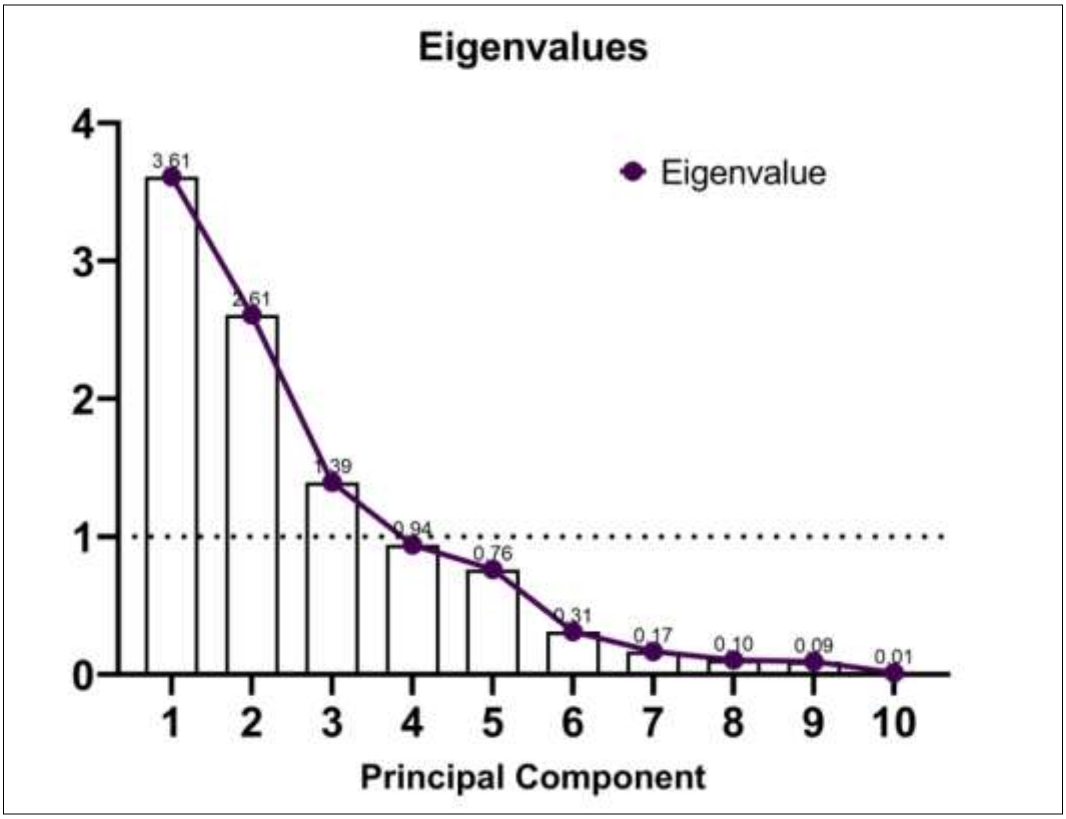

Fig 6: Scree plot showing the eigenvalues and principal components derived from PCA of different physicochemical parameters of water of Ray Pukur during the study period.

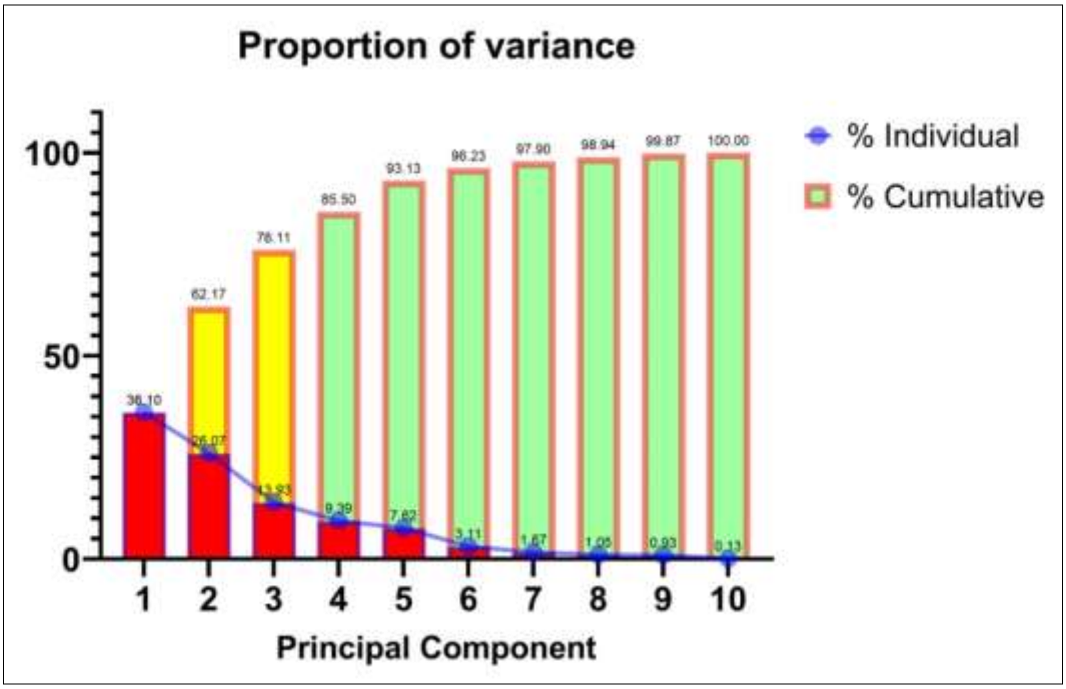

Fig 7: Proportion of variance showing different physicochemical parameters of water of Ray Pukur derived from PCA during the study period.

Discussions

The higher pH was recorded in pre-monsoon and post-monsoon due to the low level of water and higher nutrient content. The pH of the lake ranges from 7.1 to 8.1 depicting the low trophic status of the water body which is again in consonance with the oligotrophic water bodies. The present investigation was compared to previous findings (Gayathri *et al*., 2013) [37] and confirmed to be nearly identical. The range of pH showed sub-alkaline in nature (6.5 to 8.5) which was within the permissible limit as prescribed by WHO (2011) and CPCB (2011) [38]. The highest mean transparency values (55.84 cm) were found during the monsoon season in 2019-2020 may be due to the surface runoff and the lowest average value (50.63 cm) of transparency was recorded during the pre-monsoon season in 2020-2021. 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) [40]. The temperature cycle is inversely proportionate to dissolved oxygen properties (Fig 4), which differ from post-monsoon to pre-monsoon values. In Ray Pukur, the dissolved oxygen was higher (5.12 mg/l) during the post-monsoon season than during the pre-monsoon season. Low dissolved oxygen readings (3.62 mg/l) during the pre-monsoon season were most likely caused by increased microbe engagement, which required a lot of oxygen for metabolism and organic compounds decomposition (Chakraborty *et al*., 2021) [41]. 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) [42]. Free carbon dioxide concentration was found relatively high (6.9 mg/l) during the summer period due to the quick biodegradation of organic material and the high atmospheric temperature. The absence of free carbon dioxide in other seasons may be owing to its use by phytoplankton and other aquatic plants via photosynthesis, and its retention by calcium in the form of calcium bicarbonate. The Shannon Weiner diversity index had an adverse connection (r= -0.859) with the concentration of free carbon dioxide (Figure 3) in water, confirming the findings of Dutta and Patra (2013) [43]. BOD levels ranged from 1.85 mg/l to 5.1 mg/l during the study period. In pre-monsoon and monsoon seasons of the year 2019-2020, showed higher mean values (3.77 mg/l) of BOD while the lowest mean BOD value (2.68 mg/l) was found during the post-monsoon season of 2020-2021 (Table 1). Based on the result of the present study, the mean BOD value showed similarities to the earlier work in the natural water bodies of West Bengal (Dey *et al*., 2015) [26]. Both natural salt buildup in soils and agricultural runoff can result in the formation of hardness (Owokotomo *et al*., 2020) [44]. The overall highest hardness (141 mg/l) was obtained in the post-monsoon season which was significantly impacted by the unrestricted use of watersheds for agricultural purposes and human encroachment (Chukwuka and Ogbeide, 2021) [45]. The main components of alkalinity in water are the compounds of carbonates, bicarbonates, and hydroxides (Kumar *et al*. 2012) [46]. Low levels of total alkalinity values (150 mg/l) were recorded in the pre-monsoon season during the study period, but in the post-monsoon season, total alkalinity was found a bit high (179 mg/l) which was in close conformity with the findings of Mishra *et al*., (2014) [47]. Total alkalinity and the percentage of oxygen saturation both climb along with the elevation of the pH level in the water (Iseri *et al*., 2022) [41]. The level of nitrate in this wetland was discovered to be quite minimal. However, the effect of surface drainage and microbiological activity, the amount of nitrate was observed to be somewhat higher (0.76 mg/l) during the monsoon season. The activity of these microorganisms decreases during the monsoon (Kaur & Sinha, 2019) [49], resulting in a greater nitrate value. Phosphorus is typically found in water as phosphate. A maximum phosphate value (0.85 mg/l) was observed in Ray Pukur during the monsoon season due to agricultural runoff from the surrounding area. Throughout the pre-monsoon season, it was generally low which shows similarities to earlier work (Naik *et al*., 2020) [50]. This wetland is mesotrophic, as evidenced by the modest phosphorus accumulation during the year. The phosphorus levels in a mesotrophic aquatic system are typically moderately low, which makes it suitable for the aquatic environment and fish production (Das Gupta *et al*., 2016) [28].

The eigenvalues (Fig 4) of the first two main components are larger than 1.0 and contribute to 62.17 percent of the variance (Fig 5) in the data selected for the ordination diagram. It is considered good, significant, and highly significant to have a loading score of 0.30 or higher, 0.40 or higher, and 0.50 or higher (Lombarte *et al*., 2012) [51]. Loading values greater than 0.6 were obtained for each principal component in the current study (Álvarez *et al*., 2017) [53], which were statistically significant and revealed significantly related variables with PC1 and PC2 (Slathia *et al*., 2023) [52]. The first axis (PC1) was positively associated with pH and total alkalinity in water and negatively associated with the water temperature, dissolved oxygen and phosphate. The second axis (PC2) found a positive correlation with transparency and nitrate in water and a negative correlation with the total hardness. The first principal component was found high positive loadings of pH (0.747) and total alkalinity (0.710) and high negative loadings of water temperature (-0.878), dissolved oxygen (-0.803) and BOD (-0.740). The second principal component was found high positive loadings of transparency (0.894) and nitrate (0.849) and negative loadings of total hardness (-0.877). The findings demonstrated that these five first principal component variables (pH, total alkalinity, water temperature, dissolved oxygen and phosphate) were the concerning environmental variables and regulating components of the ecological health of Ray Pukur (Chu *et al*., 2018) [54]. The results described above indicate that the physicochemical parameters studies are within acceptable limits and the water quality of this wetland is good enough to support high species diversity and suitable for fish culture. Fish diversity indices were significantly impacted by multiple climatic changes like rainfall patterns, rise in temperature, transparency, etc, (Mondal *et al*., 2010) [55]. All the physicochemical parameters were found within the optimum range reflecting the good health of this wetland and the findings were relevant to the work of Kumar *et al*., (2006) [56].

A total of 22 species of fish belonging to 7 orders, 14 families, and 19 genera were obtained from the Ray Pukur wetland. Out of those fishes, Cypriniformes was the most dominating order having 5 species with 52.84% Relative Abundance, followed by Perciformes with 8 species and 28.69% Relative Abundance, Siluriformes with 5 species and 10.91% Relative Abundance, Beloniformes, Synbranchiformes, Clupeiformes and Osteoglossiformes with 1 species each and 4.06%, 3.05%, 0.40% and 0.06% Relative Abundance respectively. Shannon-Wiener diversity index $(\bar{H})$ shows a negative correlation (Fig 4) with water temperature, transparency, free carbon dioxide, BOD and phosphate while positive relation with the pH, dissolved oxygen, total alkalinity, total hardness and phosphate. Natural as well as anthropogenic activities directly impact the relative abundance of species until it becomes endangered species (De Roy *et al*., 2013) [57]. Shannon-Weiner diversity index values ranged from 2.36 – 2.47 representing moderate to light pollution and suggesting a healthy environment for aquatic species with little alterations (Iqbal *et al*., 2015) [58].

Conclusion

This wetland is large in size and the perennial type and is the major source of water for domestic, agricultural, and other household purposes from surrounding areas. The examined wetland frequently gets excessive household sewage and agricultural runoff, which could soon endanger its ecological stability. This sizable perennial water body is thought to be capable of recovering on its own through a self-sustainable process. Overall the ecological health of the wetland is good and all the limnological parameters were noticed within the optimum range during the study period. These results showed a close relationship to the findings of Bhatnagar and Devi (2013) [25], where they found most of the physicochemical parameters was within the optimum range. The results of this evaluation indicate that this wetland is suitable for domestic and aquaculture use. This Hydrological status of this wetland largely falls within the CPCB and WHO water quality standard goal range. The diversity of fish did not alter significantly during the seasonal alteration. Numerous anthropogenic activities, as well as surface runoff from surrounding areas, create significant contaminants that pose a significant risk to the health of this wetland in the near term. Ray Pukur's long-term viability as a fish culture resource necessitates continual monitoring.

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Availability of data and materials
The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

Conflict of Interest
The authors declare no conflict of interest.

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