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Impact of hydro-chemical parameters on fish biodiversity of a tropical lake in Dwarekeshwar river basin, India

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ABSTRACT

Seasonal alteration has a great impact on the ecological health status of any aquatic body as well as its flora and fauna. Seasonal change affects the quality of water, as well as species diversity, which in turn influences species richness, evenness, and relative abundance. Any changes in the physicochemical and biological properties of water bodies have a direct impact on their ecological health. The most notable feature of the Dwarekeshwar River is that it has transitory characteristics of both flash floods and monsoonal floods in its upper catchment and middle catchment areas. The present study was carried out to evaluate the impact of seasonal fluctuation and the relationship between physicochemical quality and fish diversity of a natural lake in the Dwarekeshwar river basin for the tenure of two years from March 2019 to February 2021. The water samples were collected at four sampling stations on a monthly basis, and the range of those physicochemical parameters for two years was measured. The principal component analysis results showed that pH (0.920), total alkalinity (0.807), dissolved oxygen (0.749), temperature (-0.801), and carbon dioxide (-0.894) were the main factors. A total of 31 species belonging to 6 orders and 16 families were found in terms of fish faunal diversity. Both the Shannon Weiner diversity index (2.675-2.726) and Comprehensive Pollution Index (0.504 – 0.559) indicate this particular water body is slightly polluted. The study recommends constant monitoring is needed to minimize the anthropogenic activities surrounding this Dighi.

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Fish diversity

1. Introduction

Lake is the most important surface water resource commonly utilized for drinking, bathing, fisheries, and other domestic purposes (Singh et al., 2019). According to a study by the National Environmental Engineering Research Institute, Nagpur, India, about 70% of the total surface water (river, lake, pond, sea, etc.) in India is polluted (Pidurkar et al., 2016). Lakes also provide important habitats for various flora and fauna. The hydro-logical parameters of lake water are gradually deteriorating day by day due to various natural and manmade activities such as domestic wastes (Abdalla & Khalil, 2018), sewage (Lyons et al., 2015), industrial releases (D'Ugo et al., 2018), and agricultural runoff. Any alteration in hydrological parameters (pH, phosphate, dissolved oxygen, total alkalinity, nitrate, etc.) can cause a series of physiological stresses on the growth and even survival of the aquatic organism (Carbajal-Hernández et al., 2013; Chang et al., 2017). The structural and functional states of natural water are determined by the physicochemical characteristics of water in the aquatic environment, which are primarily influenced by current environmental conditions (Michalak, 2016). In the current situation, water pollution control has become one of the prime concerns of society (Harikishore Kumar Reddy, 2017; Schweitzer & Noblet, 2018).

Multiple works have been done regarding the evaluation of physicochemical status, plankton density diversity, fish diversity, etc., by several workers (Saha et al., 2006; Mondal et al., 2010; Kumar, 2011; Koli and Muley, 2012; Bhatnagar and Devi, 2013; Dey et al., 2015; Das Gupta et al., 2016; Ansari, 2017) in various lakes throughout the world. However, nothing is known about this natural lake, which is known locally as Ballav Dighi and is located in the Dwarakeswar river basin's center catchment area. In India, when everyone is talking about the water grid and river connection projects at the national level, it is critical to examine the flood characteristics of the Dwarakeswar river basin under West Bengal in this scenario. This combination of flash floods in upper catchments and monsoonal floods in the middle section is a very rare phenomenon and gives the Dwarakeswar river basin, along with its floodplain lakes, a unique identity.

The prime focus of the study is to determine the ecological health status of the wetlands based on fish diversity and limnological parameters, which have a greater influence on fish.

2. Materials and Methods

2.1 Experimental Sites:

The higher catchments of the Dwarakeswar river basin have slopes ranging from 12 to 21 degrees, while the middle catchments have a slope of 7 to 12 degrees. As a result, the water in the intermediate section does not reach the upper catchments. The water level in the upper catchment is rising, while the lower portion is experiencing a backward onrush of water. Flooding occurs in the middle of the river. That is the cause of monsoonal flooding in the region's midsection. Ballav Dighi is a closed-type beel located in the Dwarakeswar river basin's middle catchment area in Kalipur village. It lies between 22°52'58.81"NL and 87°46'35.56"EL (Figure 1). It is situated near Arambagh Kamarpukur road in the Arambagh subdivision of the Hooghly district of West Bengal, with an area coverage of 3.36 ha. This is a perennial wetland that contains water throughout the year (Kar et al., 2007). This Dighi is flooded by the upper catchment flow of the Dwarakeswar River during the monsoon season. The people of nearby villages use this Dighi mostly for bathing, cooking, and other

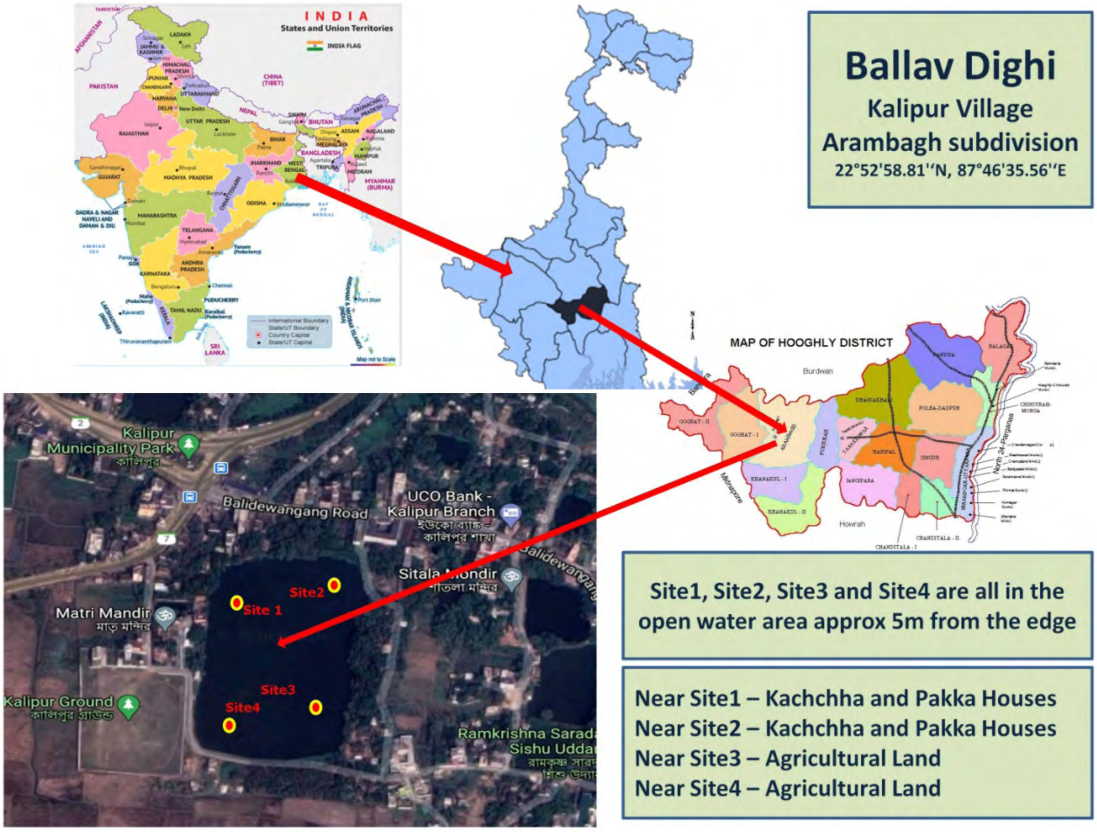

Fig. 1. Map of the study area with four sites
(Source: Google satellite)

domestic purposes. There are no significant industrial effluents dumped in this resource. Hence, the observation of any parameters out of range would be credited to anthropogenic activities.

2.2 Water quality sampling and measurement:

In this piece of work, water sampling was conducted during the pre-monsoon, monsoon, and post-monsoon seasons from March 2019 to February 2021, with monthly intervals at four sites and approximately at the same time (5:00–8:00 a.m.). Within 24–48 hours of collection, all of the samples were examined in the laboratory. Water temperature (WT) (15 cm below the surface), pH, and Transparency were analyzed on the spot. For estimation of dissolved oxygen (DO), free CO_2, BOD, total alkalinity (TA), total hardness (TH), phosphate (PO_4^-), and nitrate (NO_3^{2-}) water samples were collected in BOD bottles of 300 ml with caution to avoid agitation. The DO was fixed instantly by adding 2 ml each of manganese sulphate ($MnSO_4$) and alkaline Potassium Iodide (KI) solutions and brought to the laboratory for titration. Other parameters like total alkalinity, total hardness, nitrate, and phosphate were analyzed in the laboratory (Rakesh et al., 2013). Normal protocols were followed for sample preservation and assessment of various water quality indices (APHA, 2005; APHA, 2012). The mean and Standard Deviation (SD) of water quality throughout the study period were calculated.

2.3 Fish sampling:

Small wild fishes were taken at monthly intervals from four sites for 24 months using local nets such as gill nets, cast nets, and dragnets at monthly intervals at four sites and approximately at the same time (5:00–8:00 a.m.). Because formalin decolorizes the fish colour over time, images were taken immediately before preservation. For the preservation of fish samples, a 10% formalin solution was created. Fish were taken to the lab and fixed in this solution in separate jars, with their identification confirmed using Armantrout et al. (1994) and Jayaram KC (2010). Random fish samples were gathered from five nettings across each site to provide a 1kg sample of tiny wild fish per month for each site.

2.4 Data Analysis:

From the obtained data, the comprehensive pollution index (CPI), Shannon-Weiner species diversity index ($\overline{H}$ index) and relative abundance (RA) were determined using the following equations:

Shannon Weiner Index

$$\overline{H} = -\sum_{i=1}^{S}\left(\frac{Ni}{N}\right)\mathrm{Log}_2\left(\frac{Ni}{N}\right)$$

Where S is the total number of species, N is the total number of individuals, Ni is the number of specimens in each species.

Comprehensive Pollution Index

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

Where CPI is the comprehensive pollution index, Ci is the measured concentration of the pollutant (mg/L), Si represents the limits allowed by the CPCB (2011) 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. The CPI has been applied to classify the water quality status by the research findings of Zhao et al., (2012).

Relative Abundance

$RA = N^{th} / N \times 100$

Where, N^{th} = Total Number of individual species, N = Total Number of the species population.

Evenness Index

$(J) = \overline{H} / \log_2 S$

Where $\overline{H}$ is the S.W. Species Diversity Index and S is the total number of species

Index of Dominance

$$(ID) = \sum \left(\frac{Ni}{N} \right)^2$$

Where N is the total number of individuals, Ni is the number of specimens in each species

The limnological data of the study period was assembled for three seasons and assessments were done for seasonal variations, viz., Pre-monsoon (from February to June), Monsoon (from July to October), and Post-monsoon (from November to February). Mean ± SE of water quality was measured and compared between each sampling site using one-way analysis of variance (ANOVA) to find out significant differences in the variables assessed between study points. Tukey HSD tests were carried out to measure the significant difference at the 5% probability (α) level.

Pearson Correlation was conducted between physico-chemical parameters and fish diversity where P-value at<0.05 was used to indicate statistical significance. Comprehensive Pollution Index (CPI) was used to find get an idea about the pollution status of this Dighi using ten water quality parameters (water temperature, pH, transparency, dissolved oxygen, carbon dioxide, total alkalinity, total hardness, BOD, phosphate, and nitrate) with the standard value given by CPCB(2011) India and WHO(2011). PCA was conducted amongst these several hydrological indicators to find key elements and analyze variations in water quality (Howladar et al., 2018). For this purpose, ten water quality parameters were taken into consideration, including water temperature, pH, transparency, dissolved oxygen, carbon dioxide, total alkalinity, total hardness, BOD, phosphate, and nitrate. Notable Eigenvalues of 1.0 or higher are taken into consideration (Shrestha and Kazama, 2007) and the observed scree plot is used to identify the number of principal components (PCs) to be retained in order to comprehend the underlying data structure. The loadings of PCs were considered strong (>0.75), moderate (0.5–0.75), and weak (0.4– 0.5).

3. Results

The mean values with standard deviation (SD) and standard errors (SE) of physicochemical parameters of three different seasons in Ballav Dighi during the period of 24 months (March 2019–February 2021) are presented in Table 1. A high water temperature (32.8 °C) value was recorded in the pre-monsoon season in the year 2019-2020 and a low value (22.1 °C) was recorded in the post-monsoon in 2020-2021 year. Water pH ranged from 6.6 to 8.0, with the highest values in post-monsoon and the lowest in pre-monsoon at most of the study sites. The pH values of the Ballav Dighi water showed an increasing trend from the pre-monsoon to the post-monsoon season during the study period. DO values were found to be generally highest during the post-monsoon season and the lowest during the pre-monsoon season throughout the study period. There was a progressive increase in DO at all the sampling sites during the transition to monsoon, post-monsoon season. The seasonal variations in transparency during the two years of the study showed that it was higher in the monsoon and pre-monsoon seasons; it was lower in both consecutive years. Phosphorus concentrations were higher (1.01 mg/L and 0.96 mg/L) in monsoon and lower (0.13 mg/L and 0.16 mg/L) in pre-monsoon in both the year of the study period. Concentrations of nitrate were found to be higher (1.25 mg/L and 1.14 mg/L) in post-monsoon and lowest (0.34 mg/L) in monsoon. Total hardness was observed to be highest in post-monsoon and lowest in monsoon at all the sites. Similarly, total alkalinity was found in a higher range in the post-monsoon season of both the year of the study period.

The ANOVA test revealed no significant differences in the variables assessed between study points (P>0.05). The ANOVA test revealed statistical significance between the seasonal means (P<0.05) value. The Tukey test (P<0.01) reflects a pair-wise comparison with some significant differences between physicochemical parameters. The comprehensive pollution index (CPI) was calculated against ten physicochemical parameters with the standard value of that parameter. CPI was found to be a bit high at site 3 and lowest at site 2 in all the seasons throughout the study period. The highest CPI (0.559) was found at site 4 during the post-monsoon of the 2019-2020 year and the lowest at site 2 in the pre-monsoon of the 2020-2021 year.

Ten hydrological indicators (temperature, pH, transparency, dissolved oxygen, free carbon dioxide, biochemical oxygen demand, total alkalinity, total hardness, nitrate, and phosphate) were chosen as independent factors for PCA (principal component analysis) to assess the importance of Ballav Dighi's water quality. Eigenvalues of more than 1.0 are considered a significant principal component (Shrestha and Kazama, 2007). According to PCA, two main components (PC1 and PC2) jointly exhibited 65.42% hydrological quality differential. The first principal component (PC1) had high positive loadings of pH (0.920), total alkalinity (0.807), dissolved oxygen (0.749), and BOD (0.769) while strong negative loadings of carbon dioxide (-0.894) and temperature (-0.801). PC2 had high negative loadings of total hardness (-0.872) and high positive loadings of transparency (0.680).

Pearson correlation matrix between physicochemical parameters and Shannon Weiner fish diversity index showed some significant relationship between them. A heat map of Pearson correlation was created for the graphical representation. 31 species of fish belonging to 6 orders, 16 families, and 24 genera were obtained from the Ballav Dighi. Shannon Weiner's fish diversity index (Table 2) was calculated seasonally to find out the status of the fish.

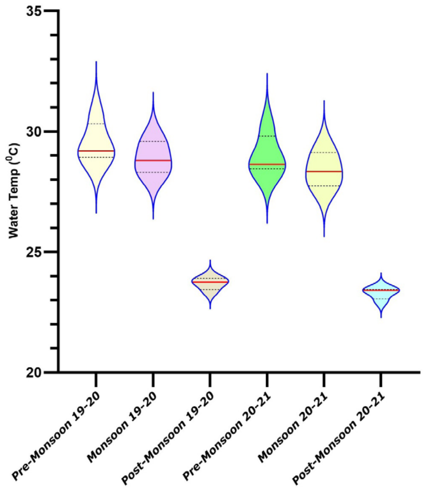

Fig. 2. Water Temperature of Ballav Dighi during various seasons

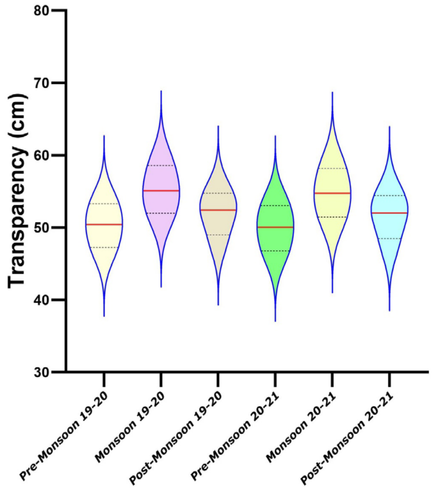

Fig. 3. Water Transparency of Ballav Dighi during various seasons

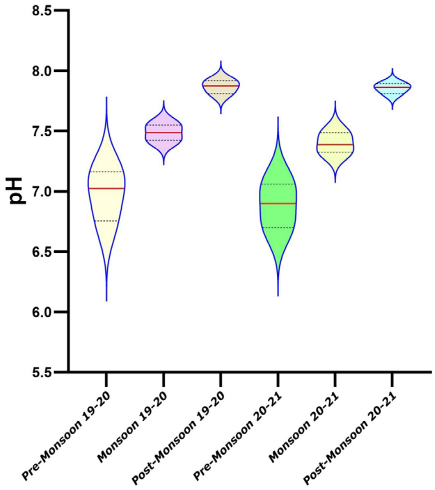

Fig. 4. Water pH of Ballav Dighi during various seasons

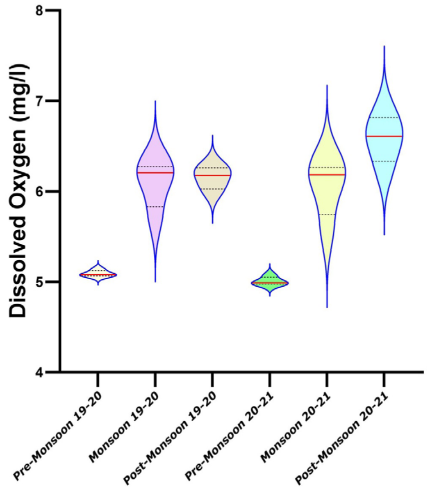

Fig. 5. Dissolved Oxygen of Ballav Dighi during various seasons

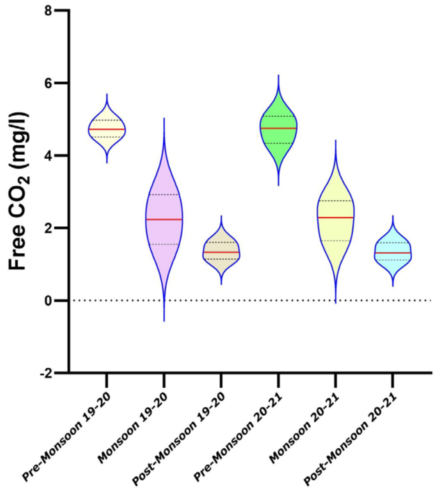

Fig. 6. Free Carbon dioxide of Ballav Dighi during various seasons

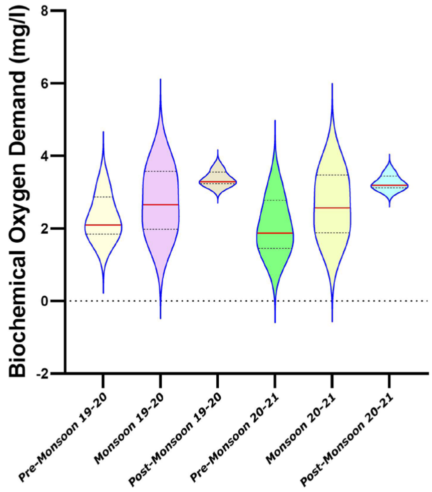

Fig. 7. Biochemical Oxygen Demand of Ballav Dighi during various seasons

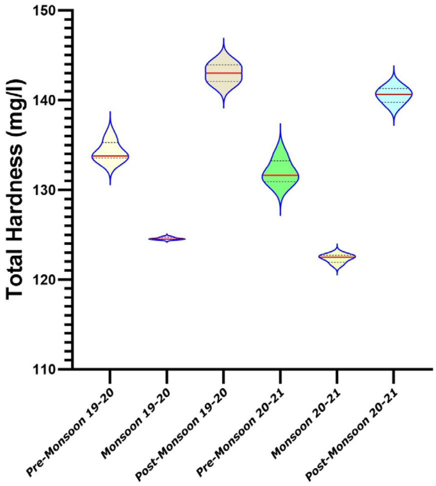

Fig. 8. Total Hardness of Ballav Dighi during various seasons

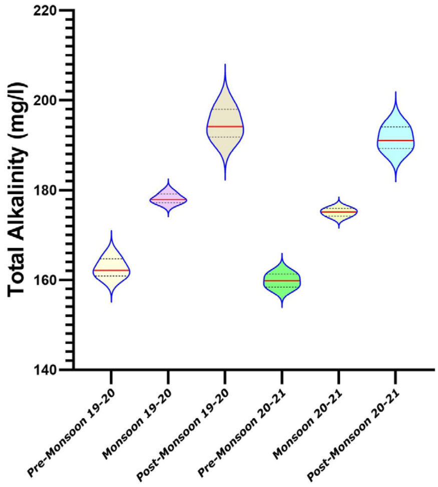

Fig. 9. Total Alkalinity of Ballav Dighi during various seasons

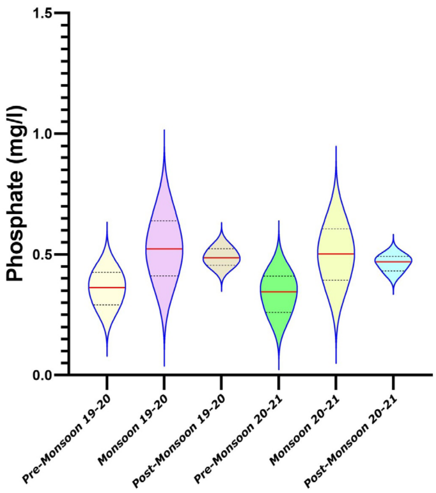

Fig. 10. Phosphate of Ballav Dighi during various seasons

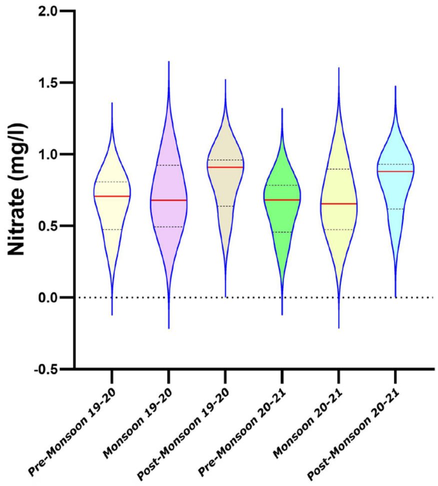

Fig. 11. WFree Carbon dioxide of Ballav Dighi during various seasons

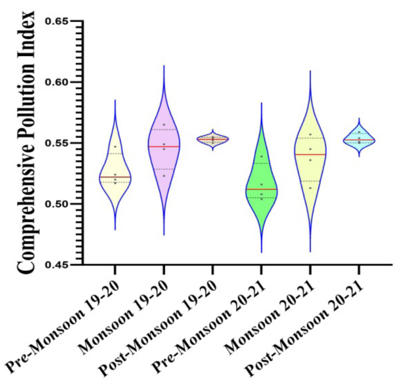

Fig. 12. Seasonal Comprehensive Pollution Index (CPI) of Ballv Dighi during the study period (4 findings per quarter).

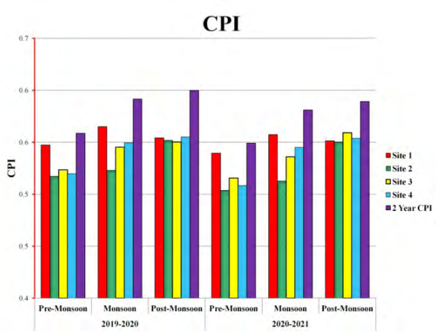

Fig. 13. Seasonal Comprehensive Pollution Index (CPI) of Ballv Dighi during various seasons in different sites

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

	March 2019 - Feb 2020		
	PRM	MON	POM
Water Temp (°C)	29.47 ± 1.39[a]	28.9 ± 1.67[a]	23.7 ± 0.84[b]
pH	6.93 ± 0.31[a]	7.58 ± 0.47[a]	8.11 ± 0.26[b]
Transparency(cm)	20.07 ± 1.95[a]	24.97 ± 0.63[b]	21.77 ± 3.03[a]
DO (mg/L)	5.09 ± 0.98[a]	6.23 ± 0.75[b]	7.27 ± 0.9[b]
Free CO2 (mg/L)	7.9 ± 1.91[a]	5.87 ± 2.37[a]	3.1 ± 1.53[b]
BOD (mg/L)	4.77 ± 1.2[a]	5.73 ± 1.25[a]	6.36 ± 0.58[b]
Total Hardness (mg/L)	134 ± 8[a]	125 ± 7[a]	143 ± 24[a]
Total Alkalinity (mg/L)	163 ± 6[a]	178 ± 9[a]	195 ± 12[a]
Nitrate (mg/L)	0.66 ± 0.18[a]	0.7 ± 0.24[a]	0.84 ± 0.3[a]
Phosphate (mg/L)	0.61 ± 0.4[a]	0.78 ± 0.55[a]	0.74 ± 0.5[a]
	March 2020 - Feb 2021		
	PRM	MON	POM
Water Temp (°C)	28.97 ± 1.38[a]	28.41 ± 1.66[a]	23.3 ± 0.82[b]
pH	6.81 ± 0.32[a]	7.45 ± 0.45[a]	7.97 ± 0.26[b]
Transparency(cm)	19.71 ± 1.92[a]	24.55 ± 0.6[b]	21.41 ± 2.97[a]
DO (mg/L)	5.01 ± 0.96[a]	6.13 ± 0.74[b]	7.15 ± 0.88[b]
Free CO2 (mg/L)	7.77 ± 1.87[a]	5.78 ± 2.33[a]	3.05 ± 1.5[b]
BOD (mg/L)	4.69 ± 1.18[a]	5.64 ± 1.23[a]	6.25 ± 0.57[b]
Total Hardness (mg/L)	132 ± 8[a]	122 ± 7[a]	141 ± 23[a]
Total Alkalinity (mg/L)	160 ± 6[a]	175 ± 9[a]	191 ± 11[a]
Nitrate (mg/L)	0.64 ± 0.17[a]	0.67 ± 0.24[a]	0.81 ± 0.29[a]
Phosphate (mg/L)	0.59 ± 0.4[a]	0.75 ± 0.54[a]	0.71 ± 0.49[a]

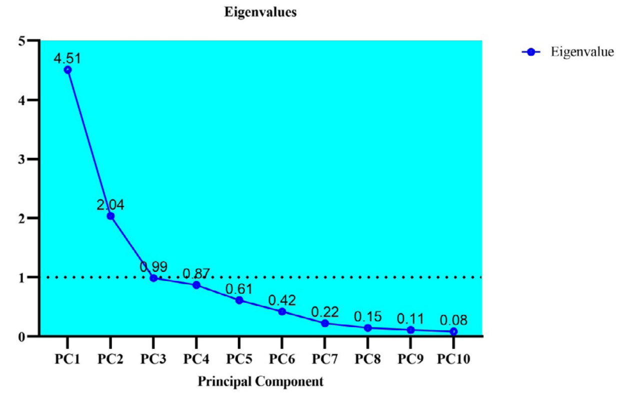

Fig. 14. Scree plot showing the eigenvalues and principal components derived from PCA regarding the different water physicochemical parameters of water of Ballav Dighi

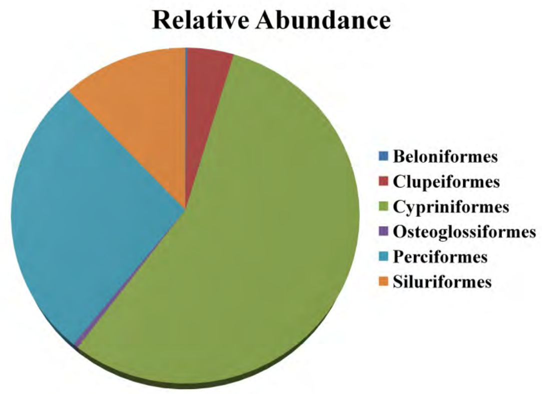

Fig. 15. Relative abundance of fish order found in numbers in Ballav Dighi from March 2019 to February 2021

Table 2. Species diversity indices and CPI in three different seasons of Ballav Dighi

	2019 – 2020			2020 – 2021		
	Pre-Monsoon	Monsoon	Post-Monsoon	Pre-Monsoon	Monsoon	Post-Monsoon
$\bar{H}$ index	2.726	2.726	2.693	2.675	2.72	2.719
Evenness Index (J)	0.785	0.808	0.819	0.779	0.805	0.809
Index of Dominance	0.106	0.093	0.086	0.097	0.095	0.093
Average CPI	0.527	0.546	0.553	0.517	0.538	0.554

Table 3. Fish species found in Ballav Dighi during the study period (2019-2021)

Order	Family	Species	Local Name	IUCN Status	Occurrence PRM	MON	POM
Beloniformes	Belonidae	*Xenentodon cancila*	Kakia	LC	+	+	+
Clupeiformes	Clupeidae	*Gudusia chapra*	Khaira	EN	++	++	+++
Cypriniformes	Cyprinidae	*Amblypharyngodon mola*	Mourola	LC	++++	++++	++++
		Chela cachius	Chela	LC	+++	+++	+++
		Esomus danricus	Dankya	LC	++	++	++
		Labeo bata	Bata	LC	++	++	++
		Osteobrama cotio	Gilachaki	LC	+	-	+
		Pethia ticto	Titpunti	LC	+++	+++	+++
		Puntius sophore	Punti	LC	++	+++	+++
		Salmophasia bacaila	Chela	LC	+	+	+
		Systomus sarana	Swarna Punti	LC	++	++	++
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	Pholui	NE	+	-	-
Perciformes	Ambassidae	*Chanda nama*	Chanda	LC	+	+	+
		Parambassis ranga	Chanda	LC	++	++	++
	Anabantidae	*Anabas cobojius*	Koi	DD	+	-	-
		Anabas testudineus	Koi	DD	-	+	+
	Badidae	*Badis badis*	Botkoi	LC	+	+	+
	Channidae	*Channa orientalis*	Cheng	NE	++	++	+
		Channa punctata	Lata	LC	++	++	++
		Channa stewartii	Tel Chang	LC	+	+	+
	Gobiidae	*Glossogobius giuris*	Bele	LC	+	+	+
	Nandidae	*Nandus nandus*	Bheda	LC	++	+++	++
	Osphronemidae	*Trichogaster fasciata*	Kholse	LC	+++	+++	+++
	Chichlidae	*Oreochromis mossambicus*	Tilapia	LC	+++	++	++
Siluriformes	Bagridae	*Mystus bleekeri*	Tengra	LC	++	+++	+++
		Mystus cavasius	Tengra	LC	+	+	+
		Mystus vittatus	Tangra	LC	+++	+++	+++
	Clariidae	*Clarias batrachus*	Magur	LC	+	+	-
	Heteropneustidae	*Heteropneustes fossilis*	Singi	LC	+	+	+
	Siluridae	*Ompok pabda*	Pabda	NT	+	+	+
		Ompok pabo	Pabda	NT	+	+	+

Overall, 31 fish species belonging to 6 Orders were recorded during the study period of two years (2019-2021) and are listed in Table 3. Here, IUCN refers to the International Union for Conservation of Nature, PRM refers to pre-monsoon, MON refers to monsoon and POM refers to post-monsoon. Here '+++'=highly abundant, '++'=moderately abundant, '+'=less abundant and '-'=absent and LC=Least Concern, NT=Near threatened, NE=Not evaluated, DD=Data deficient, EN=Endangered.

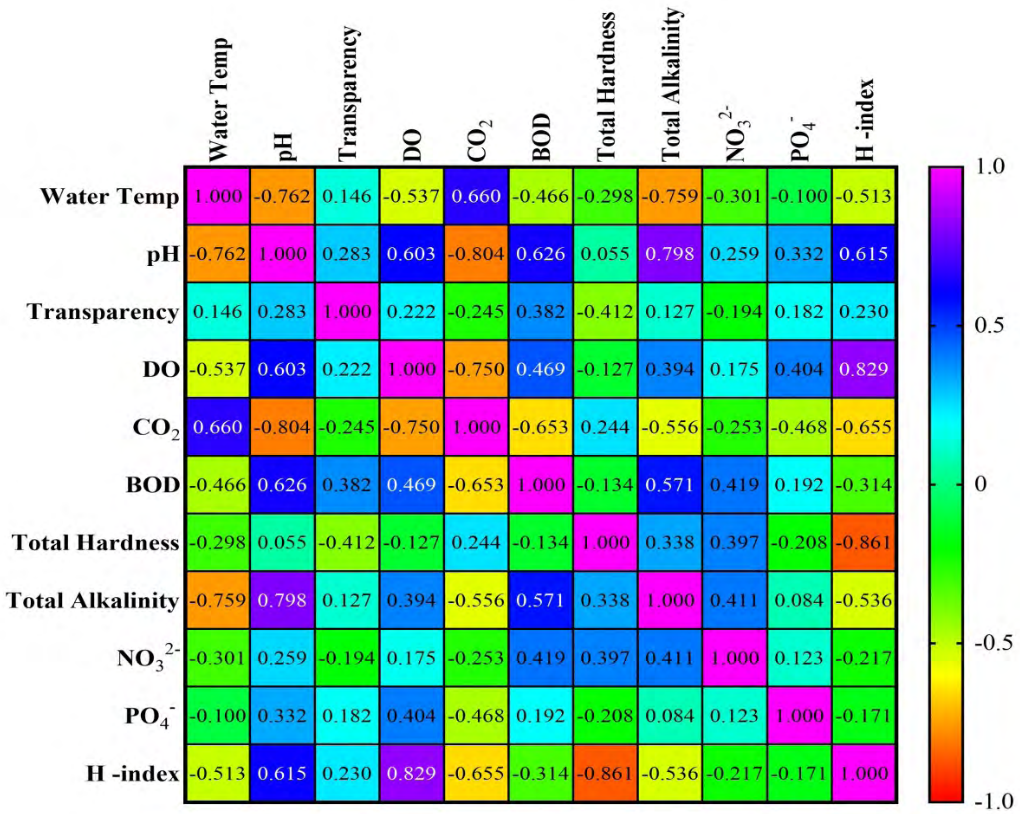

Fig. 16. Heatmap of Pearson correlation matrix between different physicochemical parameters and Shannon Wiener diversity Index of Ballav Dighi from March 2019 to February 2021

4. Discussion

A good ecological condition is critical for aquatic organism production (Ferreira et al., 2011; Ma et al., 2013). Thus, measuring and analyzing the water quality of a small lake can assist in forecasting key circumstances for aquaculture and reducing unfavourable health issues in the aquaculture industry (Mohanty et al., 2018). Water temperature plays the most important role in fish culture for survival, growth, and oxygen production (Cheng et al., 2005). In this study, there was a seasonal rising and declining pattern in the water temperature among the four study sites of the Dighi. Water temperature was observed to be slightly downward (Table 1) compared to the previous year of the study period. The water temperature indicated that it was not too high or not too low, which indicates high sun intensity helps in metabolic activities (Singh et al., 2019). The temperature of water reflected a positive correlation with carbon dioxide and a negative correlation mostly with other parameters. The water pH level of 7.6 favours the growth requirement of aquatic organisms (Mehra et al., 2000). The pH of water interacts with the values of acidity, alkalinity, and chemical processes like coagulation, disinfection, and environmental remediation, making it one of the most significant elements in water quality analysis. In this study, pH ranges were within 6.6-8.00, which indicates the medium productive nature of the Dighi (Kurbatova, 2005). Pearson correlation results indicate that pH was negatively correlated with water temperature and carbon dioxide, with a positive correlation with all other parameters. Dissolved oxygen is a very important aquatic parameter in the context of the culture of any aquatic animal. Oxygen is essential for all species' survival activities. Dissolved oxygen ranged from 3.88 mg/L to 7.58 mg/L throughout the study period. In the study, the concentration of dissolved oxygen was found to be negatively correlated with water temperature and carbon dioxide, which was similar to the study of Chaurasia and Tiwari (2011).

Carbon dioxide is highly soluble in water and the main source of carbon pathways in nature. Carbon dioxide in the water bodies is mainly contributed by the respiratory activity of animals. In the study, carbon dioxide in the water rages from 0 mg/L to 6.14 mg/L and is mostly within the range suggested by CPCB (2011) and WHO (2011). The carbon dioxide content of water was found to be negatively correlated with the Shannon Weiner fish diversity index and dissolved oxygen. Biochemical oxygen demand is the amount of oxygen required by bacteria under aerobic conditions. BOD gives an idea about the extent of pollution. On an average basis, the oxygen demand is proportional to the amount of oxidized organic matter present in the water and the BOD value can be used as a measure of waste strength. The value of BOD in water ranged from 1.01 mg/L to 4.81 mg/L, showing the presence of organic matter in the water. The range of BOD was satisfactory and found within the range suggested by CPCB (2011). The total hardness of water is not considered a vital physicochemical parameter but is necessary to assess water quality. In the present study, the total hardness of water was found within a range of 104 mg/L to 168 mg/L throughout the study period. The total hardness of water showed an inverse relationship with the Shannon-Weiner diversity index; a similar finding was also detected by Ansari (2017). The total alkalinity of water is also one important factor in aquatic habitat; high value is related to the high yield of an aquatic organism (Singh et al., 2002). The total alkalinity of Ballav Dighi ranged between 151 mg/L to 218 mg/L throughout the study period. According to Pearson correlation, the total alkalinity of water was found to have a positive correlation ($r = 0.798$) with pH. A nitrate level in wetlands has a direct influence on the eutrophication process. The value of nitrate in the Dighi varied from 0.34 mg/L to 1.25 mg/L, as per CPCB (2011), the values were within the acceptable limits.

In Ballav Dighi, nitrate showed a negative correlation with water temperature and carbon dioxide and a positive correlation with other parameters of water in the study. Phosphorus is found as phosphate in the water, which has a direct impact on aquatic organisms. In this study, phosphate levels varied from 0.13 mg/L to 1.01 mg/L throughout the study period and showed a negative correlation with water temperature and carbon dioxide. The concentration of phosphate in the water was found to moderate throughout the year, indicating a mesotrophic Dighi. A mesotrophic wetland system has intermediate levels of phosphorus and is suitable for the growth of aquatic plants and fishes (Gupta et al., 2016). The results described above indicate that all the physicochemical parameters studies were within acceptable limits and the water quality of this Dighi is suitable for fish culture. This is also relevant to Bhatnagar and Devi (2013), who found most of the physicochemical parameters were within the target range.

PCA is a conventional multivariate analysis approach that uses decreasing dimensions of large amounts of data to isolate and minimize the variables that cause water quality alteration (Zeinalzadeh and Rezaei, 2017). Principal component analysis of the study revealed that pH (0.920), total alkalinity (0.807), dissolved oxygen (0.749), temperature (-0.801), and carbon dioxide (-0.894) were with strong loadings in the first principal component, this indicated that these five variables were the basic environmental factors in the Dighi. The eigenvalues of the PCA greater than 1.0 are considered significant (Shrestha and Kazama, 2007). The eigenvalues of the first two main components are larger than 1.0 and contribute to 65.42 percent of the variance in the data. The first principal component found high positive loadings of pH (0.920), total alkalinity (0.807), and dissolved oxygen (0.749) while negative loadings of temperature (-0.801), and carbon dioxide (-0.894). The second principal component found high positive loadings of transparency (0.680) and negative loadings of total hardness (-0.872). The abiotic factors that were analyzed in the PCA showed that the very first Principal Components (water temp, pH, carbon dioxide, and total alkalinity) expressed pollution level of water whereas the second principal components (transparency and total hardness) expressed regularly changing common parameters.

In the fish diversity study, 31 species of fish belonging to 6 orders, 16 families, and 24 genera were obtained. After counting the fishes which were captured each month, Cypriniformes was the most dominating order having 9 species with 55.67% Relative Abundance (RA), followed by Perciformes with 12 species and 27.22% RA, Siluriformes with 7 species and 12.04% RA, Clupeiformes with 1 species and 4.45% RA, Osteoglossiformes with 1 species and 0.48% RA and Beloniformes with 1 species and 0.2% RA. Natural and anthropogenic activities directly impact the relative abundance of species until they become endangered species (Roy et al., 2013). The most dominating species was *Amblypharyngodon mola* with 26.33% RA, while the least species was *Anabas cobojius* with 0.01% RA. Shannon Weiner's diversity index was found to be higher in the post-monsoon seasons of both years. The Shannon Weiner diversity index showed a negative correlation with carbon dioxide, water temperature, and total hardness, while positive with pH and dissolved oxygen in the study. In this present study, the Shannon-Wiener diversity indices suggest that the water of Ballav Dighi is moderately polluted, which was compared with Jewel et al. (2018).

5. Conclusion

The present study showed that seasonal fluctuation of various hydrological parameters had a great impact on the diversity and richness of small indigenous fish species. The one-way ANOVA test revealed no significant differences in the variables assessed during the study periods. The Principal Component analysis showed that pH, free carbon dioxide, and total hardness were the main regulating factors of the ecological health of this wetland. Round the year, the presence of small indigenous fish diversity ensures healthy ecological conditions of this wetland and post-monsoon seasons were found most suitable for fish growth. The findings revealed that the water of this Dighi is fit for household use and pisciculture but not appropriate for human consumption. From the above study, we can make the overall conclusion that strict vigilance and general awareness are required so that proper conservation of this old perennial water body can be done; otherwise, exponentially increasing anthropogenic activities may contaminate this Dighi badly in the near future.

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6. References

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