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TEMPORAL DYNAMICS OF PLANKTON COMMUNITIES IN AN ABANDONED ENVIRONMENT: A COMPREHENSIVE POND STUDY

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ABSTRACT
In a year-long study of an abandoned Pond Rejali (PR) in Dhanbad, Jharkhand, plankton community study was carried out in order to find out the current ecological condition of the pond and its possible utilisation. Among the abiotic factors, variation in temperature (16-36 °C), transparency (15-19.5 cm), dissolved oxygen (1.5-8.6 mg/L), total dissolved solids (970-1250 mg/L), nitrate concentrations (0.10-0.19 mg/L), phosphate levels (0.43-1.05 mg/L), chloride content (14-65 mg/L), BOD (4.6-8 mg/L), and COD (36-76 mg/L) have been recorded. Diversity indices revealed moderately to highly diverse zooplankton communities (Shannon Diversity Index as 3.04 and Simpson's Diversity Index value as 0.95). Phytoplankton showed slightly lower diversity (Shannon Diversity Index value as 2.22).

INTRODUCTION

Aquatic ecosystems are known to harbor diverse and dynamic communities of organisms that play a crucial role in nutrient cycling and ecosystem functioning; among which zooplankton and phytoplankton play a pivotal role (Wang *et al.*, 2021). These planktonic organisms are involved in nutrient cycling, food web dynamics, and overall ecosystem health (Razak & Sharip, 2019; Wang *et al.*, 2021). While the temporal dynamics of plankton communities have been extensively investigated in various aquatic environments (Bhatt *et al.*, 2014; Deepak & Singh, 2014; Anderson, 2015; Smith, 2017; Jena *et al.*, 2017) the influence of environmental degradation on these communities remains a topic of scientific interest.

This research endeavors to shed light on the temporal dynamics of zooplankton and phytoplankton communities in an abandoned environment. specifically an unmanaged pond. Existing studies have demonstrated that zooplankton and phytoplankton communities exhibit temporal fluctuations influenced by environmental factors such as temperature, nutrient availability, and light conditions (Smith, 2017; Ma *et al.*, 2019; Tulsankar *et al.*, 2021). By assessing these dynamics in an abandoned pond, our research aims to unveil potential adaptations and temporal patterns specific to such environments.

The need for present work arises from the limited understanding of how an unused pond water environment affects the zooplankton and phytoplankton community structures. It is hypothesised that despite the degradation of the physical environment in an abandoned pond, planktonic communities may display different pattern and temporal variation different from those in well-maintained ponds. The primary objective of this study is to comprehensively analyze the temporal dynamics of zooplankton and phytoplankton communities in an abandoned pond.

MATERIALS AND METHODS

STUDY AREA

The district of Dhanbad, which is in the state of Jharkhand, is where the study was conducted. A pond named Rejali, is located in one of the blocks of Dhanbad, Govindpur, on which the current study has been performed. The pond Rejali (PR) has been abandoned for a very long time and is not used for any commercial purpose. It is situated at 23° 49 '45.45"N and 86° 31' 15.00"E on the geographical map. This perennial fresh water pond, is also known locally as Saheb Bandh or Rajni Bandh.

Sample collection and analysis

From February 2019 to January 2020, monthly surface water samples from the PR were collected for abiotic and biotic analyses.The final result was calculated using the average of the five samples. A centigrade thermometer (0 ºC to 100ºC scale) was used to measure the water's temperature (WT) at the sampling site. To measure the transparency (TSPCY) of the pond's water, a Sechhi disc was used. The pH and Total Dissolved Solids (TDS) were also determined at the sampling site using the Labtronics' Soil and Water Analysis Kit, model LT-62. Dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) were determined. In addition to these, other dissolved nutrients such as nitrate (NO_3^-), phosphate PO_4^{3-}, and chloride Cl^- have also been estimated using the standard protocols as given in APHA, 2005.

100 liter of water or zooplankton samples were filtered using

a plankton net that was made out of bolting silk cloth with a mesh size of 25 μm. The samples were then preserved in 70% alcohol. Then, using the standard literatures (Prescott, 1962; Needham and Needham, 1966; Adoni *et al.*, 1985; Agarker *et al.*, 1994; APHA, 2005), the collected zooplankton samples were identified and enumerated. Phytoplankton was preserved in 2% to 5% Lugol's solution. And finally, the keys provided in the monographs (Prescott, 1962; Edmondson, 1966; Needham & Needham, 1966; Pennak, 1978; Tonapi, 1980; Adoni *et al.*, 1985; Agarker *et al.*, 1994; APHA, 2005) were employed for phytoplankton identification. The Sedgwick-rafter cell method was used to count the plankton, and the results were expressed as unit per litre (N/L).

The following indices were calculated using various formulas as below:

Shannon-Wiener diversity index

$$H' = \sum_{n=1}^{s} Pi \ln ni/N$$

where, S = number of taxa

N = total number of individuals across all species

Pi = proportion of total number of individuals

H' = diversity index

ni = number of individuals of each species

Evenness Index

$$E = \frac{H'}{H' \max}$$

where, E = evenness index

H' max = ln S

H' = diversity index.

Simpson's Diversity Index

$$D = 1 - \frac{\sum_{i}^{s} = 1(ni-(ni-1))}{N-(N-1)}$$

where, *D* = Simpson's Diversity Index

n_i = number of individuals of the *i*-th species

N = total number of individuals in sample

S = total number of species in sample

RESULTS AND DISCUSSION

Temporal fluctuations in abiotic factors

Table 1 enlists the range (minimum/maximum), annual mean, and standard deviation values of the abiotic or physicochemical characteristics of water. The water temperature ranges from 16ºC to 36ºC, with a mean value of 25.58ºC. Water temperature can significantly impact aquatic ecosystems and the solubility of gases in water (Kazmi *et al.*, 2022; Bonacina *et al.*, 2023). Transparency, typically measured as the depth to which an object can be seen through water, is an essential indicator of water quality. Higher values indicate clearer water with fewer suspended particles, sediments, or pollutants. Environmental factors significantly impact transparency in water bodies. For example, studies show that transparency can decrease in certain seasons due to environmental factors, affecting nearby seas and ecosystems (Ma *et al.*, 2023). The minimum transparency of 15 cm suggests that in certain conditions, the water may have reduced clarity, possibly due to sedimentation or pollutant presence. The maximum transparency of 19.5 cm indicates that under optimal conditions, the water can be very clear and transparent, often seen in pristine environments. The mean transparency of 17.03 cm represents the typical clarity of the water, which can be considered relatively good for many aquatic ecosystems.

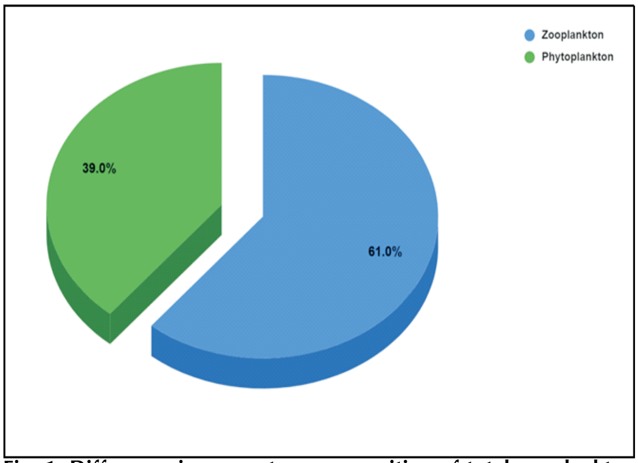

Fig. 1: Difference in percentage composition of total zooplankton and total phytoplankton groups during the study period.

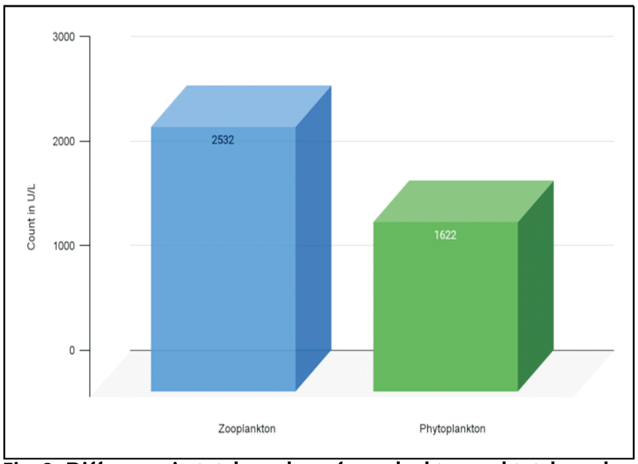

Fig. 2: Difference in total number of zooplankton and total number of phytoplankton in the PR during one year of study.

Dissolved oxygen levels vary from 1.5 mg/L to 8.6 mg/L, with a mean value of 4.6 mg/L. Adequate DO levels are crucial for aquatic organisms, and a mean value of 4.6 mg/L suggests relatively good oxygen availability in the water, promoting healthy aquatic ecosystems (Editorial, 2021). TDS levels range from 970 mg/L to 1250 mg/L, with a mean value of 1103.25 mg/L. TDS represents the total concentration of inorganic and organic substances dissolved in water (Jayakumar, *et al.*, 2009). While this mean value is within the typical range, it's important to monitor TDS as elevated levels can affect water quality and taste (Committee on the Design and Evaluation of Safer

Table 1: Temporal variations in the abiotic attributes of PR during the study period from February 2019 to January 2020.

Physicochemical parameters	Minimum value	Maximum value	Mean value	Standard deviation
WT (in °C)	16	36	25.58	6.84
pH	5.9	7.1	6.58	0.304
Transparency (in cm)	15	19.5	17.03	1.69
DO (in mg/L)	1.5	8.6	4.6	1.88
TDS (in mg/L)	970	1250	1103.25	146.35
NO_3^- (in mg/L)	0.1	0.19	0.14	0.026
PO_4^{3-} (in mg/L)	0.43	1.05	0.69	0.226
Cl^- (in mg/L)	14	65	36.91	15.84
BOD (in mg/L)	4.6	8	6.25	1.29
COD (in mg/L)	36	76	56.58	15.64

Table 2: Temporal-annual variations in different counts of zooplankton-phytoplankton population in the PR from February 2019 to January 2020.

	Zooplankton			Phytoplankton		
Months	TC	AC	SD	TC	AC	SD
Feb	387	12.9	10.9	133	6.33	7.83
Mar	219	7.3	8.87	140	1.66	8.94
Apr	115	3.83	6.35	138	6.57	8.77
May	53	1.76	3.83	143	6.8	8.96
Jun	34	1.72	2.5	75	3.57	4.69
Jul	76	2.62	3.95	79	3.96	4.78
Aug	157	5.41	5.79	86	4.3	5.13
Sep	233	8.03	6.28	140	7.8	9.26
Oct	308	10.26	6.92	168	8	9.28
Nov	393	13.1	8.31	190	9.04	10.25
Dec	493	16.43	11.17	153	7.28	9.13
Jan	564	36.38	12.79	153	7.28	9.2

TC: Total Count, AC: Average Count, SD: Standard Deviation. Count is mentioned in U/L

Table 3: Variation in the annual mean values in biodiversity indices of water samples from the PR during the study period.

	Zooplankton		Phytoplankton	
Diversity Indices	Av	SD	Av	SD
Simpson_1-D	0.95	0.05	0.88	0.01
Shannon_H	3.04	0.26	2.22	0.05
Evenness_e^H/S	0.85	0.07	0.95	0.03

Av: Average value, SD: Standard Deviation

Chemical Substitutions, 2014). Nitrate levels vary from 0.10 mg/L to 0.19 mg/L, with a mean value of 0.14 mg/L. Nitrate is a key nutrient for aquatic plants, but excessive levels can lead to eutrophication, causing harmful algal blooms and water quality issues. The mean value indicates a relatively low nitrate concentration (de Oliveira *et al*., 2020). Phosphate concentrations range from 0.43 mg/L to 1.05 mg/L, with a mean value of 0.69 mg/L. Phosphates are another essential nutrient but, like nitrates, can contribute to eutrophication when present in excessive amounts. The mean value suggests a moderate phosphate level in the water (de Oliveira *et al*., 2020). Chloride levels range from 14 mg/L to 65 mg/L, with a mean value of 36.91 mg/L. Chlorides are generally harmless to aquatic life at these levels. However, elevated chloride concentrations can be an indicator of contamination, such as road salt runoff in urban areas (de Oliveira *et al*., 2020). BOD levels vary from 4.6 mg/L to 8 mg/L, with a mean value of 6.25 mg/L. BOD is a measure of the oxygen required by microorganisms to break down organic matter in water. A mean BOD of 6.25 mg/L indicates moderate organic pollution in the water, which could impact water quality and aquatic life (Committee on the Design and Evaluation of Safer Chemical Substitutions, 2014). COD levels range from 36 mg/L to 76 mg/L, with a mean value of 56.58 mg/L. COD measures the amount of oxygen required to chemically oxidize organic and inorganic matter in water. A mean COD of 56.58 mg/L indicates a moderate level of pollution, similar to BOD, which may affect water quality and aquatic ecosystems (de Oliveira *et al*., 2020).

Temporal fluctuations in biotic factors

According to Puroshottama *et al*., 2011, plankton exhibit the present condition of a number of ecological and biological features of the aquatic environment, making them very susceptible to change and their species replacement happens when conditions in the aquatic ecosystem change.

Temporal abundance of zooplankton

The variation in the number of zooplankton has been provided in Table 2. During the present study, a total of 30 different species of zooplankton have been recorded from the PR belonging to five groups (Naseer & Sinha, 2021) as Cladocera (4 species), Copepoda (4 species), Ostracoda (2 species), Protozoa (5 species), and Rotifera (15 species). And, the Rotifers being the most dominant among the groups (Mallik & Sinha, 2016).The group order goes as Ostracoda <Cladocera<Copepoda<Protozoa<Rotifera. And these groups are represented by *Daphnia* sp., *Moina* sp., *Bosmina* sp., *Ceriodaphnia* sp., *Cyclops* sp., *Diaptomus* sp., *Mesocyclops* sp., *Nauplius* sp., *Brachionus bidentata*, *B. plicatilis*, *B. calyciflorus*, *B. quadridentatus*, *B. angularis*, *B. tridentatus*, *Keratella* sp., *Asplanchna* sp., *Filinia* sp., *Rotaria* sp., *Monostyla* sp., *Tetramastix* sp., *Platiyas* sp., *Hexarthra* sp., *Colurella* sp., *Cypris* sp., *Cypriodopsis* sp., *Paramoecium* sp., *Arcella* sp., *Amoeba* sp., *Stylonychia* sp., and *Vorticella* sp. Total count of zooplankton was recorded to be 2532 (Figure 2).

From February to June, zooplankton counts are relatively low, with the lowest average count of 1.72 in June. This could be attributed to the lower water temperatures, which can reduce the metabolic rates and reproductive activity of zooplankton (Williamson *et al*., 2020). These findings are consistent with previous study (Smith *et al*., 2018) also that highlight the influence of temperature on zooplankton abundance. The average count reaches its peak in January at 36.38, reflecting a substantial increase in zooplankton populations.

Temporal abundance of phytoplankton

Overall changes in the number of phytoplankton is being represented in Table 2. 21 different types of phytoplankton were recorded during the study period that belonged to 5 classes as Conjugatophyceae (2 sps.), Chlorophyceae (3 sps.), Cyanophyceae (5 sps), Bacillariophyceae (10 sps), and Euglenophyceae (1 sp.). Species that were observed include *Staurastrum* sp., *Closterium* sp., *Microspora* sp., *Hormidium* sp., *Chaetophora* sp., *Nostoc* sp., *Anabaena* sp., *Spirulina* sp., *Oscillatoria* sp., *Microcystis* sp., *Bacillaria* sp., *Cymbella* sp., *Diatoma* sp., *Fragilaria* sp., *Melosira* sp., *Navicula* sp., *Nitzschia* sp., *Pinnularia* sp., *Tabellaria* sp., *Synedra* sp., and *Euglena* sp. And the class wise order of phytoplankton abundance goes as Eugle nophy cea e<Conj ugatoph

Table 4: Statistical relevance (Pearson's Correlation coefficient) among different environmental variables, zooplankton, and phytoplankton in the PR from February 2019 to January 2020.

	Zooplankton	Phytoplankton	WT	pH	TSPCY	DO	TDS	NO_3^-	PO_4^{3-}	Cl^-	BOD	COD
Zooplankton	1											
Phytoplankton	0.57	1										
WT	-0.92	-0.62	1									
pH	-0.31	-0.01	0.06	1								
TSPCY	-0.73	-0.44	0.68	0.18	1							
DO	0.76	0.46	-0.92	-0.02	-0.52	1						
TDS	-0.09	0.17	0.25	0.16	0.25	-0.25	1					
NO_3^-	-0.29	0.05	0.44	0.05	0.19	-0.51	0.48	1				
PO_4^{3-}	0.6	0.66	-0.45	-0.12	-0.29	0.32	0.63	0.26	1			
Cl^-	-0.43	-0.33	0.27	0.04	0.27	-0.24	-0.73	-0.17	-0.81	1		
BOD	-0.38	-0.27	0.22	0.18	0.11	-0.22	-0.58	-0.01	-0.74	0.83	1	
COD	-0.3	-0.08	0.15	0.09	-0.07	-0.19	-0.66	0.17	-0.57	0.79	0.76	1

yceae < Chlorophyceae < Cyanophyceae < Bacillariophyceae. A total count of 1622 (Figure 2) numbers of phytoplankton have been recorded from this study.

The lowest phytoplankton counts are recorded from December to March, with the minimum AC of 1.66 observed in March. This decline in phytoplankton abundance during winter is primarily attributed to reduced light availability due to shorter photoperiods and decreased solar radiation (Bouvy *et al.*, 2012). Phytoplankton abundance starts to increase, reaching its peak during September to November. The highest TC of 190 and AC of 9.04 are observed in November. This increase in phytoplankton is closely linked to warmer water temperatures and increased nutrient availability, which facilitate higher photosynthetic activity and growth (Cloern, 2018). The relationship between temperature and phytoplankton abundance is well-documented in aquatic ecology; as water temperature rises, phytoplankton metabolism and growth rates also increase (Ashokaswathy *et al.*, 2015)

Abundance of zooplankton versus abundance of phytoplankton (Z:P)

The relative abundance of zooplankton compared to phytoplankton in a freshwater system holds ecological and environmental significance, offering insights into ecosystem health, trophic interactions, and responses to environmental changes (Weinstock, Vargas, & Collin, 2022). A definite higher level of zooplankton abundance has been discovered to be present in PR during the study than the phytoplankton abundance. Even the number of different species have been reported to be more in case of zooplankton (30 sps.) than the phytoplankton (21 sps.). The trophic condition of the ecosystem can be determined by the zooplankton to phytoplankton ratio and eutrophication may be indicated by a greater Z:P ratio (Jara García-Chicote, Armengol andRojo, 2018). In the current study consequently the percentage composition ratio of zooplankton and phytoplankton has been reported to be 61 %:39 % (Figure 1). Significance of higher zooplankton abundance compared to phytoplankton abundance in a freshwater system can be attributed to several ecological factors and has implications for the ecosystem; indicating the eutrophic condition in the bodies of water (Joseph & Yamakanamardi, 2011).

Temporal diversity of zooplankton (Table 3)

With an average Shannon's Diversity Index of 3.04, the ecosystem exhibits a moderate to high level of diversity. A diverse zooplankton community can improve nutrient cycling, enhance energy transfer, and increase overall system productivity (Loreau & Hector, 2001). The evenness index of 0.85 suggests that zooplankton species are relatively evenly distributed in the ecosystem and can lead to a more stable ecosystem with a lower risk of population crashes and disruptions in food chains (Pielou, 1966).

Temporal diversity of phytoplankton (Table 3)

The phytoplankton diversity indices in the provided table offer insights into the composition and structure of the phytoplankton community in the PR. With a value of 0.88, the Simpson's Diversity Index suggests that some species may dominate the community, potentially reducing overall diversity. A high Shannon index of 2.22 signifies a diverse and well-balanced phytoplankton community. The high evenness value of 0.95 indicates an equitable distribution of species, contributing to a balanced ecosystem. These findings underline the significance of maintaining diversity and evenness in phytoplankton communities for overall ecosystem health and functioning (Pennekamp *et al.*, 2020; Colin S. Reynolds' Legacy, 2021).

Diversity of zooplankton versus diversity of phytoplankton

The annual mean values of biodiversity indices for both zooplankton and phytoplankton in the PR show notable differences. In terms of Simpson's Diversity Index, zooplankton exhibit a higher average value of 0.95, indicating lower dominance and higher diversity. Phytoplankton, on the other hand, have a slightly lower average value of 0.88, implying that some species may have a more dominant presence in the community. While considering the Shannon Diversity Index, zooplankton once again display a higher average value, standing at 3.04. This suggests a moderately to highly diverse community. In contrast, phytoplankton have a lower average value of 2.22 for the Shannon index, indicating a slightly less diverse community than zooplankton. The Evenness index, also shows differences. Zooplankton have an evenness value of 0.85, suggesting relatively even distribution of species. Phytoplankton, with an evenness value of 0.95, exhibit an equitable distribution of species.

Correlation among biotic parameters and abiotic parameters

The provided correlation table (Table 4) depicts the Pearson's

Correlation Coefficients among various environmental variables, zooplankton and phytoplankton in the PR from February 2019 to January 2020.

There is a positive correlation of 0.57 between zooplankton and phytoplankton. This indicates that as the zooplankton population increases, so does the phytoplankton population. This relationship is expected as zooplankton often feed on phytoplankton. There is a strong negative correlation of -0.92 between WT and zooplankton. As the water temperature increases, the zooplankton population decreases significantly. This suggests that zooplankton are negatively affected by higher temperatures. There is a negative correlation of -0.62 between WT and pH. There is a strong positive correlation of 0.76 between DO and zooplankton. Zooplankton thrive when there is an abundance of dissolved oxygen, which is essential for their respiration. There is a positive though very low correlation of 0.25 between total TDS and phytoplankton. There is a positive correlation of 0.44 between NO_3^- and phytoplankton. Nitrate is a nutrient that can stimulate phytoplankton growth. There is a positive correlation of 0.63 between PO_4^{3-} and zooplankton. Zooplankton populations tend to benefit from the presence of phosphates, which can enhance their food supply. There is a strong negative correlation of -0.81 between Cl^- and COD. High Cl^- levels are associated with lower COD levels, which suggests that Cl^- may be contributing to reduced oxygen demand in the water. There is a strong positive correlation of 0.79 between BOD and COD. This indicates that BOD and COD are closely related, and an increase in one is associated with an increase in the other. There is a positive correlation of 0.76 between zooplankton and COD. Zooplankton populations may help in reducing the COD values, indicating their role in maintaining water quality.

These findings highlight the interplay of environmental variables with zooplankton and phytoplankton populations as also confirmed by (Matta *et al*., 2009). Water temperature, TSPCY, DO, phosphate, and pH appear to be more influential factors, while TDS, nitrate, chloride, BOD, and COD show weaker associations. These results align with previous research on the sensitivity of planktonic organisms to various environmental parameters (Faure, Ayata and Bittner, 2021; Lomartire, Marques and Gonçalves, 2021; Ndah *et al*., 2022).

CONCLUSION

The study of temporal fluctuations in abiotic and biotic factors in PR's aquatic ecosystem highlights the dynamic nature of this perennial pond. Water temperature, transparency, and dissolved oxygen exhibit significant variability, affecting aquatic life. Biotic factors, particularly zooplankton and phytoplankton, show diverse and stable communities. The correlation analysis underscores the complex relationships within the ecosystem. These findings enhance the understanding of the ecological dynamics in PR, essential for informed ecosystem management and conservation efforts.

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