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Seasonal Relationships Between Physicochemical Parameters and Zooplankton Distribution in The Ganga River of Sundarbans

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ABSTRACT

Zooplankton are great indicators of water quality and ecological state because they are sensitive to changes in their environment. This research looked at the distribution of zooplankton in the Ganga River, which is part of the Indian Sundarbans, and how it relates to physicochemical factors. Three sites were used to collect water and zooplankton samples on a seasonal basis: summer, monsoon, post-monsoon, and winter. Rotifera (43.60%), Cladocera (22.93%), and Protozoa (18.10%) were the most numerous zooplankton genera out of a total of 23, representing five main groupings. In summer, there were 453 individuals m^{-3} of zooplankton, the greatest abundance of all seasons. According to the correlation study, protozoa, rotifers, and cladocerans were favourably affected by dissolved oxygen and nutrients, whereas copepods were positively impacted by salinity and chloride.

Keywords: *Zooplankton, Water, Physicochemical, Environmental, Salinity.*

I. INTRODUCTION

For all forms of life and Earth's ecosystems to persist, water is an essential resource. People think of it as a resource that is very necessary. Since the existence of all living things in an ecosystem depends on water, it may be said that water is an integral part of any ecosystem. For the survival of all species on Earth, it is essential to the preservation of the environment. That part is crucial to the operation of the whole. The deeper the water gets, the more aquatic species there are generally. Maintaining human civilisation on Earth is critically dependent on the accessibility of freshwater resources. This is because water is essential for carrying out all aspects of daily living. Because they were artificially created to hold water, these bodies of water are considered to be in a semi-natural state. Their status as semi-natural is attributed to this same reason. Because of this, human settlements tended to be located near bodies of freshwater.

River water contamination has become a major issue that needs fixing in every nation. The unfiltered transportation of industrial effluents and sewage into bodies of water is one of the leading sources of pollution. These two kinds of effluent are known to pose risks to the environment. Their contamination of over 70% of the whole water supply is thought to be their fault. Harmful microbes, heavy chemicals, metals, and salts are only some of the things that have contaminated the water supply system.

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Alterations to the water quality in polluted aquatic environments lead to the extinction of the biotic community already existent in the environment. Water pollution is one of the biggest problems facing the environment today. Contaminated water contributes to several adverse health impacts experienced by people, including the transfer of illnesses that rely on water intake for transmission. Because of this, the contamination of freshwater bodies is a major issue for all nations. As a result, monitoring the water supply for contaminants at certain intervals is crucial (and should be done whenever possible).

The smallest organisms that float on the surface of water are called zooplanktons. In most cases, they are rather little; nevertheless, there are certain species that are quite large and may be seen readily. These essential biological units not only contribute significantly to the overall life of the aquatic ecosystem, but they also have the responsibility of ensuring the ecosystem's continued existence. They occupy the second tropic level, and as a consequence, they have an effect on a wide range of ecological activities, such as the food chain, the flow of energy, and a number of other functions. There are a number of factors that influence the density and diversity of zooplankton species. These factors include changes in the climate, as well as changes in the physical and chemical characteristics of water bodies.

The physicochemical characteristics of the aquatic environment are directly related to the number of various species of zooplankton that are present in the water. It is generally agreed that zooplanktons are among the most significant bioindicator species when it comes to identifying the degree of pollution that is present in bodies of water.

II. REVIEW OF LITERATURE

Kalyanrao, Shilpa et al., (2025) Tripuranth Lake is a vital source of freshwater for several purposes, including as agriculture, human consumption, irrigation, and local fauna. From January 2024 through December 2024, this study examines the monthly changes in physico-chemical parameters and zooplankton diversity to evaluate the lake's ecological health. An array of critical physico-chemical parameters were investigated, including air and water temperatures, pH, dissolved oxygen, total dissolved solids, conductivity, total alkalinity, total hardness, magnesium, calcium, and magnesium. Three Ostracoda species, twelve Rotifera species, nine Cladocera species, seven Copepoda species, and thirty-one other zooplankton species were discovered by sampling. Because of the increased nutrient availability and phytoplankton growth, the zooplankton density is highest in the warmer, oxygen-rich pre-monsoon months (April-June). There are strong correlations between physico-chemical parameters and zooplankton abundance, particularly with temperature ($r > 0.8$) and DO ($r > 0.7$). The zooplankton blooms coincided with the monsoon-time apex of temperature, pH, TDS, and DO, which exhibited strong seasonal oscillations. Photosynthesis, agricultural runoff, and evaporation all had a role in these shifts. Scientists discovered a link between zooplankton density and physico-chemical variables like nutrition levels and temperature in the neighbouring Khajikotnoor Reservoir.

Sharma, Arti & Sharma, Meenu. (2019). The purpose of this research was to get a better understanding of the zooplankton population and its relationship to the physicochemical parameters of the surface water in the Barnai pond in the Jammu district. A plankton net constructed of conventional bolting silk cloth no. 25 with a mesh size of 0.003-0.004 μm was utilised to collect zooplankton, while popular methods were employed to analyse the water parameters. Then, the drop count method was used to find the total number of zooplankton. Several diversity indices are employed in statistical data analysis, including one by Margalef, one by Pielou, and Pearson's Correlation analysis. A total of 38 zooplankton taxa and

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Nauplius larvae were discovered, distributed across five major taxonomic groups: Protozoa, Rotifera, Cladocera, Copepoda, and Ostracoda. Physicochemical parameters of Barnai pond displayed clearly discernible swings, with maximum and minimum values for each parameter across various seasons, whereas zooplankton studies revealed seasonal fluctuations, with an increase in summer and a drop in winter and monsoon.

Abdulazeez, Tariq et al., (2018). From October 2013 to September 2014, researchers in Karidna Reservoir studied the zooplanktons and other physicochemical features of the reservoir. The physicochemical and biological properties at five different sites were determined using standardised procedures, tools, and methods. Here are the results of the measured physico-chemical parameters: pH (6.19-8.63), temperature (25.94-31.54oC), electrical conductivity (38.20-64.20µS/cm), total dissolved solids (19.20-37.20 mg/l), transparency (19.40-40.10 cm), dissolved oxygen (2.40-6.81 mg/L), hardness (3.48-174.4 mg/L), calcium (2.14-3.86 mg/L), biological oxygen demand (2.91-40.85 mg/L), and chloride (2.28-3.58 mg/L). Potassium (2.51-4.04 mg/L), sulphate (0.06-0.21 mg/L), and phosphate-phosphorus (0.04-0.24 mg/L). At a significance level of $P<0.01$, the seasons demonstrated highly notable shifts in Po4-, NO3-, SO4-, EC, TDS, Transparency, D.O., and B.O.D. The other four variables—pH, hardness, alkalinity, temperature, and Cl—did not change much. If the p-value was greater than 0.01 then just calcium was taken into account. The zooplankton samples were collected by vertical hauling and then placed in a 25 cm diameter silk plankton net with a 70 µm mesh size. A 50 ml jar was fastened to the bottom of the net. There were found to be five separate groups of zooplankton, the most numerous of them being the Rotifera, which claimed seven genera. There was a continuous difference in zooplankton populations between the wet and dry seasons, and vice versa. There was a positive relationship between zooplankton of all sorts and pH and calcium. Properly monitoring the reservoir's characteristics and regulating household activities in and around the reservoir will help preserve its biodiversity for longer and delay its ageing.

Apaydın Yağcı, Meral et al., (2016). Between January 2010 and December 2010, investigators in Isparta, Turkey, conducted a monthly analysis of the zooplankton population composition in Eğirdir Lake. Three predominant categories of zooplankton were identified: rotifera (89.62 percent), codocephala (5.7 percent), and copepods (2.6 percent). In September and October, the rotifer species *Polyarthra dolichoptera* prevailed in Eğirdir Lake, however in December, the cladoceran species *Bosmina longirostris* became dominant. To create a link between environmental factors and species distribution, canonical correspondence analysis (CCA) was employed. A collection of environmental variables, such as conductivity, carbonate levels, pH, ammonium, organic substances, dissolved oxygen, dissolved oxygen saturation, chloride, and temperature, were significantly ($p< 0.05$) associated with the variation in species data. The findings of the CCA indicated that the variables represented a significant 81.9% of the overall variance. Environmental gradients seemed to influence the rotifers (*Asplanchna priodonta*) and crustaceans (*B. longirostris* and Nauplius larvae).

Abbasi, Muhammad et al., (2016). There has been scant examination of the distribution, volume, and population dynamics of zooplankton in the waters of Pakistan, especially next to the coast of Karachi. A large amount of previous study has emphasised individual species or groups of zooplankton. The goals of the proposed investigation involve assessing zooplankton density and spread in the near-shore marine environment of Karachi and linking that data to water quality parameters. The investigation demonstrated

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an increased diversity of zooplankton populations. The seasonal distribution of zooplankton taxa varied among stations; the largest abundance was seen at S2 in April (337.6 individuals/m^3), while the lowest was noted at S1 in July (19.08 individuals/m^3). Copepods, with a high of 67.74% at S1 and 73.51% at S3, constantly ruled the zooplankton population. There was a negligible relationship between abundance metrics and aquatic features, which fluctuated seasonally. It appears that the zooplankton population is mostly influenced by grazing pressure and other factors, with water properties having a little impact on this control. To illustrate, the relationship between zooplankton population and chlorophyll levels (primary production) was weak, with a coefficient of just 0.17. The abundant zooplankton community and rather uniform environmental conditions in the research locale are promising for fishery yields. To augment our insight into the marine ecosystem of the coastal waters of Karachi in the North Arabian Sea, this research also integrates contemporary data.

Akindele, Emmanuel Olusegun. (2014). Between 2009 and 2011, investigators in Tiga Lake in Kano, Nigeria, examined the zooplankton community and its correlation with the lake's physicochemical properties. The occurrence of species exhibited a positive correlation with water clarity, pH, Cl-, SO42-, and dissolved oxygen (DO) ($p<0.05$), while showing a negative correlation with total solids (TS), total suspended solids (TSS), turbidity, NO3-, and PO43- ($p<0.05$). Connectivity, total alkalinity, total dissolved solids (TDS), Ca2+, Na+, and K+ exhibited a positive correlation with zooplankton abundance ($p<0.05$). The zooplankton community in the lake was directly influenced by the overall chemical characteristics, which encompassed pH, total alkalinity, conductivity, and TDS, along with the primary ions Ca2+, Na+, and K+. All of these factors were inside the permissible limits for aquatic organisms. The distribution and abundance of zooplankton in Tiga Lake were believed to be limited by physical parameters like water clarity, turbidity, total solids (TS), and total suspended solids (TSS), along with nutrient levels, including nitrate (NO3-) and phosphate (PO43-). A key indicator of a lake's viability for aquatic organisms is the biological interplay between zooplankton and its physical-chemical properties.

III. MATERIALS AND METHODS

Study Area

This study used data collected at four different locations along the Sundarbans-boundary tidal Ganga River. Both the Bay of Bengal's tidal incursion and the Ganga River's freshwater outflow impact the research region.

Sewage from homes, water from farms, and the actions of estuaries all have an impact on the river's physicochemical properties and biological productivity in the catchment area.

Sampling Procedure

At each of the four locations, water and zooplankton samples were taken at the beginning, middle, and end of each season.

Early in the morning, we gathered surface water samples in sterile plastic bottles and sent them off to the lab for physicochemical examination. In order to evaluate the quantity and community composition of zooplankton throughout the year, samples were taken concurrently from all of the stations.

Physicochemical Analysis

A digital thermometer for water temperature (WT) and a portable pH meter for pH were used to measure these parameters on the spot. The modified Winkler technique was used to quantify the dissolved oxygen (DO).

Using a hand refractometer, the salinity was measured. Following the methods outlined by the American Public Health Association (2017), the amounts of total alkalinity, chloride, nitrate, and phosphate were measured. For every sample interval, the average values of all physicochemical parameters were determined.

Zooplankton Collection and Identification

Zooplankton samples were gathered by dragging a plankton net constructed of bolting silk at a depth of about 1 meter for 5 to 10 minutes. The net had a mouth area of 0.0855 m^2 and a mesh size of 20 µm (0.02 mm). The materials were promptly preserved with 10% buffered formalin after being put into 100 mL plastic vials.

Zooplankton were studied in a controlled environment using stereoscopic and compound microscopes from Olympus, model FX-100. Common taxonomic keys were used for identification purposes, up to the genus level. A Sedgwick-Rafter counting chamber, in accordance with the Drop Count Method, was used to quantitatively estimate the zooplankton density (individuals m^{-3}).

Data Analysis

The changes in physicochemical parameters and zooplankton density across the seasons were shown by the mean ± standard deviation (SD). Data gathering and preliminary statistical analysis were conducted using Microsoft Excel 2007. The GraphPad Prism version 5 was used to compute the diversity indices.

The link between several zooplankton groups and physicochemical characteristics was determined using Pearson's correlation coefficient analysis. At a significance level of $P < 0.05$, the correlation values were deemed statistically significant.

IV. RESULTS AND DISCUSSION

Table 1. Seasonal Physicochemical Parameters of Water at Selected Stations of the Ganga River in the Sundarbans Region

Season	WT (°C)	pH	DO (mg/L)	Salinity (ppt)	Alkalinity (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Phosphate (mg/L)
Summer	31.82±2.45	7.78±0.24	5.86±0.42	18.72±2.11	168.6±16.3	8954±425	0.78±0.12	0.38±0.05
Monsoon	28.15±1.86	7.46±0.18	6.82±0.36	8.64±1.72	154.8±14.5	4528±368	1.26±0.18	0.61±0.08
Post - Monsoon	24.94±2.08	7.62±0.22	7.24±0.39	12.38±1.95	161.5±12.8	6026±401	0.96±0.15	0.48±0.06
Winter	20.48±2.76	7.91±0.20	7.81±0.41	16.21±2.08	170.4±15.6	7812±392	0.71±0.10	0.31±0.04
Average	26.35±4.84	7.69±0.19	6.93±0.82	13.99±4.32	163.8±7.2	6830±1935	0.93±0.25	0.45±0.13

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Table 1 displays the water's physicochemical properties as they vary with the seasons as observed at several Ganga River stations in the Indian Sundarbans. During summer, the water temperature reached its peak of 31.82 ± 2.45°C, while during winter, it dropped to its lowest point of 20.48 ± 2.76°C, indicating significant seasonal variations. During the research period, the pH maintained a slightly alkaline range, between 7.46 ± 0.18 during the monsoon and 7.91 ± 0.20 in winter.

Dissolved oxygen (DO) levels changed throughout the year, reaching a minimum of 5.86 ± 0.42 mg/L in summer and a maximum of 7.81 ± 0.41 mg/L in winter. Lower water temperatures and improved oxygen solubility may explain why dissolved oxygen levels rise in the autumn and winter. Salinity varied significantly throughout the year, peaking in summer at 18.72 ± 2.11 ppt owing to increased evaporation and decreased freshwater intake, and falling to its lowest point during the monsoon at 8.64 ± 1.72 ppt due to substantial rainfall and freshwater outflow.

Throughout the research period, total alkalinity varied between 154.8 ± 14.5 mg/L during the monsoon and 170.4 ± 15.6 mg/L during winter, suggesting a modest buffering capability. The trend of chloride concentration was comparable to that of salinity, with summer having the greatest value (8954 ± 425 mg/L) and the monsoon having the lowest (4528 ± 368 mg/L). During the monsoon, nitrate concentrations were at their greatest (1.26 ± 0.18 mg/L) because of increased land runoff, whereas phosphate concentrations were at their highest (0.61 ± 0.08 mg/L) and lowest (0.31 ± 0.04 mg/L) during the winter.

Table 2. Seasonal Variation in Zooplankton Density (ind./m³) in the Ganga River of the Sundarbans Region

Zooplankton Group	No. of Genera (%)	Representative Genera (Annual Density)	Summer	Monsoon	Post-Monsoon	Winter	Annual Total
Protozoa	5 (21.74%)	*Amoeba* (37), *Arcella* (51), *Difflugia* (50), *Vorticella* (45), *Paramecium* (42)	77 (34.22%)	55 (24.44%)	43 (19.11%)	50 (22.22%)	225 (18.10%)
Rotifera	6 (26.09%)	*Asplanchna* (51), *Brachionus* (223), *Cephalodella* (52), *Keratella* (92), *Lecane* (68), *Testudinella* (56)	213 (39.30%)	85 (15.68%)	74 (13.65%)	170 (31.37%)	542 (43.60%)
Cladocera	5 (21.74%)	*Bosmina* (84), *Chydorus* (83), *Daphnia* (44), *Diaphanosoma* (38), *Moina* (36)	101 (35.44%)	67 (23.51%)	53 (18.60%)	64 (22.46%)	285 (22.93%)
Copepoda	4 (17.39%)	*Heliodiaptomus* (44), *Mesocyclops* (35), Nauplius (42), *Thermocyclops* (46)	52 (31.14%)	37 (22.16%)	32 (19.16%)	46 (27.54%)	167 (13.44%)
Ostracoda	3 (13.04%)	*Cypris* (8), *Stenocypris* (10), *Lothonura* (6)	10 (41.67%)	4 (16.67%)	2 (8.33%)	8 (33.33%)	24 (1.93%)
Total	23 (100%)	—	453 (36.44%)	248 (19.95%)	204 (16.41%)	338 (27.19%)	1243 (100%)

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In the Indian Sundarbans estuarine food chain, zooplankton serve a crucial role as secondary consumers, recycling nutrients, transferring energy across trophic levels, and providing a home for economically valuable fish larvae. A total of twenty-three zooplankton genera representing five main taxonomic groups were identified in the estuarine waters of the Indian Sundarbans during the current study. Of them, six belonged to the Rotifera genus, five to the Protozoa, four to the Copepoda, and three to the Ostracoda (Table 2). This diversity is in line with what has been seen in the Sundarbans and other tropical estuary habitats, where nutrient-rich conditions and salinity fluctuations cause copepods and rotifers to predominate in the zooplankton community.

Rotifera constituted the most abundant zooplankton group, accounting for 43.60 percent of the overall yearly abundance with 542 individuals m^{-3}. *Brachionus, Keratella, Lecane, Testudinella, Cephalodella, and Asplanchna* were the most numerous genera in this group. The second most numerous groups were the Cladocera, which included 285 individuals m^{-3} (22.93% of the total), mostly *Bosmina* and *Chydorus*. A total of 225 individuals m^{-3} (18.10%) were found to be protozoa, while 167 individuals m^{-3} (13.44%) were copepods. During the research period, Ostracoda had a somewhat reduced abundance, making up the smallest part of the community with just 24 individuals m^{-3} (1.93%).

The zooplankton density showed a strong seasonal pattern. All seasons had different total densities, with summer having the greatest at 453 persons m^{-3} (36.44%), winter at 338 individuals m^{-3} (27.19%), monsoon at 248 individuals m^{-3} (19.95%), and post-monsoon at 204 individuals m^{-3} (16.41%). Summer is when zooplankton are most abundant because of the ideal feeding conditions—high temperatures, increased salinity, and improved primary productivity. During the monsoon and post-monsoon seasons, there is a decrease in density due to the massive input of freshwater, which dilutes the salinity and increases the turbidity. Additionally, flushing effects from rainfall and river discharge contribute to this phenomenon.

Table 3. Correlation Coefficients Between Physicochemical Parameters and Zooplankton Groups in The Sundarbans

Zooplankton Group	WT	pH	DO	Salinity	Alkalinity	Chloride	Nitrate	Phosphate
Protozoa	-0.74*	0.48NS	0.69*	-0.62*	0.41NS	-0.58*	0.73*	0.76*
Rotifera	-0.51NS	0.36NS	0.59*	-0.48NS	0.27NS	-0.43NS	0.68*	0.72*
Cladocera	-0.69*	0.44NS	0.66*	-0.71*	0.39NS	-0.64*	0.52NS	0.61*
Copepoda	0.63*	0.51NS	-0.42NS	0.79*	0.47NS	0.76*	-0.34NS	-0.28NS
Ostracoda	0.36NS	0.22NS	-0.31NS	0.44NS	0.26NS	0.38NS	-0.19NS	-0.17NS

* Significant at $P < 0.05$; NS = Not Significant.

In the Indian Sundarbans, Table 3 demonstrates the relationship between the main categories of zooplankton and physicochemical characteristics. A study found that protozoa showed strong negative relationships with water temperature ($r = -0.74$), salinity ($r = -0.62$), and chloride ($r = -0.58$), and strong positive relationships with dissolved oxygen ($r = 0.69$), nitrate ($r = 0.73$), and phosphate ($r = 0.76$). There was a significant correlation between rotifera and nitrate ($r = 0.68$), phosphate ($r = 0.72$), and dioxygen ($r = 0.59$).

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The chart shows that cladocera were positively correlated with phosphate (r = 0.61) and DO (r = 0.66) but significantly negatively correlated with temperature (r = −0.69) and salinity (r = −0.71). Copepoda, on the other hand, showed positive associations with temperature (r = 0.63), salinity (r = 0.79), and chloride (r = 0.76). All of the physicochemical factors evaluated had weak and non-significant associations with ostracoda.

V. CONCLUSION

According to the current research, the composition and abundance of zooplankton populations in the Indian Sundarbans are greatly affected by seasonal changes in the physicochemical characteristics of the Ganga River. The summer months saw the highest concentration of zooplankton, a reflection of the ideal conditions for growth and reproduction, and rotifera emerged as the most abundant group of zooplankton.

The correlation analysis revealed that cladocerans, protozoa, and rotifers fared better in environments with high quantities of dissolved oxygen and nutrients. However, when the levels of salt and chloride rose, the relationships between copepods became more intimate. Studies like this are important because they highlight the role that water quality plays in protecting estuarine biodiversity and ecosystem productivity.

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