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Seasonal Influences on Zooplankton Diversity of a Sacred Grove Freshwater

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ABSTRACT

A study in the Banapureeshwar temple pond (BTP) at Kumbakonam, Thanjavur district, Tamil Nadu, India, was conducted from March 2018 to February 2019 to assess the seasonal variations in the population density of zooplankton, which serve as an ecological indicator of aquatic ecosystems. The study identified a total of 35 zooplankton species, with copepods comprising 13 species, Cladocera comprising 8 species, rotifers comprising 11 species, and ostracoda comprising 3 species. The Shanon-Weiner diversity index (H') ranged from 1.13 to 2.606, while Margalef's species richness index ranged from 0.7797 to 3.1, indicating a moderately rich zooplankton diversity in the BTP lentic ecosystem. Among the identified zooplankton groups, copepoda were found to be the dominant group, accounting for 45.7% of the total, followed by rotifers (25.7%), cladocera (23.2%), and ostracoda (5.5%). The mean seasonal abundance of zooplankton followed the order of monsoon > pre-monsoon > post-monsoon > summer.

Key words: *Zooplankton, Diversity indices, Pond ecosystem, Cladocera, seasonal influence*

Introduction

Prior to the 1980s, India's fish production was predominantly derived from inland fisheries, which experienced a decline due to increased water control structures and the degradation of natural water resources (Katia, 1999). As capture fisheries faced challenges related to diminishing resources and rising costs, aquaculture emerged as an effective alternative, becoming India's second major industry after agriculture (Ayyappan, 2004). Today, India ranks second globally in aquaculture production, which accounts for about 44% of worldwide fish production (FAO, 2016) and nearly 50% of global fish consumption (Subasinghe *et al.*, 2009). In 2017–2018, inland fisheries contributed 65% of India's total fish production, with culture fisheries making up 50% of that total. Despite its growth, aquaculture faces issues like suboptimal growth rates and nutrition deficiencies in cultured fish, necessitating the use of live feed such as zooplankton, which offers essential nutrients (Akbary *et al.*, 2010). The composition of zooplankton is sensitive to various environmental factors, and monitoring their diversity can serve as an indicator of ecosystem health (Bera *et al.*, 2014; Jose, 2015; Mukhopadhyay, 2000). Ponds, crucial for freshwater ecosystems and biodiversity conservation (Downing, 2010; Miracle *et al.*, 2010; Oertli *et al.*, 2010; De Meester *et al.*, 2010), are increasingly affected by pollution, threatening aquatic biodiversity. This study aims to investigate the species diversity of zooplankton in the Banapureeshwar

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temple pond, focusing on how seasonal variations and physical and chemical factors influence this diversity.

Materials and Methods

Study area

The Banapureeshwar temple pond, located at a latitude of 10°57'N and a longitude of 79°23'E, was the focus of the present study (Fig. 1). This pond underwent recent renovations in 2015 as part of a government initiative aimed at managing and preserving the freshwater ecosystem. To ensure a stable water level, the municipality consistently maintains the pond by replenishing it with water from external sources.

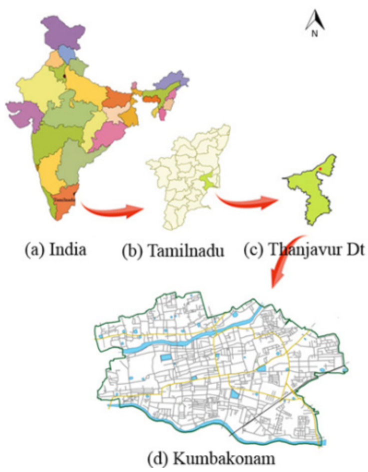

Fig. 1. Bird's eye view of study area

Sampling of zooplankton and water quality parameters

The study involved monthly sampling of zooplankton and analysis of water quality at four sites (BTP-North, BTP-South, BTP-East, and BTP-West) in the Banapureeshwar Temple Pond from March 2018 to February 2019. Data were analyzed seasonally, categorizing the year into summer (March to May), pre-monsoon (June to August), monsoon (September to November), and post-monsoon (December to February), following the methodology of Manickam *et al.* (2014). Water quality parameters, including temperature, pH, conductivity (EC), turbidity, salinity, dissolved oxygen (DO), and total dissolved solids (TDS), were assessed in accordance with APHA (2005) standards. Plankton samples were collected from the subsurface layer early in the morning (6 a.m. to 7 a.m.) using Henson's standard plankton net (mesh size 150 µm), capturing water in a zigzag pattern at depths of 50 to 100 cm (Davis, 1955). The samples were preserved in a 5% formalin solution for subsequent analysis, and zooplankton populations were quantified using Sedgwick-Rafter counting cells.

Identification of zooplanktons

The collected planktonic biomass was carefully sorted into distinct zooplankton groups using a binocular zoom dissection microscope, with the assistance of a fine needle and brush. Individual species were stained with Eosin, following the method described by Manickam *et al*. (2014), and examined under a trinocular microscope (Model BXL) equipped with a USB camera (MIDCE-5C). Identification of various zooplankton species was conducted using standard manuals, textbooks, and monographs (Sharma and Michael, 1987; Murugan *et al*., 1998; Altaff, 2004; Edmonson, 1959; Battish, 1992; Reddy, 1994) and employed a compound microscope for detailed observations.

Biodiversity indices and statistical analysis

Seasonal variations in the physico-chemical parameters of water were analyzed using a one-way ANOVA, followed by a Post Hoc Tukey Test. To explore the relationships between these parameters and zooplankton biodiversity indices, Pearson's correlation analysis was performed using IBM SPSS (v. 25.0) (Vimala *et al.,* 2024). Various biodiversity indices, including species diversity, richness, evenness, and dominance, were calculated using Shannon-Wiener's index (1949), Margalef's richness index (1958), Pielou's evenness index (1966), and the Dominance index, with analyses conducted using Paleontological Statistical software (PAST).

Results and Discussion

Seasonal variations in the physical and chemical parameters of freshwater ecosystem

Seasonal variations in the physicochemical parameters of a freshwater pond are crucial for the species composition and distribution of planktonic organisms (Mahar *et al.,* 2000). Key factors such as temperature, pH, dissolved oxygen (DO), salinity, conductivity, turbidity, and total dissolved solids (TDS) significantly influence the development of phytoplankton, which in turn sustains zooplankton populations. Fig.1 details these seasonal variations at BTP, demonstrating their effects on zooplankton community composition, diversity, richness, evenness, and dominance. Summer water temperatures averaged 30.03±1.91°C, while post-monsoon temperatures dropped to 28.11±2.02°C, attributed to increased solar radiation (Das *et al.*, 1997; Senthil Kumar *et al.*, 2002). Optimal zooplankton growth occurs between 13.5°C and 32 °C (Kamat, 2000), with temperature influencing pH, salinity, and gas solubility, thereby favoring smaller zooplankton species (Manickam *et al.*, 2018). High pH levels (7.74 ± 0.14) occurred during monsoon and post-monsoon, while the lowest (7.15 ± 0.01) was recorded in summer, affected by temperature and enhanced

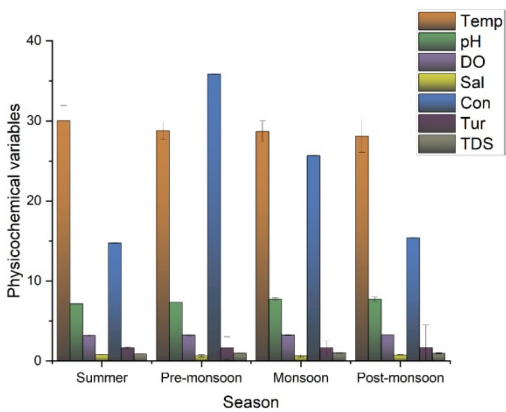

Fig. 1. Seasonal variation of physicochemical parameters of BTP

photosynthesis (Gogoi, 2019). DO levels were highest in post-monsoon (3.28 ± 0.03 mg/l) and lowest in summer (3.22 ± 0.08 mg/l), indicating the impact of organic decomposition and plankton respiration. Salinity peaked at 0.80 ± 0.03 ppt in summer, influenced by temperature increases and evaporation (Dhanasekaran *et al.,* 2017; Bhavan *et al.,* 2017). Overall, these physico-chemical variations play a critical role in shaping the dynamics of zooplankton populations in BTP. Total Dissolved Solids (TDS) and Electrical Conductivity (EC) in aquatic ecosystems often increase due to anthropogenic activities and pollutant inflow, leading to water contamination (Choudhary *et al.,* 2014; Verma *et al*., 2012). In BTP, TDS peaked at 1.03 NTU during the monsoon and dropped to 0.88 NTU in summer, significantly exceeding World Health Organization (WHO) standards, suggesting pollution from worship activities. The lower EC during monsoon could be attributed to freshwater influx and increased turbidity from silt-laden water (Gogoi *et al.,* 2019). A one-way ANOVA with a post hoc Tukey test indicated significant differences ($p < 0.05$) in water quality variables across seasons.

Diversity and distribution of zooplanktons

Zooplankton are essential ecological indicators for monitoring pollution and assessing the health of freshwater ecosystems (Karmakar *et al.,* 2021 and Krishna and Hemanth, 2017; Devi *et al.,* 2013). In BTP, 35 zooplankton species were identified across four groups: Copepoda (13 species), Cladocera (8

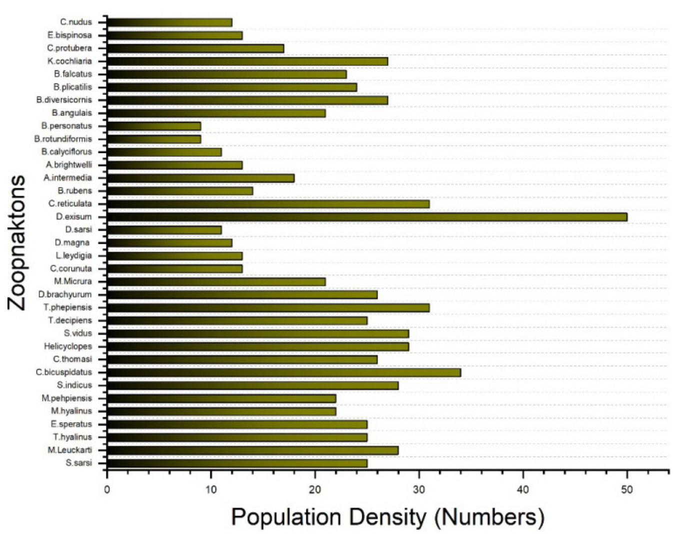

Fig. 2. Population Density of Zooplanktons at BTP during 2018-2019

species), Rotifera (11 species), and Ostracoda (3 species). Copepoda dominated with 45.7% abundance, followed by rotifers (25.7%), Cladocera (16.6%), and ostracoda (12%) (Fig. 2). Seasonal abundance ranked as monsoon >premonsoon> postmonsoon> summer.

Sinadiaptomusindus was the predominant copepod, linked to abundant diatoms and blue-green algae, crucial food sources for copepods (Dharani and Altaff, 2002). Cladocera peaked in monsoon, with low summer populations of *Daphnia magna* and others, while Rotifera, particularly *Branchionus* species, thrived during that season (Tidame and Shinde, 2012). Ostracoda were the least abundant, with *Cypris protubera* dominating in summer and premonsoon. The findings align with previous studies showing seasonal zooplankton patterns and highlight eutrophication indicators, such as Mesocyclops and Thermacyclops (Krishna and Kumar, 2017; Bhavan *et al.*, 2015; Banerjee *et al.*, 2014).

Cladocerans, including *Diaphanosoma, Daphnia, Ceriodaphnia*, and *Moina*, are key zooplankton in BTP, reflecting high nutrient levels indicative of eutrophication (Hall, 1964; Kurasawa, 1975; Boucherle and Zullig, 1983; Balakrishna *et al.*, 2013). Additionally, *Brachionuscalyciflorus*, a rotifer associated with eutrophication, was consistently present year-round in BTP, further highlighting nutrient enrichment in the pond's ecosystem (Manickam *et al.*, 2015).

The relationship between zooplankton population density and physicochemical parameters in BTP was assessed using Karl Pearson's correlation matrix (Table 3). Temperature positively correlated with rotifer (r = 0.197) and ostracod (r = 0.489) popula-

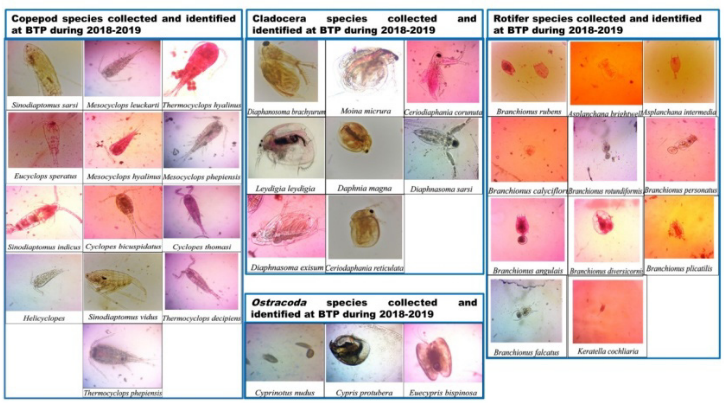

Fig. 3. Zooplanktons collected and identified at BTP during 2018-2019

Table 3. Inter and Intra relationship between physicochemical parameters of BTP water

Biodiversity Indices	Zooplankton Groups	Summer	Pre-monsoon	Monsoon	Post-monsoon
Shanon-Weiner Index (H)	Copepods	2.55	2.597	2.606	2.59
	Cladocera	1.945	1.964	2.017	1.993
	Rotifers	2.406	2.332	2.395	2.393
	Ostracoda	1.095	1.13	1.17	1.222
Evenness Index (E)	Copepods	0.9851	1.033	1.042	1.025
	Cladocera	0.874	0.8371	0.8557	0.8421
	Rotifers	1.008	1.03	0.9976	0.9953
	Ostracoda	0.9961	1.032	1.074	1.131
Margalef's Richness Index (R1)	Copepods	3.1	2.58	2.55	2.70
	Cladocera	1.873	2.002	1.584	2.377
	Rotifers	2.543	2.574	2.484	2.480
	Ostracoda	0.8049	0.8686	0.7797	1.028
Dominance	Copepods	0.07801	0.07179	0.07043	0.09269
	Cladocera	0.1591	0.1629	0.1443	0.1579
	Rotifers	0.08784	0.0928	0.09091	0.09156
	Ostracoda	0.3333	0.3111	0.2821	0.2381

Table 4. Biodiversity indices of zooplankton species identified in BTP

	Temperature	pH	DO	Salinity	Conductivity	Turbidity	TDS	Copepoda	Cladocera	Rotifers	Ostracoda
Temperature	1										
pH	-0.400	1									
DO	0.572	-0.383	1								
Salinity	-0.316	-0.125	-0.347	1							
Conductivity	-0.560	0.431	-.698*	.590*	1						
Turbidity	0.183	0.085	0.534	-.890**	-.639*	1					
TDS	-0.087	.676*	0.217	-0.556	-0.096	.598*	1				
Copepoda	-0.135	0.360	0.244	-0.572	-0.113	.652*	.725**	1			
Cladocera	-0.350	0.252	-.594*	-0.326	0.146	0.123	0.199	0.129	1		
Rotifers	0.197	0.277	0.003	-0.223	0.280	0.004	0.275	0.210	0.137	1	
Ostracoda	0.489	-0.080	0.087	-0.317	-0.229	0.069	-0.003	-0.233	0.125	-0.021	1

*. Correlation is significant at the 0.05 level (2-tailed).**. Correlation is significant at the 0.01 level (2-tailed).

tions, while pH negatively correlated with ostracods (r = -0.080). Dissolved oxygen (DO) showed a negative association with cladocerans (r = -0.594), whereas rotifers (r = 0.280) and cladocerans (r = 0.146) had positive associations with conductivity.

Turbidity positively correlated with all zooplankton groups. These results are consistent with findings by Manickam *et al.* (2018), who noted significant impacts of pH and temperature on zooplankton diversity in Ukkadam Lake, and Rajagopal *et al.* (2010), who observed a similar positive correlation between temperature and ostracod density in Virudhunagar District.

Biodiversity indices are essential indicators of ecological status (Cardoso et al., 2014). Devi *et al.* (2013) reported zooplankton biodiversity indices for BTP, including a Shannon-Wiener diversity index from 0.39 to 2.98, Margalef's species richness index between 2.92 and 2.96, an evenness index of 0.89 to 0.91, and a dominance index of 0.86 to 0.88. In the present study, the Shannon diversity index ranged from 1.095 to 2.606, the evenness index from 0.8371 to 1.032, and the richness index from 0.7797 to 3.1 across different seasons (Table 4). These findings indicate low overall diversity characterized by high evenness and low richness, likely due to a limited number of species and the dominance of a single species. This is consistent with previous literature; for instance, Manickam *et al.* (2018) reported a Shannon diversity index of 1.551 to 2.133 and an evenness index around 0.969 in Ukkadam Lake. Additionally, Praveena (2020) found a richness index ranging from 0.961 to 0.982 in Kumbakonam ponds, indicating moderate species richness. Gogoi *et al.* (2019) suggested that a Shannon diversity index exceeding 2.9 indicates moderately rich diversity, while Pielou's evenness index above 0.98 signifies even distribution. The indices from this study suggest that BTP exhibits moderate species diversity and is classified as meso-eutrophic.

Conclusion

The study clearly demonstrated that temperature, pH, TDS, and turbidity significantly influence zooplankton abundance and diversity in BTP. Furthermore, the role of pH was particularly critical in supporting high population densities of zooplankton during the monsoon and pre-monsoon seasons. Conversely, the observed decline in zooplankton numbers during the summer season can be attributed to the elevated temperatures.Given these findings, the study underscores the importance of continuous monitoring of pond ecosystems to assess the effects of climatic variations on the diversity and distribution patterns of freshwater zooplankton communities. This ongoing vigilance will aid in identifying sentinel and sensitive species, thereby contributing to the development of effective conservation strategies.

Conflict of Interest- None

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