



Seasonal Variations in Freshwater Phytoplankton and Zooplankton Diversity in Valsad Taluka, Gujarat, India

Jatin Bhandari^{1,2*} and Takhatsinh Gohil¹

¹Biology Department, B.K.M. Science College, Valsad, 396001, Gujarat, India

²Department of Biosciences, Veer Narmad, South Gujarat University, Surat, 395007, Gujarat, India
j2bhandari@gmail.com

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Abstract

Plankton communities are an essential source of food for aquatic organisms, and any undesirable changes in the marine environment may affect plankton diversity and density. Therefore, assessing planktonic communities in freshwater ecosystems is essential because they serve as bioindicators of water quality. Hence, the present research focused on evaluating the diversity and abundance of fresh water phytoplankton and zooplankton in water bodies of Valsad Taluka, Gujarat, India. The study revealed that 77 species of phytoplankton and zooplankton were recorded, belonging to 37 families and 46 genera. Specifically, 43 phytoplankton species were recorded across 25 families and 30 genera, including 15 species of Cyanophyceae, 17 of Chlorophyceae, 8 of Bacillariophyceae, and 3 of Euglenophyceae. Additionally, 34 zooplankton species were recorded across 12 families and 17 genera, including 13 Rotifera, 9 Cladocera, 8 Copepod, and 4 Ostracoda. The highest plankton diversity was observed during the monsoon season, and the lowest during the summer season. The ecological status of the water bodies in the area was categorized as moderately polluted, primarily due to municipal waste and industrial discharges. Therefore, assessing planktonic communities in freshwater bodies can be instrumental in monitoring and maintaining water quality and the health of aquatic ecosystems.

Keywords: Plankton; species composition, community structure, water quality.

Introduction

Water is a prime abiotic factor that supports life and forms a significant component of the natural environment. Any undesirable changes in the hydrographic profile can influence the life of aquatic biota, as various species of flora and fauna are sensitive to environmental fluctuation¹. Aquatic ecosystems are broadly classified into freshwater and marine systems. Freshwater resources make up only about 0.3 to 0.5% of Earth's total water, yet they are vital to both aquatic life and human populations². Rivers, lakes, ponds, pools, estuaries, streams, and wetlands constitute the major freshwater ecosystems.

Freshwater bodies deliver crucial ecosystem services, including potable water, irrigation, and support for biodiversity and recreational activities³. However, increasing anthropogenic pressures-such as the dumping of municipal waste, the introduction of veterinary antibiotics, the release of sewage sludge, and the discharge of industrial effluents-have heightened aquatic stress. These activities not only degrade water quality but also impair ecosystem functions⁴.

Pollutants can enter water bodies through point sources (e.g., industrial effluents, sewage treatment plants) or nonpoint sources (e.g., agricultural runoff, urban stormwater), both of which contribute to changes in the hydrographic and biological profiles of aquatic systems⁵. As a result, continuous water

quality monitoring is essential. Plankton communities-both phytoplankton and zooplankton-are susceptible to environmental changes and are thus reliable bioindicators⁶. Their diversity, abundance, and distribution patterns reflect the ecological health of aquatic systems.

Phytoplankton, forming the base of aquatic food webs, quickly respond to environmental changes, while zooplankton (e.g., rotifers, copepods) serve as primary consumers and further indicators of pollution⁷. In recent decades, the use of plankton communities in biomonitoring programs has become essential for evaluating water pollution and guiding restoration efforts.

The present study, therefore, aims to evaluate seasonal variation in phytoplankton and zooplankton diversity and density in freshwater bodies in Valsad Taluka, Gujarat, India, which serve as habitats for diverse aquatic flora and fauna.

Materials and Methods

Description of the Study Area: The selected freshwater bodies are located in Valsad Taluka, Gujarat, India. These include community-managed ponds, tanks, and lakes, many of which receive inflow from natural streams, agricultural runoff, and urban discharges. The specific sites were selected based on accessibility, representativeness, and anthropogenic impact. These water bodies experience seasonal changes and support local fishing communities and agricultural activities.

Physico-Chemical Characteristics of Water: Surface water samples were collected during early morning hours (5:00 AM to 7:00 AM) once every fortnight over nine months (September 2023-May 2024) from five different sites. Samples were pooled to analyse key Physico-chemical parameters such as temperature, pH, salinity, dissolved oxygen, total dissolved solids, conductivity, phosphate, chloride, total alkalinity, total hardness, calcium hardness, nitrate, and ammonia using a “µP Based Water & Soil Analysis Kit” (Model 1160).

Plankton Sampling and Identification: Plankton samples were collected using standard Henson plankton nets (25 µm for phytoplankton and 150 µm for zooplankton) by horizontal towing at surface level. One hundred liters of water were filtered for quantitative analysis, and the collected biomass was preserved in 4% neutralized formalin. Microscopic identification was carried out using standard manuals and identification keys under 40x to 100x magnification using an Inverted Biological Microscope (Model INVERSO 3000 (TC-100) CETI with IS 300 camera).

Statistical Analysis: Species diversity (H'), richness (SR), and evenness (J) were calculated using Shannon & Weaver (1949), Gleason (1922), and Pielou (1966) indices, respectively. Calculations were performed using PAST software (ver. 2.02).

Results and Discussion

Physio-chemical characteristics of freshwater bodies: The average values of the hydrographical characteristics of

freshwater bodies in Valsad Taluka, Gujarat, India, are depicted in Table-1. During the study period, all the parameters were higher in the summer season and lower in the monsoon season. Moreover, dissolved oxygen, total dissolved solids, and ammonia were found to be higher in the monsoon season and lower in the summer season.

DO, dissolved oxygen; TDS, total dissolved solids; EC, electrical conductivity. Each season value is the overall average \pm SD (n=15; 5 sites \times 3 seasons). Mean values within the same row but having different superscripts are significantly different (P<0.05).

Morphologically identified phytoplankton species: A total of 43 species of phytoplankton were recorded across 25 families and 30 genera, including 15 species of Cyanophyceae, 17 of Chlorophyceae, 8 of Bacillariophyceae, and 3 of Euglenophyceae.

Population density with percentage composition of phytoplankton species. The population density ranged from 2130 to 3188 Ind./L in freshwater ecosystems of Valsad Taluka during the study period (September 2023 to May 2024). The total density of phytoplankton during the monsoon season was 3188 Ind./L, during post-monsoon 2530 Ind./L, and in summer 2130 Ind./L, indicating that the maximum population density was noticed during the monsoon, followed by post-monsoon and summer (Table-2).

Table-1: Physico-chemical characteristics of the Valsad taluka, Gujarat, India.

Parameter	Monsoon	P. Monsoon	Summer
Water temperature (°C)	24.26 \pm 0.96 ^a	26.99 \pm 0.42 ^b	29.88 \pm 0.49 ^c
pH	7.06 \pm 0.25 ^a	7.20 \pm 0.35 ^b	8.93 \pm 0.40 ^c
Salinity(ppt)	107.92 \pm 0.06 ^a	104.15 \pm 0.22 ^b	132.48 \pm 0.20 ^c
DO (mg/l ⁻¹)	8.31 \pm 0.50 ^c	7.79 \pm 0.14 ^b	6.21 \pm 0.29 ^a
TDS (mg/l ⁻¹)	109.21 \pm 24.06 ^b	108.28 \pm 15.20 ^{ab}	104.34 \pm 24.06 ^a
EC (µS cm ⁻¹)	193.42 \pm 0.16 ^a	200.03 \pm 0.24 ^b	209.35 \pm 0.29 ^c
Phosphate (mg/l ⁻¹)	33.14 \pm 0.28 ^a	34.24 \pm 0.09 ^b	35.75 \pm 1.27 ^{bc}
Chlorides (mg/l ⁻¹)	2.65 \pm 0.45 ^a	2.98 \pm 0.70 ^b	3.69 \pm 0.51 ^c
Total alkalinity (mg/l ⁻¹)	120.80 \pm 7.04 ^a	128.23 \pm 9.10 ^b	134.36 \pm 8.86 ^c
Total hardness (mg/l ⁻¹)	6.97 \pm 0.57 ^a	7.40 \pm 0.73 ^b	8.30 \pm 0.80 ^c
Calcium hardness (mg/l ⁻¹)	68.05 \pm 1.05 ^a	71.43 \pm 2.44 ^b	77.37 \pm 3.59 ^c
Nitrate (mg/l ⁻¹)	22.42 \pm 1.27 ^a	23.50 \pm 1.80 ^{ab}	24.83 \pm 1.69 ^{bc}
Ammonia (mg/l ⁻¹)	2.53 \pm 0.80 ^c	2.45 \pm 0.68 ^b	2.13 \pm 0.01 ^a

Phytoplankton percentage composition shows that the Cyanophyceae group was most abundant in the freshwater bodies of Valsad Taluka. Seasonal variations in phytoplankton species are depicted. The Cyanophyceae group predominated in the monsoon, followed by the post-monsoon and summer seasons, with a relative abundance of 35.07%, followed by Chlorophyceae (29.47%), Bacillariophyceae (25.46%), and Euglenophyceae (10%).

Diversity indices of phytoplankton species: The calculated seasonal diversity indices, including Simpson's species dominance (D), Shannon-Wiener diversity (H), Buzas and Gibson's evenness (e^H/S), and Margalef's (R1) species richness, are presented in Table-3. The overall D values were recorded in the order of Cyanophyceae > Chlorophyceae > Bacillariophyceae > Euglenophyceae (0.162, 0.154, 0.144, and 0.137, respectively).

Similarly, H was recorded as 1.991, 1.973, 1.969, and 1.929 respectively; evenness (e^H/S) as 0.981, 1.974, 1.968, and 0.952; and R1 as 0.831, 0.820, 0.815, and 0.805 respectively. Simpson's D and evenness were highest in the monsoon season, while Shannon-Wiener H and Margalef's richness were highest in summer and lowest in monsoon.

Morphologically identified zooplankton species: A total of 34 zooplankton species were recorded across 12 families and 17 genera, including 13 Rotifera, 9 Cladocera, 8 Copepoda, and 4 Ostracoda.

Population density with % composition of zooplankton species: The population density of zooplankton ranged from 3,828 to 4,815 Ind./L across the sampled freshwater bodies of Valsad Taluka during the same study period. The highest density was recorded in the monsoon (4,815 Ind./L), post-monsoon (4,274 Ind./L) and summer (3,828 Ind./L).

Table-2: Phytoplankton density with percentage composition in the Valsad taluka, Gujarat, India.

Phytoplankton	Monsoon	P. Monsoon	Summer	Total
Groups	(2023)	(2024)	(2024)	(Ind./L) & %
Cyanophyceae	1087±42 ^a	867±29 ^b	798±32 ^c	2752 (35.07%)
Chlorophyceae	916±30 ^a	746±34 ^b	651±27 ^{bc}	2313 (29.47%)
Bacillariophyceae	798±31 ^a	698±26 ^{ab}	502±25 ^c	1998 (25.46%)
Euglenophyceae	387±32 ^a	219±28 ^{ab}	179±16 ^{bc}	785 (10%)
Total	3188	2530	2130	7848

Each season value is the overall average ± SD (n=15; 5 sites × 3 seasons). Mean values within the same row but having different superscripts are significantly different (P<0.05).

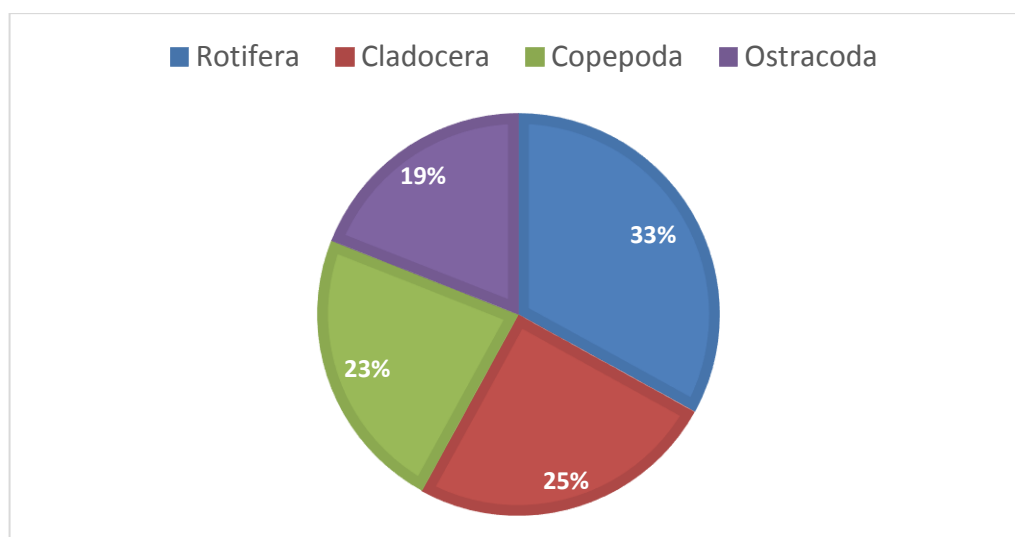


Figure-1: Percentage composition of different groups of phytoplankton recorded in the Valsad taluka, Gujarat.

Table-3: Species diversity indices of phytoplankton in the Valsad taluka, Gujarat, India.

Phytoplankton groups	Diversity Indices	Monson	Pre- Monson	Summer
Cyanophyceae (15 Species)	Dominance (D)	0.162±0.007 ^a	0.154±0.005 ^b	0.146±0.009 ^c
	Shannon (H)	1.983±0.040 ^a	1.967±0.041 ^b	1.991±0.038 ^c
	Evenness_e^H/S	0.981±0.024 ^a	0.978±0.024 ^b	0.971±0.028 ^{bc}
	Margalef (R1)	0.821±0.047 ^a	0.829±0.042 ^{ab}	0.831±0.045 ^{bc}
Chlorophyceae (17 Species)	Dominance(D)	0.154±0.006 ^a	0.144±0.008 ^b	0.130±0.006 ^c
	Shannon(H)	1.963±0.042 ^a	1.956±0.043 ^b	1.973±0.042 ^c
	Evenness_e^H/S	0.974±0.023 ^a	0.970±0.021 ^{ab}	0.967±0.027 ^{bc}
	Margalef (R1)	0.812±0.045 ^{bc}	0.817±0.042 ^a	0.820±0.046 ^a
Bacillariophyceae (8 Species)	Dominance (D)	0.144±0.004 ^a	0.136±0.006 ^b	0.127±0.008 ^c
	Shannon (H)	1.954±0.040 ^a	1.948±0.038 ^{ab}	1.969±0.032 ^c
	Evenness_e^H/S	0.968±0.020 ^a	0.961±0.017 ^{ab}	0.957±0.022 ^b
	Margalef(R1)	0.815±0.040 ^a	0.811±0.037 ^{ab}	0.807±0.040 ^b
Euglenophyceae (3 Species)	Dominance (D)	0.137±0.004 ^a	0.126±0.006 ^b	0.112±0.008 ^c
	Shannon (H)	1.926±0.040 ^a	1.914±0.038 ^b	1.929±0.032 ^c
	Evenness_e^H/S	0.952±0.020 ^a	0.912±0.017 ^b	0.895±0.022 ^c
	Margalef (R1)	0.727±0.040 ^c	0.734±0.037 ^b	0.805±0.040 ^a

Each season value is the overall average ± SD (n=15; 5 sites × 3 seasons). Mean values within the same row but having different superscripts are significantly different (P<0.05).

Table-4: Zooplankton density with percentage composition in the Valsad taluka, Gujarat, India.

Zooplankton groups	Monsoon	P-Monsoon	Summer	Total (Ind./L)&%
Rotifera	1,590±43 ^a	1,432±39 ^b	1,287±41 ^c	4,309 (33.36%)
Cladocera	1,158±36 ^a	1,067±42 ^{ab}	978±38 ^c	3,203 (24.80%)
Copepoda	1,089±37 ^a	956±32 ^{ab}	853±31 ^b	2,898 (22.44%)
Ostrocods	978±27 ^a	819±32 ^{ab}	710±33 ^{bc}	2,507 (19.40%)
Total	4,815	4,274	3,828	12,917

Each season value is the overall average ± SD (n=15; 5 sites × 3 seasons). Mean values within the same row but having different superscripts are significantly different (P<0.05).

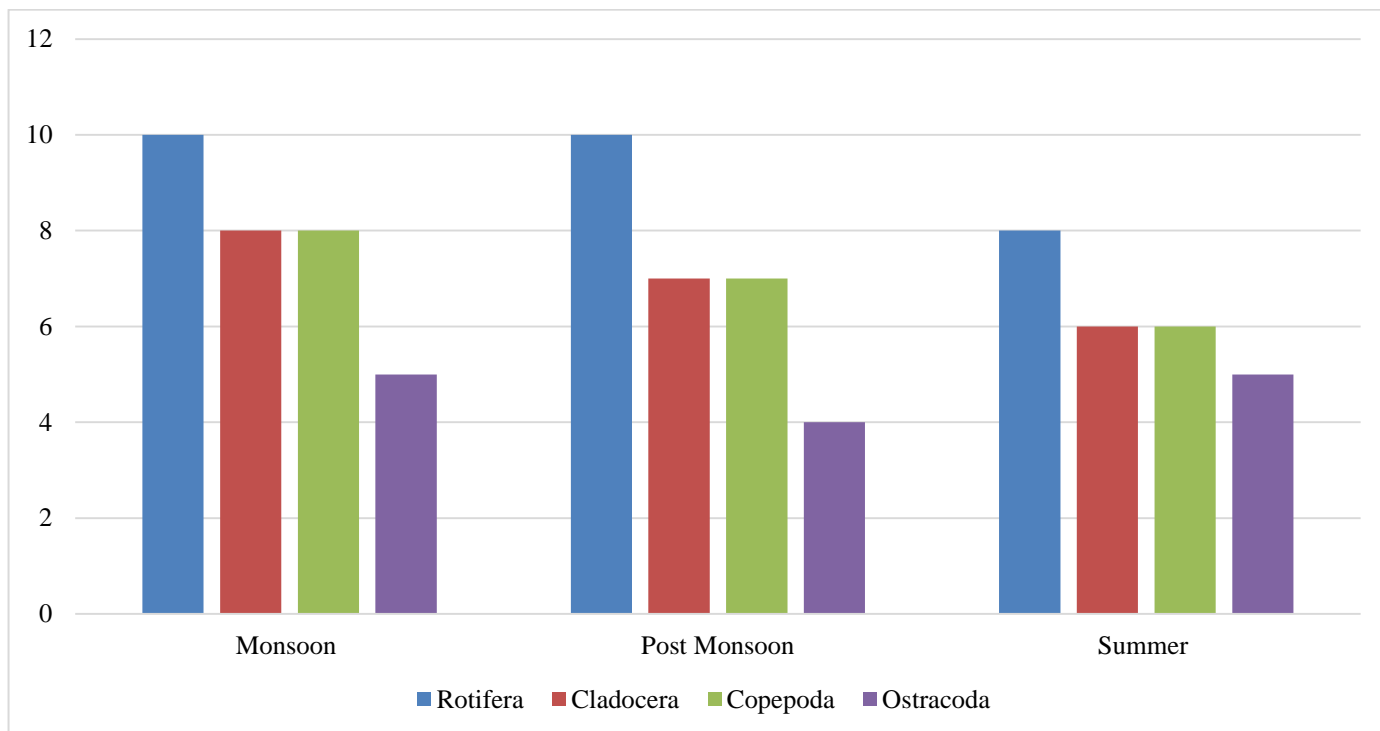


Figure-2: Seasonal variations of zooplankton species in Valsad Taluka.

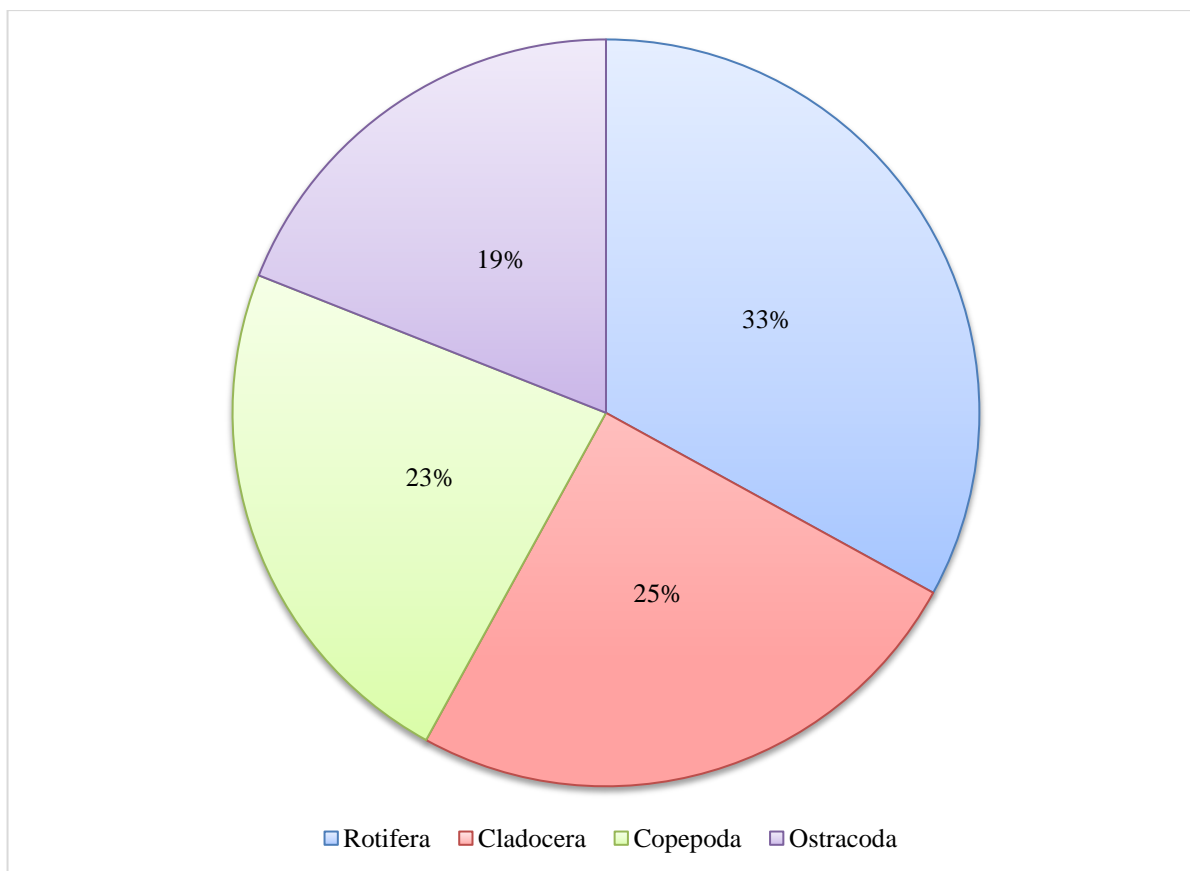


Figure-3: Percentage composition of different groups of zooplankton recorded in the Valsad Taluka.

Table-5: Species diversity indices of phytoplankton in the Valsad Taluka.

Zooplankton Groups	Diversity Indices	Monsoon (2023)	P. Monsoon (2024)	Summer (2024)
Rotifera (13 Species)	Dominance (D)	0.165±0.009 ^a	0.157±0.004 ^b	0.149±0.008 ^c
	Shannon (H)	1.969±0.042 ^a	1.960±0.038 ^{ab}	1.977±0.038 ^c
	Evenness _{e^H/S}	0.988±0.026 ^a	0.979±0.023 ^{ab}	0.973±0.025 ^{bc}
	Margalef (R1)	0.835±0.048 ^a	0.832±0.045 ^{ab}	0.837±0.041 ^{bc}
Cladocera (9 Species)	Dominance (D)	0.160±0.004 ^a	0.153±0.007 ^b	0.142±0.009 ^c
	Shannon (H)	1.963±0.040 ^a	1.957±0.032 ^{ab}	1.967±0.035 ^c
	Evenness _{e^H/S}	0.980±0.025 ^a	0.971±0.024 ^{ab}	0.964±0.021 ^{bc}
	Margalef (R1)	0.818±0.037 ^{bc}	0.824±0.041 ^{ab}	0.831±0.042 ^a
Copepoda (8 Species)	Dominance (D)	0.153±0.006 ^a	0.147±0.008 ^b	0.140±0.008 ^c
	Shannon (H)	1.960±0.038 ^a	1.954±0.030 ^{ab}	1.965±0.034 ^c
	Evenness _{e^H/S}	0.978±0.022 ^a	0.968±0.025 ^{ab}	0.961±0.023 ^{bc}
	Margalef (R1)	0.815±0.032 ^{bc}	0.821±0.038 ^{ab}	0.828±0.040 ^a
Ostracoda (4 Species)	Dominance (D)	0.142±0.005 ^a	0.135±0.009 ^b	0.131±0.008 ^c
	Shannon (H)	1.854±0.031 ^a	1.847±0.035 ^b	1.861±0.036 ^c
	Evenness _{e^H/S}	0.862±0.021 ^a	0.857±0.029 ^{ab}	0.852±0.026 ^{bc}
	Margalef (R1)	0.704±0.031 ^{bc}	0.711±0.034 ^{ab}	0.717±0.045 ^a

Each season value is the overall average ± SD (n=15; 5 sites × 3 seasons). Mean values within the same row but having different superscripts are significantly different (P<0.05).

Rotifers were the most dominant group, comprising 33.36% of the total zooplankton community, followed by Cladocera (24.80%), Copepoda (22.44%), and Ostracoda (19.40%).

Diversity indices of zooplankton species: Seasonal diversity indices for zooplankton groups are presented. Simpson's D was recorded in the order of Rotifera > Cladocera > Copepoda > Ostracoda (0.165, 0.160, 0.153, and 0.142). Shannon-Wiener diversity (H) was 1.977, 1.967, 1.965, and 1.861, respectively. Evenness (e^H/S) values were 0.988, 0.980, 0.978, and 0.862, while Margalef's R1 values were 0.837, 0.831, 0.828, and 0.717, respectively. Similar to phytoplankton, Simpson's D and evenness were higher in the monsoon and lower in the summer season, while H and R1 were higher in summer and lower in monsoon.

Discussion: A notable aspect of the present study was the focus on the impact of seasonal variation in freshwater phytoplankton and zooplankton species in selected freshwater bodies of Valsad

Taluka, Gujarat, India, based on the prevailing hydrographical characteristics of the aquatic environment. Moderate fluctuations in the biological density of water bodies necessitate close attention to hydrographic characteristics and biological conditions, as they play a crucial role in species diversity and community structure⁸.

Water temperature plays an essential role in the physiological activities of aquatic organisms, influencing feeding, reproduction, movement, and population density and diversity. In this study, temperatures increased during the summer. They decreased during the monsoon season, in line with findings by Ma, J. et al¹⁸, who emphasized the role of solar radiation, evaporation, and freshwater influx. A significant correlation was observed between water temperature and atmospheric temperature.

pH is a key indicator of water's alkalinity or acidity. High pH levels during the summer season were attributed to increased

pollution and algal blooms, while lower levels during the monsoon were due to dilution. This aligns with observations by Sharma, R. C. et al¹³ and Bhatia, R., & Jain, D.¹⁴. Salinity increased during the summer due to evaporation and reduced precipitation, with a corresponding increase in pH resulting from ion-exchange mechanisms that elevate hydrogen ion concentration.

Dissolved Oxygen (DO) levels varied seasonally, with higher concentrations recorded during the monsoon due to dilution and atmospheric interactions, and lower levels during summer due to microbial decomposition and oxygen consumption by aquatic organisms⁹. Agricultural runoff and untreated sewage discharge in Valsad Taluka were likely responsible for the observed low DO values in summer¹⁰.

Total Dissolved Solids (TDS) peaked during the monsoon, possibly due to surface runoff carrying both organic and inorganic materials, including industrial effluents and agricultural inputs¹¹. Electrical conductivity (EC), which indicates the presence of dissolved ions and the pollution status of water bodies, was higher during the summer.

Total alkalinity and hardness-mainly due to calcium and magnesium ions-also increased in summer. Excessive alkalinity negatively affects irrigation and aquatic life¹². Calcium levels were similarly higher during summer, likely due to the dissolution of minerals like gypsum and calcareous rocks¹³.

Nutrients such as nitrate, phosphate, and chloride-introduced through agricultural runoff, municipal discharge, and other anthropogenic sources-were present in elevated concentrations, indicating a eutrophic state of water bodies¹⁴. These were more prevalent during the monsoon. Ammonia levels, critical in nitrogen cycling, were also higher during the monsoon.

Most physico-chemical parameters peaked during the summer and declined in the monsoon, except for DO, TDS, and ammonia. The water bodies of Valsad Taluka are under increasing stress from human activities that alter their hydrographical profiles and biological processes. Conservation and scientific management are essential to maintain these aquatic ecosystems¹⁵.

Phytoplankton, as primary producers, are sensitive indicators of water quality. A total of 43 species were recorded from Valsad Taluka water bodies, distributed across 25 families and 30 genera, including 15 Cyanophyceae, 17 Chlorophyceae, 8 Bacillariophyceae, and 3 Euglenophyceae. Cyanophyceae dominated (35.07%), followed by Chlorophyceae (29.47%), Bacillariophyceae (25.46%), and Euglenophyceae (10%).

Cyanophyceae are known for producing harmful cyanotoxins, often linked to pollution and global warming. Dominant species included Phormidium, Oscillatoria, Spirillum, Cyndrospermopsis, and Merismopedia¹⁶. In Chlorophyceae,

the dominant taxa were Chlorella, Closterium, Tetrastrum, and Scenedesmus, which are helpful as bioindicators¹⁷. Dominant genera in Bacillariophyceae and Euglenophyceae included Gomphonema, Fragilaria, Navicula, and Euglena.

The presence of bloom-forming Cyanobacteria, such as Cyndrospermopsis raciborskii, Microcystis aeruginosa, and Nostoc corneum, indicates environmental stress. Chlorination is recommended to mitigate their impact on water quality¹⁸.

Zooplankton, as secondary producers, provide key insights into the aquatic food web. A total of 34 zooplankton species were identified across 12 families and 17 genera: 13 Rotifera, 9 Cladocerans, 8 Copepods, and 4 Ostracoda. Rotifers dominated (33.36%) and are known eutrophication indicators¹⁹. Dominant rotifers included Asplanchna brightwelli, Brachionus calyciflorus, and B. rotundiformis.

Cladocerans like Moina macrocopa and Diaphanosoma, and Copepods like Thermocyclops consimilis, T. hyalinus, and Heliodiaptomus viduus were prominent. Ostracods such as Cypretta fontinalis and Cypris decaryi were also common. The dominance of copepods and cyclopoids suggests high turbidity and eutrophication²⁰.

Biodiversity indices indicated higher Simpson's dominance (D) and evenness (e^{H/S}) during the monsoon. In contrast, Shannon-Wiener (H') and Margalef (R1) indices were higher during the summer, suggesting greater species richness and diversity in warmer conditions²¹.

The study underscores the ecological importance of understanding phytoplankton and zooplankton community structure in relation to changing hydrographical parameters. These communities serve as sensitive indicators of environmental health and water quality.

Conclusion

The aquatic ecosystems of Valsad Taluka, Gujarat, are under mounting pressure due to rapid urbanization, industrialization, and changing climatic conditions. This study highlights the significance of hydrographical characteristics and plankton diversity as practical tools for assessing freshwater health.

From September 2023 to May 2024, a total of 78 species of plankton were documented: 44 species of phytoplankton and 34 of zooplankton, spanning 39 families and 47 genera. Diversity peaked during the monsoon season and declined in summer.

The dominance of Cyanophyceae and Rotifera groups reflects eutrophic conditions likely driven by agricultural runoff, sewage input, and urban waste, indicating moderate pollution levels. Effective conservation measures, such as desilting, regulating anthropogenic activities, and enhancing community awareness, are urgently needed.

The freshwater systems of Valsad Taluka have significant ecological value and fisheries potential. Strategic management and regular monitoring can help maintain water quality, protect biodiversity, and ensure sustainable resource use in the future.

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