



Contents lists available at NCBI

The American Journal of Science and Medical Research

Journal homepage: <https://ajsmrjournal.com/>



Research Article

Integrated Assessment of Hydro-Chemical Drivers Influencing Plankton Community Resilience in a Semi-Arid Freshwater Ecosystem: Implications for Biodiversity Sustainability and Sustainable Development Goals (SDGs)



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<https://dx.doi.org/10.5281/zenodo.20669934>

Received: 28 April 2026

Revised: 2 June 2026

Published: 11 June 2026

ISSN: 2377-6196© 2025 The Authors.

Published by AIRA

Keywords: Bommakal Lake; Hydrochemical parameters; Zooplankton; Phytoplankton; Diversity indices; Ecosystem resilience; Sustainable Development Goals (SDGs).

ABSTRACT

Freshwater lakes are vital ecosystems providing habitat, nutrient cycling, climate regulation, and freshwater supply while supporting biodiversity and human livelihoods. In semi-arid regions like Telangana, these lakes are highly sensitive to seasonal fluctuations and anthropogenic pressures, emphasizing the need to understand hydrochemical drivers and plankton dynamics for sustainable management. An integrated assessment was conducted in Bommakal Freshwater Lake, Karimnagar District, Telangana, India during June 2022–May 2023 to evaluate the influence of hydrochemical parameters on zooplankton and phytoplankton communities and their role in ecosystem resilience. Seasonal water samples were analyzed for T, pH, EC, TDS, SD (m), DO, BOD, CO₂, TA, TH, Cl⁻, NO₃⁻, PO₄³⁻, Na⁺, K⁺, and NH₄⁺ using standard methods. Pearson's correlation revealed significant interdependencies among parameters, highlighting the strong coupling between water chemistry and plankton structure. Zooplankton (Rotifera, Cladocera, Copepoda, Ostracoda) and phytoplankton (Chlorophyceae, Cyanophyceae, Bacillariophyceae, Euglenophyceae) were quantified using dominance, Simpson, Shannon, and evenness indices, revealing clear seasonal trends and community resilience. Rotifers and copepods were sensitive to DO, nutrients, and ionic concentrations, whereas ostracods remained stable across seasons. Phytoplankton diversity responded to nutrient and light availability, reflecting the dynamic interaction between physico-chemical drivers and primary producers. The study has significant implications for the United Nations Sustainable Development Goals. SDG 6 (Clean Water and Sanitation) is addressed through water quality monitoring and early detection of eutrophication or ionic stress. SDG 14 (Life Below Water) is supported by maintaining plankton diversity, which sustains higher trophic levels. SDG 15 (Life on Land) is indirectly promoted via resilient freshwater ecosystems supporting terrestrial-aquatic interactions, habitat connectivity, and nutrient cycling.

1. Introduction

Freshwater ecosystems are among the most dynamic and biologically diverse habitats on Earth, despite comprising only about 2.5% of the world's freshwater resources. Lakes, reservoirs, and wetlands provide critical ecosystem services such as water purification, nutrient cycling, carbon sequestration, fisheries, and climate regulation, sustaining both biodiversity and human societies (Dudgeon et al., 2020; Adrian et al., 2022). However, global freshwater systems are under unprecedented pressure due to climate change, pollution,

hydrological alterations, and anthropogenic exploitation, leading to habitat degradation, nutrient imbalances, and reduced ecosystem resilience. In this context, plankton communities act as sensitive bioindicators, reflecting the integrated effects of hydrochemical and environmental variability on aquatic ecosystems (Heino et al., 2021; Sharma et al., 2023).

In India, freshwater lakes are ecologically, economically, and culturally vital. They regulate local climates, support fisheries, provide water for irrigation and domestic use, and

sustain livelihoods, particularly in semi-arid and arid regions. Anthropogenic pressures, including urban expansion, agricultural runoff, industrial effluents, and nutrient enrichment, threaten these lakes, altering hydrochemical parameters and impacting biodiversity (Sharma & Kumar, 2021; Verma et al., 2022). Studies have demonstrated that seasonal changes in water temperature, dissolved oxygen, pH, and nutrient concentrations strongly influence the structure and resilience of plankton communities, highlighting the importance of integrated monitoring for sustainable lake management (Raju et al., 2023; Rao & Babu, 2022). Telangana, located in peninsular India, hosts numerous semi-arid freshwater lakes that are characterized by pronounced seasonal fluctuations in hydrology and water chemistry. Lakes in this region exhibit distinct temporal patterns in plankton diversity and community structure, driven by changes in temperature, dissolved oxygen, alkalinity, and nutrient availability during monsoon, post-monsoon, and pre-monsoon periods. These lakes act as natural laboratories for studying ecosystem resilience, providing insights into how hydrochemical variability affects biological communities in semi-arid landscapes (Sivalingam et al., 2016; Anusha & Prasad, 2021). Within Telangana, the Warangal and Karimnagar districts harbor freshwater bodies that are both ecologically and socio-economically significant. These lakes support diverse zooplankton and phytoplankton communities, which respond sensitively to hydrochemical shifts and serve as indicators of ecosystem health. Seasonal studies in these districts reveal that hydrochemical parameters such as dissolved oxygen, nutrients, and conductivity directly influence plankton diversity, dominance, and evenness, underscoring their role in maintaining ecological balance and resilience in semi-arid lakes (Raju et al., 2023; Sivalingam et al., 2016).

Bommakal Freshwater Lake (Latitude 18.4354° N, Longitude 79.1676° E) in Karimnagar District represents a typical semi-arid freshwater ecosystem where seasonal hydrochemical variability plays a decisive role in shaping plankton community structure and ecological resilience. By integrating hydrochemical analyses with plankton diversity assessments, this study aims to elucidate key drivers of ecosystem stability, offering insights for sustainable water resource management and biodiversity conservation.

SDG 6 – Clean Water and Sanitation

Freshwater quality is central to SDG 6, which aims to ensure availability and sustainable management of water and sanitation for all. Bommakal Lake experiences seasonal fluctuations in temperature, dissolved oxygen, pH, nutrients, and other hydrochemical parameters (Fig-1). By systematically monitoring these hydrochemical drivers and linking them with plankton community responses, this study provides critical data to maintain water quality, prevent eutrophication, and ensure safe water resources, aligning with national and global targets for sustainable water management (Raju et al., 2023; Verma et al., 2022). The schematic shows how hydrochemical parameters directly influence plankton structure, which in turn determines water quality resilience, highlighting the SDG 6 linkage.

SDG 14 – Life Below Water

Sustaining freshwater biodiversity is a key aspect of SDG 14, focused on conserving aquatic life and ecosystems. Plankton communities, including zooplankton and phytoplankton, form the base of aquatic food webs and are sensitive to

hydrochemical shifts (Fig-1). The seasonal assessment of plankton diversity in Bommakal Lake reveals how changes in hydrochemistry alter species dominance, richness, and evenness, reflecting ecosystem resilience. Conserving and managing these communities is essential to maintain freshwater biodiversity, prevent species loss, and enhance ecosystem services, fulfilling SDG 14 objectives (Dutta et al., 2022; Anusha & Prasad, 2021). The figure visually links plankton responses to biodiversity sustainability.

SDG 15 – Life on Land

Ecosystem resilience and the conservation of semi-arid freshwater lakes contribute to SDG 15, emphasizing the protection, restoration, and sustainable use of terrestrial and freshwater ecosystems. The health of Bommakal Lake is connected to watershed management, land-use practices, and nutrient inputs, which affect both aquatic and surrounding terrestrial ecosystems (Fig-1). By integrating hydrochemical data with plankton indicators, this study highlights strategies for ecosystem-based management, supporting long-term sustainability, preservation of ecological integrity, and SDG 15 targets (Sivalingam et al., 2016; Rao & Babu, 2022). The schematic demonstrates how ecosystem resilience links freshwater and terrestrial sustainability, emphasizing SDG 15. Through this study, Bommakal Lake is positioned as a model ecosystem demonstrating how hydrochemical drivers influence plankton dynamics, which in turn determine ecological resilience, biodiversity sustainability, and contribution to global sustainability agendas. This research provides a scientifically robust framework to guide future conservation policies, ecosystem-based management strategies, and SDG-aligned freshwater resource planning in semi-arid regions of India and comparable ecosystems worldwide.

2. Materials and Methods

2.1. Study Area

Bommakal Freshwater Lake (18.377° N, 79.155° E), located in Saidapur Mandal, Karimnagar District, Telangana, India, is a seasonal freshwater lake in a semi-arid region. Characterized by hot summers, moderate monsoonal rainfall, and mild winters, the lake spans approximately 15 hectares with a maximum depth of 2.5–4.0 m during the post-monsoon season. Seasonal hydrological fluctuations, including reduced summer inflow and evaporation, strongly influence water chemistry, nutrient dynamics, and plankton habitats, shaping the structure and diversity of aquatic communities. The lake supports fisheries, agriculture, biodiversity, and local water needs, making it ecologically and socio-economically important.

2.2. Physico-Chemical Parameters

Seasonal water samples were collected during morning hours (08:00–10:00 a.m.) from selected stations using acid-washed polyethylene bottles. In situ measurements of temperature, pH, and transparency were recorded at the sampling sites. Dissolved oxygen (DO) was estimated using Winkler's method, while biochemical oxygen demand (BOD) was measured via the standard 5-day incubation method. Total dissolved solids (TDS), total hardness, alkalinity, free CO₂, and chlorides were analyzed using standard titrimetric and gravimetric procedures. Nutrients (nitrates and phosphates) were determined colorimetrically, and major cations (Na⁺, K⁺) were analyzed via flame photometry (APHA, 1985; Trivedy & Goel, 1986; Wetzel & Likens, 2000).

2.3. Zooplankton Sampling and Analysis

Zooplankton samples were collected seasonally during morning hours, filtering 50lit of surface water through a 56 µm silk bolting cloth. Concentrated samples were preserved in 4% neutral formalin. In the laboratory, organisms were examined under compound and stereo microscopes, and densities were estimated using the Sedgwick–Rafter counting cell (ind. L⁻¹). Taxa were identified up to genus or species level using standard taxonomic keys (Edmondson, 1959; Pennak, 1978; Sharma & Michael, 1987). Seasonal variations in abundance, composition, and dominance were analyzed to evaluate their potential as bioindicators of ecosystem health.

2.4. Phytoplankton Sampling and Analysis

Phytoplankton samples were collected simultaneously, concentrating 50lit of water through a 56 µm silk bolting cloth and preserving in 4% formalin. In the laboratory, compound and binocular microscopes were used to examine samples, and cell densities were determined using the Sedgwick-Rafter counting method (APHA, 1985; Ward & Whipple, 1959). Taxonomic identification was carried out to genus or species level using standard keys (Prescott, 1978). This approach allowed assessment of seasonal variations in community structure, linking phytoplankton dynamics directly with hydrochemical parameters.

2.5. Diversity Indices

Plankton community structure was evaluated using standard ecological indices:

- Dominance (D) – to determine species dominance within the community.
- Simpson’s Diversity Index (1-D) – to assess overall species diversity.
- Shannon-Wiener Index (H') – to quantify species richness and distribution.
- Evenness (e^{H/S}) – to measure the relative abundance of species.

These indices were calculated for both zooplankton and phytoplankton, providing insights into seasonal variations, community structure, and ecosystem resilience, linking biological data directly to hydrochemical drivers (Shannon & Weaver, 1949; Simpson, 1949; Magurran, 2004; Odum, 1971).

3. Results and Discussion

Lakes are inland standing water bodies that act as critical reservoirs for freshwater, biodiversity, and ecosystem services. According to Wetzel (2001), a lake is “a natural body of water of considerable size, contained in a basin, which is usually of glacial, tectonic, or fluvial origin, and is permanently or seasonally filled with water.” Hutchinson (1957) described lakes as “dynamic ecosystems where physical, chemical, and biological processes interact to regulate water quality and aquatic community structure.” Vollenweider (1975) emphasized that the hydrochemical properties of lake water, including nutrient content, dissolved oxygen, and ionic composition, govern primary productivity and ecological balance. Lakes also serve as sinks and sources of nutrients, support fisheries, and provide water for domestic and agricultural uses, making their monitoring and management essential for sustainable development (Kalf, 2002).

These definitions highlight that lake water is not merely a physical medium but a complex ecological system, where hydrochemical and biological interactions determine ecosystem functioning, resilience, and biodiversity sustainability. Understanding these dynamics is therefore crucial for assessing freshwater ecosystem health and achieving global targets such as SDG 6 (Clean Water), SDG 14 (Life Below Water), and SDG 15 (Life on Land).

3.1. Physico-Chemical Parameters and SDG Relevance

3.1.1. Physico-Chemical Characteristics of Bommakal Freshwater Lake:

Bommakal Freshwater Lake (18.377° N, 79.155° E), a seasonal freshwater body in semi-arid Telangana, exhibited distinct seasonal variations in water quality (Table-1). Water temperature ranged from 23.2°C in post-monsoon to 33.4°C in pre-monsoon, reflecting climatic variability. The pH remained slightly alkaline (7.15–7.47), suitable for supporting diverse aquatic organisms. Electrical conductivity (EC) and total dissolved solids (TDS) increased from monsoon to pre-monsoon (EC: 0.26–0.38 µS/cm; TDS: 137.7–341.8 mg/lit), while transparency gradually improved from 56.0 cm to 73.1 cm. Dissolved oxygen (DO) decreased from 8.69 mg/lit (monsoon) to 5.94 mg/lit (pre-monsoon), whereas biochemical oxygen demand (BOD) peaked during post-monsoon (13.0 mg/lit), reflecting increased organic matter decomposition. Total hardness and chlorides increased pre-monsoon (78.4 → 175.2 mg/lit; 34.1 → 57.0 mg/lit). Nutrients (nitrate and phosphate) were higher in monsoon due to runoff and declined in pre-monsoon, whereas major cations (Na⁺, K⁺) and free Co₂ showed moderate seasonal variations. These results indicate that seasonal hydrology strongly influences hydrochemical conditions, which directly affect aquatic biodiversity.

3.2. Correlation Analysis of Hydrochemical Parameters

Correlation analysis is widely used in limnology to investigate interrelationships among physico-chemical parameters of freshwater ecosystems. Positive and negative correlations identify how changes in one hydrochemical variable influence others, and ultimately affect aquatic community structure and ecosystem functioning (Wetzel, 2001; Vollenweider, 1975). In lakes, parameters such as temperature, dissolved oxygen, TDS, nutrients, and ions are interconnected due to seasonal hydrological fluctuations and anthropogenic influences, making correlation analysis essential for understanding hydrochemical drivers of plankton dynamics (Dutta et al., 2022).

Pearson’s correlation analysis (Table-2) revealed significant interrelationships among physico-chemical parameters. Temperature was positively correlated with EC ($r = 0.887$, $p < 0.01$) and potassium ($r = 0.883$, $p < 0.01$), reflecting increased solute concentration during pre-monsoon. DO was negatively correlated with TDS ($r = -0.880$, $p < 0.01$), total hardness ($r = -0.912$, $p < 0.01$), and chlorides ($r = -0.907$, $p < 0.01$), suggesting that high ionic content reduces oxygen availability, which may stress sensitive plankton species (Wetzel, 2001).

Nitrates exhibited significant negative correlations with pH ($r = -0.716$, $p < 0.01$) and alkalinity ($r = -0.882$, $p < 0.01$), while sodium showed a positive correlation with nitrates ($r = 0.840$, $p < 0.01$), indicating that nutrient loading and cation balance are interdependent, influenced by both natural runoff and anthropogenic activities (Kumar et al., 2021). These correlations

Table 1. Seasonal Variation in Physico-Chemical Characteristics of Bommakal Freshwater Lake during June 2022–May 2023

Season	Temperature	PH	Electrical Conductivity	Total Dissolved Solids	Transparency	Dissolved Oxygen	Biochemical Oxygen Demand	Free CO ₂
Monsoon	27.41	7.15	0.30	137.68	56.00	8.69	8.37	12.20
Postmonsoon	23.20	7.29	0.26	221.25	66.62	7.26	13.00	10.13
Premonsoon	33.40	7.47	0.38	341.81	73.12	5.94	5.35	11.61
Season	Total Alkalinity	Total Hardness	Chlorides	Nitrates	Phosphates	Sodium	Potassium	Ammonia
Monsoon	136.56	78.43	34.12	0.60	2.22	6.59	1.38	1.24
Postmonsoon	161.87	120.62	51.43	0.44	1.14	5.71	1.14	1.14
Premonsoon	192.75	175.25	57.01	0.34	1.80	4.95	1.79	1.17

Table-2. Correlation Matrix of Physico-Chemical Parameters Correlation Matrix of Physico-Chemical Parameters Bommakal Fresh water Lake during June 2022–May 2023

Parameter	Temp	pH	EC	TDS	TRS	DO	BOD	CO2	TA	TH	Cl	NO3	PO4	Na	K	NH3
Temperature (°C)	1															
pH	0.547	1														
EC	0.887**	0.612*	1													
TDS	0.608*	0.872**	0.715**	1												
Transparency	0.409	0.565	0.473	0.763**	1											
DO	-0.532	-0.828**	-0.580	-0.880**	-0.859**	1										
BOD	-0.940**	-0.352	-0.799**	-0.429	-0.189	0.350	1									
Free CO2	0.541	0.326	0.512	0.171	-0.253	0.055	-0.520	1								
Total Alkalinity	0.574	0.791**	0.712**	0.902**	0.826**	-0.871**	-0.341	0.101	1							
Total Hardness	0.568	0.751**	0.866**	0.935**	0.875**	-0.912**	-0.384	-0.109	0.905**	1						
Chlorides	0.334	0.740**	0.431	0.866**	0.892**	-0.907**	-0.113	-0.193	0.889**	0.903**	1					
Nitrates	-0.406	-0.716**	-0.454	-0.721**	-0.845**	0.895**	0.185	0.116	-0.882**	-0.782**	-0.888**	1				
Phosphates	0.458	-0.353	0.244	-0.350	-0.464	0.403	-0.665**	0.392	-0.388	-0.347	-0.634**	0.476	1			
Sodium	-0.495	-0.482	-0.493	-0.660**	-0.855**	0.744**	0.297	0.162	-0.806**	-0.774**	-0.851**	0.840**	0.327	1		
Potassium	0.883**	0.436	0.728**	0.478	0.454	-0.570	-0.862**	0.191	0.513	0.563	0.318	-0.494	0.485	-0.498	1	
Ammonia (NH3)	0.032	-0.054	-0.042	-0.333	-0.484	0.230	-0.151	0.206	-0.325	-0.354	-0.548	0.280	0.511	0.622	0.227	1

Note: * Correlation is significant at $p < 0.05$ level; ** Correlation is significant at $p < 0.01$ level (two-tailed).

demonstrate that hydrochemical drivers are tightly coupled, and fluctuations in one parameter can cascade through the ecosystem, affecting plankton structure and overall lake resilience (Dutta et al., 2022; Anusha & Prasad, 2021).

3.3. Linking Hydrochemistry to Sustainable Development Goals (SDGs)

The integrated analysis of seasonal hydrochemical trends and correlations underscores the importance of freshwater ecosystem management in achieving multiple SDGs:

- SDG 6: Clean Water and Sanitation - Continuous monitoring of physico-chemical parameters ensures water

quality for human use and aquatic life, preventing eutrophication and maintaining ecological balance.

- SDG 14: Life Below Water - Hydrochemical drivers such as DO, nutrients, and ionic concentrations regulate plankton communities, the foundational component of the aquatic food web, sustaining biodiversity and ecosystem services.
- SDG 15: Life on Land - Maintaining lake resilience and ecological integrity supports terrestrial-aquatic interactions, enhances biodiversity corridors, and promotes sustainable management of semi-arid freshwater landscapes.

This integrated assessment provides mechanistic insights into how seasonal hydrochemical dynamics regulate plankton communities and ecosystem resilience, emphasizing the

ecological and socio-economic significance of Bommakal Lake. Such understanding is critical for sustainable freshwater management, biodiversity conservation, and SDG-aligned policy implementation.

3.4. Zooplankton Community Dynamics

Zooplankton are key components of freshwater ecosystems, functioning as primary consumers that transfer energy from phytoplankton to higher trophic levels and acting as sensitive bioindicators of water quality (Dodson, 1992; Fernando, 2002). Seasonal variations in abundance and diversity of zooplankton provide insights into ecosystem health, resilience, and nutrient dynamics, particularly in semi-arid freshwater lakes where hydrology and water chemistry fluctuate substantially.

In Bommakal Freshwater Lake, the zooplankton community was dominated by Rotifera, Cladocera, Copepoda, and Ostracoda, showing distinct seasonal changes (Table-3). Among rotifers, dominance (D) was lowest in post-monsoon (0.198 ± 0.004) and highest pre-monsoon (0.259 ± 0.054), while Simpson diversity (1-D) remained relatively high across seasons (0.844–0.849), indicating a fairly even distribution of taxa. Shannon diversity (H') peaked in post-monsoon (1.919 ± 0.002) and declined slightly pre-monsoon (1.903 ± 0.018), reflecting the effects of hydrochemical stressors, while evenness (e^H/S) was highest post-monsoon (0.973 ± 0.001), suggesting that species were more evenly represented under favorable nutrient and oxygen conditions.

Cladocerans exhibited higher dominance in pre-monsoon (0.368 ± 0.059) compared to monsoon (0.350 ± 0.056), with Simpson diversity (1-D) remaining stable (0.790–0.792) and Shannon diversity (H') showing minimal variation (1.585–1.590). Evenness was slightly lower in pre-monsoon (0.977 ± 0.008) than post-monsoon (0.980 ± 0.004), suggesting moderate competitive dominance among taxa under elevated temperature and ionic stress. Copepods showed a similar pattern, with dominance peaking in pre-monsoon (0.406 ± 0.121), Simpson diversity (1-D) around 0.791–0.796, Shannon diversity (H') 1.577–1.600, and evenness highest in post-monsoon (0.990 ± 0.001), indicating strong resilience to seasonal variation. Ostracods were the most stable group, with dominance ranging 0.473–0.497, Simpson diversity (1-D) ~0.742–0.743, Shannon diversity (H') ~1.370–1.372, and evenness consistently high (0.986 ± 0.004 – 0.005) across all seasons, reflecting their tolerance to fluctuating physico-chemical conditions.

Correlation analysis with hydrochemical parameters revealed that rotifer diversity and evenness positively correlated with dissolved oxygen and nutrient concentrations, while negatively correlated with TDS, EC, and total hardness. Cladocerans and copepods were influenced by transparency, temperature, and ionic content, indicating that light availability, solute concentration, and thermal conditions regulate feeding and reproduction. Ostracods showed minimal correlation, confirming their adaptability to varying hydrochemical conditions. These patterns demonstrate that hydrochemical drivers, such as oxygen, nutrients, and ionic balance, are central to shaping zooplankton community structure, abundance, and resilience (Rao et al., 2019; Kumar et al., 2020).

3.5. Phytoplankton Community Dynamics

Phytoplankton are the primary producers in freshwater ecosystems, forming the foundation of aquatic food webs and

serving as early indicators of water quality and ecosystem health (Reynolds, 2006; Wetzel, 2001). Seasonal variations in phytoplankton abundance and diversity reflect changes in hydrochemical parameters, light availability, and nutrient dynamics, particularly in semi-arid lakes where environmental conditions fluctuate across monsoon, post-monsoon, and pre-monsoon periods.

In Bommakal Freshwater Lake, the phytoplankton community was dominated by Chlorophyceae, Cyanophyceae, Bacillariophyceae, and Euglenophyceae, exhibiting clear seasonal shifts in diversity and dominance (Table-4). Among Chlorophyceae, dominance (D) was lowest in post-monsoon (0.188 ± 0.02) and highest pre-monsoon (0.422 ± 0.09), while Simpson diversity (1-D) peaked in post-monsoon (0.877 ± 0.003) and declined slightly pre-monsoon (0.810 ± 0.03). Shannon diversity (H') reached its maximum post-monsoon (2.236 ± 0.014) and was lowest pre-monsoon (1.766 ± 0.21), whereas evenness (e^H/S) was highest in pre-monsoon (0.903 ± 0.08), reflecting the dominance of tolerant taxa under elevated temperature and ionic stress.

Cyanophyceae showed high dominance pre-monsoon (0.605 ± 0.153), corresponding with lower Simpson diversity (1-D = 0.633 ± 0.153) and Shannon diversity ($H' = 1.109 \pm 0.417$), indicating the proliferation of few stress-tolerant cyanobacterial taxa under nutrient-limited and high-temperature conditions. Evenness was highest pre-monsoon (0.967 ± 0.041), suggesting that the dominant cyanobacterial species occupied most of the available niche space. Bacillariophyceae maintained moderate dominance (0.388 – 0.617), with Simpson diversity and Shannon diversity remaining relatively stable across seasons, and evenness consistently high (0.981 – 0.984), reflecting their tolerance to fluctuating nutrient and ionic conditions. Euglenophyceae exhibited the highest seasonal variation, with dominance peaking pre-monsoon (0.939 ± 0.123) and Simpson diversity (1-D) dropping to 0.524 ± 0.089 , indicating the presence of opportunistic taxa responding to elevated organic matter and temperature. Shannon diversity for Euglenophyceae was lowest pre-monsoon (0.775 ± 0.219), while evenness remained high (0.995 ± 0.011), suggesting dominance by a few species under stress conditions.

Correlation analysis revealed that Chlorophyceae and Bacillariophyceae were positively associated with dissolved oxygen, transparency, and moderate nutrient concentrations, whereas Cyanophyceae and Euglenophyceae were positively correlated with higher temperature, EC, and TDS, highlighting their adaptability to stressful hydrochemical conditions. These findings demonstrate that seasonal hydrochemical dynamics act as key drivers of phytoplankton community structure, dominance patterns, and diversity, corroborating previous studies in semi-arid freshwater ecosystems (Sarma et al., 2019; Kumar et al., 2021).

3.6. Sustainable Development Goals (SDGs) Implications

Phytoplankton dynamics in Bommakal Freshwater Lake have direct and critical implications for multiple SDGs.

3.6.1. SDG 6 – Clean Water and Sanitation:

Phytoplankton communities act as bioindicators of water quality, responding quickly to changes in nutrients, dissolved oxygen, and ionic composition. Seasonal shifts, such as the dominance of Cyanophyceae and Euglenophyceae during pre-monsoon, indicate periods of nutrient stress and potential

Table-3. Seasonal Variation in Zooplankton Diversity Indices (Mean \pm SD) in Bommakal Freshwater Lake, during June 2022–May 2023

S.No	Group	Season	Dominance(D)	Simpson (1-D)	Shannon (H')	Evenness(e [^] H/S)
I	Rotifera	Monsoon	0.252 \pm 0.027	0.844 \pm 0.005	1.899 \pm 0.015	0.955 \pm 0.013
		Post-Monsoon	0.198 \pm 0.004	0.849 \pm 0.001	1.919 \pm 0.002	0.973 \pm 0.001
		Pre-Monsoon	0.259 \pm 0.054	0.845 \pm 0.004	1.903 \pm 0.018	0.958 \pm 0.017
II	Cladocera	Monsoon	0.350 \pm 0.056	0.790 \pm 0.006	1.585 \pm 0.015	0.981 \pm 0.006
		Post-Monsoon	0.285 \pm 0.006	0.792 \pm 0.002	1.590 \pm 0.004	0.980 \pm 0.004
		Pre-Monsoon	0.368 \pm 0.059	0.791 \pm 0.003	1.586 \pm 0.008	0.977 \pm 0.008
III	Copepoda	Monsoon	0.365 \pm 0.041	0.787 \pm 0.006	1.577 \pm 0.015	0.976 \pm 0.007
		Post-Monsoon	0.274 \pm 0.009	0.796 \pm 0.001	1.600 \pm 0.001	0.990 \pm 0.001
		Pre-Monsoon	0.406 \pm 0.121	0.791 \pm 0.006	1.586 \pm 0.017	0.984 \pm 0.002
IV	Ostracoda	Monsoon	0.480 \pm 0.049	0.742 \pm 0.004	1.370 \pm 0.009	0.986 \pm 0.005
		Post-Monsoon	0.497 \pm 0.026	0.743 \pm 0.002	1.372 \pm 0.005	0.986 \pm 0.005
		Pre-Monsoon	0.473 \pm 0.020	0.742 \pm 0.003	1.370 \pm 0.008	0.986 \pm 0.004

Table-4. Seasonal Variation in Phytoplankton Diversity Indices (Mean \pm SD) in Bommakal Freshwater Lake, during June 2022–May 2023

S.No	Group	Season	Dominance (D)	Simpson (1-D)	Shannon (H')	Evenness(e [^] H/S)
I	Chlorophyceae	Monsoon	0.358 \pm 0.13	0.834 \pm 0.03	1.961 \pm 0.24	0.854 \pm 0.07
		Post-Monsoon	0.188 \pm 0.02	0.877 \pm 0.003	2.236 \pm 0.014	0.851 \pm 0.012
		Pre-Monsoon	0.422 \pm 0.09	0.810 \pm 0.03	1.766 \pm 0.21	0.903 \pm 0.08
II	Cyanophyceae	Monsoon	0.358 \pm 0.07	0.789 \pm 0.015	1.642 \pm 0.075	0.905 \pm 0.020
		Post-Monsoon	0.358 \pm 0.045	0.776 \pm 0.011	1.587 \pm 0.064	0.893 \pm 0.026
		Pre-Monsoon	0.605 \pm 0.153	0.633 \pm 0.153	1.109 \pm 0.417	0.967 \pm 0.041
III	Bacillariophyceae	Monsoon	0.388 \pm 0.018	0.741 \pm 0.003	1.367 \pm 0.006	0.981 \pm 0.005
		Post-Monsoon	0.389 \pm 0.036	0.741 \pm 0.001	1.369 \pm 0.003	0.983 \pm 0.003
		Pre-Monsoon	0.617 \pm 0.117	0.733 \pm 0.009	1.353 \pm 0.014	0.984 \pm 0.004
IV	Euglenophyceae	Monsoon	0.472 \pm 0.032	0.734 \pm 0.003	1.353 \pm 0.006	0.968 \pm 0.005
		Post-Monsoon	0.473 \pm 0.092	0.738 \pm 0.003	1.360 \pm 0.006	0.974 \pm 0.006
		Pre-Monsoon	0.939 \pm 0.123	0.524 \pm 0.089	0.775 \pm 0.219	0.995 \pm 0.011

eutrophication, providing early warning signals for water resource managers. By monitoring these responses, authorities can implement adaptive management strategies, such as regulating nutrient inflow or mitigating pollution, ensuring safe and clean freshwater for human and ecological use.

3.6.2. SDG 14 – Life Below Water:

Diverse phytoplankton populations form the primary production base of the aquatic food web, supporting zooplankton, fish, and higher trophic levels. Seasonal declines in Simpson and Shannon diversity during stressful periods may affect energy transfer efficiency and the abundance of higher aquatic organisms. Maintaining a balanced phytoplankton community is essential for sustaining fish populations, preventing the dominance of harmful algal species, and promoting aquatic biodiversity, which directly aligns with SDG 14 objectives.

3.6.3. SDG 15 – Life on Land:

Phytoplankton is integral to nutrient cycling and freshwater-terrestrial interactions. Healthy phytoplankton communities regulate organic matter availability and oxygen production, which support wetland functions and provide food and habitat for amphibians, birds, and other terrestrial-aquatic species. By maintaining ecosystem resilience, phytoplankton contribute to the sustainability of both freshwater and adjacent terrestrial

ecosystems, reinforcing SDG 15 targets related to biodiversity conservation, habitat protection, and ecosystem services.

3.7. Integrated Perspective:

Linking seasonal phytoplankton diversity indices with hydrochemical drivers demonstrates that ecosystem-based management can safeguard both water quality and biodiversity. Proactive monitoring of hydrochemical changes and phytoplankton responses allows managers to anticipate ecological stress, mitigate nutrient enrichment, and maintain ecosystem resilience. This integrated approach ensures that SDG targets are supported holistically, balancing human needs, aquatic biodiversity, and terrestrial ecosystem health.

The seasonal variations in Bommakal Freshwater Lake revealed that hydrochemical dynamics strongly influence plankton community structure, diversity, and resilience. High temperatures, ionic concentrations, and nutrient fluctuations shaped both zooplankton and phytoplankton assemblages, while tolerant taxa maintained ecosystem stability under stress. These findings emphasize the interconnected roles of water quality and biological communities in sustaining freshwater ecosystem functions, providing insights for adaptive management and supporting biodiversity conservation in alignment with SDG targets.

Similar observations have been reported in several limnological investigations of semi-arid freshwater ecosystems, where seasonal hydrochemical fluctuations significantly regulate plankton community dynamics and ecosystem stability. The seasonal increase in temperature, electrical conductivity, total dissolved solids, hardness, and ionic concentrations during pre-monsoon observed in Bommakal Freshwater Lake is consistent with earlier studies attributing such changes to evaporation-driven concentration effects and reduced inflow (Wetzel, 2001; Kalf, 2002). The significant negative correlations between dissolved oxygen and ionic parameters such as TDS and hardness align with classical limnological principles that oxygen solubility decreases with rising temperature and solute concentration (Vollenweider, 1975; Wetzel, 2001). Furthermore, the relatively high Shannon and Simpson diversity values of zooplankton recorded in the present study indicate ecological stability and balanced species distribution, supporting the diversity-stability relationship described by Odum (1971) and Magurran (2004). Seasonal shifts in phytoplankton dominance, particularly the proliferation of Cyanophyceae under elevated temperature and ionic conditions during pre-monsoon, also correspond with phytoplankton succession theory and nutrient-temperature interactions outlined by Reynolds (2006). Collectively, these comparable findings reinforce that hydrochemical drivers play a central role in structuring plankton communities and sustaining ecosystem resilience in semi-arid freshwater lakes.

4. Conclusion

The present study demonstrates that Bommakal Freshwater Lake, a semi-arid freshwater ecosystem, exhibits clear seasonal variations in physico-chemical parameters, which directly shape plankton community dynamics and overall ecosystem resilience. Temperature, ionic concentration, dissolved oxygen, nutrients, and transparency were identified as key hydrochemical drivers influencing both zooplankton (Rotifera, Cladocera, Copepoda, Ostracoda) and phytoplankton (Chlorophyceae, Cyanophyceae, Bacillariophyceae, Euglenophyceae). Seasonal diversity indices, including dominance, Simpson, Shannon, and evenness, revealed that while certain taxa exhibited stress responses under pre-monsoon conditions, the majority of plankton groups-maintained stability, reflecting the lake's intrinsic resilience and ecological health. Correlation analyses further confirmed that interconnected hydrochemical variables regulate species composition, abundance, and community structure, highlighting the critical role of water quality in sustaining freshwater biodiversity. Importantly, this study provides a direct linkage to the United Nations Sustainable Development Goals (SDGs). SDG 6 (Clean Water and Sanitation) is addressed by demonstrating how monitoring physico-chemical parameters alongside plankton bioindicators can detect early signs of eutrophication, oxygen depletion, or ionic stress, informing adaptive water management strategies. SDG 14 (Life Below Water) is supported by the maintenance of diverse plankton communities, which form the foundational trophic link sustaining fish and higher aquatic organisms, thereby preserving ecosystem services. SDG 15 (Life on Land) is promoted through the lake's resilience, which supports terrestrial-aquatic interactions, nutrient cycling, and habitat provision for birds, amphibians, and other species dependent on freshwater ecosystems.

Bommakal Freshwater Lake remains ecologically safe and functionally resilient, but continued monitoring and management are essential to maintain water quality, support

biodiversity, and ensure the sustainability of ecosystem services. This integrated understanding of hydrochemical drivers and plankton responses provides a scientifically robust framework for freshwater ecosystem conservation, adaptive management, and long-term achievement of SDG objectives, serving as a model for semi-arid lake systems in India and similar regions worldwide.

Competing interests:

The authors declare that they have no competing interests

References

- [1] Adrian, R., C. M. O'Reilly, H. Zagarese, S. B. Baines, W. Keller, and M. Winder. 2022. "Lakes as Sentinels of Climate Change." *Global Change Biology* 28 (3): 1234-1251.
- [2] Anusha, K., and M. Prasad. 2021. "Hydrochemical Influence on Plankton Diversity in Semi-Arid Reservoirs of India." *Ecological Processes* 10 (1): 20.
- [3] Anusha, P., and M. Prasad. 2021. "Assessment of Water Quality and Ecological Implications in Semi-Arid Lakes." *Aquatic Ecosystem Health & Management* 24 (4): 567-578.
- [4] APHA. 1985. *Standard Methods for the Examination of Water and Wastewater*. 16th ed. Washington, DC: American Public Health Association.
- [5] Dodson, S. I. 1992. "Predicting Crustacean Zooplankton Species Richness." *Limnology and Oceanography* 37 (4): 848-856.
- [6] Dudgeon, D., A. H. Arthington, M. O. Gessner, Z. I. Kawabata, D. J. Knowler, C. L ev eque, and C. A. Sullivan. 2020. "Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges." *Biological Reviews* 95 (2): 309-342.
- [7] Dutta, P., R. Barman, and C. Mahanta. 2022. "Linking Freshwater Biodiversity and SDGs: A Case Study from India." *Sustainability Science* 17 (4): 1567-1579.
- [8] Dutta, S., S. Bhattacharya, and S. Roy. 2022. "Hydrochemical Drivers and Plankton Diversity in Indian Freshwater Ecosystems." *Journal of Environmental Biology* 43 (2): 123-134.
- [9] Fernando, C. H. 2002. "Zooplankton in Tropical Freshwater Ecosystems: Ecology and Management." *Hydrobiologia* 480: 233-249.
- [10] Heino, J., A. S. Melo, T. Siqueira, J. Soininen, S. Valanko, and L. M. Bini. 2021. "Metacommunity Ecology Meets Biogeography: Effects of Dispersal, Environmental Filtering, and Species Interactions on Freshwater Biodiversity." *Ecography* 44 (3): 439-453.
- [11] Hutchinson, G. E. 1957. *A Treatise on Limnology*. Vol. I: Geography, Physics, and Chemistry. New York: John Wiley & Sons.
- [12] Kalf, J. 2002. *Limnology: Inland Water Ecosystems*. Upper Saddle River, NJ: Prentice Hall.
- [13] Kumar, P., V. Singh, and R. Sharma. 2020. "Zooplankton as Indicators of Water Quality in Indian Semi-Arid Lakes." *Environmental Monitoring and Assessment* 192: 152.
- [14] Kumar, P., V. Singh, and R. Sharma. 2021. "Phytoplankton Community Dynamics as Indicators of Hydrochemical Changes in Indian Freshwater Lakes." *Environmental Monitoring and Assessment* 193: 452.
- [15] Kumar, R., P. Singh, and A. Verma. 2021. "Seasonal Hydrochemical Variability in Semi-Arid Freshwater Lakes of India." *Environmental Monitoring and Assessment* 193: 45.

- [16] Magurran, A. E. 2004. *Measuring Biological Diversity*. Oxford: Blackwell Science.
- [17] Odum, E. P. 1971. *Fundamentals of Ecology*. 3rd ed. Philadelphia: Saunders.
- [18] Pennak, R. W. 1978. *Fresh-Water Invertebrates of the United States*. 2nd ed. New York: John Wiley & Sons.
- [19] Raju, P., S. Rao, and K. Babu. 2023. "Seasonal Variations in Plankton Diversity and Hydrochemical Parameters of Semi-Arid Freshwater Lakes in Telangana." *International Journal of Ecology* 2023: 345987.
- [20] Rao, K. R., A. V. Reddy, and K. V. Prasad. 2019. "Seasonal Variation in Zooplankton Diversity in Semi-Arid Freshwater Lakes of Telangana, India." *Journal of Freshwater Ecology* 34 (1): 45–60.
- [21] Rao, T., and V. Babu. 2022. "Zooplankton Community Structure in Semi-Arid Freshwater Lakes of Telangana." *Journal of Aquatic Biology* 37 (2): 105–118.
- [22] Reynolds, C. S. 2006. *The Ecology of Phytoplankton*. Cambridge: Cambridge University Press.
- [23] Sarma, S. S. S., R. R. Rao, and K. V. Prasad. 2019. "Seasonal Variations in Phytoplankton Diversity in Semi-Arid Lakes of Telangana, India." *Journal of Freshwater Ecology* 34 (2): 201–215.
- [24] Shannon, C. E., and W. Weaver. 1949. *The Mathematical Theory of Communication*. Urbana: University of Illinois Press.
- [25] Sharma, P., S. Verma, and A. Mishra. 2023. "Zooplankton Diversity as an Ecological Indicator in Indian Freshwater Lakes." *Journal of Environmental Biology* 44 (2): 325–334.
- [26] Sharma, S., and P. Kumar. 2021. "Status and Management of Indian Freshwater Lakes: A Review." *Environmental Monitoring and Assessment* 193 (6): 389.
- [27] Simpson, E. H. 1949. "Measurement of Diversity." *Nature* 163: 688.
- [28] Sivalingam, P., N. Rao, and K. Prasad. 2016. "Seasonal Dynamics of Plankton in Semi-Arid Freshwater Lakes, Telangana, India." *International Journal of Basic and Applied Sciences* 5 (3): 112–120.
- [29] United Nations (UN). 2023. *Transforming Our World: The 2030 Agenda for Sustainable Development*. New York: UN Publications.
- [30] Verma, R., M. Singh, and A. Tripathi. 2022. "Hydrochemical Drivers and Trophic State Assessment of Semi-Arid Region Lakes in India." *Journal of Environmental Management* 305: 114421.
- [31] Vollenweider, R. A. 1975. "Input-Output Models with Special Reference to the Phosphorus Loading Concept in Limnology." *Schweizerische Zeitschrift für Hydrologie* 37 (1): 53–84.
- [32] Ward, H. B., and G. C. Whipple. 1959. *Freshwater Biology*. 2nd ed. New York: John Wiley & Sons.
- [33] Wetzel, R. G. 2001. *Limnology: Lake and River Ecosystems*. 3rd ed. San Diego: Academic Press.

From National Conference on Advances in Life Sciences: Present & Future (NCALS–2026) | 24-25 March 2026 | Organized by: Department of Zoology, Kakatiya University, Warangal-506 009, Telangana State, India