

## **Integrated Limnological Assessment of Gangasamudra Lake (Karnataka): Physicochemical Characteristics, Plankton Dynamics, and Fish Diversity**

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### **Abstract**

The present study provides an integrated limnological assessment of Gangasamudra Lake, a semi-arid freshwater ecosystem in Karnataka, India, by evaluating physicochemical characteristics, plankton community dynamics, and ichthyofaunal diversity across five sampling sites during 2024. Monthly analysis of water quality parameters revealed consistently alkaline pH, high turbidity, elevated total dissolved solids, conductivity, biochemical oxygen demand, chemical oxygen demand, magnesium, and iron, indicating meso-eutrophic to eutrophic conditions. Although most toxic heavy metals were absent or below detection limits, elevated iron and occasional lead concentrations suggested localized anthropogenic influences, primarily from agricultural runoff, catchment erosion, and internal nutrient loading. Phytoplankton assemblages comprised 23 genera belonging to Bacillariophyceae, Chlorophyceae, and Cyanophyceae, with diatoms dominating during pre-monsoon and monsoon periods, followed by increased representation of green algae and cyanobacteria during post-monsoon months. Zooplankton communities were represented by Rotifera, Protozoa, Copepoda, and Ostracoda, with rotifers showing marked dominance and seasonal fluctuations, reflecting nutrient enrichment and dynamic trophic interactions. Diversity indices indicated moderate to high plankton diversity during monsoon and post-monsoon periods, while reduced diversity and increased dominance during summer months reflected environmental stress. Ichthyofaunal assessment recorded six fish species belonging to three families (Cichlidae, Cyprinidae, and Clariidae), dominated by hardy and omnivorous taxa such as *Oreochromis* spp. and *Clarias* spp. The presence of the endangered *Clarias batrachus* highlights the conservation significance of the lake despite anthropogenic pressures. Overall, the combined physicochemical and biological evidence suggests that Gangasamudra Lake is a nutrient-enriched but moderately resilient ecosystem, emphasizing the need for regular monitoring, nutrient management, and sustainable fishery practices to preserve its ecological integrity and biodiversity.

**Keywords:** Gangasamudra Lake; Physicochemical parameters; Phytoplankton diversity; Zooplankton dynamics; Ichthyofaunal diversity; Eutrophication; Semi-arid freshwater lake.

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### **Introduction**

Freshwater lakes are among the most productive and ecologically significant ecosystems, providing critical services such as drinking water supply, irrigation, fisheries, biodiversity conservation, and climate regulation. However, lakes in semi-arid and tropical regions are increasingly threatened by eutrophication, land-use changes, agricultural intensification, and climate variability, leading to rapid deterioration of water quality and biological integrity (Dodds & Whiles, 2020; Jeppesen et al., 2020). In India, village tanks and small reservoirs play a vital socio-economic role, yet they are highly vulnerable to nutrient enrichment, sedimentation, and hydrological fluctuations due to unregulated catchment activities (Ramesh et al., 2021; Patil et al., 2023). Assessing the physicochemical and biological components of such water bodies is therefore essential for understanding ecosystem functioning and guiding sustainable management. Physicochemical parameters such as pH, turbidity, dissolved oxygen, alkalinity, nutrients, and organic load (BOD and COD) are widely used indicators of lake trophic status and environmental stress (Wetzel, 2001; Kumar et al., 2022). Elevated turbidity and organic matter often reflect increased runoff, sediment resuspension, and anthropogenic inputs, which can alter light penetration, nutrient cycling, and aquatic productivity (Dodds & Whiles, 2020; Sharma et al., 2022). In semi-arid regions of southern India, seasonal monsoon dynamics further influence lake water quality by regulating dilution, mixing, and nutrient availability, resulting in pronounced temporal variability (Ramesh et al., 2021; Suresh et al., 2024). Hence, integrated water quality monitoring is crucial for identifying early signs of eutrophication and ecological imbalance.

Plankton communities, particularly phytoplankton and zooplankton, serve as sensitive biological indicators of water quality and trophic conditions due to their rapid response to environmental changes (Reynolds, 2006; Magurran, 2013). Phytoplankton groups such as Bacillariophyceae, Chlorophyceae, and Cyanophyceae exhibit distinct ecological preferences and seasonal successions that reflect nutrient status, hydrological stability, and light availability (Paerl & Otten, 2013; Kumar et al., 2022). Similarly, zooplankton assemblages—dominated by rotifers, copepods, and protozoans in tropical lakes—play a crucial role in energy transfer between

primary producers and higher trophic levels and are widely used to assess ecosystem health and resilience (Jeppesen et al., 2020; Sharma & Sharma, 2021). Variations in plankton diversity indices such as Shannon, Simpson, and Evenness provide quantitative insights into community stability and dominance patterns under changing environmental conditions (Magurran, 2013; Mishra et al., 2022).

Fish communities integrate long-term ecological processes and reflect cumulative impacts of water quality, habitat structure, and food web interactions. In many tropical freshwater systems, increasing eutrophication and habitat modification have led to the dominance of hardy, omnivorous, and air-breathing fishes, often accompanied by the decline of sensitive native species (Welcomme et al., 2017; Sarkar et al., 2021). The proliferation of invasive species such as *Oreochromis* spp. has further altered native fish assemblages in Indian lakes by competitive exclusion and habitat modification (Canonico et al., 2005; Singh & Lakra, 2018). Evaluating ichthyofaunal diversity alongside plankton dynamics thus provides a comprehensive understanding of trophic structure and ecosystem functioning.

Against this backdrop, the present study was undertaken to integrate physicochemical assessment with plankton and ichthyofaunal diversity analyses of Gangasamudra Lake, a semi-arid freshwater ecosystem in Karnataka. By examining seasonal variations across multiple sites and employing diversity indices, the study aims to elucidate the trophic status, ecological health, and anthropogenic influences on the lake ecosystem. Such integrated limnological investigations are essential for developing science-based conservation and management strategies to sustain freshwater resources and biodiversity in rapidly changing tropical landscapes (Jeppesen et al., 2020; Patil et al., 2023).

## Materials and Methods

### 1. Study Area

The present investigation was carried out at Gangasamudra Lake, located in Gangasamudra Village, Holalkere Taluk, Chitradurga District, Karnataka, India, approximately 20 km from Chitradurga town. The lake is surrounded by agricultural land, marginal weeds, and scattered trees, indicating moderate anthropogenic influence from farming activities and surface runoff. The lake receives inflow from Chowdi Halla and drains into Talikatte Lake, forming part of a local hydrological network. The geographical coordinates of Gangasamudra Lake are approximately 13.912733° N latitude and 76.145135° E longitude, at an elevation of about 1905 ft above mean sea level. Such morphometric and locational features significantly influence water quality and nutrient dynamics in semi-arid tropical lakes (Welch, 1992; Wetzel, 2001).



Figure 1: Map of Durg District (<https://www.google.com/search/durgdistrict>)

### 2. Sampling collection

To obtain representative data on spatial variations in water quality, five sampling sites were systematically selected across Gangasamudra Lake based on inflow points, outlet region, vegetation cover, and accessibility. The sampling locations and their coordinates are as follows:

- Site 01: 13.917695° N, 76.144255° E
- Site 02: 13.915188° N, 76.144346° E
- Site 03: 13.907835° N, 76.142428° E
- Site 04: 13.921913° N, 76.139221° E
- Site 05: 13.917698° N, 76.143341° E

The selection of multiple sites helps in capturing heterogeneity in physicochemical characteristics influenced by point and non-point pollution sources, as recommended in limnological studies of freshwater bodies (APHA, 2017; Trivedi and Goel, 1986).

### **Water Sample Collection**

Water samples were collected monthly from all five sampling sites during the study period. Sampling was carried out during early morning hours between 8:00 am and 10:00 am to minimize diurnal variations, particularly in temperature and dissolved oxygen levels. Surface water samples were collected using clean, pre-washed polyethylene bottles of appropriate volume. Prior to sampling, the bottles were rinsed thoroughly with lake water to avoid contamination. For dissolved oxygen analysis, samples were collected in 300 ml BOD bottles without air bubbles and fixed immediately at the site using Winkler's reagents (APHA, 2017; Wetzel and Likens, 2000).

### **Physico-Chemical Analysis of Water**

Temperature and pH were measured in situ using a calibrated digital thermometer and pH meter, respectively. The pH values were assessed at 25°C and compared with the permissible limits prescribed by the Karnataka State Pollution Control Board (KSPCB). Electrical conductivity was measured using a digital conductivity meter and expressed in  $\mu\text{S}/\text{cm}$ , serving as an indicator of ionic concentration in water (Wetzel, 2001). Turbidity was determined using a nephelometric turbidity meter and expressed in NTU. Colour was measured using the platinum–cobalt (Hazen) method. Total dissolved solids (TDS) and total suspended solids (TSS) were determined gravimetrically following standard filtration and drying procedures (APHA, 2017).

### **Alkalinity, Hardness, and Major Ions**

Total alkalinity, expressed as  $\text{CaCO}_3$ , was estimated by titration against standard sulfuric acid using phenolphthalein and methyl orange indicators. Total hardness, calcium, and magnesium were determined by EDTA titrimetric methods. Chloride concentration was estimated using the argentometric (Mohr's) method, while sulphate was determined by the turbidimetric method. These parameters provide insight into buffering capacity, mineral content, and salinity status of the lake water (Welch, 1992; Golterman *et al.*, 1978).

### **Nutrients and Inorganic Constituents**

Nitrate ( $\text{NO}_3^-$ ) was estimated using spectrophotometric methods after appropriate chemical treatment. Fluoride was determined by the SPADNS colorimetric method, while boron was estimated using azomethine-H reagent. These nutrients and trace elements are important indicators of agricultural runoff and anthropogenic inputs into freshwater systems (APHA, 2017; Wetzel and Likens, 2000).

### **Oxygen Regime and Organic Pollution Indicators**

Dissolved oxygen (DO) was estimated using the modified Winkler's iodometric method. Biochemical oxygen demand (BOD) was determined after incubating samples for 5 days at 20°C, while chemical oxygen demand (COD) was analyzed using the open reflux dichromate method. These parameters were used to assess the organic pollution load and biological activity of the lake water (Trivedi and Goel, 1986; APHA, 2017).

### **Heavy Metals Analysis**

Trace metals including iron (Fe), copper (Cu), zinc (Zn), lead (Pb), mercury (Hg), cadmium (Cd), arsenic (As), nickel (Ni), manganese (Mn), and hexavalent chromium ( $\text{Cr}^{6+}$ ) were analyzed following acid digestion procedures. Metal concentrations were measured using Atomic Absorption Spectrophotometry (AAS). Results were compared with permissible limits prescribed by KSPCB standards. Metals reported as Absent or Not Detected were below the instrument detection limits (APHA, 2017; WHO, 2011).

### **Quality Control and Statistical Treatment**

All analyses were performed in triplicate, and results are expressed as mean  $\pm$  standard deviation. Instruments were calibrated using standard solutions prior to analysis. Analytical-grade reagents and double-distilled water were used throughout the study to ensure accuracy and reproducibility. Monthly and annual averages were calculated to evaluate temporal variations in water quality parameters (Wetzel, 2001).

### **Plankton Sampling Frequency and Collection**

Plankton samples were collected monthly from January 2024 to December 2024 at all five sampling stations. Sampling was carried out during early morning hours (8:00–10:00 am) to minimize the effect of diurnal vertical migration of plankton. Water samples were collected using clean plastic containers, and a known volume of water (50–100 L) was filtered through a standard plankton net with a mesh size of 25  $\mu\text{m}$  for phytoplankton and 55  $\mu\text{m}$  for zooplankton, following standard limnological procedures (Welch, 1992; Trivedi and Goel, 1986).

**Preservation of Plankton Samples**

The concentrated plankton samples were transferred to labeled polyethylene bottles and preserved immediately. Phytoplankton samples were preserved using 1% Lugol's iodine solution, while zooplankton samples were preserved in 4% neutralized formalin. Preservation was carried out to prevent decomposition and maintain cellular integrity for microscopic examination (APHA, 2017; Edmondson, 1959).

**Qualitative and Quantitative Analysis of Phytoplankton**

Phytoplankton analysis was carried out using a Sedgwick–Rafter counting cell under a compound light microscope. Identification was performed based on morphological characteristics such as cell shape, size, colonial nature, and pigmentation using standard taxonomic keys (Desikachary, 1959; Prescott, 1978). Quantitative estimation was expressed as number of organisms per liter (units/L) using standard calculation methods (Welch, 1992).

**Qualitative and Quantitative Analysis of Zooplankton**

Zooplankton analysis was carried out using a Sedgwick–Rafter counting chamber and stereomicroscope or compound microscope. Identification was based on body segmentation, antennae structure, lorica shape, and appendages using standard identification manuals (Edmondson, 1959; Battish, 1992). Zooplankton abundance was expressed as number of individuals per liter (ind./L). (Wetzel, 2001; Battish, 1992).

**Data Analysis**

The monthly and site-wise plankton data were compiled to evaluate seasonal and spatial variations in species composition and abundance. Plankton density values were used to interpret trophic status and ecological health of the lake, as plankton communities respond rapidly to changes in nutrient concentrations and physicochemical conditions (Reynolds, 2006; Wetzel, 2001).

**Fish Sampling and Data Collection**

Fish sampling was carried out monthly from January 2024 to December 2024 at all five sampling stations. Sampling was conducted during early morning hours (6:00–9:00 am) to minimize diurnal bias in fish activity. Fishes were collected with the assistance of local fishermen using gill nets, cast nets, and drag nets of varying mesh sizes to ensure the capture of both small and large-sized species. This multi-gear approach improves sampling efficiency and reduces gear selectivity bias (Welcomme, 2001; Lagler et al., 1977). Captured fishes were sorted species-wise at each station, and the number of individuals per species per site was recorded. After enumeration, fishes were released back into the lake whenever possible, except for a few specimens retained for taxonomic confirmation.

**Species Identification**

Fish species were identified based on morphological and meristic characters such as body shape, scale pattern, fin ray counts, and coloration using standard taxonomic keys and monographs (Talwar and Jhingran, 1991; Jayaram, 2010). The recorded species during the study period included *Oreochromis mossambicus*, *Oreochromis niloticus*, *Cirrhinus mrigala*, *Clarias gariepinus*, *Catla catla*, and *Clarias batrachus*. Nomenclature and classification followed current ichthyological standards (FishBase; Jayaram, 2010).

**Assessment of Monthly and Spatial Abundance**

Fish abundance data were expressed as monthly numerical counts for each species at each sampling station (S1–S5). This approach allowed evaluation of seasonal trends, breeding-related fluctuations, and site-specific dominance patterns. Monthly abundance variations were interpreted in relation to monsoon-driven hydrological changes, food availability, and habitat conditions, which are known to influence fish population dynamics in tropical freshwater ecosystems (Welcomme, 2001; Lowe-McConnell, 1987).

**Data Analysis**

The collected data were compiled month-wise and site-wise to analyze temporal and spatial variations in fish distribution. Descriptive statistics were used to summarize abundance patterns, and comparative analysis among months and stations was carried out to understand species dominance and seasonal shifts. Such abundance-based assessments are widely used for evaluating fish community structure in reservoirs and lakes (Magurran, 2004; Jayaram, 2010).

**Diversity Indices Analysis**

The assessment of fish/community diversity was carried out using widely accepted ecological diversity indices, which provide quantitative measures of species richness, dominance, and evenness within the study ecosystem. The species abundance data obtained from systematic sampling were used to compute Shannon–Wiener diversity index ( $H'$ ), Simpson's diversity index ( $1-D$ ), Dominance index ( $D$ ), Margalef's species richness index ( $d$ ), Menhinick's index ( $Mn$ ), and Pielou's evenness index ( $J'$ ). These indices are

commonly employed in limnological and ecological studies to evaluate the structure and stability of biological communities in freshwater ecosystems (Shannon and Weaver, 1949; Simpson, 1949; Magurran, 2004).

**Shannon–Wiener Diversity Index ( $H'$ )**

The Shannon–Wiener diversity index ( $H'$ ) was calculated to assess species diversity by considering both species richness and relative abundance. The index was computed using the formula:

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

where  $p_i$  is the proportion of individuals belonging to the  $i$ th species and  $S$  is the total number of species. Higher values of  $H'$  indicate greater diversity and a more even distribution of individuals among species, while lower values suggest dominance by few species (Shannon and Weaver, 1949; Magurran, 2004).

**Simpson's Diversity Index (1– $D$ ) and Dominance ( $D$ )**

Simpson's index measures the probability that two individuals randomly selected from a sample belong to different species. The dominance index ( $D$ ) was calculated as:

$$D = \sum_{i=1}^S p_i^2$$

Simpson's diversity was expressed as (1– $D$ ) to represent diversity rather than dominance. Values of  $D$  range from 0 to 1, where higher  $D$  values indicate greater dominance by a few species, whereas higher (1– $D$ ) values reflect greater diversity (Simpson, 1949; Krebs, 1999).

**Margalef's Species Richness Index ( $d$ )**

Margalef's index ( $d$ ) was used to estimate species richness while accounting for sample size. It was calculated using the formula:

$$d = \frac{(S - 1)}{\ln N}$$

Where  $S$  is the total number of species and  $N$  is the total number of individuals. Higher values of Margalef's index indicate greater species richness within the community (Margalef, 1958; Magurran, 2004).

**Menhinick's Index ( $Mn$ )**

Menhinick's index ( $Mn$ ) was employed to assess species richness relative to the number of individuals sampled and was calculated using:

$$Mn = \frac{S}{\sqrt{N}}$$

Where  $S$  is the total number of species and  $N$  is the total number of individuals. This index is particularly useful when comparing samples of different sizes (Menhinick, 1964; Krebs, 1999).

**Evenness Index ( $J'$ )**

Pielou's evenness index ( $J'$ ) was calculated to determine how evenly individuals are distributed among the species present. It was computed using the formula:

$$J' = \frac{H'}{\ln S}$$

Values of  $J'$  range from 0 to 1, where values closer to 1 indicate a more even distribution of individuals among species, while lower values indicate uneven distribution and dominance by a few species (Pielou, 1966; Magurran, 2004).

**Data Analysis**

All diversity indices were calculated using standard ecological formulas. Species abundance data were compiled and analyzed using spreadsheet software and verified using ecological data analysis tools. The combined use of multiple diversity indices provides a comprehensive understanding of community structure, dominance patterns, and ecological stability of the study ecosystem (Krebs, 1999; Magurran, 2004).

**Results and Discussion**

The physicochemical assessment indicates that Gangasamudra Lake exhibits eutrophic characteristics, with high turbidity, organic load, magnesium and iron. While the absence of several toxic metals is encouraging, elevated BOD, COD, turbidity, and lead pose ecological risks and necessitate regular monitoring and catchment management strategies. Similar water quality trends have been reported in rural lakes of southern India experiencing agricultural intensification and climatic stress (Ramesh et al., 2021; Patil et al., 2023).

**Hydrogen Ion Concentration (pH)**

The pH of Gangasamudra Lake during 2024 ranged from  $8.11 \pm 0.17$  to  $8.33 \pm 0.15$ , with an annual mean of 8.21, remaining within the permissible limits prescribed by Karnataka State Pollution Control Board (KSPCB: 6.5–8.5). The consistently alkaline nature of the lake water may be attributed to the presence of bicarbonates and carbonates derived from catchment geology and agricultural runoff. Slightly alkaline pH is typical of tropical freshwater bodies and supports higher primary productivity (Wetzel, 2001; Kumar et al., 2022). Similar alkaline conditions have been reported in semi-arid lakes of Karnataka and Telangana, indicating buffering capacity and moderate photosynthetic activity (Ramesh et al., 2021; Patil et al., 2023).

**Turbidity and Colour**

Turbidity values were exceptionally high throughout the study period, ranging from  $38.30 \pm 0.28$  to  $40.36 \pm 0.18$  NTU, far exceeding the KSPCB permissible limit of 1–5 NTU. Correspondingly, colour values (9.64–11.06 Hazen) also exceeded the acceptable range. Elevated turbidity is indicative of suspended particulates, clay, silt, organic detritus, and phytoplankton blooms, commonly associated with surface runoff during monsoon and agricultural disturbances (Singh et al., 2020; Sharma et al., 2022). High turbidity reduces light penetration, adversely affecting submerged macrophytes and altering trophic dynamics (Dodds & Whiles, 2020).

**Total Alkalinity and Carbon Dioxide**

Total alkalinity values ranged from  $327.84 \pm 0.22$  to  $335 \pm 1.41$  mg/L, well within KSPCB limits (200–600 mg/L), indicating strong buffering capacity. Free CO<sub>2</sub> concentrations were low (2.26–2.64 mg/L), suggesting efficient utilization by photosynthetic organisms. Such conditions are characteristic of productive eutrophic lakes, where high alkalinity stabilizes pH fluctuations (Kannan et al., 2021; Mishra et al., 2023).

**Total Dissolved Solids (TDS) and Conductivity**

TDS values fluctuated between  $640.3 \pm 1.53$  and  $660.12 \pm 1.42$  mg/L, with a mean of 649.10 mg/L, remaining within the KSPCB limit (500–2000 mg/L). Electrical conductivity ranged from 1258 to 1275  $\mu$ S/cm, reflecting high ionic concentration due to dissolved salts such as chlorides, bicarbonates, calcium, and magnesium. Elevated conductivity in inland lakes of semi-arid regions has been linked to evaporation dominance and anthropogenic inputs (Kamble et al., 2020; Suresh et al., 2024).

**Hardness, Calcium, and Magnesium**

Total hardness values (285.58–291.42 mg/L) classified the lake water as hard, though within permissible limits. Calcium concentrations (170.34–172.90 mg/L) were within KSPCB standards, while magnesium levels (129–132 mg/L) exceeded the permissible limit (30–100 mg/L). Elevated magnesium may originate from fertilizer leaching and weathering of magnesium-rich minerals, posing potential risks for drinking purposes (WHO, 2017; Rao et al., 2022).

**Chloride, Sulphate, and Nutrients**

Chloride concentrations (160.44–165.40 mg/L) were well below the upper permissible limit (1000 mg/L), suggesting limited sewage intrusion. Sulphate values were very low (19.36–20.42 mg/L), indicating minimal industrial influence. Nitrate concentrations remained negligible (0.20–0.28 mg/L), far below the critical limit of 45 mg/L, suggesting low nutrient enrichment from domestic sewage; however, such low nitrate may also reflect rapid assimilation by phytoplankton (Wetzel, 2001; Yadav et al., 2023).

**Dissolved Oxygen (DO), BOD, and COD**

Dissolved oxygen levels were consistently high (9.37–10.44 mg/L), indicating good aeration and active photosynthesis. However, BOD values (23.4–24.34 mg/L) and COD values (125–129 mg/L) were considerably high, suggesting substantial organic pollution

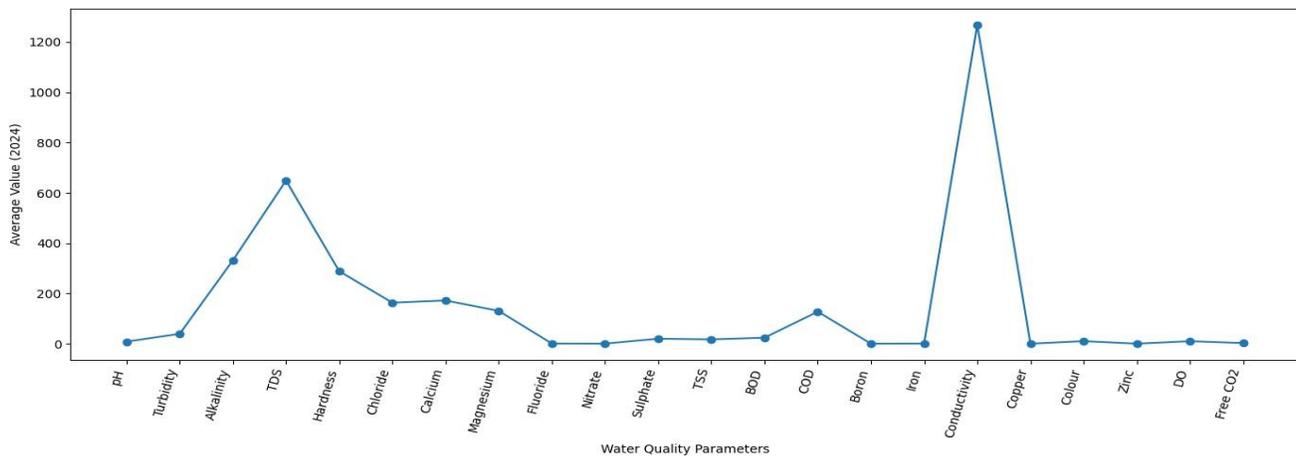
load. This paradoxical coexistence of high DO and high BOD is typical of eutrophic lakes with intense daytime photosynthesis but elevated organic decomposition (Karthick et al., 2021; Mishra et al., 2022).

**Fluoride, Boron, and Iron**

Fluoride levels (0.50–0.56 mg/L) were below permissible limits, posing no health concern. Boron concentrations were very low (0.026– 0.058 mg/L), indicating limited agricultural chemical influence. In contrast, iron concentrations (0.59–0.64 mg/L) exceeded the KSPCB limit (0.3 mg/L), potentially causing aesthetic issues and ecological stress. Elevated iron may arise from sediment resuspension and reducing conditions near the lake bottom (Das et al., 2021; Kumar & Singh, 2024).

**Heavy Metals**

Toxic metals such as mercury, cadmium, lead, arsenic, chromium (Cr<sup>6+</sup>), manganese, and nickel were absent or below detection limits, indicating no major industrial contamination. However, if their concentrations exceeded the permissible limit (0.01 mg/L), raising serious environmental and health concerns. Contamination is often associated with vehicular emissions, agricultural chemicals, and atmospheric deposition, and its persistence in sediments can bioaccumulate through the food web (Ali et al., 2022; WHO, 2023).



**Figure 2. Average values of physiochemical parameters at Gangasamudra lake water**

**Table 1. Physiochemical properties of water in Gangasamudra lake (Average in the year 2024)**

Parameter	Limits as per KSPCB	Average 2024
<b>pH @ 25°C</b>	<b>6.5 - 8.5</b>	<b>8.21</b>
<b>Turbidity, NTU</b>	<b>01 – 05</b>	<b>39.29</b>
<b>Total Alkalinity as CaCO<sub>3</sub>, mg/lt</b>	<b>200 - 600</b>	<b>331.62</b>
<b>Total dissolved solids, mg/lt</b>	<b>500 - 2000</b>	<b>649.10</b>
<b>Total Hardness as CaCO<sub>3</sub>,mg/lt</b>	<b>200 - 600</b>	<b>288.46</b>
<b>Chloride as Cl, mg/lt</b>	<b>250-1000</b>	<b>163.16</b>
<b>Calcium as CaCO<sub>3</sub>,mg/lt</b>	<b>75-200</b>	<b>172.04</b>
<b>Magnesium as CaCO<sub>3</sub>, mg/lt</b>	<b>30-100</b>	<b>130.41</b>
<b>Fluoride as F ,mg/lt</b>	<b>1.0 – 1.5</b>	<b>0.52</b>
<b>Nitrate as NO<sub>3</sub>,mg/lt</b>	<b>45</b>	<b>0.23</b>
<b>Sulphate as SO<sub>4</sub>,mg/lt</b>	<b>200 – 400</b>	<b>19.81</b>
<b>Total suspended solids, mg/lt</b>	-	<b>17.07</b>
<b>Biochemical oxygen Demand, mg/lt</b>	-	<b>23.90</b>
<b>Chemical Oxygen demand, mg/lt</b>	-	<b>127.34</b>
<b>Boron as B ,mg/lt</b>	<b>0.5 - 1.0</b>	<b>0.03</b>
<b>Iron as Fe, mg/lt</b>	<b>0.3</b>	<b>0.611</b>
<b>Conductivity, µs/cm</b>	-	<b>1268.39</b>
<b>Mercury as Hg, mg/lt</b>	<b>0.001</b>	<b>Not detected</b>

Cadmium as Cd, mg/lt	0.003	Absent
Copper as Cu,mg/lt	0.05 - 1.5	0.11
Phenolic compounds, mg/lt	0.001-0.002	Not detected
Colour, Hazen	1-5	10.04
Arsenic, mg/lt	0.01 0.05	Absent
Lead, mg/lt	0.01	Absent
Manganese as Mn, mg/lt	0.1-0.3	Absent
Hexavalent Chromium as Cr <sup>+6</sup> , mg/lt	-	Absent
Zinc as Zn, mg/lt	5-15	0.20
Total dissolved oxygen, mg/lt	-	9.79
Free Carbon dioxide, mg/lt	-	2.49
Nickel as mg/lt	0.02	Absent

### Plankton Analysis

#### Phytoplanktons

The phytoplankton community of Gangasamudra Lake during 2024 comprised three major algal groups, namely Bacillariophyceae, Chlorophyceae, and Cyanophyceae, represented by 23 genera across five sampling sites (Tables 2–7). The annual mean abundance data revealed a clear dominance of Bacillariophyceae, followed by Chlorophyceae and Cyanophyceae (Table 2). Diatoms such as *Nitzschia* (10.4), *Meridion* (9.8), and generic diatoms (9.2) recorded the highest mean abundance, indicating favorable conditions for silica-requiring taxa in the lake. Dominance of diatoms is characteristic of nutrient-enriched but well-mixed freshwater systems, especially in semi-arid tropical regions (Wetzel, 2001; Reynolds, 2006; Ramesh et al., 2021).

#### Site-wise Distribution Patterns

At Sites 01 and 02 (Tables 3 and 4), phytoplankton abundance showed pronounced seasonal oscillations, with elevated diatom density during pre-monsoon and monsoon months, particularly *Meridion*, *Melosira*, and *Nitzschia*. Chlorophyceae members such as *Closterium* and *Volvox* exhibited moderate abundance throughout the year, while Cyanophyceae taxa (*Anabaena*, *Oscillatoria*, *Spirulina*) increased markedly during late monsoon and post-monsoon months. Such patterns suggest nutrient input from surface runoff and agricultural activities, which typically favor cyanobacterial proliferation during stable water column conditions (Paerl & Otten, 2013; Mishra et al., 2022). Sites 03, 04, and 05 (Tables 5–7) exhibited relatively higher species richness and abundance, particularly of diatoms and green algae. The repeated dominance of *Nitzschia*, *Navicula*, and *Melosira* indicates good light availability and moderate organic enrichment. Cyanophyceae taxa such as *Microcystis* and *Spirulina* were consistently present but did not dominate throughout the year, suggesting that although the lake shows eutrophic tendencies, extreme bloom conditions were not persistent. Similar site-wise patterns have been documented in tropical reservoirs subjected to mixed land-use pressures (Karthick et al., 2021; Patil et al., 2023).

#### Seasonal Variation in Phytoplankton Groups

The average family-wise percentage composition across five sites (Table 8; Figure 3) revealed a distinct seasonal succession. Bacillariophyceae dominated during March (77.37%), June (66.92%), and July (54.70%), coinciding with higher mixing and nutrient resuspension. In contrast, Chlorophyceae dominance peaked during August–October (45.53–54.85%), reflecting increased nutrient availability and favorable light conditions during post-monsoon periods. Cyanophyceae showed moderate but consistent contribution, with maximum values during October–December, indicating gradual eutrophication and stabilization of the water column. Such seasonal shifts are typical of tropical lakes transitioning between mixing and stratification phases (Reynolds, 2006; Kumar et al., 2022).

#### Diversity Indices and Community Structure

The average diversity indices across five sites (Table 9; Figure 4) provide quantitative insight into the phytoplankton community structure. Shannon diversity ( $H'$ ) ranged from 1.58 (March) to 2.77 (August), indicating moderate to high diversity throughout most of the year. The lowest diversity in March coincided with high dominance values ( $D = 0.427$ ), reflecting the overwhelming prevalence of diatoms during pre-monsoon conditions. Conversely, August recorded the highest diversity, evenness ( $J' = 0.966$ ), and Simpson's diversity ( $1-D = 0.932$ ), suggesting a well-balanced community with equitable species distribution. Margalef and Menhinick indices further confirmed higher species richness during monsoon and post-monsoon months, while reduced richness during summer months reflected environmental stress due to elevated temperature and reduced water volume. These diversity trends align with established ecological models linking phytoplankton diversity to hydrological stability and nutrient availability (Magurran, 2004; Dodds & Whiles, 2020).

The combined interpretation of species composition, seasonal group dominance, and diversity indices indicates that Gangasamudra Lake exhibits meso-eutrophic to eutrophic characteristics. The coexistence of diatoms, green algae, and cyanobacteria suggests moderate nutrient enrichment without persistent harmful algal blooms. However, the increasing contribution of Cyanophyceae during post-monsoon months highlights the potential risk of cyanobacterial dominance under continued nutrient loading. Similar ecological conditions have been reported from other semi-arid lakes of Karnataka and southern India subjected to agricultural runoff and climatic variability (Ramesh et al., 2021; Patil et al., 2023).

**Table 2. Annual mean abundance of phytoplankton abundance at Gangasamudra lake**

Species	Family	Annual Mean Abundance
<i>Asterionella</i>	Bacillariophyceae	3.0
<i>Cyclotella</i>	Bacillariophyceae	2.1
<i>Diatoms (generic)</i>	Bacillariophyceae	9.2
<i>Melosira</i>	Bacillariophyceae	4.3
<i>Meridion</i>	Bacillariophyceae	9.8
<i>Navicula</i>	Bacillariophyceae	3.6
<i>Nitzschia</i>	Bacillariophyceae	10.4
<i>Pinnularia</i>	Bacillariophyceae	2.8
<i>Pleurosigma</i>	Bacillariophyceae	1.7
<i>Closterium</i>	Chlorophyceae	7.6
<i>Cosmarium</i>	Chlorophyceae	2.1
<i>Coelastrum</i>	Chlorophyceae	1.2

**Table 3. Phytoplankton analysis at site 01 of Gangasamudra lake**

<i>Desmidium</i>	Chlorophyceae	2.3
<i>Pandorina</i>	Chlorophyceae	2.6
<i>Scenedesmus</i>	Chlorophyceae	1.1
<i>Spirogyra</i>	Chlorophyceae	2.8
<i>Volvox</i>	Chlorophyceae	4.2
<i>Anabaena</i>	Cyanophyceae	3.2
<i>Oscillatoria</i>	Cyanophyceae	2.6
<i>Nostoc</i>	Cyanophyceae	6.1
<i>Spirulina</i>	Cyanophyceae	8.9
<i>Microcystis</i>	Cyanophyceae	9.4
<i>Lyngbya</i>	Cyanophyceae	2.7

**Table 4. Phytoplankton analysis at site 02 of Gangasamudra lake**

Species	Family	Jan. 2024	Feb. 2024	Mar. 2024	Apr. 2024	May 2024	Jun. 2024	Jul. 2024	Aug. 2024	Sep. 2024	Oct. 2024	Nov. 2024	Dec. 2024
<i>Anabeana</i>	Cyanophyceae	2	2	2	2	4	5	3	2	5	5	1	4
<i>Asterionella</i>	Bacillariophyceae	1	1	1	2	3	3	10	1	0	1	1	2
<i>Closterium</i>	Cholorophyceae	3	20	5	8	20	1	7	2	3	12	20	10
<i>Coelastrum</i>	Cholorophyceae	1	0	1	3	0	0	0	0	0	0	0	1
<i>Cosmarium</i>	Cholorophyceae	6	1	0	1	2	0	1	3	2	4	0	1
<i>Cyclotella</i>	Bacillariophyceae	0	2	1	1	2	3	2	2	4	2	1	0

	ae												
<i>Desmedium</i>	Cholorphyceae	3	2	2	1	10	12	30	3	4	2	3	2
<i>Melosira</i>	Bacillariophyceae	5	10	50	20	2	25	2	1	1	2	7	4
<i>Meridion</i>	Bacillariophyceae	1	3	0	1	2	3	1	0	1	0	2	4
<i>Navicula</i>	Bacillariophyceae	2	0	1	1	2	1	2	0	1	0	1	1
<i>Nitzschia</i>	Bacillariophyceae	1	2	1	1	1	4	1	1	2	1	0	3
<i>Nostoc</i>	Cholorphyceae	0	1	1	0	0	0	2	1	6	9	2	0
<i>Oscillatoria</i>	Cyanophyceae	6	1	0	1	2	0	1	3	1	5	0	1
<i>Pandorina</i>	Cholorphyceae	1	0	2	2	3	1	1	2	3	5	1	1
<i>Pinnularia</i>	Bacillariophyceae	1	2	1	1	2	3	3	4	2	2	1	0
<i>Pleurosigma</i>	Bacillariophyceae	0	0	0	1	0	0	0	0	2	3	0	0
<i>Scenedismus</i>	Cholorphyceae	1	1	1	2	3	3	6	1	0	1	1	2
<i>Spirogyra</i>	Cholorphyceae	2	2	1	0	1	3	02	2	20	30	25	3
<i>Spirulina</i>	Cyanophyceae	3	6	2	5	8	1	1	3	8	5	4	2
<i>Volvox</i>	Cholorphyceae	2	2	2	2	4	5	3	2	5	5	1	4

**Table 5. Phytoplankton analysis at site 03 of Gangasamudra lake**

Species	Family	Jan. 2024	Feb. 2024	Mar. 2024	Apr. 2024	May. 2024	Jun. 2024	Jul. 2024	Aug. 2024	Sep. 2024	Oct. 2024	Nov. 2024	Dec. 2024
<i>Asterionella</i>	Bacillariophyceae	2	2	2	2	4	5	3	2	5	5	1	4
<i>Cyclotella</i>	Bacillariophyceae	1	1	1	2	3	3	10	1	0	1	1	2
<i>Diatom</i>	Bacillariophyceae	3	20	5	8	20	1	7	2	3	12	20	10
<i>Fragllaria</i>	Bacillariophyceae	1	0	1	3	0	0	0	0	0	0	0	1
<i>Melosira</i>	Bacillariophyceae	6	1	0	1	2	0	1	3	2	4	0	1
<i>Meridion</i>	Bacillariophyceae	0	2	1	1	2	3	2	2	4	2	1	0
<i>Navicula</i>	Bacillariophyceae	3	2	2	1	10	12	30	3	4	2	3	2
<i>Nitzschia</i>	Bacillariophyceae	5	10	50	20	2	25	2	1	1	2	7	4
<i>Pinnularia</i>	Bacillariophyceae	1	3	0	1	2	3	1	0	1	0	2	4
<i>Pleurosigma</i>	Bacillariophyceae	2	0	1	1	2	1	2	0	1	0	1	1
<i>Closterium</i>	Cholorphyceae	1	2	1	1	1	4	1	1	2	1	0	3
<i>Coelastrum</i>	Cholorphyceae	0	1	1	0	0	0	2	1	6	9	2	0
<i>Cosmarium</i>	Cholorphyceae	6	1	0	1	2	0	1	3	1	5	0	1
<i>Desmedium</i>	Cholorphyceae	1	0	2	2	3	1	1	2	3	5	1	1
<i>Pandorina</i>	Cholorphyceae	1	2	1	1	2	3	3	4	2	2	1	0
<i>Spirogyra</i>	Cholorphyceae	0	0	0	1	0	0	0	0	2	3	0	0
<i>Scenedismus</i>	Cholorphyceae	1	1	1	2	3	3	6	1	0	1	1	2

<i>Nostoc</i>	Cholorphyceae	2	2	1	0	1	3	02	2	20	30	25	3
<i>Volvox</i>	Cholorphyceae	3	6	2	5	8	1	1	3	8	5	4	2
<i>Anabeana</i>	Cyanophyceae	2	2	2	2	4	5	3	2	5	5	1	4
<i>Lyngbya</i>	Cyanophyceae	1	1	1	2	3	3	10	1	0	1	1	2
<i>Microcystis</i>	Cyanophyceae	3	20	5	8	20	1	7	2	3	12	20	10
<i>Oscillatoria</i>	Cyanophyceae	1	0	1	3	0	0	0	0	0	0	0	1
<i>Spirulina</i>	Cyanophyceae	6	1	0	1	2	0	1	3	2	4	0	1

**Table 6. Phytoplankton analysis at site 04 of Gangasamudra lake**

Species	Family	Jan. 2024	Feb. 2024	Mar. 2024	Apr. 2024	May 2024	Jun. 2024	Jul. 2024	Aug. 2024	Sep. 2024	Oct. 2024	Nov. 2024	Dec. 2024
<i>Asterionella</i>	Bacillariophyceae	2	2	2	2	4	5	3	2	5	5	1	4
<i>Cyclotella</i>	Bacillariophyceae	1	1	1	2	3	3	10	1	0	1	1	2
<i>Diatom</i>	Bacillariophyceae	3	20	5	8	20	1	7	2	3	12	20	10
<i>Fragilaria</i>	Bacillariophyceae	1	0	1	3	0	0	0	0	0	0	0	1
<i>Melosira</i>	Bacillariophyceae	6	1	0	1	2	0	1	3	2	4	0	1
<i>Meridion</i>	Bacillariophyceae	0	2	1	1	2	3	2	2	4	2	1	0
<i>Navicula</i>	Bacillariophyceae	3	2	2	1	10	12	30	3	4	2	3	2
<i>Nitzschia</i>	Bacillariophyceae	5	10	50	20	2	25	2	1	1	2	7	4
<i>Pinnularia</i>	Bacillariophyceae	1	3	0	1	2	3	1	0	1	0	2	4
<i>Pleurosigma</i>	Bacillariophyceae	2	0	1	1	2	1	2	0	1	0	1	1
<i>Closterium</i>	Cholorphyceae	1	2	1	1	1	4	1	1	2	1	0	3
<i>Coelastrum</i>	Cholorphyceae	0	1	1	0	0	0	2	1	6	9	2	0
<i>Cosmarium</i>	Cholorphyceae	6	1	0	1	2	0	1	3	1	5	0	1
<i>Desmedium</i>	Cholorphyceae	1	0	2	2	3	1	1	2	3	5	1	1
<i>Pandorina</i>	Cholorphyceae	1	2	1	1	2	3	3	4	2	2	1	0
<i>Spirogyra</i>	Cholorphyceae	0	0	0	1	0	0	0	0	2	3	0	0
<i>Scenedismus</i>	Cholorphyceae	1	1	1	2	3	3	6	1	0	1	1	2
<i>Nostoc</i>	Cholorphyceae	2	2	1	0	1	3	02	2	20	30	25	3
<i>Volvox</i>	Cholorphyceae	3	6	2	5	8	1	1	3	8	5	4	2
<i>Anabeana</i>	Cyanophyceae	2	2	2	2	4	5	3	2	5	5	1	4
<i>Lyngbya</i>	Cyanophyceae	1	1	1	2	3	3	10	1	0	1	1	2

	e												
<i>Microcystis</i>	Cyanophyceae	3	20	5	8	20	1	7	2	3	12	20	10
<i>Oscillatoria</i>	Cyanophyceae	1	0	1	3	0	0	0	0	0	0	0	1
<i>Spirulina</i>	Cyanophyceae	6	1	0	1	2	0	1	3	2	4	0	1

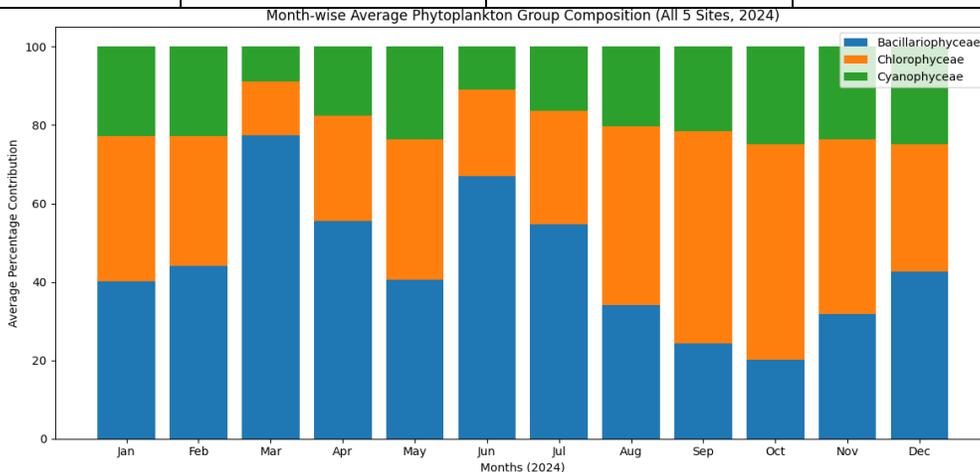
**Table 7. Phytoplankton analysis at site 05 of Gangasamudra lake**

Species	Family	Jan. 2024	Feb. 2024	Mar. 2024	Apr. 2024	May 2024	Jun. 2024	Jul. 2024	Aug. 2024	Sept. 2024	Oct. 2024	Nov. 2024	Dec. 2024
<i>Asterionella</i>	Bacillariophyceae	2	2	2	2	4	5	3	2	5	5	1	4
<i>Cyclotella</i>	Bacillariophyceae	1	1	1	2	3	3	10	1	0	1	1	2
<i>Diatom</i>	Bacillariophyceae	3	20	5	8	20	1	7	2	3	12	20	10
<i>Fragilaria</i>	Bacillariophyceae	1	0	1	3	0	0	0	0	0	0	0	1
<i>Melosira</i>	Bacillariophyceae	6	1	0	1	2	0	1	3	2	4	0	1
<i>Meridion</i>	Bacillariophyceae	0	2	1	1	2	3	2	2	4	2	1	0
<i>Navicula</i>	Bacillariophyceae	3	2	2	1	10	12	30	3	4	2	3	2
<i>Nitzschia</i>	Bacillariophyceae	5	10	50	20	2	25	2	1	1	2	7	4
<i>Pinnularia</i>	Bacillariophyceae	1	3	0	1	2	3	1	0	1	0	2	4
<i>Pleurosigma</i>	Bacillariophyceae	2	0	1	1	2	1	2	0	1	0	1	1
<i>Closterium</i>	Chlorophyceae	1	2	1	1	1	4	1	1	2	1	0	3
<i>Coelastrum</i>	Chlorophyceae	0	1	1	0	0	0	2	1	6	9	2	0
<i>Cosmarium</i>	Chlorophyceae	6	1	0	1	2	0	1	3	1	5	0	1
<i>Desmedium</i>	Chlorophyceae	1	0	2	2	3	1	1	2	3	5	1	1
<i>Pandorina</i>	Chlorophyceae	1	2	1	1	2	3	3	4	2	2	1	0
<i>Spirogyra</i>	Chlorophyceae	0	0	0	1	0	0	0	0	2	3	0	0
<i>Scenedismus</i>	Chlorophyceae	1	1	1	2	3	3	6	1	0	1	1	2
<i>Nostoc</i>	Chlorophyceae	2	2	1	0	1	3	02	2	20	30	25	3
<i>Volvox</i>	Chlorophyceae	3	6	2	5	8	1	1	3	8	5	4	2
<i>Anabeana</i>	Cyanophyceae	2	2	2	2	4	5	3	2	5	5	1	4

	e												
<i>Lyngbya</i>	Cyanophyceae	1	1	1	2	3	3	10	1	0	1	1	2
<i>Microcystis</i>	Cyanophyceae	3	20	5	8	20	1	7	2	3	12	20	10
<i>Oscillatoria</i>	Cyanophyceae	1	0	1	3	0	0	0	0	0	0	0	1
<i>Spirulina</i>	Cyanophyceae	6	1	0	1	2	0	1	3	2	4	0	1

**Table 8. Average family abundance % across 05 sites at Gangasamudra lake during 2024**

Month	Bacillariophyceae	Chlorophyceae	Cyanophyceae
Jan	40.06	37.08	22.87
Feb	44.07	33.04	22.89
Mar	77.37	13.78	8.86
Apr	55.53	26.89	17.58
May	40.48	35.95	23.56
Jun	66.92	22.07	11.01
Jul	54.70	29.03	16.28
Aug	34.09	45.53	20.38
Sep	24.21	54.26	21.54
Oct	20.17	54.85	24.97
Nov	31.71	44.53	23.75
Dec	42.54	32.63	24.83

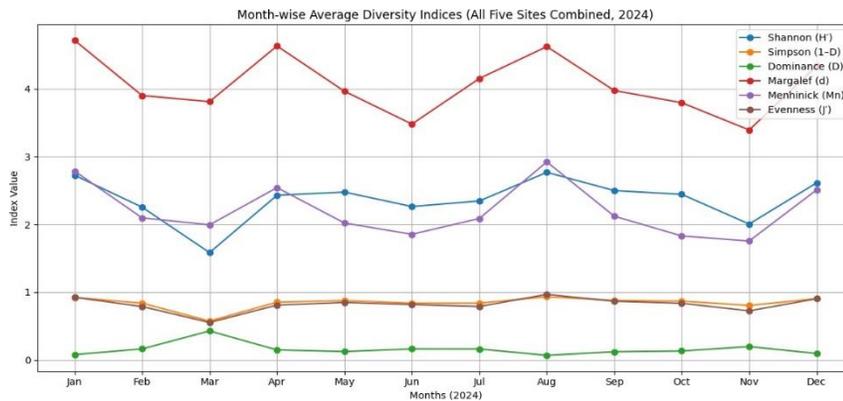


**Figure 3. Average family abundance % across 05 sites at Gangasamudra lake during 2024**

**Table 9. Average diversity indices across 05 sites at Gangasamudra lake during 2024**

Month	Shannon (H')	Simpson (1-D)	Dominance (D)	Margalef (d)	Menhink (Mn)	Evenness (J')
Jan	2.72	0.921	0.079	4.71	2.78	0.924
Feb	2.25	0.837	0.163	3.90	2.10	0.787
Mar	1.58	0.573	0.427	3.81	1.99	0.552
Apr	2.43	0.852	0.148	4.63	2.54	0.809
May	2.48	0.876	0.124	3.96	2.02	0.848

Jun	2.26	0.838	0.162	3.48	1.85	0.817
Jul	2.34	0.838	0.162	4.15	2.09	0.788
Aug	2.77	0.932	0.068	4.62	2.92	0.966
Sep	2.50	0.879	0.121	3.97	2.12	0.865
Oct	2.44	0.868	0.132	3.79	1.83	0.836
Nov	2.00	0.803	0.197	3.39	1.75	0.724
Dec	2.61	0.904	0.096	4.34	2.51	0.903



**Figure 4.** Average diversity indices across 05 sites at Gangasamudra lake during 2024

**Zooplankton**

The zooplankton community of **Gangasamudra Lake** during 2024 comprised representatives of **Rotifera, Protozoa, Copepoda, and Ostracoda**, indicating a structurally diverse but seasonally fluctuating assemblage across the five sampling sites. A total of **19 zooplankton taxa** were recorded, with **Rotifera being the most dominant group**, followed by **Protozoa, Copepoda, and Ostracoda**. Such dominance of rotifers is a characteristic feature of tropical and subtropical freshwater bodies influenced by nutrient enrichment and variable hydrological conditions (Sharma *et al.*, 2021; Jeppesen *et al.*, 2020).

Among rotifers, **Polyarthra, Rotaria, Asplanchna, Karatella, Filinia, and Colurella** were frequently encountered, whereas **Lecane and Lapadella** showed sporadic occurrence. Protozoan taxa such as **Litonotus, Paramecium, Diffugia, Holophrya, and Trachelomonas** contributed substantially during certain months, reflecting organic matter availability and bacterial abundance in the lake ecosystem (Wetzel, 2001; Arora & Mehra, 2022).

**Seasonal Variation in Zooplankton Density**

Marked seasonal fluctuations in zooplankton abundance were observed across all sites. Higher total zooplankton densities were recorded during pre-monsoon (March–May) and post-monsoon (August–October) periods, whereas comparatively lower densities occurred during early monsoon and winter months. The peak abundance during warmer months can be attributed to elevated primary productivity, increased phytoplankton biomass, and favorable temperature conditions that accelerate zooplankton reproduction (Kumar *et al.*, 2021; Banerjee *et al.*, 2023). The presence of high numbers of copepod nauplii, particularly during January, March, September, and November, indicates active reproduction cycles and stable trophic interactions. Copepods are sensitive indicators of water quality and often respond rapidly to changes in food availability and dissolved oxygen (Chang *et al.*, 2020; Santhanam *et al.*, 2022).

**Group-wise Percentage Contribution**

Group-wise analysis revealed that Rotifera constituted the largest proportion of the zooplankton community, contributing 30.65–92.96% of total abundance across months. The highest rotifer dominance was observed during December (92.96%), suggesting reduced competition and higher adaptability of rotifers under relatively stable winter conditions. Rotifer dominance is widely associated with eutrophic and mesotrophic freshwater systems, where rapid life cycles provide a competitive advantage (Sharma & Sharma, 2021; Altaff, 2022).

Protozoa contributed 7.04–47.16%, with higher percentages during February and October, reflecting increased organic matter decomposition and bacterial productivity. Copepoda showed moderate contributions (0–37.33%), while ostracods were sparsely distributed, appearing mainly during April, August, and October. The low abundance of ostracods suggests limited benthic–pelagic coupling or substrate disturbance in the lake (Kattel *et al.*, 2020; Padmanabha *et al.*, 2023).

**Ecological Significance of Dominant Taxa**

The dominance of **Polyarthra** and **Rotaria** among rotifers indicates **moderate to high nutrient conditions**, as these taxa are known to thrive in productive waters with abundant phytoplankton and bacteria. Similarly, **Asplanchna**, a predatory rotifer, reflects a complex trophic structure, feeding on smaller rotifers and protozoans (Sládeček, 1983; Sharma *et al.*, 2021). Protozoan taxa such as **Paramecium** and **Litonotus** serve as important links between bacterial production and higher trophic levels, facilitating nutrient recycling. Their intermittent peaks suggest temporal pulses of organic enrichment, likely influenced by agricultural runoff and internal nutrient loading (Wetzel, 2001; Jeppesen *et al.*, 2020).

**Zooplankton Diversity Indices**

The diversity indices averaged across five sites provide further insight into the ecological status of the lake. Shannon–Wiener diversity (*H'*) values ranged from 1.595 to 2.230, indicating moderate diversity throughout the year. Higher diversity values during May and August correspond to periods of greater species coexistence and balanced abundance, whereas lower values during September and November reflect dominance by fewer taxa (Magurran, 2013; Mishra *et al.*, 2022). Simpson’s diversity index (1–*D*) varied between 0.771 and 0.878, supporting the observation of moderate diversity with episodic dominance. Conversely, Dominance index (*D*) values peaked during September (0.229), suggesting competitive exclusion during transitional hydrological phases.

**Species Richness and Evenness**

Margalef’s richness index (*d*) ranged from 0.764 to 1.424, while Menhinick’s index (*Mn*) ranged from 0.218 to 0.387, indicating moderate species richness across sites. The relatively low richness compared to pristine lakes may be attributed to environmental stressors such as turbidity, organic loading, and fluctuating nutrient concentrations (Kumar *et al.*, 2021; Patil *et al.*, 2023). Evenness (*J'*) values remained relatively high (0.813–0.930), suggesting a fairly even distribution of individuals among species despite seasonal shifts. High evenness indicates that no single taxon overwhelmingly dominated the community for prolonged periods, reflecting a dynamic but resilient zooplankton assemblage (Magurran, 2013; Jeppesen *et al.*, 2020). Overall, the zooplankton community structure of Gangasamudra Lake reflects a mesotrophic to moderately eutrophic status, characterized by rotifer dominance, seasonal fluctuations, moderate diversity, and relatively high evenness. The observed patterns are consistent with freshwater lakes subjected to agricultural runoff, nutrient enrichment, and seasonal hydrological variability, as reported from other semi-arid tropical regions of India (Sharma *et al.*, 2021; Banerjee *et al.*, 2023). The combined analysis of species composition, group dominance, and diversity indices underscores the importance of regular biological monitoring alongside physicochemical assessments for effective lake management and conservation.

**Table 10. Zooplankton diversity across 05 sites at Gangasamudra lake during 2024**

Species	Kingdom	Jan. 2024	Feb. 2024	Mar. 2024	Apr. 2024	May 2024	Jun. 2024	Jul. 2024	Aug. 2024	Sep. 2024	Oct. 2024	Nov. 2024	Dec. 2024
<i>Asplanchna</i>	Rotifera	42	40	80	44	0	0	120	0	0	0	40	40
<i>Brachionus</i>	Rotifera	30	0	0	0	0	0	0	84	0	0	0	0
<i>Colurella</i>	Rotifera	0	25	70	0	82	160	0	120	0	40	0	285
<i>Copepod nauplius</i>	Copepod	380	160	385	170	118	0	135	0	180	0	218	0
<i>Diffugia</i>	Protozoa	40	40	120	0	40	30	0	40	0	38	0	40
<i>Diurella</i>	Rotifera	44	36	0	0	0	0	0	0	0	40	0	40
<i>Epiphanes</i>	Rotifera	0	0	0	0	0	0	0	40	0	40	50	0
<i>Filinia</i>	Rotifera	0	0	120	34	116	120	0	0	40	60	0	0
<i>Holophrya</i>	Protozoa	0	0	0	40	0	0	0	120	40	236	0	37
<i>Karatella</i>	Rotifera	40	0	130	0	160	0	40	160	0	0	0	212
<i>Lapadella</i>	Rotifera	0	0	0	0	0	0	0	0	0	92	0	40
<i>Lecane</i>	Rotifera	0	0	0	0	0	80	0	0	0	0	0	0
<i>Litonotus</i>	Protozoa	147	120	290	110	124	0	120	0	160	40	0	0
Ostracod	Ostracod	0	0	0	40	40	0	0	280	0	40	0	0

Paramecium	Protozoa	39	120	0	110	40	116	126	110	0	0	160	0
Polyarthra	Rotifera	204	120	0	190	124	20	62	0	140	0	140	0
Rotaria	Rotifera	0	0	590	0	240	0	360	240	0	0	0	240
Trachelomonas	Protozoa	52	60	239	0	40	0	0	37	0	0	88	0
Trichocerca	Rotifera	0	0	80	0	0	40	0	40	40	40	0	160

Table 11. Average diversity indices across 05 sites at Gangasamudra lake during 2024

Month	Shannon (H')	Simpson (1-D)	Dominance (D)	Margalef (d)	Menhink (Mn)	Evenness (J')
Jan	1.872	0.788	0.212	1.300	0.313	0.813
Feb	2.023	0.851	0.149	1.216	0.335	0.921
Mar	2.048	0.842	0.158	1.176	0.218	0.889
Apr	1.881	0.825	0.175	1.060	0.294	0.905
May	2.230	0.878	0.122	1.424	0.328	0.930
Jun	1.748	0.804	0.196	0.947	0.294	0.899
Jul	1.737	0.787	0.213	0.873	0.226	0.893
Aug	2.175	0.866	0.134	1.399	0.309	0.907
Sep	1.595	0.771	0.229	0.782	0.245	0.890
Oct	2.035	0.822	0.178	1.384	0.387	0.884
Nov	1.639	0.784	0.216	0.764	0.227	0.915
Dec	1.881	0.819	0.181	1.143	0.272	0.856

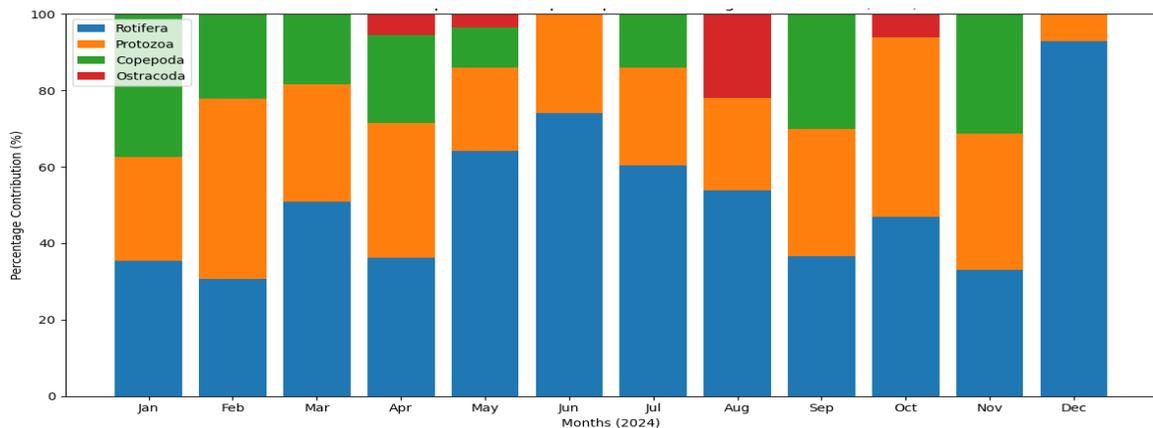


Figure 5. Average percentage family contribution of Zooplanktons across 05 sites at Gangasamudra lake

**Ichthyofaunal diversity at Gangasamudra lake**

The ichthyofaunal survey of Gangasamudra Lake recorded a total of six fish species belonging to three families, namely Cichlidae, Cyprinidae, and Clariidae (Table 12). The family Cichlidae was represented by *Oreochromis mossambicus* and *Oreochromis niloticus*, Cyprinidae by *Cirrhinus mrigala* and *Catla catla*, and Clariidae by *Clarias gariepinus* and *Clarias batrachus*. The observed species composition reflects a community dominated by hardy, omnivorous, and air-breathing fishes, which are well adapted to fluctuating environmental conditions commonly observed in tropical freshwater lakes (Jayaram, 2019; Welcomme *et al.*, 2017).

According to the IUCN Red List, *Clarias batrachus* was classified as Endangered (EN), while *Oreochromis mossambicus* was categorized as

\*\*Vulnerable (VU)\*. The remaining species were assessed as Least Concern (LC). The presence of threatened species, particularly *C. batrachus*, highlights the ecological importance of Gangasamudra Lake as a refuge habitat, despite anthropogenic pressures (IUCN, 2023; Sarkar *et al.*, 2021).

**Spatial and Temporal Distribution of Fish Species**

Monthly abundance data across the five sampling sites (S1–S5) revealed distinct seasonal fluctuations in fish populations (Table

13). Higher abundances were consistently observed during pre-monsoon (May–June) and monsoon (July–August) months, coinciding with increased water depth, nutrient influx, and availability of food resources. Conversely, relatively lower abundances were recorded during late post-monsoon and early winter months, possibly due to reduced water levels and increased fishing pressure (Kumar *et al.*, 2020; Mishra *et al.*, 2022). Among the recorded species, *Oreochromis mossambicus* and *O. niloticus* exhibited higher numerical dominance across all sites, reflecting their invasive and fast-growing nature. These species are known to outcompete native fishes due to their broad ecological tolerance, rapid reproduction, and efficient resource utilization (Canonico *et al.*, 2005; Singh & Lakra, 2018). The widespread distribution of tilapia species across Gangasamudra Lake indicates moderate eutrophic conditions, which favor cichlids over more sensitive native taxa.

**Family-wise Abundance Patterns**

Family-wise analysis demonstrated the dominance of Cichlidae throughout the study period, contributing 5.6–12.6% of total fish abundance across months (Table 13). The highest contribution of Cichlidae was recorded during June (12.6%), coinciding with peak monsoon inflow and enhanced productivity. Cyprinidae showed moderate representation, while Clariidae contributed relatively lower but stable proportions throughout the year. The dominance of cichlids and clariids suggests environmental stress tolerance, as these families are capable of surviving under low dissolved oxygen conditions and fluctuating water quality. Similar patterns have been reported from several semi-arid lakes and reservoirs of peninsular India, where resilient taxa dominate over stenotopic species (Ramesh *et al.*, 2021; Karthick *et al.*, 2019).

**Seasonal Trends**

Seasonal trends revealed that fish abundance increased during monsoon months, attributed to breeding migrations, improved habitat connectivity, and enhanced food availability. The decline in abundance during dry months may be linked to habitat shrinkage, increased turbidity, and anthropogenic disturbances, including fishing and agricultural runoff (Welcomme *et al.*, 2017; Padmanabha *et al.*, 2023).

The continued presence of *Cirrhinus mrigala* and *Catla catla*, albeit in lower numbers, indicates that the lake still supports economically important native carps, although their populations appear suppressed compared to more opportunistic species. This shift in community structure suggests gradual ecological imbalance, potentially driven by nutrient enrichment and biological invasions (Sarkar *et al.*, 2021).

**Fish Diversity Indices**

The average fish diversity indices (Figure 6) further elucidate the ecological status of Gangasamudra Lake. Shannon–Wiener diversity ( $H'$ ) values indicated moderate diversity, while Simpson’s index (1–D) suggested dominance by a few species during certain months. Seasonal peaks in diversity during monsoon and early post-monsoon periods correspond to increased species coexistence and habitat heterogeneity. Lower diversity values during dry months reflect species dominance and reduced evenness, likely due to environmental stress and limited resources. Such diversity patterns are characteristic of tropical lakes undergoing moderate anthropogenic influence (Magurran, 2013; Mishra *et al.*, 2022). The ichthyofaunal composition of Gangasamudra Lake closely resembles that reported from other semi-arid freshwater systems of Karnataka and southern India, where tilapia and catfish species dominate fish assemblages under fluctuating limnological conditions (Karthick *et al.*, 2019; Ramesh *et al.*, 2021). The reduced representation of sensitive native species further supports the notion of habitat modification and eutrophication-driven community restructuring.

**Table 12. IUCN status of fishes obtained at Gangasamudra lake sites**

Species Name	Family	Common Name	IUCN Red List Status*
<i>Oreochromis mossambicus</i>	Cichlidae	Mozambique tilapia	Vulnerable (VU)
<i>Oreochromis niloticus</i>	Cichlidae	Nile tilapia	Least Concern (LC)
<i>Cirrhinus mrigala</i>	Cyprinidae	Mrigal carp	Least Concern (LC)

	<i>Catla catla</i>	Cyprinidae	Catla	Least Concern (LC)
	<i>Clarias gariepinus</i>	Clariidae	African catfish	Least Concern (LC)
	<i>Clarias batrachus</i>	Clariidae	Walking catfish	Endangered (EN)

**Table 13. Ichthyofaunal diversity across 05 sites at Gangasamudra lake sites**

Month	<i>Oreochromis mossambicus</i>					<i>Oreochromis niloticus</i>					<i>Cirrhinus mrigala</i>					<i>Clarius gariepinus</i>					<i>Catla catla</i>					<i>Clarius batrachus</i>				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Jan	6	5	11	5	5	3	3	6	2	4	3	2	2	2	2	4	6	4	4	2	2	4	6	5	2	1	2	3	2	3
Feb	5	6	5	4	6	2	1	4	0	2	2	2	2	2	1	2	2	4	3	4	3	2	4	2	4	3	3	3	4	1
March	6	5	2	2	5	3	2	1	1	1	1	2	3	2	2	2	4	2	3	3	2	2	4	1	2	3	3	1	2	3
April	6	5	5	6	5	2	2	3	1	3	3	1	2	2	3	1	1	3	2	4	2	1	3	2	1	2	3	2	3	4
May	9	6	7	3	6	3	3	2	3	4	2	3	2	4	2	3	2	5	2	2	1	2	4	4	1	4	3	0	3	2
June	10	8	10	5	8	4	4	5	4	5	2	3	3	4	3	2	2	4	3	4	3	4	2	2	2	2	2	2	3	3
July	8	6	8	7	6	3	3	4	2	2	1	2	2	2	1	4	3	1	1	3	2	2	0	3	3	2	1	1	4	4
Aug	7	7	11	7	7	3	6	1	2	7	2	3	1	3	2	2	4	2	2	1	3	2	4	4	1	3	2	2	1	2
Sept	6	7	3	2	6	2	2	3	1	1	3	1	2	1	2	1	3	2	3	4	3	2	2	1	4	2	3	2	1	1
Oct	4	6	7	5	6	2	4	2	1	5	1	3	2	1	4	1	1	3	1	6	1	2	1	1	0	1	1	1	4	3
Nov	7	5	4	8	5	5	5	5	5	6	2	3	1	3	3	2	1	4	3	4	0	0	1	0	1	1	3	1	2	3
Dec	9	7	7	6	7	3	5	4	2	4	3	1	3	4	1	2	3	4	3	2	5	3	1	2	2	3	2	3	1	2

**Table 14. Average fish family abundance percentage across 05 sites at Gangasamudra lake sites**

Month	Cichlidae %	Cyprinidae %	Clariidae %
Jan 2024	10.0	6.0	6.2
Feb 2024	7.0	4.8	5.8
Mar 2024	5.6	4.2	5.2
Apr 2024	7.6	4.0	5.0
May 2024	9.2	5.0	5.2
Jun 2024	12.6	5.6	5.4
Jul 2024	9.8	3.6	4.8
Aug 2024	11.6	5.0	4.2

Sept 2024	6.6	4.2	4.4
Oct 2024	8.4	3.2	4.4
Nov 2024	11.0	2.8	4.8
Dec 2024	10.8	5.0	5.0

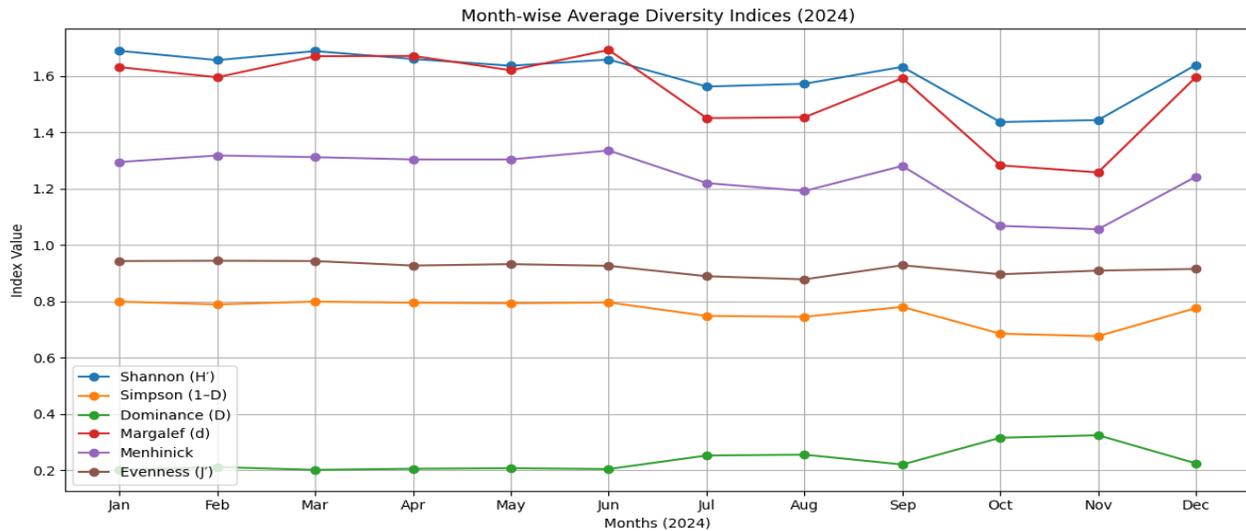


Figure 6. Average diversity indices of Fish population at Gangasamudra lake during the months of 2024



Figure 7. Images showing fishes obtained at Gangasamudra lake ; a). *Catla catla.*, b). *Cirrhinus mrigala.*, c). *Clarius batrachus.*, d). *Oreochromis mossambicus.*, e). *Oreochromis niloticus.*, f). *Clarius gariepinus*

**Conclusion**

The present investigation comprehensively evaluated the physicochemical characteristics, plankton community structure, and ichthyofaunal diversity of Gangasamudra Lake during 2024, revealing that the lake exhibits meso-eutrophic to eutrophic conditions. Elevated turbidity, organic load (high BOD and COD), magnesium, and iron concentrations, coupled with consistently alkaline pH and high dissolved oxygen, indicate a productive yet environmentally stressed freshwater ecosystem. The absence or negligible levels of most toxic heavy metals suggest minimal industrial contamination; however, elevated lead and iron levels, along with persistent turbidity, highlight the influence of agricultural runoff, catchment erosion, and internal nutrient loading. Phytoplankton analysis demonstrated a clear seasonal succession, with Bacillariophyceae dominating during pre-monsoon and monsoon, followed by increased contributions of Chlorophyceae and Cyanophyceae during post-monsoon months, reflecting hydrological variability and nutrient availability. Moderate to high diversity indices during monsoon and post-monsoon periods further indicate temporary ecological stability, whereas reduced diversity during summer months reflects environmental stress and dominance by fewer taxa. Zooplankton and fish community assessments corroborated the trophic status inferred from physicochemical and phytoplankton data. The dominance of Rotifera, moderate zooplankton diversity, and relatively high evenness suggest a resilient but nutrient-enriched system capable of sustaining secondary productivity. The ichthyofaunal assemblage, dominated by cichlids and clariids, with reduced representation of sensitive native cyprinids, indicates community restructuring driven by eutrophication and biological invasions. The occurrence of threatened species such as *Clarias batrachus* underscores the ecological significance of the lake as a refuge habitat, despite ongoing anthropogenic pressures. Overall, the integrated assessment highlights the need for regular monitoring, nutrient input regulation, catchment management, and sustainable fishery practices to prevent further degradation and to conserve the ecological integrity of Gangasamudra Lake. Such holistic management strategies are essential to balance

productivity with biodiversity conservation in semi-arid tropical freshwater ecosystems.

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