***Original Research Article***

**Assessment of physico-chemical parameters and zooplankton diversity in the Panjapur Lake, Tiruchirappalli, Tamil Nadu, South India.**

**Abstract:**

The biological resources and water quality of freshwater lakes, particularly zooplankton communities, are significantly affected by anthropogenic activity. This study examined zooplankton biodiversity and hydrobiological features of the perennial Panjapur Lake in the Tiruchirappalli area of Tamil Nadu, India. Eight distinct seasons (summer, pre-monsoon, monsoon, and post-monsoon) were studied monthly for two years, from March 2022 to February 2024, to assess seasonal variations in physicochemical characteristics, species composition, and zooplankton biodiversity. The 41 zooplankton species identified were Rotifera, Cladocera, Copepoda, and Ostracoda. The study found a positive correlation between water quality control methods and zooplankton numbers. The results showed that Ostracoda had the lowest diversity and dispersion, whereas Rotifera was the most prevalent. During the two-year investigation, zooplankton populations were found to be at their lowest during the monsoon season and reached their highest levels in the summer. As a result, in addition to educational efforts in schools, colleges, universities, and the general public, campaigns should be initiated to increase awareness about zooplankton diversity, the indicators used in hydrobiological studies, and their ecological importance.

**Keywords:** Zooplankton, Biodiversity, Hydrobiology, Panjapur, Lake, Tiruchirappalli.

1. **INTRODUCTION**

The concept of "Plankton" was first coined by Victor Hansen in 1887 to describe a wide variety of small organisms and organic matter present in aquatic habitats (Welch, 1953). Zooplankton, which are microscopic and free-swimming, represent a diverse group of tiny aquatic animals found in different aquatic ecosystems. These drifting or wandering animals play a crucial role in the trophic structure of aquatic environments and are integral to the energy transfer processes. Unlike algae and phytoplankton, zooplankton are animals that do not synthesize food (Manickam et al., 2024). Zooplankton are important in aquatic ecosystems and serve as the primary conduit for energy transfer from phytoplankton to larger aquatic life forms (Vaghela et al., 2023; Muthukumaravel et al. 2025). In a broad sense, plankton are considered an index of fertility (Prasad, 1969), and fish landings are directly proportional to the quantity of plankton. Studies on zooplankton species composition and seasonal variations in aquatic systems are essential for predicting the productivity of an area and its fisheries potential. These include various taxonomic categories, such as protozoa, Rotifera, and crustaceans from the Cladocera, Copepoda groups, and another Ostracoda group. Zooplankton serve as bioindicators for assessing water quality and are vital for purification. They are an essential food source for carnivorous and omnivorous fishes. In aquatic food webs, zooplankton are critical for secondary production across all aquatic habitats, facilitating energy transfer from lower to higher trophic levels. In these ecosystems, plankton are responsible for secondary production, either directly or indirectly. Additionally, zooplankton contribute significantly to nutrient recycling and energy cycling in their environments. Because of their short life cycles and quick responses to changes in aquatic conditions, such as pH, color, odor, and taste, zooplankton are used as indicators of the overall health of water bodies. They inhabit pelagic zones, which are regions where light penetrates ponds, lakes, rivers, and the oceans.

Water is vital for all life forms, making it impossible for organisms to survive without it. Globally, water is extensively used for various purposes, including drinking, bathing, washing, irrigation, and aquaculture. Primary sources of water include lakes, ponds, rivers, and underground reservoirs. The functional parameters of an ecosystem, shaped by the interactions among its physical, chemical, and biological elements, serve as strong indicators of its ecological importance. These interactions influence the trophic dynamics of aquatic environments and lead to the formation of unique niches that support diverse species. This, in turn, provides a habitat for plants, animals, and microorganisms within the ecosystem. Water is a fundamental component necessary for the growth and survival of all living organisms on Earth, covering nearly 71% of the planet's surface in both freshwater and marine forms (Khanna et al., 2007; Akhtar et al., 2023; Buhungu et al., 2023; Vaghela et al., 2023). They are a crucial natural resource for ecosystems, humans, and other organisms. Although water has traditionally been regarded as an inexhaustible resource, its increasing demand for various uses has begun to outpace the natural replenishment rate. Numerous water quality problems stem from industrial operations, untreated sewage, urban and domestic waste, and intensive farming. The most prevalent chemical contaminants in freshwater sources globally are excess phosphates and nitrates, which originate mainly from the use of fertilizers (Manickam et al., 2024; Paulraj et al., 2024). Although the water quality is deteriorating, new contaminants, including pesticides and antibiotics, have been identified in various environments. To protect the ecological balance of freshwater ecosystems and reduce their harmful effects, it is vital to understand the dynamics, composition, and structure of biotic communities (Manickam et al., 2023; Pinto et al., 2023; Vaghela et al., 2023; Buhungu et al., 2023).

Freshwater resources on Earth play a vital role in various sectors, including industry, agriculture, fisheries, and household activities (Akhtar et al., 2016; Akhtar et al., 2023). In the last 20 years, the decline in freshwater quality has accelerated owing to a range of natural and human-induced factors, presenting a significant global challenge (Mahananda et al., 2005; Akhtar et al., 2023). Industrial chemicals, agricultural fertilizers, and household sewage are major factors that contribute to the decline in water quality and pose risks to freshwater ecosystems. Freshwater sources are becoming increasingly scarce due to rampant pollution, overuse of water resources, and other human activities (Patil and Tijare, 2001; Singh and Mathur, 2005; Gupta and Shukla, 2006; Akhtar et al., 2023; Buhungu et al., 2023; Vaghela et al., 2023). From a socioeconomic perspective, artificial bodies of water, such as ponds, lakes, and reservoirs, are indispensable to human communities. They enable worldwide irrigation, ensure the availability of drinking water, produce electricity, and aid in the expansion of the agriculture, urban development, and industrial sectors. Regarding abiotic features, lakes, which have lower flow velocities and water storage capacities than rivers, share similarities with natural lakes. Understanding this information is essential for the sustainable management of aquatic resources, utilization of aquatic organisms, and promotion of conservation efforts. Therefore, it is imperative to conduct a preliminary survey of phytoplankton and zooplankton in water bodies.

Lentic environments, such as ponds, lakes, and wetlands, host a variety of biological communities, including phytoplankton, zooplankton, zoobenthos, macrophytes, fish, and aquatic birds. These communities are crucial for maintaining ecological balance, nutrient cycling, ecosystem resilience, and aquatic food webs. Fish depend on zooplankton and macrophytes not only as primary food sources but also as potential bioindicators of pollution within lake ecosystems. However, in recent decades, various human activities have posed significant threats to lake ecology, adversely affecting the distribution, abundance, and diversity of macrophytes and zooplankton. In addition, the physicochemical characteristics of eutrophic lakes have strayed from their optimal range. The zooplankton community serves as a vital bioindicator of aquatic health because it contributes to nutrient recycling, supports other biological communities, maintains soil fertility, and is integral to the aquatic food web, providing essential nutrients for nearly all freshwater fish. Zooplankton diversity and community structure patterns can indicate ecological changes by reflecting the living and non-living factors in aquatic ecosystems. Phytoplankton serves as the primary food source for zooplankton, which are small organisms that drift or swim in water. Zooplankton play a critical role in the trophic structure of aquatic ecosystems and facilitate energy transfer. Our limited understanding of plankton dynamics presents a significant challenge to fully understand life processes within freshwater systems (Manickam *et al*., 2017a, 2024). Numerous health stressors that drastically diminish biodiversity also affect aquatic ecosystems. Aquatic environments are expected to face greater biodiversity loss and its consequences in the future than terrestrial ecosystems (Sala *et al*., 2000; Manickam *et al*., 2020a, 2024). Zooplankton, predominantly heterotrophic organisms inhabiting the water column, largely serve as filter feeders, consuming sediments that consist of organic detritus, bacteria, and phytoplankton. Although physicochemical methods can offer valuable insights into the effects of pollution on water quality, shifts in the trophic conditions of water are also evident in the structure of the biotic community, including species distribution, patterns, and diversity (Emmanuel et al., 2014; Manickam et al., 2017a; Buhungu et al., 2023; Vaghela et al., 2023; Paulraj et al., 2024; Kumari, 2025).

Physical and chemical properties, along with the nutritional status of aquatic environments, play essential roles in ecological functions. These elements act as indicators of the overall well-being of their environments because of the brief lifespan and quick reaction of organisms to alterations in water conditions, such as pH, color, odor, and taste. Numerous studies have focused on the zooplankton populations in various lakes, reservoirs, and shallow water bodies. Water quality significantly affects plankton productivity, the biology of organisms in cultivation, and their eventual output. Zooplankton refers to the microscopic organisms that float in water, encompassing a wide variety of protozoans, micro-crustaceans, and planktonic micro-invertebrates. Freshwater zooplankton plays a crucial role in aquatic ecosystems, food chains, and ecological processes in ponds, lakes, and reservoirs (Anyanwu et al. 2014, 2015; Sharma, 2020; Anyanwu et al., 2022; Buhungu et al., 2023; Vaghela et al., 2023). Their high sensitivity to environmental changes makes zooplankton valuable indicators of ecosystem health. Previous research has explored the connections between zooplankton morphology, basin age, and environmental factors. Zooplankton also serves as a crucial live food source for many carnivorous and omnivorous fish, providing the high-nutrient protein necessary for larval development. As bio-indicators, zooplankton are important for assessing water pollution levels. The tendency of these organisms to disperse and be rapidly replaced plays a crucial role in shaping the trophic structure and ecological dynamics of the reservoirs. Indian lakes, ponds, and reservoirs support a wide range of plankton communities that are shaped by abiotic factors and fluctuations in nutrient availability. This study aimed to investigate the zooplankton populations and water quality metrics in the lake ecosystems of the Tiruchirappalli District in Tamil Nadu, South India, using a case-study approach.

1. **MATERIALS AND METHODS**

**2.1 Study area**

This study focuses on a freshwater lake in Panjapur, Tamil Nadu, located in Southern India. As shown in Figure 1, sampling activities were carried out from March 2022 to February 2024, with specific sites designated for sampling in each pond.

**2.2 Physico-chemical parameters**

Samples were collected between 5:00 and 7:00 AM, promptly transported to the laboratory, and kept under ice-cold conditions to ensure that their physicochemical properties were analyzed on the same day. Atmospheric and surface water temperatures were recorded onsite using a standard centigrade thermometer. Measurements for pH, salinity, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO) were performed using the "µP Based Water and Soil Analysis Kit Model-1160. Biological oxygen demand (BOD) was evaluated after incubating for three days at 27 °C using a Sanyo BOD incubator. Other parameters, including chemical oxygen demand (COD), total alkalinity, chloride, phosphate, sulfate, and ammonia, were determined using the titration method outlined by APHA (2005) and Manickam et al. (2015b, 2024). A Millipore filtering system was employed to quantify reactive silicate, nitrate, and dissolved inorganic nitrite in the water samples. According to the standard methods described by Strickland and Parsons (1972), the findings were reported in micrograms. Analysis of the data revealed four distinct seasons over two years from March 2022 to February 2024: the pre-monsoon season from June to August in both 2022 and 2023, the monsoon season from September to November in 2022 and 2023, the post-monsoon season from December 2022 to February 2023, and again from December 2023 to February 2024, and the summer season from March to May in both 2022 and 2023.

**2.3 Qualitative (species composition) and quantitative (population density) analysis of zooplankton**

The Towing-Henson standard plankton net, featuring a 150 µm mesh, was used to gather samples from reservoirs for qualitative evaluation of zooplankton. During this process, the boat maintained a steady speed for five to ten minutes, while the net was moved in a zig-zag fashion at depths between 0.50 meters and 1.00 meters (refer to Fig. 2). For the quantitative study of zooplankton, a 5-liter plastic container was employed to filter 100 liters of water through a bolting silk plankton net (No. 10, mesh size: 150 µm). The collected plankton biomass was preserved in specimen vials containing 4 or 5 % formalin, and subsequently subjected to stereomicroscopic examination after rapid filtration from the water. The zooplankton samples were categorized as Rotifera, Cladocera, copepods, and ostracods. The specimens were meticulously separated using a fine needle and brush under a binocular stereozoom dissection microscope (Magnus, Japan). Subsequently, the plankton species were mounted on small slides with a drop of 20% glycerin for staining.

**2.4 Biological analysis and identification of zooplankton species**

Zooplankton were identified using various reference sources such as standard textbooks, manuals, and bibliographies that specialize in freshwater zooplankton (Battish, 1992; Murugan et al., 1998; Altaff, 2004; Manickam, 2015; Manickam et al., 2019a). For this task, an inverted biological microscope (Model Number INVERSO 3000 (TC-100) CETI) with a camera (Model IS 300) and compound microscope were used. A Sedgwick Rafter counting cell was filled with 1 ml of the zooplankton sample, which was collected using a wide-mouthed pipette. The samples were allowed to settle before counting. For each species, gender, and developmental stage of plankton, three–five counts were conducted, and the average of these counts was determined. To calculate the total number of plankton in a one-liter water sample, we used the formula provided by Santhanam et al. (1989) and Manickam et al. (2019a): N = n × v/V, where v is the milliliters of concentrated plankton, V is the total litter of filtered water, and n is the average number of plankton per mL of filtered water.

**2.5 Statistical analysis and diversity indices**

For each zooplankton group, the average population density per liter (ind./L or ind./m3) was calculated. The total number of species in the zooplankton community, along with individual diversity indices such as Shannon's diversity index (H'), species evenness, and richness, were evaluated using the PAST software (Paleontological Statistics), Version 2.02. These computations were used for statistical analysis. Correlation coefficients (r) were determined for zooplankton and physicochemical parameters, and analysis of variance (ANOVA) tests were conducted for hydrological parameters concerning station and season. Shannon and Weaner’s species diversity index (H'), species richness (SR), and evenness index (J) were calculated using PAST (Paleontological Statistics), Ver. 2.02.

1. **RESULT**

**3.1 Atmospheric, Surface water Temperature (°C) and Rainfall**

The physicochemical parameters (hydrobiological) of a selected lake were examined over two years (March 2022 to February 2024). In this investigation, the atmospheric and surface water temperatures of the study area were recorded, ranging from 26.0 to 31.0 °C for atmospheric temperature and 25.0 to 30.0 °C for surface temperature ( Fig. 2). The lowest temperatures in the lake were observed during the post-monsoon season and monsoon, whereas the highest temperatures occurred in the summer for the two years. Correspondingly, the research area experienced the lowest air and surface water temperatures in the post-monsoon and monsoon seasons and the highest in the summer. Additionally, rainfall was significantly higher during the monsoon season, measuring between 6.40 and 209.6 ml/m, and lower in the post-monsoon period. Consequently, the rainfall period contributes to the dilution of nutrients in surface water.

**3.2 Electrical Conductivity (EC), Total Dissolved Solids (TDS) and pH**

The electrical conductivity (EC) in the pond's region varied between 515.0 and 679.0, as shown in Fig. 2. Electrical conductivity (EC) values peaked from summer to the pre-monsoon period, whereas the lowest values were recorded during the post-monsoon season throughout the study. In this analysis, the total dissolved solids (TDS) in the lake varied between 360.0 and 474.0 mg/L (. 2). The highest TDS levels were observed from the summer to the pre-monsoon phase, while the post-monsoon season exhibited the lowest measurements, as shown in the lake area study (Fig. 2). The pH levels in the pond study area varied from 7.2 to 8.0, as depicted in Fig. 2. During the summer, the pH levels were higher, whereas the lowest pH values were found in the post-monsoon period of the first year and the monsoon season of the second year. The decrease in pH in the study area was largely due to the combination of rainfall and wastewater during the monsoon season.

**3.3 Salinity, Total Alkalinity (TA) and Total Hardness (TH)**

During the study periods, total salinity levels fluctuated between 0.17 and 0.33 parts per thousand (ppt). The highest salinity was detected in the summer months, whereas the post-monsoon season exhibited the lowest salinity levels (Fig. 2). Typically, salinity was minimal during the post-monsoon and monsoon seasons, and peaked during the summer months. The total alkalinity spanned from 124.0 152.0 mg/L (. 2). The lowest alkalinity readings occurred in both the summer and monsoon seasons, whereas the highest was recorded in the summer and pre-monsoon periods. Alkalinity peaked just before the monsoon and was the lowest during the monsoon. Furthermore, the total hardness (TH) in the pond study area ranged from 152.0 to 184.0 mg/L (see Fig. 2). The maximum total hardness values were observed during the pre-monsoon season of the second and summer seasons, whereas the minimum values were noted in the post-monsoon season of the first year.

**3.4 Calcium, Magnesium, Sodium, Potassium, and Iron**

The analysis of water samples from the pond at this research location revealed calcium concentrations between 35.0 and 46.4 mg/L (. 2). The first year saw elevated calcium levels during the summer and pre-monsoon periods, whereas the second year had the lowest levels during the summer and monsoon seasons. The influx of rain and wastewater during the monsoon notably reduced the calcium concentrations in the area. Additionally, magnesium levels varied from 11.52 to 18.0 mg/L, with the highest concentrations observed in the summer and post-monsoon seasons over the two years, while the lowest were during the summer and pre-monsoon periods. Sodium concentrations were found to range from 44.0 to 72.0 mg/L, with the lowest levels in the post-monsoon season and the highest in the pre-monsoon months (see Fig. 3). Potassium levels ranged from 9.0 to 17.0 mg/L, peaking in the summer and monsoon seasons, with the lowest levels recorded during the monsoon season of the second year (refer to Fig. 3). Furthermore, Figure 3 indicates that total iron concentrations ranged from 0.08 to 0.21 mg/L, with the lowest levels in the summer and post-monsoon seasons, and the highest during the summer and monsoon of the second year (see Fig. 3).

**3.5 Nitrite (NO2), Nitrate (NO3-), Ammonia (NH3) and Chloride (Cl-)**

The study found that NO2 concentrations ranged from 0.12 to 0.50 mg/L. The lowest NO2 levels were observed in the post-monsoon period, whereas the highest levels were recorded during the summer ( Fig. 3). A marked increase in NO2 was noted in the pre-monsoon season, followed by a decrease during the monsoon season of the second year. Interestingly, the summer season had the lowest NO2 value, whereas the post-monsoon season had the highest, with total NO3 levels fluctuating between 3.0 and 5.20 mg/L ( Fig. 3). Furthermore, the NH3 concentrations in the pond varied from 0.18 to 5.50 mg/L. As illustrated in Figure 3, NH3 levels were highest during the monsoon and lowest during the summer of the first year and pre-monsoon in the second year. Additionally, the total chloride (Cl-) concentration ranged from 62.0 to 125 mg/L, as depicted in Figure 3. Peak Cl- levels were found in both the summer and pre-monsoon seasons, while the lowest levels were recorded during the monsoon season of the second year (see Fig. 3).

**3.6 Sulphate (SO2 ), Phosphate (PO43-), Turbidity and Dissolved Oxygen (DO) mg**/L

The SO2 concentrations measured ranged from 10.0 to 29.0 mg/L. As depicted in Figure 3, the peak SO2 levels were recorded during the summer preceding the monsoon season, whereas the lowest levels were noted after the monsoon season. Moreover, the PO43- levels in the lake varied between 0.50 and 0.98 mg/L, with the monsoon season exhibiting the lowest concentrations and the summer season the highest (refer to Fig. 3). Recent observations have indicated that the pond's turbidity ranged from 0.20 to 0.32 mg/L. Figure 4 shows that turbidity was the highest during the summer and monsoon seasons, with the post-monsoon period having the lowest levels. The dissolved oxygen (DO) levels in the study area were found to be between 5.5 and 9.0 mg/L (see Fig. 5). These findings suggest that DO levels were at their lowest during the post-monsoon period and peaked in the summer, likely due to increased photosynthetic activity from nearby vegetation, whereas the pre-monsoon months displayed different DO levels.

**3.7 Copper (mg/L), Zinc (mg/L), Chromium (mg/L) and Cadmium (mg/L)**

In the study area, copper (Cu) concentrations ranged from 0.0001 to 0.0011 mg/L. As depicted in Figure 5, the post-monsoon season had the highest Cu levels, whereas the pre-monsoon and monsoon seasons had the lowest concentrations. Zinc (Zn) levels in this region varied between 0.76 and 3.13 mg/L, as illustrated in Figure 5. The data indicate that Zn concentrations were at their lowest during the pre-monsoon period, with peaks occurring in the summer and monsoon seasons. Chromium (Cr) levels in the area ranged from 0.0001 to 0.0009 mg/L, with the highest concentrations found in the post-monsoon season and the lowest during the monsoon season, as shown in Figure 5. Additionally, cadmium (Cd) concentrations in the lake ranged from 0.0001 to 0.0007 mg/L, with the lowest levels observed from the pre-monsoon to the monsoon season. In contrast, the highest concentrations were observed in the summer and post-monsoon seasons (Fig. 5).

**3.8 Analysis of species composition and percentage composition and population density**

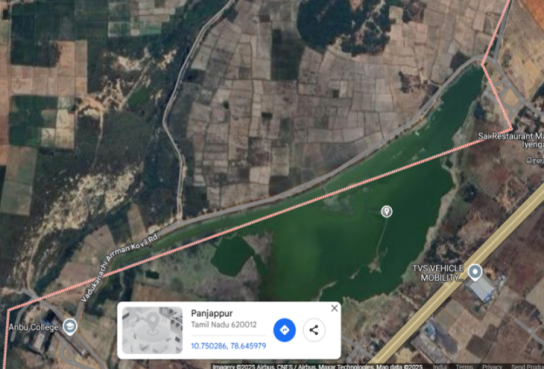
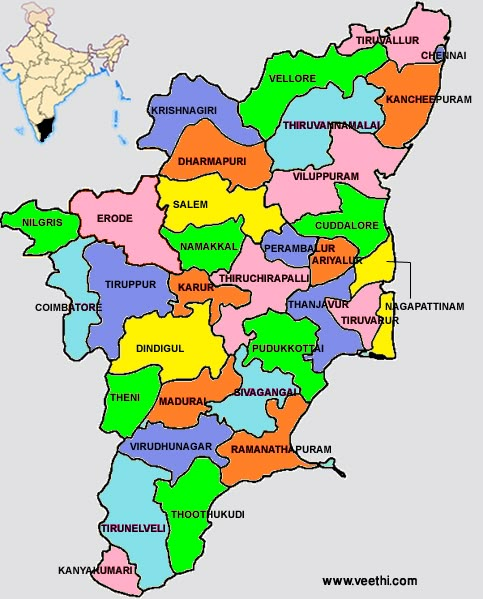
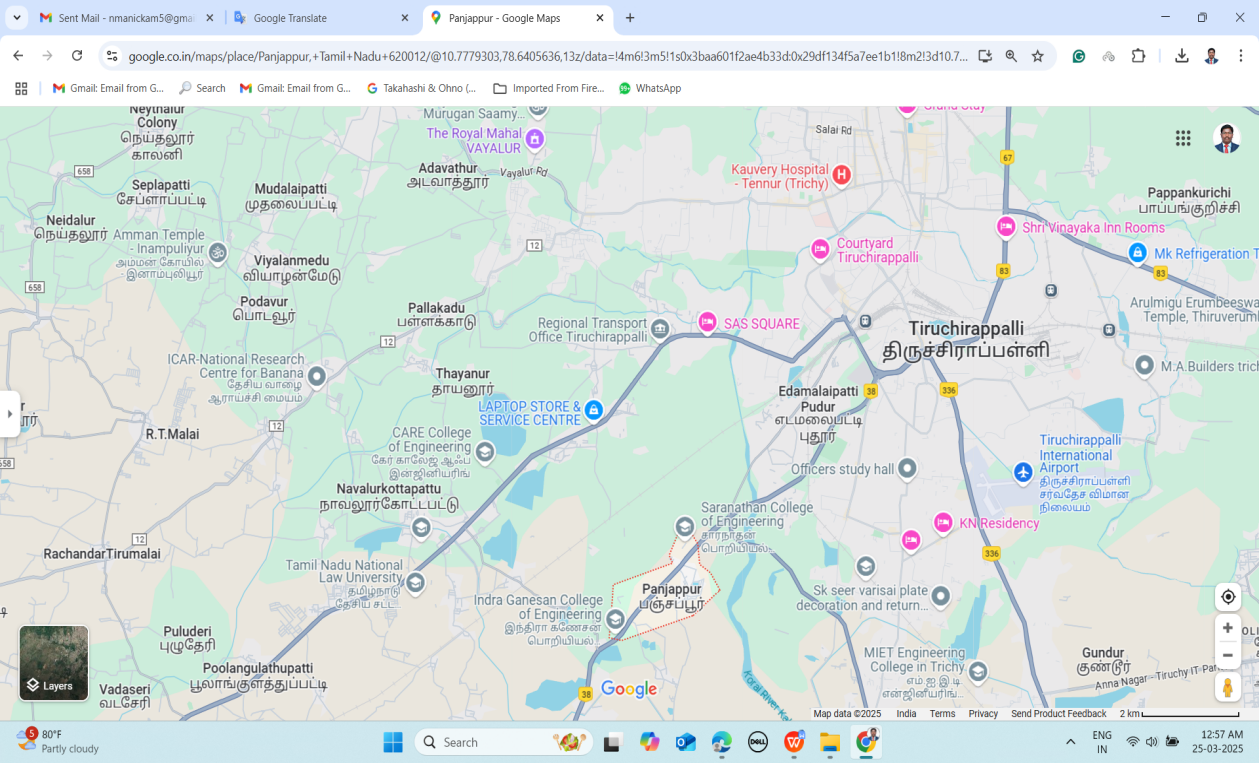
During a two-year investigation from March 2022 to February 2024, researchers identified 41 different zooplankton species in Panjapur Lake, situated in Tiruchirappalli, Tamil Nadu, Southern India (Table 1). Of these, 15 species were part of the Rotifera group, which included four families and five genera. The cladocera group comprised nine species across four families and six genera, whereas the copepoda group also had nine species but spanned two families and seven genera. Additionally, 8 species were classified under ostracoda, encompassing 1 family and 8 genera. This study revealed that Rotifera made up the largest share of the zooplankton population in Panjapur Lake, representing 42% of the total, followed by copepods at 26%, cladoceras at 22%, and ostracods at 10% (Fig. 6). The density of zooplankton in the lake fluctuated between 8,348 and 20,365 individuals per cubic metre (Fig. 7).

**3.9 Shannon's diversity index, species richness, and species evenness of zooplankton**

In Panjapur Lake, the Shannon diversity index for zooplankton ranged between 6.105 and 7.822 (Fig. 7). The zooplankton species richness in the lake ranged from 0.237 to 0.428 (Fig. 7). The pre-monsoon season (June 2022–August 2022) had the lowest species richness, whereas the monsoon season (September 2023–November 2023) had the highest. Additionally, the species evenness of the zooplankton in Panjapur Lake ranged from 2.352 to 2.928 (Fig. 7). The monsoon season (September 2023–November 2023) recorded the lowest evenness, whereas the pre-monsoon season over the two years showed the highest evenness.

**Table 1: List of freshwater zooplankton recorded in Panjapur Lake, Tiruchirappalli, Tamil Nadu, Southern India.**

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| **S. No.** | **Zooplankton** | **Family** | **Genus** | **Species** |
|  | Rotifers | Brachionidae (Ehrenberg, 1838) | *Brachionus* (Pallas, 1776) | *Brachionus angularis* (Gosse, 1851) |
|  | *Brachionus bidentata* (Anderson, 1889) |
|  | *Brachionus budapestinesis* (Daday, 1885) |
|  | *Brachionus calyciflorus* (Pallas, 1776) |
|  | *Brachionus caudatus personatus* (Ahlstrom,1940) |
|  | *Brachionus diversicornis* (Daday, 1883) |
|  | *Brachionus falcatus* (Zacharias, 1898) |
|  | *Brachionus quadridentatus* (Hermann, 1783) |
|  | *Brachionus rubens* (Ehrenberg, 1838) |
|  | *Keratella* (Bory de St. Vincent, 1822) | *Keratella cochlearis* (Gosse, 1851) |
|  | *Keratella tropica* (Apstein, 1907) |
|  | Lecanidae (Remane, 1933) | *Lecane* (Nitzsch, 1827) | *Lecane papuana* (Murray, 1913) |
|  | Asplanchnidae (Harring & Myers, 1933) | *Asplanchna* (Gosse, 1850) | *Asplanchna brightwelli (Gosse, 1850)* |
|  | *Asplanchna intermedia* (Hudson, 1886) |
|  | Filinidae (Bartos, 1959) | *Filinia* (Bory de St. Vincent, 1824) | *Filinia longiseta* (Ehrenberg, 1834) |
|  | Cladocera | Sididae (Baird, 1850) | *Diaphanasoma* (Fischer, 1850) | *Diaphanosoma sarsi* (Richard, 1895) |
|  | *Diaphanosoma excisum* (Sars, 1885) |
|  | *Daphnia* (Muller, 1785) | *Daphnia carinata* (King, 1853) |
|  | Daphnidae (Straus, 1850) | *Ceriodaphnia* (Dana, 1853) | *Ceriodaphnia cornuta* (Sars, 1853) |
|  | *Ceriodaphnia reticulata* (Jurine, 1820) |
|  | Moinidae (Goulden, 1968) | *Moina* (Baird, 1850) | *Moina brachiata* (Jurine, 1820) |
|  | *Moina micrura* (Kurz, 1874) |
|  | *Moinodaphnia* (Herrick, 1887) | *Moinodaphnia macleayi* (King, 1853) |
|  | Chydodridae (Stabbing, 1902) | *Alonai* (Baird,1843) | *Alona rectangula* (Sars, 1862) |
|  | Copepode (Calanoida & Cyclopoida) | Diaptomidae (Baird, 1850) | *Heliodiaptomus* (Kiefer, 1932) | *Heliodiaptomus viduus* (Gurney, 1916) |
|  | *Sinodiaptomus* (Kiefer, 1937) | *Sinodiaptomus* *indicus* (Sewell, 1934) |
|  | Cyclopoidae (Dana, 1853) | *Eucyclops* (Claus, 1893) | *Eucyclops speratus* (Lilljeborg, 1901) |
|  | *Mesocyclops* (Claus, 1893) | *Mesocyclops hyalinus* (Rehberg, 1880) |
|  | *Mesocyclops leuckarti* (Claus, 1857) |
|  | *Thermocyclops* (Kiefer, 1927) | *Thermocyclops hyalinus* (Rehberg, 1880) |
|  | *Thermocyclops decipiens* (Kiefer, 1929) |
|  | *Apocyclops* (Lindberg, 1942) | *Apocyclops dengizicus* (Lepeschkin, 1900) |
|  | *Acanthocyclops* (Kiefer, 1927) | *Acanthocyclops vernalis* (Fischer, 1853) |
|  | Ostracods | Cyprididae (Baird, 1845) | *Cypris* (Muller, 1776) | *Cypris protubera* (Muller, 1776) |
|  | *Eucypris* (Vavra, 1891) | *Eucypris bispinosa* (Victor & Michael, 1975) |
|  | *Strandesia* (Stuhlmann, 1888) | *Strandesia elongate* (Hartmann, 1964) |
|  | *Cyprinotus* (Brady, 1886) | *Cyprinotus nudus* (Brady, 1885) |
|  | *Heterocypris* (Claus, 1892) | *Heterocypris dentatomarginatus* (Baird, 1859) |
|  | *Hemicypris* (Sars, 1903) | *Hemicypris anomala* (Klie, 1938) |
|  | *Candonocypris* (Sars, 1895) | *Candonocypris dentatus* (Victor & Michael, 1975) |
|  | *Cypretta* (Vavra, 1895) | *Cypretta fontinalis* (Hartmann, 1964) |



**Fig. 1**. Satellite view of the study area and photograph of the sampling sites in Panjapur Lake (Tiruchirappalli District, Tamil Nadu, South India).

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**Fig. 2.** Physicochemical parameters (atmospheric and surface water temperature, rainfall, EC, TDS, pH, Salinity, Alkalinity, Total Hardness, Calcium and Magnesium) in Panjapur Lake.

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**Fig. 3.** Physicochemical parameters (sodium, potassium, iron, nitrite, nitrate, ammonia, chloride, sulfate, phosphate, and turbidity) in Panjapur Lake.

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**Fig. 4.** Physicochemical parameters (DO, Cu, Zn, Cr, and Cd) in Panjapur Lake.

**Fig. 5.** Percentage composition of zooplankton species in the study area.

**Fig. 6.** Month wise zooplankton population density in the study area

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**Fig. 7.** Freshwater zooplankton biodiversity indices in Panjapur Lake from March 2022 to February 2024.

**Discussion**

Freshwater ecosystems are essential for human survival and critical for all forms of life. Lakes and ponds are integral to the hydrological cycle and fulfill various roles within the biosphere. The importance of ponds and lakes to human communities is substantial because they provide vital water resources for household needs, agriculture, and industrial activities. This study specifically examined how seasonal changes affect the populations of freshwater zooplankton species in Panjapur Lake, and how the hydrographical conditions currently present in aquatic environments are fundamental in shaping these ecosystems. Even minor shifts in the biological density of these water bodies require prompt evaluation of both the hydrographical and biological factors. These hydrographic characteristics are crucial for determining the diversity of species and organization of communities within aquatic ecosystems (Sharma et al., 2016; Mohan et al., 2022; Buhungu et al., 2023; Vaghela et al., 2023; Manickam et al., 2024; Paulraj et al., 2024). Currently, global lake and pond ecosystems are facing significant challenges, many of which are a result of human activities. This highlights the urgent need for research and educational programs aimed at raising public awareness of the importance of preserving and conserving these ecosystems. Lakes are vital surface water resources and play a key role in supporting biodiversity. They are critical for rainwater harvesting and groundwater replenishment, and directly and indirectly benefit the livelihoods of many communities, particularly by providing drinking water and irrigation. The benefits of ponds go beyond their visual appeal; they are essential for water conservation and irrigation and serve as habitats for a variety of species. Lakes/ponds are crucial for maintaining the ecological balance of their respective regions.

Together, these ecosystems support a higher diversity of species than any other freshwater environment, including the numerous rare ones. Lakes have played a vital role in cultural history. By preserving these bodies of water, we can protect a range of habitats and the biodiversity they support, thus ensuring the survival of valuable biological resources. In addition, it is crucial to promote awareness of the importance of environmental conservation. The protection of ponds has become an acknowledged approach to tackle challenges related to water scarcity and the depletion of groundwater. Water scarcity is a critical issue in the global community. Even with numerous ponds available, many people struggle to meet their water needs, prompting some to cease agricultural practices because of this shortage. Maintaining ponds is essential for meeting rising water demand. Moreover, lakes provide sustainable solutions for pollution and water management challenges. They are effective in processes such as denitrification, sedimentation, and removal of phosphorus, nitrogen, and sediments from surface water. Additionally, ponds help recharge the groundwater table, benefiting both the community and the environment, especially during the summer months. However, pollution remains a serious threat to many ponds, particularly to those that have been neglected. A significant number of these lakes remain unmaintained owing to management difficulties. Research by Non-Governmental Organizations has revealed that around 40% of village lakes and ponds in India have been converted for residential or commercial use in the last century.

Despite their relatively small sizes, these lakes play a vital role in water harvesting because of their abundance. Their unique biodiversity and specific ecological roles are essential for environmental health. Various initiatives have been launched by both government agencies and local communities to restore many of these lakes and meet community needs. Diminishing water resources is a significant factor that contributes to the decline in agriculture in the region. Neglecting these ponds has led to problems such as algal blooms and eutrophication. Restoration efforts are expected to enhance groundwater recharge, thereby addressing the water requirements of the community. Improving the health of these ponds is crucial to combat eutrophication and pollution while also safeguarding their ecological importance to promote sustainable usage practices. This study aims to revive the ecological value of ponds and create a sustainable environment for future generations. This investigation delves into the physical and chemical attributes of ponds, lakes, and reservoirs located in the Dharmapuri, Krishnagiri, and Coimbatore regions of Tamil Nadu. This indicates that human activities are the predominant factors leading to unfavorable conditions observed in these aquatic environments, as supported by the findings of recent research (Manickam et al., 2012b, 2014, 2015a, 2024; Paulraj et al., 2024). Significant variations in the physicochemical properties of water suggest different environmental conditions that could be associated with shifts in water consumption, rainfall, and temperature (Atobatele et al. 2008; Manickam et al. 2014; Manickam, 2015; Buhungu et al., 2023; Vaghela et al., 2023; Paulraj et al. 2024).

Temperature plays a crucial role in the primary productivity of reservoirs, lakes, and ponds. The number of plankton in these aquatic environments varies with shifts in the water temperature. Temperature affects all physiological and metabolic activities in aquatic life, including the feeding, movement, reproduction, and distribution of both zooplankton and phytoplankton. It has been recognized as a critical element in aquatic environments (Manickam *et al*. 2024). Temperature significantly influences the physical, chemical, and biological dynamics of aquatic ecosystems. For example, the water temperature in the temple pond was higher than that in the inaccessible pond. Elevated temperatures can enhance DO production of dissolved oxygen (Manickam *et al*., 2024; Paulraj *et al*., 2024). Additionally, water temperature can drastically alter the rates of chemical and biological reactions in water, thereby affecting the organisms that inhabit these environments. Water temperature is crucial for the physiological functions and life processes of aquatic organisms and significantly affects their feeding, reproduction, movement, density, and diversity. Elevated temperatures in waterbodies can have a profound impact on these aspects. Additionally, maintaining appropriate water temperature is vital for aquatic life, as there is a notable correlation between water temperature and atmospheric temperature in the surrounding environment. Factors such as solar radiation intensity, evaporation, and the influx of freshwater primarily determine water temperature (Mohan *et al*., 2022; Manickam *et al*., 2012b, 2017a, 2024; Paulraj *et al*., 2024). The results of the study showed that water temperatures increased during the summer and decreased during the monsoon season. Additionally, the presence of human-made pollutants that deteriorate water quality might be responsible for the higher average levels of total dissolved solids (TDS) observed (Dhanasekaran et al., 2017; Vaghela et al., 2023; Paulraj et al., 2024; Manickam et al., 2024).

The investigation revealed that the total dissolved solids (TDS) in the pond peaked during the summer, with the lowest levels observed after the monsoon. This summer increase in TDS was likely due to stagnant water conditions. In May, the breakdown of organic matter releases by-products into the water, causing many plant species to undergo decay-like conditions, potentially leading to an increase in dissolved solids (Verma et al., 1978; Manickam et al., 2014, 2017b, 2024; Paulraj et al., 2024). The accumulation of human-generated waste may have contributed to the highest average TDS levels, adversely affecting water quality. Chlorides primarily originate from inorganic salts, such as NaCl, KCl, and CaCl2, which are present in soil, natural chloride salt deposits, industrial and municipal wastewater, and animal waste (Gopalkrushna, 2011; Paulraj et al., 2024; Manickam et al., 2015b, 2024). The ability of water to dissolve contaminants such as sewage and industrial waste facilitates the introduction of chlorides into water. Smitha et al. (2007) reported different findings, and similar results were reported by Swaranlatha and Rao (1998), Manickam et al. (2015b, 2024), and Paulraj et al. (2024). The pH is a vital measure of acidity and alkalinity. An increase in the pH of aquatic systems indicates higher water pollution levels (Manickam et al., 2017a; Mohan et al., 2022; Paulraj et al., 2024; Manickam et al., 2024), often due to the erosion of carbonate rocks and increased evaporation, which can harm aquatic life. In this study, pH levels rose during the summer due to higher pollution and algal blooms, whereas a decrease was observed during the monsoon, which was attributed to significant water dilution. The carbonic acid system and the interaction between carbonates primarily control the water pH. It is well known that pH is directly related to carbonate ions (CO3) and inversely related to free carbon dioxide (Zafar, 1964). The pH values ranged within the alkaline spectrum, reaching their lowest in December and peaking from May to July in the reservoir/pond, which is consistent with previous findings (Manickam et al., 2012b, 2017a; 2024; Manickam, 2015). Salinity is ecologically crucial because it affects the populations of brackish and freshwater phytoplankton and zooplankton, which vary in size based on salinity level (Manickam et al., 2015a, 2017b; 2024). It is a key factor for aquatic organisms and significantly influences the biological processes in aquatic environments.

The rise in salinity in aquatic environments is largely due to increased water evaporation and reduced precipitation. As salinity increases, pH levels also tend to increase because higher salinity enhances the presence of hydrogen ions on the surface of the water. Research has shown that salinity is highest during the summer months and lowest during the wet season. Significant changes in salinity have been documented between the monsoon and summer periods (Kubley, 1982; Manickam, 2015; Manickam et al., 2017a, 2024). This pattern was attributed to the influx of substantial freshwater and cooler temperatures, leading to higher salinity in the summer and lower levels during the monsoon. Elevated salinity can negatively affect the density and diversity of plankton production (Horne and Goldman, 1994; Aravinth et al., 2023; Vaghela et al., 2023; Manickam et al., 2024). Because most dissolved salts in water are ionic, this property allows water to conduct electricity. Previous studies corroborate these findings, indicating that electrical conductivity (EC) is highest in summer and lowest during the monsoon in freshwater ecosystems (Manickam et al., 2015a; 2024). A sudden increase in water conductivity during the monsoon and post-monsoon seasons suggests the presence of contaminants (Manickam et al., 1984; Manickam et al., 2024). Total alkalinity is a chemical property that helps neutralize water acidity, whereas hardness indicates the presence of total polyvalent cations, mainly divalent cations such as calcium and magnesium. High alkalinity in water can impart a bitter taste, negatively affect irrigation, damage soil quality, and disrupt aquatic life (Malik et al. 2020; Mohan et al. 2022; Manickam et al. 2024). This study found that the total alkalinity and hardness were higher from summer to pre-monsoon and lower during the monsoon and post-monsoon seasons. Calcium is essential for all aquatic organisms and is typically present due to the dissolution of gypsum and calcareous rocks in aquatic environments (Mohan et al., 2022; Manickam et al., 2024). The research showed that the highest calcium levels occurred from summer to pre-monsoon, whereas the lowest levels were recorded during the monsoon to post-monsoon periods.

Phosphates are mainly derived from human excrement, leaching of phosphorus-rich geological formations, and breakdown of organic materials (Girija et al., 2007; Manickam et al., 2015b, 2024). Murdoch et al. (2001) and Manickam et al. (2024) linked high concentrations of phosphates and nitrates to eutrophication, which results in increased algal blooms and a subsequent reduction in dissolved oxygen levels in water bodies. Our findings indicate that all three reservoirs at the sampling locations exhibited high phosphate concentrations. Although sulfate is typically present in natural waterways, industrial pollutants such as sulfuric acid, bisulfate, and aluminum sulfate from water treatment facilities can elevate these levels. This study revealed that water samples from agricultural sites had the highest sulfate concentrations. Elevated sulfate levels in drainage water can lead to gastrointestinal issues, including diarrhea and laxative effects (Prasad, 2003; Manickam, 2015; Manickam *et al*., 2017b, 2024). Nitrogenous organic substances and microorganisms naturally break down in both the soil and water environments, resulting in the formation of ammonia. According to Manickam et al. (2015b, 2024), seasonal variations in natural ammonia levels may occur because of the decomposition and death of bacteria, phytoplankton, and other aquatic life forms. Human activities also contribute to ammonia sources, such as industrial emissions, sewage discharge into natural water bodies, and fertilizer runoff. Elevated levels of ammonia and nitrite are often linked to sewage and domestic waste discharges (Mohanraj et al., 2000; Manickam et al., 2015b, 2024).

Phosphates and nitrates are reliable indicators of eutrophication. According to Kudesia et al. (1986), nitrites and certain harmful aromatic compounds can give water a brown color and unpleasant odor, rendering it unsuitable for drinking, irrigation, or aquaculture. Nitrate, a contaminant found in both natural water bodies and the atmosphere, is integral to the biological nitrogen cycle (Manzoori et al. 1998; Manickam 2015; Manickam et al. 2015b, 2024). The major sources of nitrate include fertilizers, decaying organic matter from plants and animals, industrial and domestic wastewater, and atmospheric deposition. Consequently, monitoring the nitrate levels in aquatic environments is crucial. As noted by Saxena (1998), Manickam (2015), Manickam et al. (2015a), and others, nitrates, which are essential nutrients for plants, enter ecosystems through various pathways such as inorganic fertilizers from septic systems, animal feed, agricultural inputs, manure, industrial discharges, and sanitary landfills. The highest nitrate concentrations observed during the monsoon season may be due to organic materials in the catchment area. While nitrogen loading and phosphorus levels have increased due to human activities and detergent use, silicate concentrations have remained relatively constant over time (Gilpin et al., 2004; Manickam et al., 2015b). Silica is utilized by microorganisms, invertebrates, and plants for its growth and structural functions. The current findings show that SiO2 concentrations reached their peak during the summer and late monsoon, which is attributed to runoff and the seasonal opening of upstream channels from the Thoppaiyar, Nagavathy, and Panchapalli reservoirs.

According to Gajbhiye and Desai (1981), qualitative analysis of zooplankton species composition acts as an ecological marker for aquatic ecosystems. The dynamics of zooplankton populations are significantly affected by factors such as dissolved oxygen levels, light intensity, food availability, and predation. Studies have shown that low pH and high salinity can decrease both plankton diversity and density (Horne and Goldman, 1994; Manickam et al., 2014, 2015b, 2017a). Previous research on Haledharmapuri Lake, a perennial freshwater lake, supports these findings. In Dharmapuri Town, Tamil Nadu, India, researchers have identified 55 zooplankton species, including 13 rotifera, seven cladocera, eight copepoda, and five ostracods (Dhanasekaran et al., 2012b, 2017b; Manickam et al., 2017, 2024). In addition, 55 other species have been recorded in this area. Bhavan et al. (2015) documented 36 zooplankton species in Sulur Lake (Coimbatore District, Tamil Nadu), consisting of 11 Rotifera, 10 Cladocera, seven copepods, and six ostracods. Manickam et al. (2015a) identified 47 zooplankton species in Barur Lake, located in Krishnagiri District, Tamil Nadu, which included 18 rotifera, 11 cladocera, 11 copepods, and seven ostracods. Previous studies have reported 33 zooplankton species in both the Sulur and Ukkadam lakes (Manickam et al., 2017a). The current understanding of cladocera and copepod composition is consistent with the findings of other studies (Manickam et al. 2004; Manickam et al. 2015a). Water temperature affects the life cycle characteristics of zooplankton by influencing their metabolic rates and activity levels, which in turn affect their growth and reproduction (Burns, 1969). Mergeay et al. (2006) found a link between high population density and environmental conditions, including water temperature, which is crucial for hatching resting cladoceran eggs in natural aquatic environments. Wright (1965) noted that increased nutrient concentrations in the water body are associated with higher zooplankton densities.

The findings of this study agree with those of Bhavan et al. (2015) and Manickam et al. (2015b, 2024). The physical and chemical properties of the environment significantly influence the distribution and abundance of zooplankton, with Rotifera emerging as the most prevalent group. Because these organisms are indicators of eutrophication, it is imperative to control human activities in watershed areas to prevent water pollution (Manickam et al., 2012b, 2017b, 2024). The physicochemical conditions of the reservoir are crucial for determining the density and distribution of the zooplankton communities. The availability of food sources, such as phytoplankton, combined with favorable environmental conditions likely contributed to the high zooplankton populations observed during the summer months. Similar findings were also reported by Manickam et al. (2014) at the Thoppaiyar reservoir in Dharmapuri, Tamil Nadu; Ramakrishna (2014) at Yelahanka Lake in Bangalore, India; Gayathri et al. (2014) at Doddavoderhalli Lake in Bangalore; Dede and Deshmukh (2015) along the Bhima River near Ramwadi village in Solapur District, Maharashtra, India; Bhavan et al. (2015) at Sulur Lake in Coimbatore District, Tamil Nadu; and Manickam (2015) at Barur Lake in Krishnagiri District, Tamil Nadu.

Jayabhaye (2010), Manickam et al. (2014, 2015b, 2017a, 2024), and Ezhili et al. (2013), Manickam (2015), and Dhanasekaran et al. (2017) corroborated, that factors like high turbidity, low light, cloudy weather, and heavy rainfall likely contribute to the generally low zooplankton population density seen during the monsoon season at all study locations. Research by Kannan and Job (1980) and Manickam et al. (2017b) shows that in the Thoppaiyar, Nagavathy, and Panchapalli reservoirs in Tamil Nadu, zooplankton diversity is highest in summer and lowest during the monsoon and pre-monsoon periods. Odum (1983) described two main methods for evaluating species diversity in different ecological settings: diversity and relative abundance curves and diversity indices, which mathematically express the importance of various species. Typically, species diversity is reduced in stressed and polluted ecosystems (Bass and Harrel 1981). In contrast, the monsoon season brings several factors that affect the diversity and density of copepods, rotifers, cladocerans, and ostracods, such as water temperature, turbidity, and transparency (Edmondson, 1965). Additionally, elements such as bacteria, plankton, and suspended detritus may influence the minimum and maximum zooplankton populations observed in the summer. Total alkalinity is a chemical property that helps neutralize water acidity, whereas hardness indicates the presence of total polyvalent cations, mainly divalent cations such as calcium and magnesium. High alkalinity in water can result in a bitter taste, negatively impact irrigation, harm soil quality, and disrupt aquatic life (Mohan et al. 2022; Buhungu et al., 2023; Manickam et al. 2024). In this study, the total alkalinity and hardness were higher during the summer and pre-monsoon periods, with lower levels during the monsoon and post-monsoon seasons. The growth and population dynamics of freshwater flora and fauna are influenced by both Ca and Mg levels. The lowest values recorded in the post-monsoon month may be due to calcium deficiency in the sandy substrate of the pond and its surrounding soil. The calcium concentrations in freshwater lakes and ponds vary from pre-monsoon to summer (Surana et al. 2010; Jain and Kumar, 2021; Buhungu et al., 2023; Vaghela et al., 2023) with higher calcium levels during the pre-monsoon season. Conversely, lower levels of calcium and magnesium were observed in the ponds during the post-monsoon season. The findings of this study may reflect the dilution of pond water during the rainy season, leading to a decrease in Ca and Mg levels. This perspective is supported by the work of Surana et al. 2010; Jain and Kumar, 2021; Buhungu et al., 2023.

Sodium can be leached from rocks and subsequently found in water bodies. When water interacts with igneous rocks, it can dissolve the sodium from these natural sources. Additionally, Na can enter natural water systems through municipal wastewater discharge and runoff from various sources. Generally, waters with high mineral content tend to have elevated sodium concentrations. The sodium levels in the lake water were within an acceptable range. In this study, strong negative correlations between metals, especially iron, and the presence of zooplankton species indicate that these metals may have affected the aquatic biota. This suggests that iron is a significant contributor to potential ecological risks and associated health concerns. Nitrate, a pollutant found in both natural water sources and in the atmosphere, is essential for the biological nitrogen cycle (Manzoori et al. 1998; Manickam 2015; Manickam et al. 2015b, 2024). Fertilizers, decomposing organic matter from flora and fauna, industrial and domestic wastewater, and atmospheric deposition are primary contributors to nitrate. Consequently, it is crucial to monitor and regulate nitrate concentrations in water bodies. As noted by Saxena (1998), Manickam (2015), and Manickam et al. (2015a), nitrates, which act as nutrients for plants, infiltrate ecosystems through various channels, including septic systems, animal feed, agricultural fertilizers, manure, industrial effluents, and sanitary landfills. The highest nitrate levels observed during the monsoon season were likely due to organic material from the surrounding catchment area. Although human activities and detergent use have led to increased nitrogen and phosphorus levels, silicate concentrations have remained relatively constant over time (Gilpin et al., 2004; Manickam et al. 2015b; Buhungu et al., 2023; Manickam etr al., 2024). Silica is utilized by microorganisms, invertebrates, and plants for its growth and structural functions. The current findings reveal that Si2O3 levels reached their peak during the summer and late monsoon, which is attributed to runoff and the seasonal opening of upstream pond channels.

In soil and water, nitrogenous organic compounds and microorganisms decompose naturally to produce ammonia. As noted by Manickam et al. (2015b, 2024), seasonal fluctuations in natural NH3 levels can arise from the breakdown and death of bacteria, phytoplankton, and other aquatic organisms. Additionally, human activities contribute to NH3 emissions through industrial discharge, sewage released into rivers, and runoff from fertilizers. High levels of NH3 and nitrite are frequently associated with sewage and household wastes (Manickam et al., 2000; Manickam et al., 2015b, 2024). Chlorides primarily originate from inorganic salts such as NaCl, KCl, and CaCl2. These salts are commonly present in the soil, naturally occurring chloride salt layers, industrial and municipal wastewater, and animal waste (Gopalkrushna, 2011; Manickam et al., 2015b, 2024). Chlorides enter water because of the solvent action of water on contaminated materials such as sewage and industrial waste. Although Smitha et al. (2007) found different results, Swaranlatha and Rao (1998) and Manickam et al. (2015b, 2024) reported similar findings. Nutrient levels, including sulfate and phosphate, were within permissible limits for samples from Guwahati, Assam (Das et al., 2003), and the three districts of Krishnagiri, Vellore, and Tiruvannamalai (Paulraj et al., 2024) in Tamil Nadu, India.

Chlorides primarily originate from inorganic salts such as NaCl, KCl, and CaCl2. These substances are frequently found in the soil, natural chloride salt deposits, industrial and municipal wastewater, and animal waste (Gopalkrushna, 2011; Manickam et al., 2015b, 2024). The solvent properties of water facilitate the leaching of chlorides from contaminated sources such as sewage and industrial waste. While Smitha *et al*. (2007) found differing results, similar findings were reported by Swaranlatha and Rao (1998) and Manickam *et al.* (2015b, 2024). In samples collected from Guwahati, Assam (Das et al., 2003), as well as from the districts of Krishnagiri, Vellore, and Tiruvannamalai in Tamil Nadu, India (Paulraj et al., 2024), the concentrations of nutrients, such as sulfate and phosphate, were found to be within permissible levels. Turbidity, which indicates the degree of cloudiness (APHA, 2005), serves as a measure of how effectively light can pass through water. This phenomenon is primarily caused by suspended substances including clay, silt, organic matter, plankton, and various particulate materials (Alley, 2007). The presence of cyclopoids indicates the dominance of higher trophic levels in the water and serves as an effective bioindicator of elevated turbidity caused by suspended solids (Balakrishna *et al*., 2013). Increased turbidity leads to a reduction in the availability of food (Cole *et al*., 1999), as it raises water temperatures; suspended particles tend to absorb more solar heat. As a result, the concentration of dissolved oxygen (DO) may decline because warmer water contains less dissolved oxygen compared than cooler water.

Previous studies have shown an inverse relationship between dissolved oxygen (DO) and temperature (Paulraj et al., 2024; Manickam et al., 2024). As the temperature increases, the ability of oxygen to dissolve in water bodies diminishes. Furthermore, the oxygen levels in water are influenced by atmospheric pressure and the rate of photosynthesis. Generally, the highest DO concentrations were observed at the lowest temperature. A positive link between DO and pH was also observed. The reduced DO levels observed in summer were likely due to the breakdown of organic material and the respiration of zooplankton. Copper (Cu) and zinc (Zn), while non-toxic at low concentrations (APHA, 2005), are vital for human health and plant and animal growth (World Health Organization, 1996). However, they can impart an unpleasant taste to drinking water and high Zn levels can cause a cloudy appearance. The metals were assessed using the same methods as those used for Fe and Mn. In the study area, the permissible limits for Cr and Cd were monitored, indicating low levels of these toxic elements in the pond. During the rainy season, species evenness was relatively high, indicating a decrease in plankton diversity. Peet (1974) described species diversity as including both the richness and evenness of species as well as the fair distribution of individuals among these species. This analysis is consistent with Odum’s (1983) findings, which suggest an inverse relationship between dominance values and measures of species richness, evenness, and overall diversity. Throughout the research period, primary crops flourished in reservoirs, lakes, and ponds, benefiting from nutrient accumulation due to the influx of freshwater from monsoon rain. This phenomenon is supported by the plankton populations and seasonal environmental changes. However, the lentic water system may have created physicochemical conditions that inhibited zooplankton growth, as evidenced by the significant decline in their population during the monsoon season (Manickam, 2015; Manickam et al., 2017b, 2024; Buhungu et al., 2023; Vaghela et al., 2023; Paulraj et al., 2024). The lowest zooplankton populations recorded during this season may be associated with lower temperatures (Marshall and Orr, 1972). Bias and Agrawal (1995) observed that a strong population of primary producers, higher temperatures, and increased water clarity were linked to the zooplankton population in summer, which subsequently enhanced food availability. As the alkalinity of water gradually increases, the number of zooplankton also increases (Manickam et al., 2015b, 2024; Paulraj et al., 2024). Rotifera species identified in B. calyciflorus are considered effective indicators of eutrophication (Sampaio et al., 2002; Manickam et al., 2012b, 2015b, 2017a; Bhavan et al., 2015a; Dhanasekaran et al., 2017; Manickam et al., 2024).

Species of copepods, such as Heliodiaptomus viduus, Mesocyclops hyalinus, and Thermocyclops hyalinus, along with ostracods, such as Cypris protubera and Hemicypris anomala, as well as rotifers, including B. calyciflorus, B. falcatus, Filinia longiseta, and cladocerans, such as D. sarsi and C. cornuta, are known to withstand pollution and indicate the accumulation of organic matter in the lake (Goel and Charan et al., 1991; Manickam et al., 2012b, 2014, 2015b, 2017a, b, 2024; Bhavan et al., 2015a; Dhanasekaran et al., 2017; Kowthaman et al., 2019). Typically, the monsoon season is linked to a reduction in zooplankton populations owing to dilution effects and decreased photosynthetic activity among primary producers. Similar results have been observed by Manickam (2015) and Bais and Agrawal (1993). During the monsoon season, the population tends to decline because of this dilution. In the reservoir ecosystem, the combination of hard water and dissolved oxygen during the summer months also encouraged the growth of zooplankton. Various researchers have reported similar patterns (Manickam, 2015; Manickam et al., 2015a, 2017a,b, 2024). Many species continue to encounter challenges due to dissolved oxygen levels, temperature, salinity, and other physical or chemical factors that affect the environmental conditions necessary for zooplankton survival. The presence of these five rotifer species indicated a gradual and ongoing process of organic pollution, pushing the reservoirs toward eutrophication. The diversity and density of these species reflect their abundance under favorable conditions; however, they tend to disappear under adverse conditions and reappear when the environment becomes conducive again.

**Conclusion**

The results of this study indicated that the physical and chemical properties of Panjapur Lake, located in the Tiruchirappalli District of Tamil Nadu, South India, fall within acceptable limits. This conclusion was supported by the absence of unusual values during the study period. The lake's physical and chemical conditions are vital for influencing the distribution and population density of zooplankton species. Consequently, it is crucial to implement measures to reduce freshwater pollution by restricting activities, such as bathing, laundry, and other human interactions within the pond ecosystem. Additionally, the data gathered in the reports are crucial for decision-makers to efficiently manage and safeguard water bodies in pond ecosystems.

**Data availability**

The data will be made available upon request.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in this manuscript.

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**Reference**

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