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*Original Research Article*

# Impact of Seasonal Fluctuation on Diatom Diversity in Natanahalli Lake, Kurubahalli Lake, Yelemuddanahalli Lake and Katnalu Lake of Krishnarajanagara Taluk, Mysuru District, Karnataka, India

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## ABSTRACT

As a foremost contributor to primary productivity in the aquatic ecosystem, diatoms play a pivotal role in the food chain. Due to their ubiquitous nature, they are copiously present in aquatic environments. The present study was undertaken to investigate the diversity and ecology of phytoplankton in four lakes of K.R.Nagar Taluk, Mysuru. Our appraisal reveals the presence of diverse diatom communities confirming that diatoms are an important bio indicators for assessing ecological quality of the lakes studied with respect to organic pollution and anthropogenic eutrophication. Overall identified diatoms in four lakes are predicted as water quality indicators. *Synedra ulna* and *Navicula rynocephala* were considered as the most common anthropogenic eutrophication indicator. *Navicula halophila* and *Synedra acus* were proved to be organic pollution indicators in polluted lakes. So our findings highlighted that diatom species diversity was rich in Kurubahalli lake, Yelemuddanahalli lake and Katnalu lake compared to Natanahalli lake. Analysis of all the values obtained in each lake revealed that Kurubahalli lake was polluted by organic pollution whereas Natanahalli lake, Yelemuddanahalli lake and Katnalu lake was polluted by human activities.

***Keywords:*** *Synedra ulna, Navicula rynocephala, Navicula halophila, Synedra acus,* anthropogenic pollution**,** organic pollution

## INTRODUCTION

Wetland is considered to be one of the main biological hotspots and also sinks for pollution. Today, wetlands are one of the most dying out habitats in India, often converted for agriculture, industry or settlements. Many are affected by industrial effluents, sewage, household wastes and sedimentation and so there is a need to protect from adverse anthropogenic effects. Thus, water quality monitoring helps in uphold our understanding of these conditions to protect them. Water is nature's most essential gift to man, which keeps him alive, by meeting the basic necessities of the smaller living unit cell. Availability of potable water of acceptable quality in nature is becoming rare day by day, especially in rural area. Water pollution has reached alarming proportion in the recent years. Pollutants bring about physical, chemical and biological changes and make the water unfit for drinking and harmful to aquatic life. In India, lakes, rivers and other freshwaters support a large diversity of biota representing almost all taxonomic groups. Algae in open waters represent the floristic diversity and macrophytes dominate the wetlands. It is difficult to analyze the algal diversity in many lakes with reference to

different habitats endemicity to India, as well as the seasonal variations and anthropogenic disturbances. Water quality is directly proportional to the human population and its various activities. More than 50,000 small and large lakes are polluted to the point of being considered dead. Various phytoplankton groups prefer to exist in various kinds of water. [1] In each group, there may be certain species which resist pollution while others may be very sensitive. Freshwater ecology in the southern parts of Karnataka was initiated as far back as 1973, as the first work on Limn logical studies in ponds and lakes of Dharward. [2]

Plankton, particularly phytoplankton, has been used as indicators of water quality, because of their short life span and quick responses to environmental changes their standing crops and species composition indicate the quality of water in which they are found. Clean water supports a great diversity of organisms, whereas, very few organisms survive in polluted water with one or two dominant forms. Phytoplankton constitutes the basis of the nutrient cycle of an ecosystem and hence play an important role in maintaining equilibrium between living organisms and abiotic factor. [3] Many workers such as Rao, [4] Bharathi and Hosamani, [5] Palidebnath and Mukherjee, [6] Hosmani. [7] Venkataramaiah [8] have published their work on environment and ecology of phytoplanktons in fresh water in different lakes of our subcontinent. Fresh water lakes play a vital role in hydrobiological, biological and bio-geochemical aspects of the environment. Therefore, the management and the practices must be integrated on the basis of ecological values and sustainability to create long term vision.

Fresh waters conceivably the most defenceless habitats and the most likely to be changed by the activities of man. This important resource is becoming increasingly scarce in many parts of the world due to the severe impairment of water quality. Environmental wastes contribute at least 2/3 of the organic matter into water source. [9] These activities, including wastewater discharge, changes of habitat structure and connectivity aspects, as well as altered flow regimes, are often complex and difficult to describe directly in terms of their ecological repercussions. Phytoplankton encountered in the water body reflects the average ecological condition and therefore, they may be used as indicator of water quality & assessing the degree of pollution. [10] Our mission was to study the diversity and abundance of phytoplankton in relation to the level of pollution in four lakes of K.R Nagar Taluk, Mysuru Dist, Karnataka, India.

## MATERIALS AND METHODS

### Study area

Karnataka is located in 11º 30' North and 18º 30' North latitudes and 74º East and 78º 30' East longitude. Karnataka state is in the western part of India. The state extends to 805 km from north to south and about 283 km from east to west. The total area of the state is 192,493 sq km. Mysuru district is located between latitude 11º45' to 12º40' north and longitude 75º57' to 77º15' east. It is bounded by Mandya district to the southeast, Kerala state to the south, Kodagu district to the west and Hassan district to the north. It has an area of 6,845 km². In this town only Krishnarajanagara town is situated as one of the taluk of the mysuru district, Karnataka state, India **Fig. 1** which coordinates 12.46º north and 76.39º east of latitude and longitude. Krishnarajanagara was founded between 1925 and 1930 as new town, when flood by river Kaveri damaged the nearby old town called as Yadatore. For water quality assessment 4 lakes were selected which are located in K.R. Nagar Taluk they are Natanahalli lake, Kurubahalli lake, Yelemuddanahalli lake and Katnalu lake.

### Sampling

The sampling was made in the winter (October 2015) and summer (March 2016). Water is sampled from four different lakes of Krishnarajanagara taluk i.e,

Natanahalli lake, Kurubahalli lake, Yemuddanahalli lake and Katnalu lake. The sampling was made in the early morning from different lakes of Krishnarajanagara taluk **Fig.3** by scrubbing the upper surface of water, the samples were collected about 1-2 feet depth. All these lakes are located in K. R. Nagar surroundings with different distances. These lakes are used for many purposes ie., domestic uses like bathing, washing, drinking and some lakes were used for fish culturing with permission from Pisciculture department. Different varieties of small fishes introduced into the lakes in the month of June and July, they allow fishes to grow and after attaining specific size, were harvested and marketed either locally or outside places through the department of fisheries. The following varieties of fish are reared in the lakes are Grass crap, Silver crap, Catla catla, Tilapia, Labeorohita etc., These lakes are also important for agriculture purposes, mainly for coconut plantations and major crops like potato, maize, ragi and other vegetable crops **Table 1**. Satellite locations of all lakes are shown in **Fig 2**, Photographs with sampling sites **Fig 3**.

**Table1: Showing sampling sites of four lakes**

| Lakes | Distance from K.R.Nagar (km) | Longitude | Latitude | MSL (ft) | Shape | Size (acres) | Location | Storage capacity (q secs) | Uses |
|---|---|---|---|---|---|---|---|---|---|
| **1. Natanahalli lake** | 22 | 76° 20' | 12°37' | 2733 | Half moon shape | 3 acre | East | 10 q.sec | Fish culture, agriculture |
| **2.Yelemuddanahalli lake** | 24 | 76° 19' | 12° 37' | 2734 | Irregular shape | 9 acre | North | 25 q.sec | Fish culture, agriculture |
| **3.Kurubahalli lake** | 27 | 76° 18' | 12° 36' | 2735 | L –shape | 5 acre | west | 15 q.sec | Domestic purposes |
| **4. Katnalu lake** | 26 | 76° 13' | 12° 36' | 2690 | Rectangle shape | 6.5 acre | South | 18 q.sec | Domestic uses, fish culture |

**Assessment of water sample for indicator organisms:**

The samples were taken by adding 30ml of 4% formaldehyde for 1000ml of each samples and about 10 ml of Lugol's iodine solution is added to each sample in plastic bottles to sustain the color of organisms for the purpose of identification and it is kept for one day in undisturbed manner for sedimentation process. After sedimentation the supernatant is decanted and the remaining lower portion about 150 ml of the solution is transferred into a clean bottle and observed the samples under microscope (10X and 40X) magnifications.

A drop of sedimented sample taken on a clean glass slide observed with the preferred magnification using microscope. The identified Diatoms are converted into Diatoms per litre (1ml equals to 28 drops). The recorded data was tabulated by using Van Dam software for monitoring diatoms as ecological indicators. [11]

**Analysis of ecological values:**

Based on the assessment of diatoms as indicator organisms, the data obtained is tabulated by using Van Dam software for monitoring analysis of ecological values for two different seasons and three different variables in all lakes.

**Taxonomic guidance:**

While analysing the data to identify the organisms taxonomic guides consulted includes. [5,12] The four lakes selected for present study are Krishnarajanagara taluk lakes. The diatoms were identified with subjected to [11] software for obtaining the ecological condition of each lake.

**Statistical Analysis:**

The data of the present study in the months of October (2015) to March (2016) analyzes the ecological condition of the lakes with respect to present environmental conditions based on the data [11] the diatoms were identified. Identification of diatoms was done with respect to their values through the data given by. [13]

**Photographs showing geographical location of Krishnarajanagara taluk.**

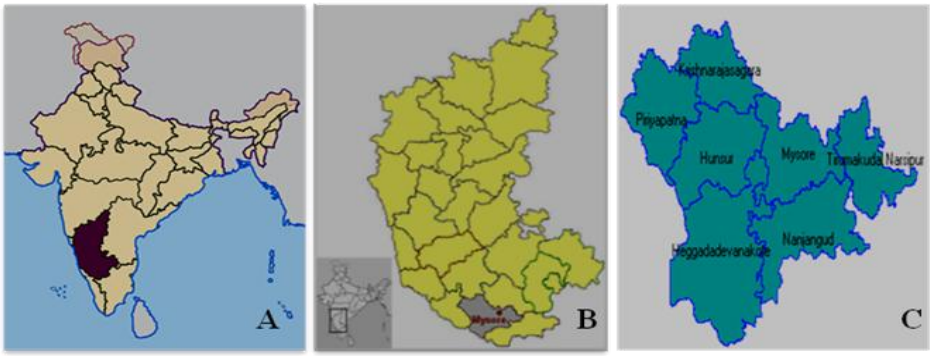


**Fig:1 Map showing geographical location of**
**A) India - Karnataka; B) Karnataka - Myuru; C) Mysuru District**

**Photographs showing Satellite maps of Krishnarajanagara taluk lakes**


**Fig:2 (A) Natanahalli lake; (B) Kurubahalli lake; (C) Yelemuddanahalli lake; (D) Katnalu lake**

**Photographs showing views and sampling sites**


**Fig: 3 Photographs showing views of lakes and sampling sites of A) Natanahalli lake; B) Kurubahalli lake; C) Yelemuddanahalli lake; D) Katnalu lake**

## RESULT

In order to assess the water quality of Natanahalli lake, Kurubahalli lake, Yelemuddanahalli lake, and Katnalu lake of Krishnarajanagara taluk, Mysuru district, in the present study diatoms were identified in all the lakes and their ecological values are determined using the data of Van Dam. The ecological values are represented in **Table 2**. The identified diatoms from all the lakes are shown in **Fig.4**

**Table 2: Classification of ecological indicator values (Van Dam, Martens and Sinkeldam, 1994)**

**Table 2.1: To identify pH (R) values**

| No: | Classes | pH range |
|---|---|---|
| 1 | Acido bionic | Optimal occurrence at pH<5.5 |
| 2 | Acidophilus | Mainly occurring at pH<7 |
| 3 | Circumneutral | Mainly occurring at pH values above 7 |
| 4 | Alkaliphilus | Mainly occurring at pH >7 |
| 5 | Alkali bionic | Exclusively occurring at pH >7 |
| 6 | Indifferent | No apparent optimum |

**Table 2.2: To identify Salinity (H) values**

| No: | Salinity | Chloride | Salinity |
|---|---|---|---|
| 1 | Fresh | <100 | < 0.2 |
| 2 | Fresh brackish | <500 | < 0.9 |
| 3 | Brackish fresh | 500 – 1000 | 0.9 – 1.8 |
| 4 | Brackish | 1000 – 5000 | 1.8 – 1.9 |

**Table 2.3: To identify Nitrogen uptake metabolism (N) values**

| | |
|---|---|
| 1 | Nitrogen autotrophic taxa tolerating very small concentrations of organically bound nitrogen |
| 2 | Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen |
| 3 | Facultative bound nitrogen heterotrophic taxa needing periodically elevated concentrations of organically bound nitrogen |
| 4 | Obligate nitrogen heterotrophic taxa needing continuously elevated concentrations of organically bound nitrogen |

**Table 2.4: To identify Moisture retention (M) values**

| | |
|---|---|
| 1 | Never or only very rarely occurring outside water bodies |
| 2 | Mainly occurring in water bodies, sometimes on wet places |
| 3 | Mainly occurring in water bodies also rather regularly on wet and moist places |
| 4 | Mainly occurring on wet and moist or temporarily dry places |
| 5 | Nearly exclusively occurring outside water bodies |

**Table 2.5: To identify Trophic (T) state**

| | |
|---|---|
| 1 | Oligotrophic |
| 2 | Oligo - mesotrophic |
| 3 | Mesotrophic |
| 4 | Meso - eutrophic |
| 5 | Eutrophic |
| 6 | Hyper eutrophic |
| 7 | Oligo - eutrophic (Hyper eutraphentic) |

**Table 2.6: To identify Oxygen requirements (O) values**

| | |
|---|---|
| 1 | Continuously high(about 100% saturation) |
| 2 | Fairly high(above 75% saturation) |
| 3 | Moderate(about 50% saturation) |
| 4 | Low(above 30% saturation) |
| 5 | Very low(about 10% saturation) |

**Table 2.7: To identify Saprobity (S) values**

| No: | Saprobity | Water quality class | Oxygen saturation (%) | BOD 20( mg/l) |
|---|---|---|---|---|
| 1 | Oligosaprobous | I/II- III | >85 | 2 |
| 2 | B- Mesosaprobous | II | 70 - 85 | 2 -4 |
| 3 | Alpha mesosaprobous | III | 25 - 70 | 4 - 13 |
| 4 | Alph/ meso/ polysaprobous | III- IV | 10 - 25 | 13 - 22 |
| 5 | Polysaprobous | IV | <10 | 22 |

The above tables give the ecological data regarding diatoms. [11] It includes the values of pH from 1-6, it indicates circumneutral, alkaliphelous, acidobiontic etc. Salinity is another ecological value it includes chloride content of the water sample or it may be fresh/fresh brackish/brackish etc. Nitrogen uptake metabolism includes the identified taxa are autotrophic or facultative or obligate. Moisture retention value depends upon the water bodies such as wet or dry. Trophic state is also one of the ecological values included under the software, here the organisms come under oligo, meso and eutrophic state were identified. Oxygen requirement is another one it explains about the percentage of saturation. Saprobity is the last ecological value here the water quality class, percentage of saturation and biological oxygen demand can be clearly illustrated. This ecological value is adapted in water analysis of Natanahalli lake, Kurubahalli lake, Yelemuddanahalli lake and Katnalu lake of Krishnarajanagara taluk, Mysuru district.

## Diversity of Diatoms in four different lakes


**Fig: 4 a- *Stauroneis phoeicenteron* (SPHO); b- *Fragilaria brevistriata* (FBRE); (c) *Gyrosigma acuminatum* (GYAC); d- *Pinnularia acrosphaeria* (PACR) *;* e- *Navicula rynocephala* (NRHY); *f- Gomphonema gracile* (GGRA).**

**Table 3: Distribution of Diatoms in Natanahalli lake during winter (2015) and summer seasons (2016).**

| No: | Species | Winter season | Summer season |
|---|---|---|---|
| 1 | *Gomphonema gracile* (GGRA) | 12,600 | **33,600** |
| 2 | *Synedra ulna* (SULN) | 21,000 | 12,600 |
| 3 | *Navicula rynocephala* (NRHY)) | 16,800 | 12,600 |
| 4 | *Stauroneis phoeicenteron* (SPHO) | **29,400** | 8,400 |
| 5 | *Cymbella cymbiformis* (CCYM) | 8,400 | 29,400 |

## Ecological values of Winter and Summer seasons in Natanahalli lake:

The ecological values for the identified diatoms in the Natanahalli lake are represented in **Table 4**. About 16 ecological values are predicted in the table. In both winter and summer seasons the pH range of this site is Acido bionic because of its range is < 5.5, salinity is less because of brackish water and about 50% saturation is done because of moderate oxygenation. Nitrogen-autotrophic taxa tolerating elevated concentrations of organically bound nitrogen is also same.

In winter season its trophic status is Oligotrophic, moisture condition is wet hence organisms occurring in most places of water bodies. It consists of oligosaprobous, biological oxygen demand is high, water quality class is I/II-III, oxygen saturation is >85% and it has 4.09% (low) of Index of Diatom Saprobic Eutrophication (IDSE). Here organic pollution is not found, hence there is no organic pollution indicators, as well as about 37.50% moderate indicators of anthropogenic eutrophication are predicted in high number ie., *Navicula rynocephala* (NRHY) and *Stauroneis phoeicenteron* (SPHO) are the two important indicators of anthropogenic eutrophication. The total population found in this lake is 79,800 and diversity is 1.78% and total number of species is 4 with 4 different genera.

In summer season its trophic status is oligo-eutrophic (Hyper eutraphentic), moisture condition is slight lower than winter season. It consists of polysaprobous, biological oxygen demand is 0-10, water quality class is IV, oxygen saturation is <10, it has 4.14% (low) of Index of Diatom Saprobic Eutrophication (IDSE). Here organic pollution is not found hence there are no organic pollution indicators, as well as about 23.81% moderate indicators of anthropogenic eutrophication are predicted ie., *Navicula rynocephala* (NRHY) and are the two important indicators of anthropogenic eutrophication. The total population found in this lake is 96,600 and diversity is 2.20% and total number of species is 5 and 5 genera.

**Table 4: Ecological values of Winter and Summer seasons in Natanahalli lake of K.R.Nagar taluk, Mysuru District.**

| No: | Ecological indicators | Ecological values of winter season | Ecological values of summer season |
|---|---|---|---|
| 1 | Number of species | 4 | 5 |
| 2 | Population | 79,800 | 96,600 |
| 3 | Diversity | 1.78 | 2.20 |
| 4 | Evenness | 0.89 | 0.95 |
| 5 | Number of genera | 4 | 5 |
| 6 | $p^H$ (R) | Acido bionic, optimal occurrence at $p^H$ <5.5 | Acido bionic, Optimal occurrence at $p^H$<5.5 |
| 7 | Salinity(H) | Fresh brackish, chloride < 500 & salinity 0.9 | Fresh brackish, chloride < 500 & salinity 0.9 |
| 8 | Nitrogen uptake metabolism(N) | Nitrogen-autotrophic taxa tolerating very small concentrations of organically bound nitrogen. | Nitrogen autotrophic taxa tolerating very small concentrations of organically bound nitrogen |
| 9 | Oxygen requirement(O) | Continuously high (about 100% saturation) | Continuously high (about 100% saturation) |
| 10 | Saprobity(S) | Oligosaprobous [Water quality class is I, Oxygen saturation is >85, BOD 20 (mg/l) is <2] | Oligosaprobous[Water quality class is I, Oxygen saturation is >85, BOD 20 (mg/l) is <2] |
| 11 | Trophic state | Mesotrophic | Oligo - eutrophic (Hyper eutraphentic) |
| 12 | Moisture retention(M) | Mainly occurring in water bodies also rather regularly on wet and moist places | Mainly occurring in water bodies, sometimes on wet places |
| 13 | IDSE / % (Louis -Lecreoq index) | 4.09 % (low) | 4.14 % ( low) |
| 14 | % Indicators of org.Pollution | 0.0 | 0.0 |
| 15 | % indicators of anthropogenic eutrophication | 37.50 % ( moderate) | 23.81 % (moderate) |
| 16 | Indicator organisms | NRHY, SPHOS | NRHY |

**Table 5: Distribution of Diatoms in Kurubahalli lake during winter (2015) and summer seasons (2016)**

| No: | Species | Winter season | Summer season |
|---|---|---|---|
| 1 | *Synedra acus* (SACU) | 16,800 | 25,200 |
| 2 | *Gomphonema gracile* (GGRA) | 12,600 | **33,600** |
| 3 | *Gyrosigma acuminatum* (GYAC) | **50,400** | 12,600 |
| 4 | *Fragilaria construens*(FCON) | 12,600 | 21,000 |
| 5 | *Navicula halophila* (NHAL) | 12,600 | 25,200 |
| 6 | *Synedra ulna* (SULN) | 8,400 | 21,000 |

**Table 6: Ecological values of Winter and Summer seasons in Kurubahalli lake of K.R.Nagar taluk, Mysuru District**

| No | Ecological indicators | Ecological values of winter season | Ecological values of summer season |
|---|---|---|---|
| 1 | Number of species | 6 | 6 |
| 2 | Population | 1,00,800 | 1,38,600 |
| 3 | Diversity | 2.15 | 2.46 |
| 4 | Evenness | 0.93 | 0.95 |
| 5 | Number of genera | 5 | 6 |
| 6 | $p^H$ (R) | Acido bionic, optimal occurrence at $p^H$ <5.5 | Acido bionic, Optimal occurrence at $p^H$<5.5 |
| 7 | Salinity(H) | Fresh brackish, chloride < 500 & salinity 0.9 | Fresh brackish, chloride < 500 & salinity 0.9 |
| 8 | Nitrogen uptake metabolism(N) | Nitrogen-autotrophic taxa tolerating very small concentrations of organically bound nitrogen. | Nitrogen autotrophic taxa tolerating very small concentrations of organically bound nitrogen |
| 9 | Oxygen requirement(O) | Continuously high(about 100% saturation) | Continuously high(about 100% saturation) |
| 10 | Saprobity(S) | α- mesosaprobous [Water quality class is III, Oxygen saturation is 25-70, BOD 20(mg/l) is 4-13] | Oligosaprobous [Water quality class is I, Oxygen saturation is >85, BOD20(mg/l) is <2] |
| 11 | Trophic state | Eutrophic | Mesotrophic |
| 12 | Moisture retention(M) | Mainly occurring in water bodies also rather regularly on wet and moist places | Mainly occurring in water bodies, sometimes on wet places |
| 13 | IDSE / % (Louis -Lecreoq index) | 3.66 % (low) | 3.65 % (low) |
| 14 | % Indicators of org. Pollution | 13.64 % (low) | 16.67 % (low) |
| 15 | % indicators of anthropogenic eutrophication | 18.18 % ( low) | 40 % (moderate) |
| 16 | Indicator organisms | NHAL, SACU | NHAL, SACU, SULN |

## Ecological values of Winter and Summer seasons in Kurubahalli lake:

The ecological values for the identified diatoms in the Kurubahalli lake are represented in **Table 6**. About 16 ecological values are predicted in the above table. In both winter and summer seasons the $p^H$ range of this site is Acido bionic because of its range is < 5.5, salinity is less because of Fresh brackish and about 100% saturation is done because of continuous high oxygenation.

In winter season its trophic status is Eutrophic, moisture condition is wet hence organisms occurring in moist places of water bodies. It consists of Alpha mesosaprobous, biological oxygen demand is 4 - 13, water quality class is III, oxygen saturation is 25 - 70%, and it has 3.66% (low) of Index of Diatom Saprobic Eutrophication (IDSE). Here organic pollution is 13.64% as well as about 18.18 % (low) moderate indicators of anthropogenic eutrophication are predicted in high number i.e. *Navicula halophila* (NHAL) *and Synedra acus* (SACU) are the two important indicators of anthropogenic eutrophication. The total population found in this lake is 1,00,800, and diversity is 2.15% and total number of genera are 5 with 6 species.

In summer season its trophic status is Mesotrophic, moisture condition is slight lower than winter season. It consists of oligosaprobous, biological oxygen demand is >75%, water quality class is I/II -III, oxygen saturation is > 85, it has 3.65% (low) of Index of Diatom Saprobic Eutrophication (IDSE). Here organic pollution is 16.67% as well as about 40% moderate indicators of anthropogenic eutrophication are predicted i.e. *Synedra acus* (SACU) and *Synedra ulna* (SULN) are the two important indicators of anthropogenic eutrophication. The total population found in this lake is 1,38,600 and diversity is 2.46% and total number of 6 genera and 6 species.

**Table 7: Distribution of Diatoms in Yelemuddanahalli lake during winter (2015) and summer seasons (2016)**

| No: | Species | Winter season | Summer season |
|---|---|---|---|
| 1 | *Gomphonema gracile* (GGRA) | 16,800 | 21,000 |
| 2 | *Navicula rynocephala* (NRHY) | 16,800 | 16,800 |
| 3 | *Cymbella cymbiformis* (CCYM) | 4,200 | 8,400 |
| 4 | *Pinnularia acrosphaeria* (PACR) | **29,400** | **37,800** |
| 5 | *Achnanthes exigua* (AEXI) | 12,600 | 29,400 |
| 6 | *Asterionella formosa* (AFOR) | 8,400 | 16,800 |

**Ecological values of Winter and Summer seasons in Yelemuddanahalli lake:**

The ecological values for the identified diatoms in the Yelemuddanahalli lake is represented in **Table 8**. About 16 ecological values are predicted in the above table. In both winter and summer seasons the $p^H$ range of this lake is Acido bionic because of its range is < 5.5, salinity is less because of fresh brackish water and about 90% saturation is done because of continuous high oxygenation.

In winter season its trophic status is oligo - mesotrophic, moisture condition is wet hence organisms occurring in water bodies. It consists of oligosaprobous, biological oxygen demand is high, water quality class is I/II-III, oxygen saturation is >85%, and it has 4.07% (low) of Index of Diatom Saprobic Eutrophication (IDSE). Here organic pollution is not found, hence there is no organic pollution indicators, as well as about 21.74% moderate indicators of anthropogenic eutrophication are predicted i.e. *Navicula rynocephala* (NRHY) is the important indicator of anthropogenic eutrophication. The total population found in this lake is 88,200 and diversity is 2.37% and total number of genera are 6 with 6 species.

In summer season its trophic status is also oligo-mesotrophic, moisture condition is same as that of winter season. It consists of oligosaprobous, biological oxygen demand is high, water quality class is I/II-III, oxygen saturation is > 85%, and it has 4.06% (low) of Index of Diatom Saprobic Eutrophication (IDSE). Here the organic pollution is not found; hence there are no organic pollution indicators, as well as about 11.11% moderate indicators of anthropogenic eutrophication are predicted i.e. *Navicula rynocephala* (NRHY) is the important indicator of anthropogenic eutrophication. The total population found in this lake is 1,30,200 and diversity is 2.46% and total number of genera are 6 with 6 species.

**Table 8: Ecological values of Winter and Summer seasons in Yelemuddanahalli lake of K.R.Nagar taluk, Mysuru District**

| No: | Ecological indicators | Ecological values of winter season | Ecological values of summer season |
|---|---|---|---|
| 1 | Number of species | 6 | 6 |
| 2 | Population | 88200 | 1,30,200 |
| 3 | Diversity | 2.37 | 2.46 |
| 4 | Evenness | 0.92 | 0.95 |
| 5 | Number of genera | 6 | 6 |
| 6 | $p^H$ (R) | Acido bionic, optimal occurrence at $p^H$ <5.5 | Acido bionic, Optimal occurrence at $p^H$<5.5 |
| 7 | Salinity(H) | Fresh brackish, chloride < 500 & salinity 0.9 | Fresh brackish, chloride < 500 & salinity 0.9 |
| 8 | Nitrogen uptake metabolism(N) | Nitrogen-autotrophic taxa tolerating very small concentrations of organically bound nitrogen. | Nitrogen autotrophic taxa tolerating very small concentrations of organically bound nitrogen |
| 9 | Oxygen requirement(O) | Continuously high(about 100% saturation) | Continuously high (about 100% saturation) |
| 10 | Saprobity(S) | Oligosaprobous [Water quality class is I, Oxygen saturation is >85, BOD20(mg/l) is <2] | Oligosaprobous [Water quality class is I, Oxygen saturation is >85, BOD20(mg/l) is <2] |
| 11 | Trophic state | Oligo-mesotrophic | Oligo- mesotrophic |
| 12 | Moisture retention(M) | Mainly occurring in water bodies also rather regularly on wet and moist places. | Mainly occurring in water bodies also rather regularly on wet and moist places |
| 13 | IDSE / % (Louis -Lecreoq index) | 4.07 % (low) | 4.06 % (low) |
| 14 | % Indicators of org.Pollution | 0.0 | 0.0 |
| 15 | % indicators of anthropogenic eutrophication | 21.74 % (moderate) | 11.11 % (low) |
| 16 | Indicator organisms | NRHY | NRHY |

**Table 9: Distribution of diatoms in Katnalu lake during winter (2015) and summer seasons (2016)**

| No: | Species | Winter season | Summer season |
|---|---|---|---|
| 1 | *Synedra acus* (SACU) | 12,600 | 21,000 |
| 2 | *Pinnularia acrosphaeria* (PASA) | 12,600 | 21,000 |
| 3 | *Navicula rynocephala* (NRHY) | **25,200** | **29,400** |
| 4 | *Eunotia arcus* (EARC) | 12,600 | 21,000 |
| 5 | *Fragilaria construens* (FCON) | 21,000 | 25,200 |
| 6 | *Asterionella formosa* (AFOR) | 4,200 | 00 |

**Table 10: Ecological values of Winter and Summer seasons in Katnalu lake of K.R.Nagar taluk, Mysuru District**

| No: | Ecological indicators | Ecological values of winter season | Ecological values of summer season |
|---|---|---|---|
| 1 | Number of species | 6 | 5 |
| 2 | Population | 88,200 | 1,17,600 |
| 3 | Diversity | 2.17 | 2.48 |
| 4 | Evenness | 0.93 | 0.96 |
| 5 | Number of genera | 5 | 6 |
| 6 | $p^H$ (R) | Acido bionic, optimal occurrence at $p^H$ <5.5 | Acido bionic, Optimal occurrence at $p^H$<5.5 |
| 7 | Salinity(H) | Fresh brackish, chloride < 500 & salinity 0.9 | Fresh brackish, chloride < 500 & salinity 0.9 |
| 8 | Nitrogen uptake metabolism(N) | Nitrogen-autotrophic taxa tolerating very small concentrations of organically bound nitrogen. | Nitrogen autotrophic taxa tolerating elevated levels of organically bound nitrogen |
| 9 | Oxygen requirement(O) | Meso-eutrophic | Low (above 30% saturation) |
| 10 | Saprobity(S) | B- mesosaprobous [water quality class is II,oxygen saturation is 70-85%,BOD 20(mg/l) is 2-4. | B- mesosaprobous [water quality class is II,oxygen saturation is 70-85%,BOD 20(mg/l) is 2-4. |
| 11 | Trophic state | Oligo - eutrophic(Hyper eutrophication) | Meso - eutrophic |
| 12 | Moisture retention(M) | Mainly occurring in water bodies, sometimes on wet places. | Never or only very rarely occurring outside water bodies |
| 13 | IDSE \ % (Louis –Lecreoq index) | 3.74 % (low) | 3.76 % (low) |
| 14 | % Indicators of organic pollution | 0.0 | 0.0 |
| 15 | % indicators of anthropogenic eutrophication | 50 % (high) | 36 % (moderate) |
| 16 | Indicator organisms | NRHY, SACU | NRHY, SACU |

## Ecological values of Winter and Summer seasons in Katnalu lake of K.R.Nagar taluk, Mysuru District

The ecological values for the identified diatoms in the Katnalu lake are represented in **Table 10**. About 16 ecological values are predicted in the above table. In both winter and summer seasons the pH range of this lake is Acido bionic because of its range is < 5.5, salinity is less because of Fresh brackish water and about 90% saturation is done because of continuous high oxygenation.

In winter season its trophic status is Oligo - eutrophic, moisture condition is wet; hence organisms occurring in water bodies. It consists of B-mesosaprobous, biological oxygen demand is moderate, water quality class is II, oxygen saturation is 70-85%, and it has 3.74% (low) of Index of Diatom Saprobic Eutrophication (IDSE). Here organic pollution is not found, hence there is no organic pollution indicators, as well as about 50% high indicators of anthropogenic eutrophication are predicted i.e. *Navicula rynocephala* (NRHY) and *Synedra acus* (SACU) are the important indicator of anthropogenic eutrophication. The total population found in this lake is 88,200 and diversity is 2.17% and total number of 5 genera with 6 species.

In summer season its trophic status is also Meso eutrophentic, moisture condition is same as that of winter season. It consists It consists of oligosaprobous, biological oxygen demand is high, water quality class is I/II-III, oxygen saturation is >85%, and it has 3.76% (low) of Index of Diatom Saprobic Eutrophication (IDSE). Here organic pollution is not found; hence there are no organic pollution indicators, as well as about 36% moderate indicators of anthropogenic eutrophication are predicted ie., *Navicula rynocephala* (NRHY) and *Synedra acus* (SACU) are the important indicator of anthropogenic eutrophication. The total population found in this lake is

1,17,600 and diversity is 2.48% and total number of genera are 6 with 6 species.

The above table gives the data of identified species in two different seasons of Katnalu lake of K.R.Nagar taluk, Mysuru district. The identified species are *Synedra acus* (SACU), *Pinnularia acrosphaeria* (PASA), *Navicula rynocephala* (NRHY), *Eunotia arcus* (EARC), *Fragilaria construens* (FCON) and *Asterionella formosa* (AFOR). The *Navicula rynocephala* (NRHY) is the most common and abundantly found species both in winter and summer season total having 54,600 population and *Asterionella formosa* (AFOR) is the least species found in this lake and it can be seen only in one site and in other sites is completely absent, with an average of 4200 population. The other species are moderately found in all the sites and are significantly different.

## DISCUSSION

In recent decades, a significant effort has been put forth all over the world to assess water quality attending to not only to chemical parameters (nutrients, metals, pesticides, etc.,) which are obviously important, but also to biological indicators. In fact, one of the undesirable consequences of pollutants is their effect on biota. In this case, the direct study of the effects of pollution on biota is of great interest. Water quality assessments based on the use of diatoms are now well developed and their value is predicted in international level. Diatom assemblages support Paleo-ecological investigations, historical reconstruction of water quality and the determination of prevailing water quality conditions. Diatoms provide a fine level of diagnostic resolution of the causes underlying changes in water quality and environmental condition as indicators of pollution. [14,15] Software of [11] serves as an important role in determining the ecological status of the water body.

Increasing anthropogenic influence on lotic environments as result of civilization has captured public interest because of the consequent problems associated with deterioration of water quality. [16] Diatom structure depends on variety of environmental factors that includes biological parameters as well as with physic-chemical parameters. [17] Diatoms are not only the source of food for young and adult fish, but also influence the abiotic features in the lake. Diatoms are not only for fishery management but also they are the biological indicators of pollution. [18]

In the present study the different types of diatoms were identified in four lakes of K.R.Nagar taluk, Mysuru district. Species recorded in more numbers included *Gomphonema gracile* (GGRA), *Synedra acus* (SACU) and *Pinnularia acrosphaeria* (PASA). Species recorded in moderate numbers are *Fragilaria brevistriata* (FBRE), *Navicula rynocephala* (NRHY), *Achnanthes exigua* (AEXI), *Fragilaria construens (*FCON) and *Navicula halophila* (NHAL*)*and finally species recorded in least numbers are *Synedra ulna* (SULN), *Gyrosigma acuminatum* (GYAC), *Stauroneis phoeicenteron* (SPHO), *Cymbella cymbiformis* (CCYM), *Asterionella formosa* (AFOR), *Pinnularia acrospharia (*PACR*)* and *Eunotia arcus* (EARC).

Our study also predicts the variation in identified diatoms which can be influenced by the environmental factors those organisms are used as ecological indicators in water quality assessment. Density of organisms is depending upon the abiotic factors either indirectly or directly in the aquatic ecosystem. *Synedra ulna* (SULN) appears only in Natanahalli which indicates the disturbances in lakes due to human activity. *Navicula halophila* and *Synedra acus* which indicates organic pollution in Kurubahalli lake are in concurrence with the results [19] who was the first to show a clear nexus between organic pollution and blue-green algae and the centric diatoms. The genera like *Scenedesmus, Navicula, Nitzschia, and Ankistrodesmus* are the species found in organically polluted waters [20] supported.

[21,22] Similar observations were registered [14] who gave a detailed account of dominant species of diatoms being used as indicators of water quality. Their occurrence might be due to ability of these groups of phytoplanktons to survive in adverse conditions and to adjust with the environment.

The phytoplankytons showed highest degree of organic pollution with dominance of *Scenedesmus*, *Navicula*, *Nitzschia*, etc., throughout the study, which considered to be indicators of organic pollution [23-25] which are in accordance with our work with *Nitzchia* and *Gomphonema* species, similar observations were encountered. [26,27]

Our results are similar to the reports of [28-30] which shows algal forms are good indicators of water pollution and their presence show some signs of water pollution, organic pollution and relationship between diatoms and environment, to analyze the water quality. The ecological data of each lake differs ie., we can see acido bionic, optimal $p^H$ range is less than 7. This $p^H$ values depends upon the presence of species in all the lakes, the lakes studied are fresh brackish, chloride content is less than 500 and salinity is less. As same to salinity, all the lakes include nitrogen tolerating autotrophic species. But oxygenation varies with different saturations ie., in Natanahalli lake, Kurubahalli lake and Yelemuddanahalli lake we find 100% saturation. The Katnalu lake has 75% of saturation and then 50% of saturation Oligo/ ά - meso/ ß - mesosaprobous type of saprobity can be seen along with water quality class I/ II/ III and biological oxygen demand is about 20 (mg/l) is 1-13.

At the same time moisture tolerance is same in all the lakes as here the species occurring mainly on water bodies but in some cases they found on wet places. Index of diatom saprobic eutrophication (IDSE) value differs in each seasons i.e, in winter and summer are 4.09% - 4.14% in Natanahalli lake, 3.66% - 3.65% in Yelemuddanahalli, 4.07% - 4.06% in Kurubahalli lake and 3.74% - 3.76% in Katnalu lake. Organic pollution is not found in majority of lakes but found in few lakes ie., in Kurubahalli 13.64% and indicators are *Nitzchia* and *Gomphonema* species.

In all the four lakes we can see the indicators of anthropogenic eutrophication. *Navicula rynocephala* (NRHY), *Synedra acus* (SACU) *and Synedra ulna* (SULN) are the three major anthropogenic eutrophication indicators in both seasons of all the four lakes of K.R.Nagar taluk. The total population and diversity also varies from one lake to the other ie., 1.78% & 1,76,400 in Natanahalli lake, 2.15% & 2,39,400 in Yelemuddanahalli lake, 2.37% & 2,18,400 in Kurubahalli lake and 2.17% & 2,05,800 in Katnalu lake.

## SUMMARY AND CONCLUSION

Water quality analysis is used to describe the condition or environmental health of a water body. It is used to check the purity of water. It is necessary for the protection of aquatic forms and humans which are highly influenced by water. In the present survey all the lakes were fresh brackish water and acido bionic which shows acidophilus nature. But the saturation and trophic state is varies from lake to lake. The ecological values are not remain constant they vary from winter to summer seasons.

The present investigation reveals the presence of diatom communities in the studied lakes which are Nitrogen tolerant, autotrophic taxa impact, anthropogenic eutrophication activity and organic pollution. Anthropogenic eutrophication is nothing but the enrichment of water quality by nutrients through human activity and organic pollution occurs when excess of organic matter such as sewage, manure etc., and enters the water. Anthropogenic activity has drastically increased in winter season in most of the lakes such as Natanahalli lake, Yelemuddanahalli lake and Katnalu lake than the summer season. They strongly influence the water quality such as pH, color, taste and odour, because pesticides

and fertilizers used by agriculturists, also by domestic wastes in the surrounding area of polluted lakes.

Diatoms are the major ecological indicators of water quality and also indicate $p^H$, salinity, nitrogen uptake metabolism, oxygen requirement, saprobity, trophic state, moisture retention, diatom index, percentage and indicators of organic pollution, percentage and indicators of anthropogenic eutrophication of each lake is analysed in our survey. As such, the presence or absence of the robust biological indicator-diatoms in the habitat indicate the pollution gradients in lakes and useful in assigning their role. Abundance of these organisms in relation to others would greatly help in detecting the degree of contamination, water quality variables, state of actual health and ecological status of lake ecosystems of India, which is the need of the hour. If the present state of pollution affairs continues, situation may arise that these lakes might become ecologically inactive lakes.

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