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Research Article

SEASONAL INSTABILITY ON DIATOM DIVERSITY IN MAHADEVARAHALLI LAKE, MANGALAPURA LAKE, NAGATHIHALLI LAKE AND YADAPURA LAKE OF ARSIKERE TALUK, HASSAN DISTRICT, KARNATAKA, INDIA

[1]Purushotham, S.P. and [2]*Anupama, N.

Department of Botany, Maharani's Science College for Women,
Mysuru-570005, Karnataka, India

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ABSTRACT

Water is the life blood of our Planet. The study on hand has focused on the present status of diatom diversity and to determine pollution level in four lakes of Arsikere Taluk. The aquatic organisms were used as bio indicators for pollution and also as bio-monitors to understand the interaction between organism's responses to environmental alteration and their legal effect. This study is aimed to evaluate the water quality in Arsikere Taluk lakes using diatoms as indicators together with physico-chemical parameters. Overall, the identified diatoms in four lakes were water quality indicators. In Mahadevarahalli lake S. ulna and N. rhynocephalia were proved as anthropogenic indicators and N. halophila was responsible for organic pollution. In Mangalapura lake S. ulna and N. rhynocephalia were liable for anthropogenic pollution with no organic indicators and no organic pollution. Nagathihalli lake was contaminated by organic pollution indicator N.mutica and anthropogenic indicator N. rhynocephalia showing both organic as well as anthropogenic pollution. Absence of both anthropogenic and organic indicator were observed in Yadapura lake. Results of the present study cautions to stop the pollution quick and not to make the water sick.

INTRODUCTION

Water is the origin of life and the blue arteries of Earth. It is crystal clear that forming pollution is easy but resolving the impact of it is thorny. Developments of industry and rapid growth of world population cause many environmental problems and decreases the quality of limited freshwater of the world. Pollution of freshwater resources effects harmfully many aquatic and terrestrial organisms, which are sensitive to environmental changes and members of food chain. So monitoring water quality is a necessity both for human health and ecosystem health as one of the best protection techniques of aquatic ecosystems (Atici *et al*., 2018). Using bio-indicator organisms, which is being used for a long time in scientific community, is an effective environmental monitoring method. Diatoms can be found in every surface of water at any time and form a large part of the benthos (often 90 - 95%), are one of the most important aquatic producer groups and have quick reactions to the environmental variables. So the diatoms are an important part of water quality monitoring organisms and long been used to assess environmental conditions in a number of countries as indicators of water pollution (Tan *et al*., 2017). Microclimate and seasonal change in a particular area also play an imperative role in the presence and absence of some species (Sharma and Kumari, 2018) which may function as indicators of pollution (Suresh, 2015). Diatoms are the main primary producers and chemical modulators in freshwater aquatic ecosystems (Mangadze *et al*., 2015) and represent an important carbon and energy source for secondary consumers (Venkatachalapathy and Karthikeyan, 2015). Because diatoms are very sensitive to environmental changes and/or to disturbances such as eutrophica¬tion, acidification, land use and pollution, they are considered to be powerful indicators of water quality in freshwater systems (Rimet *et al*., 2015). Moreover diatoms have distinct ecological tolerances (Bahls, 1993) and short generation time (Zalack *et al*., 2010; Tan *et al*., 2014b), making them suitable indicator organisms for water quality changes over short time scales.

Corresponding author:* **Anupama N
Department of Botany, Maharani's Science College for Women, Mysuru-570005, Karnataka, India

MATERIALS AND METHODS

Study Area

Karnataka is located 110 30' North and 18030' North latitudes and 740 East and 78030' East longitude. Hassan is lying between 12°13′ and 13°33′ North latitudes and 75°33′ and 76°38′ East longitude, Hassan District has a total area of 6826.15 km². Chikmaglur District is surrounded to the north-west, Chitradurga to the north, Tumkur District to the east, Mandya District to the south east, Mysore District to the south, Kodagu to the south-west and Dakshina Kannada District to the west. Hassan stands around 3,084 feet (940 m) above the sea level. Hassan has 8 Taluks which are Arsikere, Alur, Arakalgud, Belur, Channarayapatna, Hassan, Holenarsipur and Sakaleshpur. Arsikere is located at 13.31°N 76.26°E. Arasikere is situated about 44 km from Hassan. It has an average elevation of 807 meters (2,648 ft). In our study four lakes of Arsikere Taluk viz. Mahadevarahalli Lake, Mangalapura Lake, Nagathihalli Lake and Yadapura Lake were selected to study the diatoms diversity Fig.1.

Sampling

The sampling was made in the winter (October 2015) and summer (March 2016). Water was sampled from four different lakes of Arsikere taluk ie., Mahadevarahalli Lake, Mangalapura Lake, Nagathihalli Lake and Yadapura Lake. The sampling was made in the early morning from four lakes of Arsikere taluk shown in Fig 3. By scrubbing the upper surface of water, the samples were collected from 1-2 feet depth. All these lakes are located in Arasikere surroundings with different distance and are used for many purposes ie., domestic uses like bathing, washing and drinking for humans and animals. Some of the lakes are used for fish culturing. Fishermen got license from the Pisciculture Department. Different varieties of small fishes are introduced into the lake in the month of June and July. They allow fishes to grow and after attaining specific size, they harvest and market either locally or outside places through the Department of Fisheries. The varieties of fish reared in the lake are Grass crap, Silver crap, Catla, Tilapia (julebi), Labeo rohita etc. These lakes are also important for agricultural purposes, mainly for Coconut plantations and major crops like Tomato, Potato, Ragi, Maize and other vegetable crops. Satellite locations and sampling sites of the selected lakes are shown in Fig 2&3.

Photographs showing geographical location of Hassan Taluks

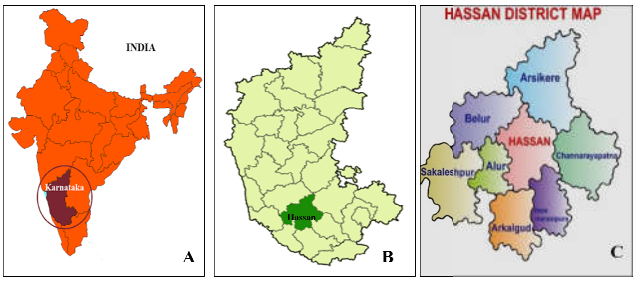

Fig 1 Map showing geographical location of

A) India - Karnataka; B) Karnataka- Hassan ; C) Hassan District- Arsikere Taluk

Photographs showing Satellite maps of Arsikere Taluk Lakes, Hassan District

Fig 2 (A) Mahadevarahalli Lake; (B) Mangalapura Lake; (C) Nagathihalli Lake; (D) Yadapura Lake

Photographs showing views and sampling sites

Fig 3 Photographs showing views of lakes and sampling sites of

(A) Mahadevarahalli Lake; (B) Mangalapura Lake; (C) Nagathihalli Lake; (D) Yadapura Lake

Assessment of water sample for indicator organisms

The samples were taken by adding 30ml of 4% formaldehyde for 1000 ml of each sample. 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).

A drop of sedimented sample taken on a clean glass slide was observed with the preferred magnification using microscope. The identified Diatoms are converted into Diatoms per litre (1 ml equals to 28 drops). The recorded data was tabulated by using Van Dam software for monitoring diatoms as ecological indicators (Van Dam *et al*., 1994).

Table 1 Showing sampling sites of 4 lakes

Lakes	Distance from Arsikere (km)	Longitude	Latitude	MSL (ft)	Shape	Size (acres)	Location	Storage capacity (TMC)	Uses
1 .Mahadevarahalli Lake	23	76^0 20' 23''	13^0 71' 23''	2648	Rectangle shape	25.50	South	0.102	Domestic uses, fish culture
2 . Mangalapura Lake	22	76^0 21' 54''	13^0 76' 54''	2645	Rectangle shape	20.20	South	0.091	Domestic uses
3 .Nagathihalli Lake	7	76^0 26' 25''	13^0 32' 41''	2648	Rectangle shape	134.10	North	0.256	Fish culture, agriculture
4 .Yadapura Lake	4	76^0 25' 24''	13^0 31' 41''	2643	L shape	20.30	West	0.096	Domestic uses

Fig 4 A) *Actinocyclus ehrenbergii* (AEHR) ; B) *Navicula cari* (NCAR); C) *Navicula mutica* (NMUT); D) *Navicula similis* (NSIM); E) S. *ulna* (SULN); F) *Fragilaria arcus* (FARC); G) *Gyrosigma scalprosiles* (GSCA); H) *Navicula halophila* (NHAL); I) *Navicula sphaerophoria* (NSPH); J) *Navicula rhynocephalia* (NRHY); K) *Asterionella formosa* (AFOR); L) *Pinnularia gibba* (PGIB).

Analysis of ecological values for Arasikere taluk lakes

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

Taxonomic guidance

While analyzing the data to identify the organisms taxonomic guides consulted includes, Hosmani *et al.* (2012) and Karthick *et al*. (2010).

In the selected lakes, diatoms from water samples were identified and subjected to Van Dam *et al*. (1994) software to obtain the ecological conditions of each lake.

Statistical analysis

The data of the present study were analyzed in the months of October (2015) to March (2016). The ecological conditions of the lakes with respect to present environmental conditions based on the data given by Van Dam *et al.* (1994) the diatoms were identified. Identification of diatoms was done with respect to their values through the data given by Kelly (2003).

Van Dam software

Van Dam software for monitoring diatoms as ecological indicators is used. This software has an inbuilt with the ecological data for about more than 10000-15000 diatom species along with complete name, reference, family type, sensibility, p^H, salinity, oxygen requirement, saprobity, trophic state, moisture retention, indicators & percentage of organic pollution, indicators & percentage of anthropogenic eutrophication.

RESULTS

Diatoms are the common types of phytoplankton. A change in nutrients or a number of other factors will allow some members of the diatom community to grow and reproduce more quickly while others are out competed, thus the community composition as a whole changes in response to change in the environmental conditions. The present study reveals that some species of diatoms can be used to depict the water quality of lakes in the form of bio-indicators and also seasonal variation in aquatic condition. In the lakes of Arsikere taluk to assess the water quality in two seasons ie., in winter (2015) and summer (2016), Van Dam software was used (Van Dan *et al*., 1994), to know the ecological values of diatoms. The diatoms were identified in four lakes and their ecological status is determined using Van Dam *et al*. (1994). Classification of Van Dam software ecological values are represented in Table 2. The diatoms in winter (2015) & summer (2016) seasons in four lakes of Arsikere taluk were identified along with acronyms. Ecological values of four lakes of Arsikere taluk are classified and are shown in the Table 4, 6, 8 & 10. The identified diatoms of four lakes are displayed in the Table. 3, 5, 7 & 9.

Table 2 Classification of ecological indicator values (Van DamandMartensSinkeldam,1994)

Table 2.1 To identify p^H values

p^H	Classes	p^H Range
1	Acidobiontic	Optional occurrence at pH < 5.5
2	Acidophilous	Mainly occurring at pH < 7
3	Circumneutral	Mainly occurring at pH values about 7
4	Alkaliphilous	Mainly occurring at pH > 7
5	Alkalibiontic	Exclusively occurring at pH > 7
6	Indifferent	No apparent optimum

Table 2.2 To identify Salinity values

	Water	Cl^-(Mg l^{-1})	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 concentrations of organically bound nitrogen
3	Facultative bound nitrogen-heterotrophic taxa needing periodically elevated concentrations of organically bound nitrogen
4	Obligately 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	Hypereutrophic
7	Oligo to eutrophic (Hypoeutraphentic)

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

	Saprobity	Water quality class	Oxygen saturation (%)	BOD 20 (mg l^{-1})
1	Oligosaprobous	I	>85	<2
2	β-mesosaprobous	II	70-85	2-4
3	α- mesosaprobous	III	25-70	4-13
4	α-meso-/polysaprobous	III-IV	10-25	13-22
5	Polysaprobous	IV	<10	>22

The above tables give the ecological data regarding the diatoms. This data was given by Van Dam and Martens and Sinkeldam, 1994. It includes the values of p^H from 1-6, it indicates acidobiontic, alkaliphilous, circumneutral, alkaliphilous, alkalibiontic etc. Salinity is another ecological value it includes chloride content of the water sample or it may be fresh/ fresh brackish/ brackish fresh, brakish. Nitrogen uptake metabolism includes the identified Taxa, whether autotrophic (or) facultative (or) obligate. Moisture retention value includes depending upon the water bodies such as wet (or) dry. Trophic state is also one of the ecological values included under this software. Here the organisms come under oligo, meso and eutrophic state were identified. Oxygen requirement is the other one it explains about the percentage of saturation. Saprobity explains water quality class, oxygen saturation and Biological Oxygen Demand (BOD). These ecological values are adapted to assess water quality of lakes of Arsikere Taluk, Hassan District.

Diatoms of Mahadevarahalli Lake

Table 3 Distribution of Diatoms in Mahadevarahalli lake during winter (2015) and summer seasons (2016)

Diatoms in Mahadevarahalli lake	winter	summer
Achnanthus exigua(AEXI)	12600	12600
Actinocyclus ehrenbergii (AEHR)	0	42000
Navicula cari(NCAR)	4200	4200
Navicula halophila(NHAL)	0	8400
Navicula rhynocephalia (NRHY)	0	4200
Navicula sphaerophoria (NSPH)	84000	8400
Synedra ulna(SULN)	0	4200

The above Table 3 gives the data of identified species in Mahadevarahalli lake in winter and summer seasons. In this lake about 4 genera and 7 species are identified. The identified species are *Achanthus exigua* (AEXI), *Actinocyclus ehrenbergii* (AEHR), *Navicula cari* (NCAR), *Navicula halophila* (NHAL), *Navicula rhynocephalia* (NRHY*), Navicula sphaerophoria* (NSPH) and *Synedra ulna* (SULN).

In the winter season *Actinocyclus ehrenbergii* (AEHR), *Navicula halophila* (NHAL), *Navicula rhynocephalia* (NRHY*)* and *Synedra ulna* (SULN) are absent. In summer all are present. In summer *Actinocyclus ehrenbergii* (AEHR) is highest in population about 42000 and in winter *Navicula sphaerophoria* (NSPH) is highest in population about 84000. Other species are moderately found in two seasons.

Table 4 Ecological values of winter (2015) & summer (2016) seasons in Mahadevarahalli lake

No	Ecological Indicator	Ecological values of winter	Ecological values of summer
1	Number of species	3	7
2	Population	1,00,800	84,000
3	Diversity %	0.79	2.22
4	Evenness	0.50	0.79
5	Number of genera	2	4
6	p^H(R)	Alkalibiontic, Exclusively occurring at pH > 7	Alkaliphilous, Mainly occurring at pH > 7
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 concentrations of organically bound nitrogen
9	Oxygen requirement(O)	Continuously high (about 100% saturation)	Countinuously high (about 100% saturation)
10	Saprobity (S)	Oligosaprobous, [water quality class is I, oxygen saturation is > 85%, BOD 20(mg/l^{-1}) is < 2]	Oligosaprobous, [water quality class is I, oxygen saturation is >85%, BOD 20(mg/l^{-1}) is < 2]
11	Trophic state	Oligo-mesotrophic	Oligo to eutrophic (hypoeutrophic)
12	Moisture retention (M)	Nearly exclusively occurring outside water bodies	Mainly occurring in water bodies, sometimes on wet places
13	IDSE/ % (Louis-Lecreoq) Index	3.60 moderate	3.15 moderate
14	% of organic pollution Indicator	0	10% Low
15	Organic pollution Indicator organism	Nil	NHAL
16	% of anthropogenic eutrophication indicator	0	10% Low
17	Anthropogenic pollution Indicator organism	Nil	NRHY, SULN

Ecological values of Mahadevarahalli lake

Seventeen ecological values of the identified diatoms in Mahadevarahalli lake are represented. The p^H range of this lake is highly Alkalibiontic, exclusively occurring at p^H more than 7. In winter season Alkaliphilous, mainly occurring at p^H greater than 7 in summer season. Salinity is less because of fresh brackish water and chloride content is less than 500 and salinity is less than 0.9. Nitrogen-autotrophic taxa tolerating very small concentrations of organically bound nitrogen in winter and nitrogen-autotrophic Taxa tolerating elevated concentrations of organically bound nitrogen in summer season Table 4.

In winter season, its trophic status is Oligo-mesotrophic, moisture condition is nearly exclusively occurring outside the water bodies. Saprobity consists of Oligosaprobous, biological oxygen demand is lesser than 2, water quality class is I, oxygen saturation is >85%. It has 3.60% (moderate) of Index of Diatom Saprobic Eutrophication (IDSE). Here organic pollution is not found as organic pollution indicator is absent. No indicators of anthropogenic eutrophication and hence anthropogenic eutrophication is absent. The total population found in this lake is 1,00,800 and diversity is 0.79% and total number of species is 3 and genera are 2.

In summer season this lake's ecological value for trophic status is Oligo to eutrophic (hypoeutrophic), biological oxygen demand, water quality class, oxygen saturation and Index of Diatom Saprobic Eutrophication (IDSE) are same in winter. Moisture retention is mainly occurring in water bodies, sometimes on wet places. Here organic pollution is found about 10%, organic pollution indicator is *Navicula halophila* (NHAL). Anthropogenic eutrophication is takes place about 10%. Indicators of anthropogenic eutrophication are *Navicula rhynocephalia* (NRHY) and *Synedra ulna* (SULN). The total population found in this lake is 84,000 and diversity is 2.22% and total number of species are 7 and genera are 4. 3 genera are newly predicted in summer season. This data is predicted by using Van Dam software.

Diatoms in Mangalapura Lake

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

Diatoms in Mangalapura lake	winter	summer
Cymbella cymbelliformis (CCYM)	21000	8400
Navicula Arabica (NARA)	0	8400
Navicula rhynocephalia (NRHY)	0	4200
Navicula sphaerophoria (NSPH)	21000	21000
Pinnularaia acrosphaeria (PACR)	0	8400
Synedra ulna(SULN)	12600	21000

Diatoms of Mangalapura Lake

The above Table 5 gives the data of identified species in Mangalapura Lake in winter and summer seasons. In this lake about 4 genera and 6 species are identified. The identified species are *Cymbella cymbelliformis* (CCYM*), Navicula arabica* (NARA), *Navicula rhynocephalia* (NRHY), *Navicula sphaerophoria* (NSPH), *Pinnularaia acrosphaeria (*PACR) and *Synedra ulna* (SULN).

In the winter season, *Navicula arabica* (NARA), *Navicula rhynocephalia* (NRHY*)* and *Pinnularaia acrosphaeria* (PACR) are absent and whereas, in summer all species are present. In winter and summer *Navicula sphaerophoria* (NSPH) is highest in population about 21000. Other species are moderately found in two seasons.

Table 6 Ecological values of winter (2015) & summer (2016) seasons in Mangalapura lake

No	Ecological Indicator	Ecological values of winter	Ecological values of summer
1	Number of species	3	6
2	Population	54,600	71,400
3	Diversity %	1.55	2.37
4	Evenness	0.98	0.92
5	Number of genera	3	4
6	pH(R)	Acidophilous, Mainly occurring at pH < 7	Alkaliphilous, Mainly occurring at pH > 7
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 concentrations of organically bound nitrogen
9	Oxygen requirement(O)	Continuously high (about 100% saturation)	Moderate (above 50% saturation)
10	Saprobity (S)	Oligosaprobous, [water quality class is I, oxygen saturation is >85%, BOD 20(mg/l^{-1}) is < 2]	α/ meso/ polysaprobous, [water quality class is III-IV, oxygen saturation is 10-25%, BOD 20(mg/l^{-1}) is 13-22]
11	Trophic state	Oligo-mesotrophic	Oligo to eutrophic (hypoeutrophic)
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/ % (LouisLecreoq) Index	0 low	3.77 Low
14	% of organic pollution Indicator	23.08 moderate	0
15	Organic pollution Indicator organism	Nil	Nil
16	% of anthropogenic eutrophication indicator	0	35.29% Moderate
17	Anthropogenic pollution Indicator organism	SULN	NRHY, SULN

Ecological values Mangalapura Lake

Seventeen ecological values of the identified diatoms in Mangalapura Lake are represented in **Table 6.** The p^H range of this lake is acidophilous, occurring at p^H less than 7 in winter. Highly alkaliphilous, occurring at p^H more than 7 in summer. Salinity is less because of fresh brackish water and chloride content is less than 500 and salinity is lesser than 0.9 with moderate oxygenation. Nitrogen uptake metabolism is shows nitrogen-autotrophic taxa tolerating very less concentrations of organically bound nitrogen in winter and nitrogen-autotrophic taxa tolerating elevated concentrations of organically bound nitrogen in summer season.

In winter season, its trophic status is Oligo-mesotrophic, moisture condition is mainly occurring in water bodies also rather regularly on wet and moist places. It consists of Oligosaprobous, biological oxygen demand is lesser than 2, water quality class is I, oxygen saturation is >85%, it has 0% (low) of Index of Diatom Saprobic Eutrophication (IDSE). Here organic pollution is found about 23.08% (moderate), organic pollution indicator is absent. No anthropogenic eutrophication, but indicator of anthropogenic eutrophication *Synedra ulna* is found. The total population found in this lake is 54,600 and diversity is 1.55%. The total number of species is 3 and genera are 3.

In summer season, this lake's ecological value for trophic status is Oligo to eutrophic (hypoeutrophic). Saprobity is alpha/ meso/ polysaprobous, biological oxygen demand is 13-22, water quality class III to IV, oxygen saturation is 10-25%. Index of Diatom Saprobic Eutrophication (IDSE) is about 3.77% (low). Here organic pollution is not found because organic pollution indicator is absent. The indicators of anthropogenic eutrophication are *N. rhynocephalia* (NRHY) and *S. ulna* (SULN) hence; anthropogenic eutrophication is 35.29%. The total population found in this lake is 71,400 and diversity is 2.37%. The total number of species are 6 and 4 genera. The evenness is 0.9 and one genera is newly predicted in summer season.

Diatoms in Nagathihalli Lake

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

Diatoms in Nagathihalli lake	winter	summer
Actinocyclus ehrenbergii (AEHR)	0	67200
Cocconeis placentula (CPLA)	12600	58800
Cymbella cymbelliformis (CCYM)	16800	8400
Asterionella Formosa (AFOR)	8400	8400
Fragilaria arcus (FARC)	0	50400
Gyrosigma scalprosiles (GSCA)	21000	8400
Navicula arabica(NARA)	33600	42000
Navicula mutica(NMUT)	42000	42000
Navicula rhynocephalia (NRHY)	8400	8400
Navicula similis (NSIM)	16800	42000
Navicula sphaerophoria (NSPH)	105000	105000
Pinnularaia gibba (PGIB)	8400	25200

Diatoms of Nagathihalli Lake

The above **Table. 7** gives the data of identified species of diatoms in Nagathihalli lake during winter and summer seasons. In this lake about 8 genera and 12 species were identified. The identified species are *Actinocyclus ehrenbergii* (AEHR), *Cocconeis placentula* (CPLA), *Cymbella cymbelliformis* (CCYM*), Asterionella Formosa* (AFOR), *Fragilaria arcus* (FARC), *Gyrosigma scalprosiles* (GSCA), *Navicula arabica* (NARA), *Navicula mutica* (NMUT), *Navicula rhynchocephalia* (NRHY*), Navicula similis* (NSIM), *Navicula sphaerophoria (NSPH), Pinnularaia gibba* (PGIB). This lake is rich in species compare to other lakes in this study in both seasons.

In the winter season, *Actinocyclus ehrenbergii* (AEHR) and *Fragilaria arcus* (FARC) are absent and whereas in summer all species are present. In both seasons *Navicula sphaerophoria* (NSPH) is highest population about 105000. Other species are moderately found in two seasons.

Table 8 Ecological values of winter (2015) & summer (2016) seasons in Nagathihalli lake

No	Ecological Indicator	Ecological values of winter	Ecological value for summer
1	Number of species	10	12
2	Population	2,73,000	4,66,200
3	Diversity %	2.77	3.12
4	Evenness	0.83	0.90
5	Number of genera	6	8
6	p^H (R)	Circumneutral, mainly occurring at pH values about 7	Alkaliphilous, Mainly occurring at pH > 7
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 elevated concentrations of organically bound nitrogen	Nitrogen-autotrophic taxa tolerating elevated concentrations of organically bound nitrogen
9	Oxygen requirement(O)	Continuously high (about 100% saturation)	Countinuously high (about 100% saturation)
10	Saprobity (S)	α-mesosaprobous, [water quality class is III, oxygen saturation is 25-70%, BOD 20(mg/l^{-1}) is 4-13]	β-mesosaprobous, [water quality class is II, oxygen saturation is 70-85%, BOD 20(mg/l^{-1}) is 2 - 4]
11	Trophic state	Eutrophic	Eutrophic
12	Moisture retention (M)	Mainly occurring in water bodies, sometimes on wet places	Mainly occurring in water bodies also rather regularly on wet and moist places
13	IDSE/ % (Louis-Lecreoq) Index	3.72% Low	3.93% Low
14	% of organic pollution Indicator	15.38% Low	9.17% Low
15	Organic pollution Indicator organism	NMUT	NMUT
16	% of anthropogenic eutrophication indicator	3.08%	1.83%
17	Anthropogenic pollution Indicator organism	NRHY	NRHY

Ecological values of Nagathihalli Lake

From the above Table 8, seventeen ecological values are given to the identified organisms in the Nagathihalli Lake. Two seasons of this lake are predicted in the present study by using Van Dam software. Here p^H of the lake is circumneutral, mainly occurring at p^H values about 7 and Alkaliphilous, mainly occurring at p^H above 7 in winter and summer seasons respectively. Salinity, nitrogen uptake metabolism, oxygen requirement and trophic state are same in both seasons.

In the winter season, saprobity is alpha-mesosaprobous, water quality class is III, oxygen saturation is 25-70% and biological oxygen dissolved in water is 4-13. In summer saprobity is beta-mesosaprobous, water quality class is II, oxygen saturation is 70-85% and biological oxygen dissolved is 2-4. Moisture retention is mainly occurring in water bodies, sometimes on wet places in winter and mainly occurring in water bodies also rather regularly on wet and moist places in summer. Oxygen saturation and Index of Diatom Saprobic Eutrophication (IDSE) about 3.72% (low) in winter and 3.93% (low) in summer.

Here organic pollution is found about 15.38% in winter and 9.17% in summer. Organic pollution indicator in winter as well as summer season was *Navicula mutica* (NMUT). Anthropogenic eutrophication is takes place about 3.08% and 1.83% in winter and summer seasons respectively. Indicators of anthropogenic eutrophication are *Navicula rhynocephalia* (NRHY) in both seasons. The total population found in this lake is 2,73,000 in winter and 4,66,200 in summer. The diversity is 2.77% and 3.12%. Total numbers of species are 10 &12 and genera are 6 & 8 in winter & summer seasons respectively.

Diatoms in Yadapura Lake

Table 9 Distribution of Diatoms in Yadapura lake during winter (2015) and summer seasons (2016)

Diatoms in Yadapura lake	winter	Summer
Achnanthus exigua (AEXI)	4200	4200
Cymbella cymbelliformis (CCYM)	8400	0
Fragilaria arcus (FARC)	12600	0
Navicula cari (NCAR)	4200	4200

The above Table 9 gives the data of identified species of diatoms in Yadapura Lake during winter and summer seasons. In this lake about 4 genera and 4 species are identified. The identified species are *Achanthus exigua* (AEXI), *Cymbella cymbelliformis* (CCYM*), Fragilaria arcus* (FARC) and *Navicula cari* (NCAR)**.** In the winter season all species are present and in summer *Cymbella cymbelliformis* (CCYM*), Fragilaria arcus* (FARC) are absent. In winter, *Fragilaria arcus* (FARC) is highest in population about 12600. Other species are moderately found in two seasons.

Table 10 Ecological values of winter (2015) & summer (2016) seasons in Yadapura lake

No	Ecological Indicator	Ecological values of winter	Ecological values of summer
1	Number of species	4	2
2	Population	29,400	8,400
3	Diversity %	1.84	1.84
4	Evenness	0.92	0.92
5	Number of genera	4	2
6	p^H(R)	Alkaliphilous, mainly occurring at pH > 7	Alkaliphilous, Mainly occurring at pH > 7
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)	Countinuously high (about 100% saturation)
10	Saprobity (S)	β-mesosaprobous, [water quality class is II, oxygen saturation is 70-85%, BOD 20(mg/l^{-1}) is 2 - 4]	β-mesosaprobous, [water quality class is II, oxygen saturation is 70-85%, BOD 20(mg/l^{-1}) is 2 - 4]
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	4.29%	4.29%
14	% of organic pollution Indicator	0	0
15	Organic pollution Indicator organism	Nil	Nil
16	% of anthropogenic eutrophication indicator	0	0
17	Anthropogenic pollution Indicator organism	Nil	Nil

Ecological values of Yadapura Lake

From the above **Table 10,** seventeen ecological values of the identified diatoms in Yadapura lake are represented. The p^H range of this lake is highly Alkaliphilous, mainly occurring at p^H above 7 and salinity is less because of fresh brackish water and moderate oxygenation. Nitrogen-autotrophic Taxa tolerating very small concentrations of organically bound nitrogen. Its trophic status is Oligo-mesotrophic, moisture condition is mainly occurring in water bodies also rather regularly on wet and moist places. It consists of beta-mesosaprobous, biological oxygen demand is 2-4, water quality class is II, oxygen saturation is 70-85%. The index of Diatom Saprobic Eutrophication (IDSE) is moderate and it is about 4.29%. Here organic pollution is not found, as there are no organic pollution indicators and anthropogenic eutrophication is also not found as the indicators of anthropogenic eutrophication are absent. The total population found in this lake is 29,400 and diversity among those is 1.84%. The total number of species is 4 and genera are 4.

DISCUSSION

Pollution of freshwater resources has become one of the most important problems of humanity and as it is known, continuous monitoring of the quality of aquatic ecosystems is one of the best protection techniques. Species diversity of our lakes show a relationship with the species obtained with work done by Zelnik *et al*. (2018). Diatoms are a large part of benthic habitats (often 90-95%) and have become an important part of water quality control. The most important feature is that they can be present in all surface waters, anytime, samples collected from them can be maintained for a long period of time (Abbass *et al.,* 2014). 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 underline the change in water quality and environmental condition (Harding *et al.,* 2005), diatoms were considered as bio-monitoring tool; analysis of the lake sample predicts that the diatoms are useful in providing an indication of the ecological condition (Taylor *et al.,* 2007).

Diatoms are a foremost group of algae among the most common types of phytoplankton. They are not only the source of food for young and adult fish, but also influence the abiotic features in the lake and they are also the biological indicators of pollution. (Kumar, 2015). Usually diatoms are widely used in the stream of bio-assessment due to their broad distribution, extraordinary variability and the ability to integrate changes in water quality. It also confirms that the diatoms are sensitive to organic and nutrient contamination and revealed the importance of suspended solids (Maria *et al.,* 2009). Increasing anthropogenic influence on lotic environments as a result of civilization as captured public interest because of the consequent problems associated with weakening of water quality. Diatoms are expansively used for monitoring of water quality (Bere *et al.,* 2010). Seasonal variation of diatoms density and species richness were studied, where diatoms structure depends on variety of environmental factors that include biological parameters as well as physico-chemical parameters (Patil *et al.,* 2013). Our results are in concurrence with the results reported by Mursaleen *et al.* (2018) where physicochemical parameters and diatoms characteristics showed seasonal variation and distribution of the diatoms species in the water bodies was strongly influenced by the physic-chemical properties of the water, such as light availability, temperature, turbidity, concentration of dissolved oxygen and nutrients etc.

The values of physico-chemical parameters in the lake are always below the drinking water quality standards (Shreelakshmi and Shailaja, 2018). Our results are in agreement with the observations of Srinivas *et al*. (2018) with physico-chemical parameters and results obtained by Karthikeyan *et al.* (2018) with severely polluted Cauvery river due to discharge of untreated sewage disposal and industrial effluents into the lake causing anthropogenic and organic pollution. Decreases in water quality in our studied lakes are in line with the results of Sidabutar *et al*. (2017) due to human activities. The values recorded for environmental variables and distribution of samples indicated for seasonal variation by natural fluctuation, p^H, dissolved oxygen and nutrients with changes in temperature are in relation to reports of Quevedo *et al*. (2018). Our results are in parallel with the results gained by Jadav *et al*. (2017) that the diversity of diatoms varies seasonally which are higher in winter season and lower during summer season indicating more pollution in the lakes. Other studies demonstrated the relationship between diatoms and environment, to analyze the water quality by Taylor (2007), Basavarajappa (2011), Hosmani (2012), Bere (2014) and Kumar (2015) etc. The Van Dam *et al*. (1994) software serves as an important role in determining the ecological status of the water body.

SUMMARY AND CONCLUSION

Pure water is the world's first and foremost medicine. The study evaluated the nature of sensitivity and tolerance of Diatom taxa to specific environmental factors. From the results it is concluded that there is deterioration of water quality in the water bodies undertaken for the study. Diatoms encountered during this study are most influential ecological indicators of degradation levels and also the ecological conditions of selected water bodies. They are right tools for bio-monitoring as indicator value of diatoms is well accepted and highly used across the countries. It is an ideal means by which progress towards integrated water resources management can be monitored. The government and people should take utmost care, which is everyone's responsibility to be a part of solution but, not a part of pollution.

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