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Bacillariophyceae as Ecological Indicators of Water Quality in Two Lakes of Mysore

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Abstract:

The insights for Biomonitoring and ecological assessments, focusing mainly on the diatom communities in two lakes of Mysore have been explored in this paper. The OMNIDIA GB 5.3 software has been used to derive the Louis Laclercq IDSE/5 index. The findings from the study show that the diversity of Bacillariophyceae was found to be considerably high in Karanji Lake when compared to Kukkarahalli Lake. Organic pollution was not detected in both the lakes while the level of anthropogenic pollution was 'low' to 'moderate' in both the lakes. On the other hand, level of degradation remained 'low' always in Karanji Lake while it was 'low' to 'moderate' in Kukkarahalli Lake. *Synedra ulna* was the most common species indicating the anthropogenic pollution. The ecological indicator values represent deteriorating water quality in both the lakes, the main reason being human interferences causing a direct impact on the lake ecosystems. Biomonitoring has been proven to be necessary supplementary to the traditional monitoring techniques and hence the importance of Bacillariophyceae as ecological indicators of water quality has been stressed.

Keywords: Anthropogenic Pollution, Bacillariophyceae, Biomonitoring, Ecological Indicators, Louis-Laclercq, Organic Pollution, *Synedra*.

1.0 Introduction:

Classically, monitoring of water quality with regards to physical and chemical parameters reflects instantaneous measurements while biotic parameters developed during the recent years have served as an excellent tool in the area of water pollution studies and provides better evaluation of environmental changes (Kalyoncu and Serbetci, 2013). Bacillariophyceae in particular are of at most importance as potential indicators of water quality due to their sensitivity and strong response to many physical, chemical and biological changes (Suphan*et al.,* 2012). The first studies of diatoms and river pollution were carried out 60 years ago, and the suitability of these micro-algae as bio assessment indicators for monitoring river quality was quickly demonstrated (Rimet F., 2012). Few related studies have been carried out in the past on algae as Bioindicators of pollution by Hosmani and Bharathi (1980), Lavoie et al., (2004), Park (2006), Barinova (2010), Basavarajappa*et al.,* (2010), Salomoni*et al.,* (2011), Al-Homaidan (2011), Andrejic et al., (2012) Ozbay (2011), Mahendra et al., (2013), Patil et al., (2013) and Kalyoncu et al., (2013). Biomonitoring, mainly species richness will allow detection of disturbances in a water body (Eckhout*et al.,* 1996). Diversity measures are more useful in Lake Ecosystem, which harbor a large variety of algal species in general and species diversity within genera.Bacillariophyceae are ubiquitous in their distribution (Bilgrami and Saha, 2004) and their cells remain unchanged for many years under varied environmental conditions and hence can be used as water quality indicators (Michels, 1998). They are considered key organisms in ecological quality analyses of water courses and have been applied for more than a decade in several countries of Europe (Solak and Acs, 2011).

Among the various diatom indices developed for monitoring pollution in water body, the Palmer's algal index of pollution (1969), is a classical index which has been used by several researchers till date and some of them are Ramakrishnan (2003), Jafari and Gunale (2006), Hosmani (2013) and Kshirsagar (2013). However, the index has not been updated with the new algal species or genera indicating organic pollution. Salmoni*et al.,* (2011) used Water Quality Biological Index (WQBI) proposed by Lobo *et al.,* (2004) which incorporates an integrated response of the epilithic diatom community to Eutrophication processes and organic pollution in

south Brazilian rivers. Gomes and Licursi (2001) used the Pampeano Diatoms Index (PDI) to evaluate the water quality of rivers and streams and Junshum et al., (2008) used algal genus pollution index, Saprobic index and Shannon-Weaver index to classify water quality around Mae Moh Power Plant of Thailand. Almeida (2001) used SLA and LMI indices for detection of organic pollution and CEC and SPI indices for evaluation of organic and also inorganic pollutions based on the sensitivity of each taxon.

The Louis-Laclercq Diatomic Index of Saprobity-Eutrophication (IDSE/5), (2008) is an advanced pollution index among all the other indices and is mainly based on the occurrence of only diatom species in aquatic ecosystems. Degradation levels, evenness, percentage indicators of organic and anthropogenic pollution and the species indicating organic and anthropogenic pollution are estimated by this index. It also determines the ecological indicator values which in turn help to know the Trophic state of an ecosystem based on the prevailing conditions of that ecosystem (Hosmani, 2012a and Kalyoncu&Serbetci, 2013). However, most of the studies have mainly dealt with the application of diatom indices for rivers,and there is lack of such studies on inland fresh waters. The paper is an attempt to use various biological indices to determine the extent of pollution based on members of Bacillariophyceae.

2.0 Materials and Methods:

2.1 ***Study area****:* Mysore is one of the third-largest cities of Karnataka**,** India, and is located at the base of Chamundi hills about 146 km (91 mi), southwest of the state capital Bangalore with coordinates of 11^0 39' and 12^0 50' north latitude and 75^0 45' and $77^0$45' east longitude. It is spread across an area of 128.42 km^2 (50 sq mi) and is an important tourist center.

Karanji Lake

Karanji Lake (Fig 1) is a picturesque Lake located at the footsteps of Chamundi hills and behind Mysore Zoo. It is situated between $12^0$18'10" and 12.30278^0 north latitude and $76^0$40'25" and 76.67361^{0}E longitude and is spread over an area of 90 hectares with a water spread area of about 55 hectares and foreshore area of about 35 hectares. It has an immense ecological value and is home to more than 90 species of resident and migratory birds. It also supports several species of butterflies and small mammals. The Lake attracts painted storks, pelicans, darters and a host of other winged beauties. It is a great support for the sustaining of the adjoining Chamarajendra Zoological Gardens. Sewage from the adjoining residential areas, The Zoological gardens and effluent from the Dairy industry find a sink in the lake and hence make the water polluted.

Kukkarahalli Lake

This lake (Fig 2) was once a beautiful and precious lake of Mysore city that inspired many poets and writers is situated $12^0$18' north and $76^0$38' east and is owned by the University of Mysore. It has abundant growth of aquatic weeds and edible fish but has an unrestricted entry to public. With an area of 0.52 sqkms and 0.38 sqkms water spread area, surrounded by a marshy area of 0.06 sqkms and 0.19 sqkms dry land area is located in the heart of the city. With the entry of city sewage for the past three decades it has a reduced catchment area of 410 hectares; water spread area of 48 hectares and a foreshore area of 56 hectares. The water emits a stinking odour during summer months.

2.2 Sampling stations

Composite samples were collected once in 15 days for a period of five months (Dec 2013 to April 2014) from the two lakes which are situated at a distance of 6.1 km apart. The lakes differ in size and shape, nutrient concentration, nature of aquatic life, usage and level of human disturbance.

2.3 Collection and Analysis of samples

The sampling, preservation, identification and enumeration of Bacillariophyceae were done according to Lackey's drop method (1938) modified by Suxena (1987). Photo-micrographs were obtained (40*10x) using the Labomed photographic microscope equipment after mounting the specimens on a slide. The Louis Laclercq IDSE/5 index (2008) was calculated using the OMNIDIA GB 5.3 software (Lecointe et al., 2003). Identification was done using the monographs of Sarode and Kamath (1984) and Taylor (2007).

3.0 Results and Discussions:

3.1 Distribution of Bacillariophyceae

The Bacillariophyceae of Karanji and Kukkarahalli lakes are listed in Table 1 and 5 respectively. A total of 10 diatom taxa were identified from the two lakes with five common taxa. The dominant species of Karanji Lake were *Cocconiesplacentula, Eunotiamonodam, Navicularhomboidica, Nitzschiaspathulata* and *Synedra ulna* and that in Kukkarahalli Lake were *Cocconiesplacentula, Navicularhomboidica, Nitzschiaspathulata* and *Synedra ulna*.

3.2 IDSE/5 and Diversity indices

The Louis-Laclercq IDSE/5 index (2008) derived from the OMNIDIA GB 5.3 software is presented in Table 2 and 6 for Karanji and Kukkarahallilakes respectively.

In Karanji Lake, the number of species ranged from a minimum of five to a maximum of seven. The number of species, population and diversity was slightly high during March. This may be due to the high level of disturbance due to human activities (Anthropogenic pollution). The evenness of species was high during April and remained low during the previous months which indicate low level of disturbances. The number of genera remained same as the number of species throughout the sampling period. The IDSE/5 index value was 'low' during all the months indicating the level of degradation (rate of conversion of organic matter into carbon dioxide and water by the microorganisms) to be 'low' always. The level of organic pollution was not detected throughout the sampling period. However, the level of anthropogenic pollution was 'low' to 'moderate' and the percentage indicators of anthropogenic pollution was high during February and March, the indicators being *Synedra ulna* and *Stauroneisphoenicenteron*.

In Kukkarahalli Lake, the number of species of Bacillariophyceae were in the range of a minimum of four to a maximum of five. The population, diversity and evenness of species were high during April and remained low during the rest of the months. The number of genera remained same as the number of species throughout the sampling period. The IDSE/5 index value was 'low' to' moderate' indicating the rate of conversion of organic matter into carbon dioxide and water by the microorganisms was varying between low and moderate. The level of organic pollution was not detected even in this lake, whereas the level of anthropogenic pollution was 'low' to 'moderate' from December to April. Synedra ulna was the only specie indicating anthropogenic pollution in Kukkarahalli Lake throughout the study and was common in both the lakes.

3.3 Ecological Indicator Values

Seven ecological indicator values were derived for each Lake using the OMNIDIA GB 5.3 software (Tables 4 and 7). The indicator values were generated according to the classification given by VanDam, Martens and Sinkeldam (1994) and the same is presented in Table 3. These values mainly indicate the conditions required for the growth and survival of Bacillariophyceae and also determine the Trophic state of the lake.

In Karanji Lake, the pH was Alkaliphilous throughout the sampling period. The water was mainly of Fresh-brackish type which indicates that the salinity was moderate. The value of nitrogen uptake indicated the presence of nitrogen autotrophic taxa tolerating elevated concentrations of organically bound nitrogen throughout the study. Oxygenation was 'moderate' throughout indicating above 50% saturation. The level of Saprobitywas β-mesosaprobous most of the times which indicates quite high oxygen saturationand low oxygen consumption. The value of moisture tolerance indicates that the species cannot survive in extreme dry conditions. The Trophic state of the lake was hypoeutrophentic most of the times and was eutrophentic during the rest of the period indicating

deteriorating water quality with increasing temperature.

In KukkarahalliLake, the pH remained Alkaliphilous during most of the period except once where it was Circumneutral. This difference in pH was mainly the effect of rain a week before the collection of sample. The value of salinity remained same all throughout indicating the type of water to be Fresh-brackish. The value of nitrogen uptake indicated the presence of forms of nitrogen autotrophic taxa of low and high tolerance to the organically bound nitrogen. The oxygenation was moderate with above 50% saturation whether it was reaching 100% saturation only during April which again may be the effect of rain. The water was mainly α-meso-/polysaprobous indicating low oxygen saturation and high oxygen consumption.The value of moisture tolerance indicated the presence of species occurring mainly in water bodies and sometimes on wet surfaces. The Trophic state of the lake was Oligo-to eutrophentic (hypoeutrophentic) to eutrophenticmost of the period.

Fig b: Kukkarahalli Lake

Fig a: Karanji lake

Table 1: Bacillariophyceae of Karanji Lake (Org/L)

Sl No.	Planktons	Acronym	1	2	3	4	5	6	7	8	9	10
1	***Cocconiesplacentula***	CPLA	2800	2800	11,200	5600	2800	4200	7000	16,800	9800	2800
2	***Eunotiamonodam***	EMON	2800	2800	2800	2800	2800	4200	2800	2800	2800	2800
3	***Gomphonemagracilli***	GGRA	0	0	0	0	0	0	0	2800	0	0
4	***Melosiraislandica***	MISL	0	0	0	8400	0	2800	0	0	0	0
5	***Navicularhomboidica***	NRHO	4200	4200	4200	11,200	4200	4200	4200	15,400	2800	2800
6	***Nitzschiaspathulata***	NSPH	2800	2800	4200	2800	4200	9800	4200	4200	2800	2800
7	***Stauroneis phoenicnteron***	SPHO	0	0	0	0	4200	0	0	2800	0	0
8	***Synedra ulna***	SULN	4200	4200	7000	4200	4200	4200	4200	14,000	2800	2800

Table 2: ISDE/5 and Diversity Indices of Karanji Lake

Sl No.	Particulars	1	2	3	4	5	6	7	8	9	10
1	**Number of species**	5	5	5	6	6	6	5	7	5	5
2	**Population**	16,800	16,800	29,400	35,000	22,400	29,400	22,400	58,800	21,000	14,000
3	**Diversity**	2.29	2.29	2.15	2.39	2.56	2.46	2.26	2.41	2.06	2.32
4	**Evenness**	0.99	0.99	0.93	0.92	0.99	0.95	0.97	0.86	0.89	1
5	**Number of genera**	5	5	5	6	6	6	5	7	5	5
6	**IDSE/5**	3.74	3.74	3.58	3.74	3.65	3.87	3.74	3.52	3.87	3.87
7	**% Indicators of Organic Pollution**	0	0	0	0	0	0	0	0	0	0
8	**% Indicators of Anthropogenic Eutrophication**	25%	25%	23.81%	12%	37.5%	14.29%	18.75%	28.57%	13.33%	20%
9	**Degradation**	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
10	**Organic Pollution**	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
11	**Anthropogenic Eutrophication**	Moderate	Moderate	Moderate	Low	Moderate	Low	Low	Moderate	Low	Low
12	**Organic Pollution Indicators**	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
13	**Anthropogenic Pollution Indicators**	SULN	SULN	SULN	SULN	SULN & SPHO	SULN	SULN	SULN & SPHO	SULN	SULN

Table 3: Classification of Ecological Indicator values (VanDam, Martens and Sinkeldam (1994))

Table 3.1: (R) pH (1-6)

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 3.2: (H) Salinity (1-4)

Water Quality		Cl^- (mg/L)	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	1.8-9.0

Table 3.3: (N) Nitrogen Uptake (1-4)

1	Nitrogen-autotrophic taxa tolerating very small concentrations of organically bound nitrogen
2	Nitrogen-autotrophic taxa tolerating elevated concentrations of organically bound nitrogen
3	Facultatively 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 3.4: Saprobity (1-5)

1	Oligosaprobous
2	β-mesosaprobous
3	α-mesosaprobous
4	α-meso- /polysaprobous
5	Polysaprobous

Table 3.5: (M) Moisture (1-5)

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 3.6: Trophic State (1-7)

1	Oligotrophentic
2	Oligo-mesotrophentic
3	Mesotrophentic
4	Meso-eutrophentic
5	Eutrophentic
6	Hypereutrophentic
7	Oligo-to eutrophentic (hypoeutrophentic)

Table 3.7: (O) Oxygen requirements (1-5)

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

Table 4: Ecological Indicator Values of Karanji Lake

Sl No.	Particulars	1	2	3	4	5	6	7	8	9	10
1	**pH**	4	4	4	4	4	4	4	4	4	4
2	**Salinity**	2	2	2	1	2	2	2	2	2	2
3	**Nitrogen Uptake**	2	2	2	2	2	2	2	2	2	2
4	**Oxygenation**	3	3	3	3	3	3	3	3	3	3
5	**Saprobity**	4	4	2	2	2	2	2	2	2	4
6	**Trophic State**	7	7	5	7	7	7	5	5	5	7
7	**Moisture**	2	2	2	2	2	2	2	2	2	2

Table 5: Bacillariophyceae of Kukkarahalli Lake (Org/L)

Sl No.	Planktons	Acronym	1	2	3	4	5	6	7	8	9	10
1	***Cocconiesplacentula***	CPLA	2800	2800	4200	2800	2800	4200	2800	2800	2800	5600
2	***Cymbellacymbiforms***	CCYM	0	0	2800	1400	0	0	0	0	0	2800
3	***Gomphonemagracilli***	GGRA	0	0	0	0	0	0	0	0	0	12,600
4	***Gyrosigmascalproides***	GSCA	0	0	0	0	0	0	0	0	2800	0
5	***Navicularhomboidica***	NRHO	4200	4200	4200	4200	4200	2800	4200	2800	2800	21,000
6	***Nitzschiaspathulata***	NSPH	2800	1400	4200	2800	4200	5600	1400	4200	2800	0
7	***Synedra ulna***	SULN	2800	1400	2800	1400	2800	2800	4200	4200	2800	2800

Table 6: ISDE/5 and Diversity Indices of Kukkarahalli Lake

Sl No.	Particulars	1	2	3	4	5	6	7	8	9	10
1	**Number of species**	4	4	5	5	4	4	4	4	5	5
2	**Population**	12,600	9800	18,200	15,400	14,000	15,400	12,600	14,000	14,000	44,800
3	**Diversity**	1.97	1.84	2.30	2.23	1.97	1.94	1.89	1.97	2.32	1.90
4	**Evenness**	0.99	0.92	0.99	0.96	0.99	0.97	0.95	0.99	1	0.82
5	**Number of genera**	4	4	5	5	4	4	4	4	5	5
6	**IDSE/5**	3	3	3.90	3.64	3	3	3	3	3.48	4.19
7	**% Indicators of Organic Pollution**	0	0	0	0	0	0	0	0	0	0
8	**% Indicators of Anthropogenic Eutrophication**	22.22%	14.29%	15.38%	18.18%	20%	18.18%	33.33%	30%	20%	6.25%
9	**Degradation**	Moderate	Moderate	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Low
10	**Organic Pollution**	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
11	**Anthropogenic Eutrophication**	Moderate	Low	Low	Low	Low	Low	Moderate	Moderate	Low	Nil
12	**Organic Pollution Indicators**	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
13	**Anthropogenic Pollution Indicators**	SULN	SULN	SULN	SULN	SULN	SULN	SULN	SULN	SULN	SULN

Table 7: Ecological Indicator Values of Kukkarahalli Lake

Sl No.	Particulars	1	2	3	4	5	6	7	8	9	10
1	**pH**	4	4	4	4	4	4	4	4	4	3
2	**Salinity**	2	2	2	2	2	2	2	2	2	2
3	**Nitrogen Uptake**	2	2	2	2	2	2	2	2	2	1
4	**Oxygenation**	3	3	3	3	3	3	3	3	3	1
5	**Saprobity**	4	2	2	4	4	2	4	4	4	1
6	**Trophic State**	7	5	5	7	7	5	7	7	7	3
7	**Moisture**	2	2	2	2	2	2	2	2	2	3

4.0 Conclusions:

As it is important to useadvanced and well-developed software in order to obtain accurate results, OMNIDIA GB 5.3 software was used in this study to derive the Louis Laclercq IDSE/5 index and the ecological indicator values. According to the results obtained, the number of species of Bacillariophyceae and also the diversity of species were high in Karanji Lake when compared to Kukkarahalli Lake. The population of species was also consistent and high in Karanji Lake. However, the species were relatively evenly distributed in both the lakes.

The IDSE/5 index value was 'low' in KaranjiLake for most of the period indicating the level of degradation to be 'low'. Whereas, in KukkarahalliLake, the IDSE/5 index value was 'moderate' most of the period indicating the level of degradation in the lake to be 'moderate'. The level of organic pollution was not detected in both the lakes. However, the level of anthropogenic pollution remained 'low' to 'moderate' in KaranjiLake and 'moderate' in KukkarahalliLake for most of the period indicating high level of disturbance from human activities. *Synedra ulna* was the most common indicator of anthropogenic pollution in both the lakes.

The ecological indicator values which play an important role in any aquatic environment werederived using the software. According to the results, the pH was predominantly Alkaliphilous in both the lakes and the water was of fresh-brackish type indicating the salinity to be moderate. The value of nitrogen uptake indicated the dominance of nitrogen-autotrophic taxa tolerating elevated concentrations of organically bound nitrogen. The water mainly belonged to the category of α-meso-/polysaprobous in Kukkarahalli Lake and β-mesosaprobous in Karanji Lake. The Trophic state was hypoeutrophentic to eutrophentic in both the lakes which clearly indicated the deteriorating water quality mainly due to high level of human interferences. The lakes were predominated by the presence of species mainly occurring in water bodies, sometimes on wet places.

The results indicate that both the lakes are striving with deteriorating water quality, mainly due to the anthropogenic pollution which in turn is due to the high level of disturbances created by human interferences such as cattle rearing, fishing, unrestricted entry of huge quantity of sewage and effluents from the surrounding residential areas and industries. These activities are causing low Dissolved Oxygen levels and high Biological Oxygen Demand which in turn is making the lakes eutrophentic. Therefore, effective and strong conservative measures should be taken to prevent the lakes from enteringHypereutrophentic state and to ensure the sustenance of aquatic flora and fauna.

Some of the important conservative measures required to be taken are to stop the entry of sewage and industrial effluents into the lake or at least to ensure primary and secondary treatment of the wastewater priorto discharge. Also, it is important to calculate the Total Maximum Daily Load (TMDL) of wastewater that the lake can withstand without causing harm to the aquatic life and to ensure that the wastewater being discharged is within the prescribed limits as mentioned by the Central Pollution Control Board.

It was therefore inferred from the study that the Bacillariophyceae are the most powerful ecological indicators which alone can be used to determine the nature of pollution, degradation levels and also the ecological conditions of lake waters. Bacillariophyceae serve as an important tool in monitoring water quality of lakes.

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