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Study on the Diatoms diversity in the lakes of Davangere district for its ecological significance

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ABSTRACT
The present study was focused on evaluating the diatoms biodiversity in the lakes of Davangere District, Karnataka, India. The variations in the Diatoms diversity were described by the physicochemical constituents of study sites. The water quality and microalgal studies were carried out in the six lakes from September 2018 to August 2019. A total of 110 microalgal genera belonging to 5 major classes' viz., Chlorophyceae, Bacillariophyceae, Euglenophyceae, Cyanophyceae, and Dinophyceae were identified from the study area. Among them, Bacillariophyceae covers the (31%) diatoms and contributes 33 genera with Navicula, Melosira, Cyclotella, Diploneis, Pinnularia, Rhopalodia, and Ulnaria, as a predominant genus frequently documented in *Bathi (S2) and Devarbelekere (S3) lake. These lakes were highly enriched with phosphate, nitrate, sulphate, and organic constituents.* Aulacoseira, Fragilaria, Mastagloia, Nitzschia, Sellaphora, Tabularia, Synedra, and Gomphonema genera were *dominant in high D.O. and low nutrient constituents as in Shanthisagar (S6), Kondaji (S4), Kundwada (S5) and Anaji (S1) lakes. Among the 79 species documented, the diversity of diatoms was considerably high in Bathi Lake (24%) and least in Shanthisagar Lake (8%). Diversity indices showed a trend with a variation in pollution and irrespective of* the seasons; *Species diversity (H'), Evenness (J), and Richness (D) were used to support the data. Statistical analysis indicated that nutrients such as PO^{4-}, NO^{3-}, Cl^{-}, Mg^{++}, SO^{4-}, DO, pH, temperature, and turbidity were the most important factors regulating the variation in the structure of the diatom's community. Hence, diatoms play a significant role as an ecological indicator of the aquatic ecosystem.*
Keywords: *Bacillariophyceae, Diversity indices, Davangere, Ecological Indicator, Water quality.*

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INTRODUCTION

Biodiversity plays a central role in making life sustainable on this planet for all organisms. The fate of the human species is interlinked with the ecosystem whether plants, animals, or microbes living around us and it is critically affecting our lives. The simplest way to understand this is to just remember the mode of energy transfers, nutrient, oxygen, and water cycling going on [1]. As water is the essence and core of life on the earth which dominates the chemical composition of all organisms, it is obvious that the quality of water affects the species composition, abundance, productivity, and physiological conditions especially, the indigenous population of aquatic organisms. Therefore, the nature and health of any aquatic community are an expression of the quality of the water [2]. Monitoring of water quality with regards to physical and chemical parameters reflects instantaneous measurements, while, biotic parameters developed during recent years have served as an excellent tool in the area of water pollution studies and provide a better evaluation of environmental changes [3]. Biological monitoring is a fast and cost-effective approach for assessing the effects of environmental stressors, making it an essential tool [4]. The role of microbial diversity in ecosystem functioning is becoming increasingly recognized. Microalgae are a large group of organisms that are extremely diverse and heterogeneous from evolutionary and ecological viewpoints. However, estimates of their diversity are nebulous and require substantial input from systematic, dispersal analyses, and biogeography. Microalgae are an integral part of the aquatic ecosystem as primary producers, which transfer energy from abiotic components to different trophic levels. Documentation of the patterns in the biodiversity of primary producers might be important due to its innate relationship with ecosystem function [5].

Communities are generally regarded as the most appropriate indicators for conservation biology since inference can be made at the ecosystem level as opposed to being limited to an individual species or population [6]. Diatoms are unicellular, eukaryotic, microscopic algae of class Bacillariophyceae. They are a highly successful and distinctive group of ubiquitous organisms found in almost all fresh water and marine ecosystems where they occur as free-floating or attached forms and also have been found to harbor moist soils [7]. They are useful proxies for the ecological analysis of the parameters like pH, salinity, temperature, hydrodynamic condition, nutrient concentration, etc. As primary producers, diatoms are most directly affected by physical and chemical factors. Their high species diversity and their siliceous frustules all enable the diatoms to function as sound environmental indicators. [8]. Diatoms are an extremely diverse group with around 200 genera, comprising around 10 to 12,000 known species. However, different studies escalate the estimated number of species to 0.2 to10 million, this huge variation in the estimation is due to limited knowledge about their diversity [9]. The past few decades have seen a tremendous rise in diatoms research, as reflected in the publication. An undercurrent of excitement is moving around, but challenges are roaring high. Practically, a good isolation practice is the only solution that will fill this void [10]. Various indices have the main objectives of the present work were to survey the current taxonomic composition of diatoms in lakes of the Davangere district and evaluate their relationships with any relevant environmental variables. Davangere district is the sixth largest city which is situated at the heart of the state of Karnataka and rapid urbanization and migration have led to high densities, infrastructure, and extreme congestions that have impacted environmental conditions and aquatic biodiversity. There is little documentation about the exploration of diatom flora in the lakes from this locality. The knowledge obtained from this research can be used to create a database that can be employed to evaluate the impact of anthropogenic activity on the diversity of diatoms and will also be the basis of a reference resource for the screening and application of these freshwater diatoms in the future.

MATERIAL AND METHODS

Study area:

Davanagere district is located in the mid-eastern region of the Karnataka state, between the 13° 45' 00" N to 14° 50' 00" N latitude and 75° 30' 00" E to 76° 30' 00" E longitude and its elevation is about 602.5 m above the mean sea level. The district has six taluks such as Harihar, Davangere, Honnali, Channagiri, Jagalur and Harpanahalli **(Fig.1A).** The district has spread into three agro-climatic zones, namely the central dry zone, southern transition zone, and northern dry zone, this climatic condition and anthropogenic activity play a vital role in describing the ecological status of the lake **(Table-1).** The lakes selected for the study include Anaji (**S1**), Bathi (S2), Kondaji (S3), Kundvada (S4), Devarabelakere (S5), and Shanthisagar (S6).

Collection and analysis of water samples:

The water samples were collected monthly once from September 2018 to August 2019 from the sampling sites. The temperature, color, pH, conductivity, TDS and D.O parameters in these water samples were analyzed. Further, the water samples were collected in a sterile screw-capped container and taken to the laboratory for determining nutrient and organic constituents by standard methods [11].

Study of diatoms:

The study of diatoms was done monthly from the selected sampling sites by using the modified Lackey's drop method. Here, the diatoms were studied by collecting 2L of surface water sample in a clean polyethene bottle and fixed immediately with acidified Lugol's iodine solution (10 mL). The samples were oxidized with acid H_2SO_4 (20% v/v) for a few hours to remove the organic matter, carbonates and washed with distilled water as described by [12]. The total number of diatoms present was calculated (cells/L) using a stereomicroscope (Lawrence and Mayo, India) with 40X magnification. The diatoms were identified using standard keys as provided by [13],[14] and Algae Base [15].

Diversity indices:

Population dynamics and community structure of aquatic ecosystems are understood from diversity indices. Therefore, in the present investigation, the variations in taxonomic distinctness were calculated as follows:

$$No\ of\ Organisms/\ L = \frac{N1 \times A1}{A2 \times N2 \times V}$$

A1=Area of a coverslip, mm^2, A2=Area of one microscopic field mm^2, N1=Number of organisms counted in all fields, N2=No. of fields counted. V=Volume of sample in the coverslip.

Relative abundance (R): it measures the abundance of a specific species and was calculated: $R = \frac{Y}{X} \times 100$

Using Eq. (1) [16] Where Y= the number of water bodies (sites) from which the species were obtained and *X*=is the total number of sites studied. Besides the Relative abundance (R), expressed as the % of species per sample, Species Richness, Dominance and Evenness were also evaluated. These included the Shannon index (H′), Pielou's (J') diversity, Simpson's (l) dominance, and inverted Simpson's (1 − l) index.(Inyang)[17].

Statistical Analysis:

The data were statistically analyzed by MS Excel-2010, One-way ANOVA, and Pearson's correlation using Graphpad prism v8.4 *to* establish the relationship between the diatom's diversity with physicochemical parameters. Sampling sites were grouped based on diatoms distribution. Hierarchical Cluster Analyses (HCA) was carried out with the h-cluster function of R using single-linkage Euclidean distance [18]. Venn diagrams were generated by using the InteractiVenn tool [19] to represent the specific and common Bacillariophyceae members of different sites. Multivariate analyses were performed with Principal Components Analysis (PCA) and *Canonical Correspondence Analysis (CCA)* according to [20], to determine the relationship between physicochemical parameters and distribution of diatoms in different stations using the PAST v 4.03.

RESULTS AND DISCUSSION:

The present study signifies the distribution of diatoms with the water quality and its environmental parameters in the lakes of the Davangere district. **(Table-1)** shows the mean value of physicochemical parameters of the six selected sampling sites, physical parameters like temperature, pH, and nutrients such as nitrate, phosphate, sulphate, and carbonates have played a vital role in diatomic distribution. Temperature and pH were slightly varied among the study sites concerning to its seasonal changes and the average temperature of water samples was 27.5^{o}C and pH was 7.3±0.6 which is optimum for the growth of diatoms. Our results revealed a significant difference in the physical condition and chemical content of water which has led to diversified diatoms in the selected sites. The pH 7 to 8 and temperature 28^{o}C of water was optimum and almost similar in all the study area and this has favored the growth of diatoms. Dissolved oxygen, temperature, and pH, are important environmental parameter that decides the ecological health of a stream and protects aquatic life [21]. The dissolved oxygen concentration varied from 3-7 mg/L where S6 (7), S4 (6.5), and S1 (6) were less polluted and concentrated with high dissolved oxygen (>6) throughout the year. The S2 site was noted with 3 mg/L less D.O in the summer season, this is also due to input of nutrients; increased nutrients may have led to high conductivity and decreased dissolved oxygen. Temperature affects the diffusion rates of chemicals and decreases the amount of dissolved oxygen and these changes affect the reproductive rates and metabolism of diatoms [22]. Nutrients like nitrate and phosphate, sulphates, and chlorides are directly proportional to human activity and influence the growth of microalgae. The S2 was highly concentrated with nitrate (1.8 mg/L), phosphates (1.2 mg/L), chloride (98 mg/L) and sulphates (55.3 mg/L), followed by S3 (1 mg/L), (0.8 mg/L), (71 mg/L) and (48 mg/L). Site S6 showed low nitrate (0.2 mg/L), phosphates (0.1 mg/L), chloride (29 mg/L), and sulphate (17 mg/L) concentration, probably because of the use of mineral fertilizers, as well as higher erosion, increased weathering and evapotranspiration from flooded terraces [23]. The distribution of diatoms and physicochemical parameters showed statistically significant differences (P< 0.05) for temperature, dissolved oxygen, conductivity, alkalinity, sulphate, calcium, nitrate, transparency, turbidity, magnesium, and phosphate. The Pearson correlation studies between diatoms and the water constituents showed a positive correlation with DO and temperature, pH, specific conductivity, TA and Mg^{++}, Ca^{++}, and a negative correlation with turbidity, phosphate, and nitrate **(Table-2).** Current results have shown that light, temperature, and pH are important factors for the growth and density of algae, which also confirms the data from [24].

The current study documented a total of 110 microalgal genera belonging to six different classes' viz., Chlorophyceae, Bacillariophyceae, Euglenophyceae, Cyanophyceae, and Dinophyceae were identified from the six study areas. Among them, Bacillariophyceae contributed 31% of diatoms; including 7 families with 33 genera and 79 species in the six study sites, and site S2 was highly diversified with 25% of diatoms followed by S3 (18%), S4 (17%), and least was observed with S6 (11%) **(Fig. 2A).** Diatoms survive well in a variety of habitats, such as oceans, lakes, estuaries, and wetlands, etc. The clear water along with the presence of Bacillariophyta (diatoms) members is a bio-indicator of good water quality [25]. Based on its diversity and high relative abundance*, Navicula, Aulacoseira, Cyclotella, Fragilaria, Melosira, Mastagloia, Nitzschia, Pinnularia, Rhopalodia, Sellaphora* genera were found predominantly throughout the study period. *Out of* these genera, *Cyclotella stelligera* (3.9%), *Navicula rostellata* (2.9%), *Aulacoseira granulate* (2.7%), *Melosira islandica* (2.7%), *Sellaphora bacillum* (2.5%), *Pinnularia dolosa* (2.4%) and *Tabularia fasciculata* (2.4%), accounted for the top seven species from the whole community of diatoms in all the study sites **(Fig. 2B**) and served as a pollution indicator as they are predominant species in all the study sites and these species have proved to be pollutant tolerant, which were also proved in earlier studies [26]. This makes diatom a potential tool in bioassay than any other aquatic species because of its easy sampling and frustules identification [27]. Diatom's diversity indices for the lakes of the Davangere district were reported here site-wise **(Table-3).** Based on the Shannon-Diversity Index, S2 (3.09) exhibited the most diversified and the least was in S6 (2.6) and (2.87) was the total mean index of six sites, According to May (1975) [28], the Shannon-Weaver diversity index was related to both the total number of species and their relative abundances and can be designated as a positive function of a total number of species. The Shannon diversity (3.0) is high in S2 and S3 sites in our results and these values of the Shannon Wiener index proportionally correlate to the low values of Simpson's (dominance) index [29]. Dominance index (D) ranges from 0 to 1 and since the value was more than 0.5, all the sites were significantly dominant with 0.8-0.9 indices. The highest value was in S2 (0.95) followed by S3 (0.94) and the least was documented in S1 (0.82). The species' evenness (J) ranged from 0.78 to 0.96, the significant species' evenness noted in S6 (0.96) and S2 (0.89)**.** Species diversity is frequently used in ecological status assessment for explaining the spatial and temporal patterns of biotic communities [30]. Diatom community structure closely followed the pollution increase gradient with species richness, diversity, and equitability generally differing among sampling sites, tending to be higher in relatively unpolluted compared to pollute sites [31].

The PCA biplot explains the distribution of diatoms within the study area and the PC1 (65%) signifies the positive correlation of the S2 and S3 sites with dominant species of *Navicula, Cyclotella, Diploneis, Fragilaria Melosira, Pinnularia, Rhopalodia, and Ulnaria* with high eigenvalue (2.8), while PC2 (12%) correlates with site S4, S5, S1and S6 and species of *Nitzschia, Aulacoseira, Mastagloia, Sellaphora, Tabularia, Synedra, Gomphonema* were depicted on this axis. Meanwhile, the least observed diatom species like *Craticula, Biremis, Diatoma, Eunotia,* and *Achnanthes* were negatively correlated with low relative abundance **(Fig. 3).** The CCA triplot was used to determine the relationships between diatoms and environmental variables, in the percentage of variance axis-1 (f1-30%) correlating with axis-2 (f2-26%) representing the status of different site. Phosphate, nitrate, sulphates, BOD, conductance, and turbidity were positively correlated in the S2, S3, and S5 sites with high eigenvalue (1.8) and species of *Aulacoseira, Cyclotella, Diploneis, Fragilaria Pinnularia, Rhopalodia, Sellaphora, Tabularia, Ulnaria, Synedra, and Gomphonema, Discostella, Eunotia, Sellaphora* were found on this axis **(Fig. 4).** The application of diatom indices indicated strong correlations with physical and chemical parameters and lots of studies have linked diatom indices with water quality around the world [32]. On either side, DO, temperature, magnesium, and calcium were strongly correlated with S1 and S6 site, and species of *Navicula, Nitzschia, Aulacoseira, Mastagloia, Sellaphora, Melosira,* was depicted on this axis. CCA was effective in explaining diatom species-environment relationships and CCA results indicate that E.C, PO^{4-}, NO^{3-}, Cl^{-}, Mg^{++}, SO^{4-}, and D.O, pH, and temperature were the important factors in structuring benthic diatom communities in the study area. The HCA plot of this study was based on diatoms abundance, where sites S2, S3, and S1 were placed in a close cluster with a high diversity of diatoms. Site S5 and S6 were distantly clustered with them, whereas Site S4 is an out-group with even diatom diversity **(Fig. 5A).** The Venn diagram describes the distribution of diatoms of six sites species of *Diploneis suborbcularis, Aulacoseira granulate, Cyclotella bodanica Fragilaria biceps, Mastagloia braunii, Melosira islandica, Navicula oblonga, Navicular ostellata, Pinnularia dolosa, Rhopalodia gibba, Sellaphora bacillum,* and *Ulnaria biceps* species were predominant and seen in all the lakes throughout the study period. Taylor *et al.* 2014, [33] considered presence of *Cyclotella meneghiniana, Nitzschia palea,* and *Cocconesis placentula* as characteristics of extremely polluted water. Site S2 was documented with (16) unique species followed by S3 (6) and whereas S2 & S3 sites were seen with most of the common species **(Fig.5B).** The species *Navicula bottnica, Navicula hasta, Navicula rynocephala, Nitzschia linearis, Nitzschia palea, Pinnularia borealis, Sellaphora bisexualis, Stauroneis phoenicenteron, Ulnaria ulna, Gomphonema lanceolatum* were occasionally observed in S4 (7) S1 (4), S5 (4) and S6 and these sites share similar species based on its water quality and climatic conditions. Meanwhile, some rare species of *Achnanthes, Biremis, Caloneis, Craticula, Diatoma, Eunotia, Gramatophora, Pennium* spp. were documented in the particular sites as tabulated in **(Table-2).** *Navicula Aulacoseir, Nitzschia, and Cyclotella* were stressed to be a good indicator of organic pollution as the species comfortably occur in the most heavily polluted zones. Hosamani (2014), [34] reported the dominance of organic pollution indicator diatom species like *Cyclotella automus, Cyclotella meneghiniana, Melosira varians, Navicula cryptocephala, Nitzschia intermedia* from 7 polluted lakes in Mysore. *Pinnularia Sellaphora, Stauroneis, Ulnaria, Gomphonema* species appeared frequently in the mild pollution zone in which other species cannot occur which was also proven in earlier studies by Pumas *et al.* 2018*;* Halder *et al.* 2019 [18, 35].

Overall these lakes studied in the Davangere district S2 site were stressed by human activities like agricultural runoff industries outlet and transportation and some migratory birds nearby have increased the nutrient level which favored the growth of microalgae and highly diversified with Chlorophyceace members, this accumulation caused eutrophication with a decrease in oxygen concentration, similarly site S3 was contaminated from agricultural runoff and fishing, but the large quantity of water and its flow rate reduced the microalgal diversity. The presence of large numbers of Myxophyta members indicated heavy pollution and eutrophication of water bodies and this increase in the microalgae leads to poor water quality. Water quality of S4 and S5 lakes were similar in composition with moderate human activity and migratory birds contributed to nutrient and diatoms composition were significantly diversified, site S1 water quality was clear and supported most diatoms growth as it was not affected much by external factors and S6 site was the cleanest water source in the Davangere district with large stretch and its mentioned as Asia second largest lake and have only a few diatoms documented in specific water holding points like gravels and grasses found moreover these lakes (S4, S5, S6) were used for consumption purpose hence the movement of water also affected the variation in diversity of diatoms. Diatoms` axenic culture is the first step towards a complete study of an organism and maintaining their pure culture can be further used in different applications such as bioindicators, nutraceuticals, cosmetics, phycoremediation, aquaculture, etc [10]. Overall, the present study on the diversity of diatoms showed that the diatoms distribution showed the same trend between different sites and this may be due to variations in water quality affected by anthropogenic activity and climatic conditions.

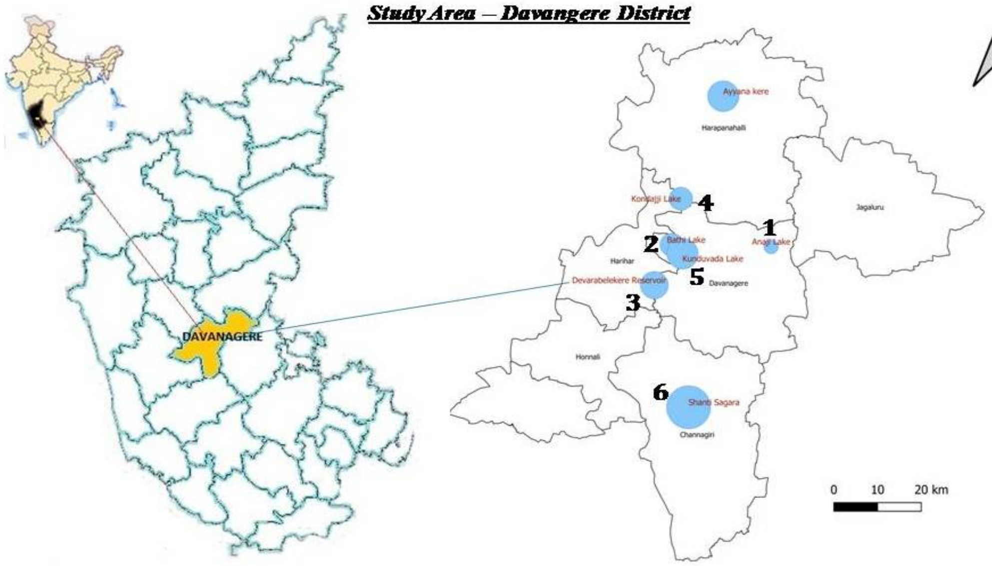

Figure 1. A. Location map of the selected study area. 1-Anaji, 2-Bathi, 3-Devarabelakere, 4-Kondaji, 5- Kundvada, and 6-Shanthisagar.

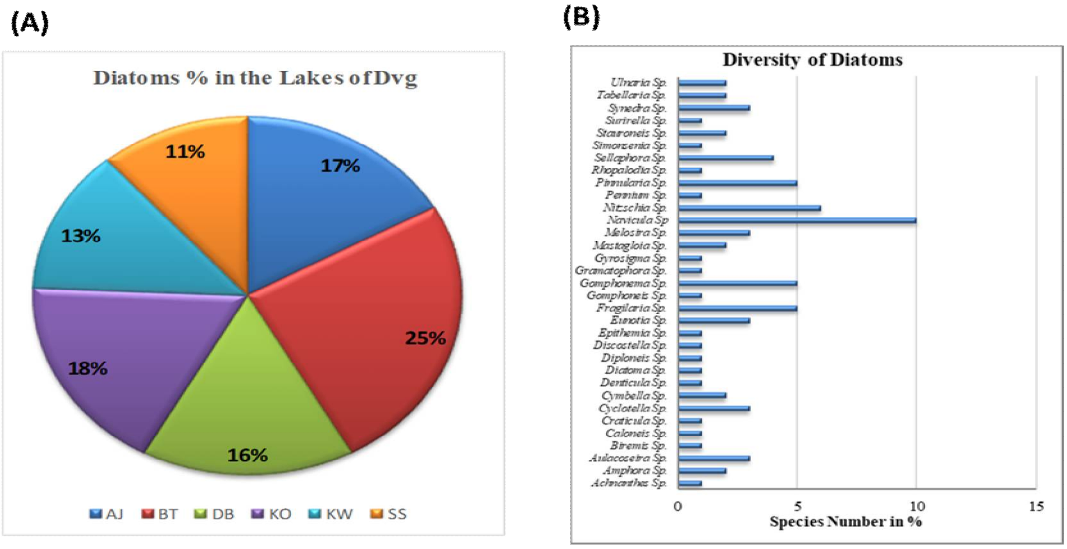

Figure 2. A. A graphical presentation of all the micro algal taxa from the six study sites and B. Number of diatom's species in percent.

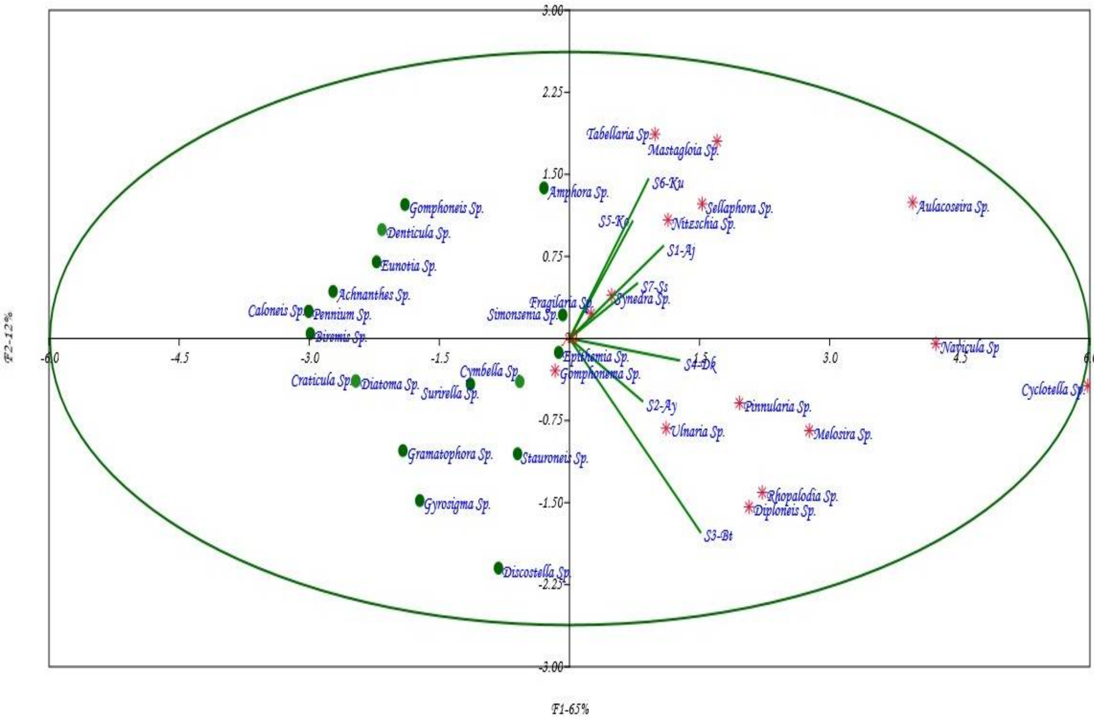

Figure 3. Principal component analysis of diatom diversity.

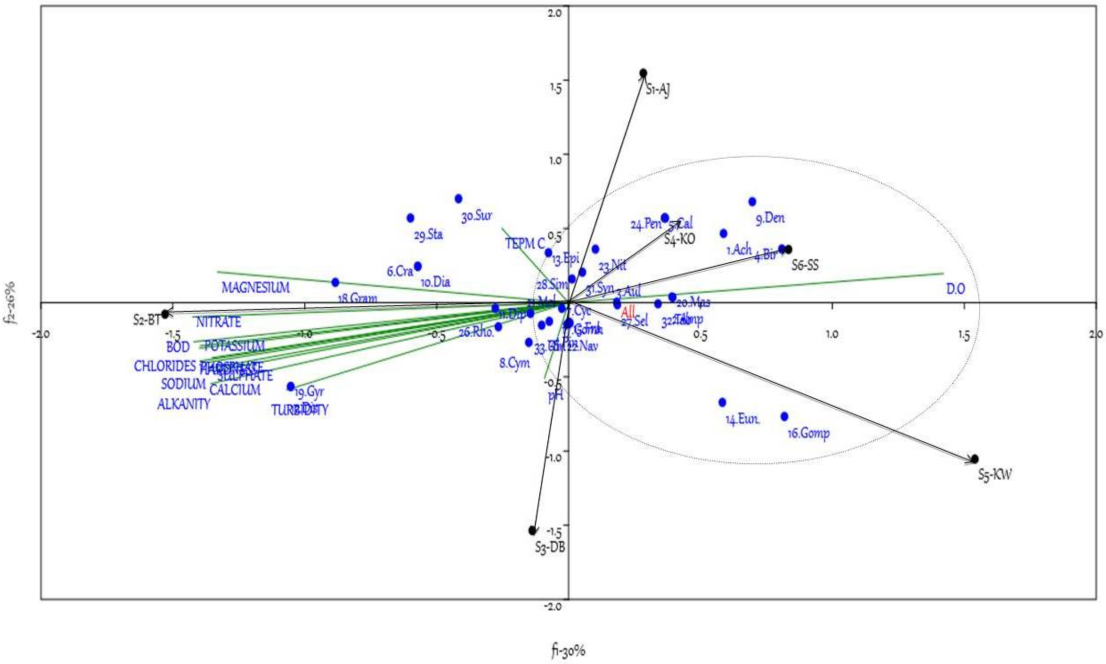

Figure 4. Canonical correspondence analysis of diatom diversity and water quality.

1. *Achnanthes* sp., 2. *Amphora* sp., 3. *Aulacoseira* Sp, 4. *Biremis* Sp, 5.*Caloneis* sp., 6.*Craticula* sp.,7.*Cyclotella* sp., 8.*Cymbella* sp., 9.*Denticula* sp.,10.*Diatoma* sp.,11.*Diploneis* Sp,12.*Discostella* sp.,13.*Epithemia* sp.,14. *Eunotia* sp., 15.*Fragilaria* sp., 16. *Gomphoneis* sp., 17.*Gomphonema* sp., 18.*Gramatophora* sp., 19.*Gyrosigma* sp., 20. *Mastagloia* sp., 21.*Melosira* sp, 22.*Navicula* sp., 23.*Nitzschia* sp., 24. *Pennium* sp., 25.*Pinnularia,* sp., 26. *Rhopalodia* sp., 27.Sellaphora sp., 28.*Simonsenia* sp., 29.*Stauroneis* sp., 30. *Surirella* sp., 31. *Synedra* sp., 32. *Tabellaria* sp., 33.*Ulnaria* sp.

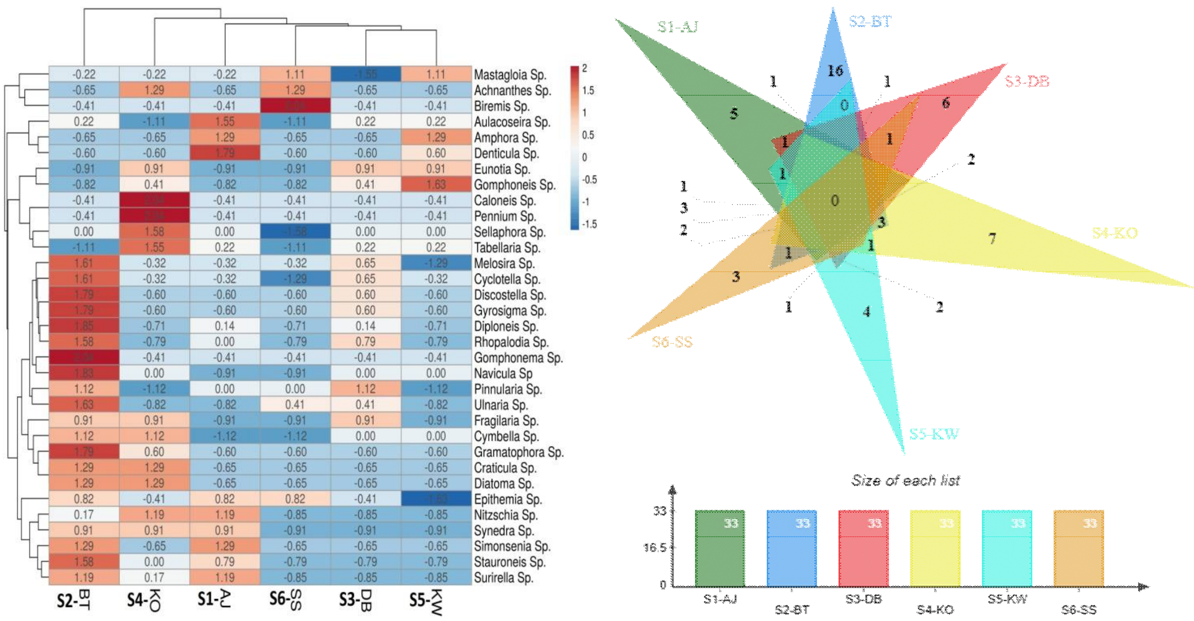

Figure 5. A. Hierarchical clustering of 6 study sites according to diatom species composition using Ward's linkage as per diatom richness. B. Venn diagram showing the diversity of diatoms in each lake.

Table 1. Location description and Physiochemical parameters of lake water sample of Davangere district.

Sl. No.	Parameters	Location					
		S1	S2	S3	S4	S5	S6
1.	**Colour**	Turbid, Mud	Green, Turbid	Clear	Clear	Clear	Clear
2.	**Odour**	None	Fishy	Fishy	None	None	None
3.	**Coordinates**	(14.4693° N, 76.0813°E)	(14.4729°N, 5.8716°E)	(14.3981°N, 75.8323°E)	(14.5714°N, 75.8897°E)	(4.4550°N, 75.8926°E)	(14.1279°N, 75.9057° E)
4.	**Biotic stress**	Agricultural	Agricultural and Urban settlements	Agricultural and Urban settlements	Agricultural	Urban settlements	Agricultural, Urban settlements
5.	**Temperature (°C)**	28±4.0	27±4.0	27±4.0	27±40	27±40	26±4.0
6.	**PH**	7.7±0.3	7.6±0.4	7.9±0.2	7.7±0.3	7.7±0.3	7.4±0.2
7.	**Conductivity (µs/cm)**	322.6±94.6	803.3±296.9	576.4±178.2	306.4±50.6	249.8±56.6	225.3±45.96
8.	**Turbidity (NTU)**	5.5±1.5	8.8±4.3	13.1±12.0	6.5±6.4	2.7±1.8	2.62±0.19
9.	**D.O (mg/L)**	6.8±0.2	5.3±0.3	6.4±0.4	6.9±0.3	7.2±0.2	7.4±0.14
10.	**B.O.D (mg/L)**	3.7±0.3	6.6±1.7	3.9±1.2	4.3±0.8	2.9±0.3	2.7±0.23
11.	**C.O.D (mg/L)**	23.9±3.9	49.2±24.3	32.9±8.7	23.0±4.2	17.3±2.9	17.8±4.30
12.	**T.S.S (mg/L)**	21.0±1.6	41.9±21.7	27.8±7.1	21.5±2.3	15.0±4.1	12.7±5.40
13.	**T.D.S (mg/L)**	211.7±49.9	497.7±210.3	393.3±138.6	193.7±46.7	161.8±37.4	143.5±39.62
14.	**Total Alkalinity as CaCO3 (mg/L)**	83.6±18.7	168.8±65.6	138.0±40.9	81.1±10.0	71.2±21.1	75.0±38.24
15.	**Hardness as CaCO3(mg/L)**	89.5±15.5	194.3±65.5	114.7±52.6	88.7±15.1	78.4±23.2	70.7±24.91
16.	**Calcium as CaCO3 (mg/L)**	48.8±10.7	112.7±46.8	72.4±23.9	51.5±9.7	47.5±13.3	40.5±14.87
17.	**Magnesium as CaCO3 (mg/L)**	31.6±10.5	43.3±29.1	32.2±13.3	35.7±6.9	21.2±12.9	20.4±11.81
18.	**Sulphate (mg/L)**	30.6±5.1	55.3±24.1	48.2±20.6	27.5±13.0	22.3±10.1	17.1±5.38
19.	**Chlorides (mg/L)**	47.3±9.3	98.2±40.3	71.4±29.0	40.6±4.9	33.8±8.6	29.3±9.74
20.	**Sodium (mg/L)**	23.3±9.9	45.2±19.2	33.4±9.1	20.2±5.7	18.6±6.1	14.9±5.66
21.	**Potassium (mg/L)**	2.2±1.2	3.6±0.9	3.1±0.7	2.1±0.9	1.5±0.7	1.2±0.40
22.	**Nitrate as N (mg/L)**	0.6±0.2	1.8±0.7	0.9±0.3	0.6±0.3	0.3±0.1	0.2±0.16
23.	**Phosphate (mg/L)**	0.5±0.2	1.2±0.5	0.8±0.2	0.3±0.1	0.3±0.1	0.1±0.06
24.	**Fluoride (mg/L)**	0.4±0.1	0.9±0.3	0.6±0.1	0.4±0.1	0.2±0.1	0.2±0.08
25.	**Ecological status**	Moderately polluted	Polluted	Moderately polluted	Moderately polluted	Moderately polluted	Less polluted
26.	**Water quality (WQI)**	B	C/D	C	B	B	B

Table 2. Values of Pearson correlation studies between water sample constituents and diatoms.

	TP	pH	CON	TUR	DO	BOD	COD	TSS	TDS	ALK	HAR	CA	MG	SUL	CL	SO	PT	Nt	Phos	FL	D
R	0.29	0.53	0.9	0.82	-0.9	0.93	0.89	0.93	0.9	0.87	0.88	0.91	0.84	0.92	0.9	0.91	0.93	0.87	0.89	0.94	1
R^2	0.09	0.28	0.81	0.67	0.81	0.87	0.79	0.86	0.81	0.76	0.78	0.82	0.71	0.85	0.81	0.84	0.86	0.76	0.8	0.88	1
P value	0.57	0.28	0.01	0.05	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.04	0.01	0.01	0.01	0.01	0.02	0.02	0.01	1
P Sum	Ns	ns	*	*	*	**	*	**	*	*	*	*	*	**	*	*	**	*	*	**	
P sig	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	

**= P <0.05, **= P <0.01, ns = Non significant*

Table 3. The list of diatom species identified in the lakes of Davangere district.

Sl.No.	BACILLARIPHYCEAE	Species	S1	S2	S3	S3	S4	S5	R.A %
1.	*Achnanthes* sp.	1	0	0	0	1	0	1	0.8
2.	*Amphora* sp.	2	2	1	1	1	2	1	3.1
3.	*Aulacoseira* sp.	3	4	3	3	2	3	2	6.7
4.	*Biremis* sp.	1	0	0	0	0	0	1	0.4
5.	*Caloneis* sp..	1	0	0	0	1	0	0	0.4
6.	*Craticula* sp.	1	0	1	0	1	0	0	0.8
7.	*Cyclotella* sp.	3	3	5	4	3	3	2	7.8
8.	*Cymbella* sp.	2	0	2	1	2	1	0	2.4
9.	*Denticula* sp.	1	2	0	0	0	1	0	1.2
10.	*Diatoma* sp.	1	0	1	0	1	0	0	0.8
11.	*Diploneis* sp.	1	2	4	2	1	1	1	4.3
12.	*Discostella* sp.	1	0	2	1	0	0	0	1.2
13.	*Epithemia* sp.	1	2	2	1	1	0	2	3.1
14.	*Eunotia* sp.	3	0	0	1	1	1	0	1.2
15.	*Fragilaria* sp.	6	1	2	2	2	1	1	3.5
16.	*Gomphoneis* sp.	1	0	0	1	1	2	0	1.6
17.	*Gomphonema* sp.	5	1	2	1	1	1	1	2.7
18.	*Gramatophora* sp.	1	0	2	0	1	0	0	1.2
19.	*Gyrosigma* sp.	1	0	2	1	0	0	0	1.2
20.	*Mastagloia* sp.	2	2	2	1	2	3	3	5.1
21.	*Melosira* sp.	3	2	4	3	2	1	2	5.5
22.	*Navicula* sp.	9	2	5	3	3	3	2	7.1
23.	*Nitzschia* sp.	6	3	2	1	3	1	1	4.3
24.	*Pennium* sp.	1	0	0	0	1	0	0	0.4
25.	*Pinnularia* sp.	5	2	3	3	1	1	2	4.7
26.	*Rhopalodia* sp.	1	2	4	3	1	1	1	4.7
27.	*Sellaphora* sp.	4	2	2	2	3	2	1	4.7
28.	*Simonsenia* sp.	1	2	2	1	1	1	1	3.1
29.	*Stauroneis* sp.	2	2	3	0	1	0	0	2.4
30.	*Surirella* sp.	1	2	2	0	1	0	0	2
31.	*Synedra* sp.	3	2	2	1	2	1	1	3.5
32.	*Tabellaria* sp.	2	2	1	2	3	2	1	4.3
33.	*Ulnaria* sp.	3	1	3	2	1	1	2	3.9

Note: (-): 0 cell/m3; (1): 1-10 cell/m3; (2): 11-100 cell/m3; (3): 101-1000 cell/m3; (4): 1001-10000 cell/m3; (5) : >10000 cell/m3

Table 4. Diversity indices of diatoms distribution in the lakes of Davangere District.

Sl No	DIVERSITY INDICES	STATION					
		S1	S2	S3	S4	S5	S6
1	Shannon_H	2.995	3.16	3.007	3.256	2.929	2.919
2	Dominance_D	0.052	0.046	0.055	0.042	0.059	0.058
3	Simpson_1-D	0.9475	0.9536	0.9447	0.957	0.9403	0.9417
4	Evenness_e^H/S	0.952	0.9065	0.8797	0.8943	0.8909	0.9262

CONCLUSION

Davangere is fastest growing district possessing pollution to water bodies and potential threat to primary producers such as planktonic diatom, which might be a valuable indicator community for water quality assessment. Out of six lakes studied 31% of diatoms documented and Bathi lake was highly diversified, Shanthisagar lake was very even in distribution. The present result showed that the *C. stelligera, N. rostellata, A. granulate, M. islandica, S. bacillum,* and *P. dolosa, T. fasciculata* were predominant species in all the study sites. The high relative abundance species of *Navicula, Aulacoseira, Cyclotella, Diploneis, Fragilaria, Melosira, Mastagloia, Nitzschia, Pinnularia, Rhopalodia, Sellaphora, Tabularia, Ulnaria, Synedra, and Gomphonema seems to be the potential ecological indicators.* The present research signifies the ecologically important role of diatoms in the aquatic environment of Davangere District. Water quality variables such as PO_4^-, NO_3^-, Cl^-, Mg^{++}, SO_4^-, DO, pH, temperature, and turbidity were strongly correlated with diatoms assemblages and status of aquatic ecosystem. *Further, the study contributes towards the conservation of freshwater source and their sustainable usage.*

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