DIVERSITY INDICES OF PLANKTON IN POWAI LAKE, MUMBAI, INDIA

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ABSTRACT
Plankton species of Powai lake were investigated in five stations, designated as station A, B, C, D and E respectively. Sampling was done in the morning before 8:00am, on monthly basis for a period of twelve months (November 2016 to October 2017) covering pre-monsoon, monsoon and post-monsoon seasons and analysed. Pour-through method was adopted. The monthly trend of Shannon-Weiner index for the lake could be depicted as month of March >August >July= September= October>June> April>May> November> January> December> February. The species richness index ranged from 0.632 (October) to 1.095 (January). The minimum number (15001) of plankton species was recorded in station B whereas the maximum number (26320) was observed for station C. The concentration of dominance was highest in station A > D > C > B = E. Powai lake is fairly rich in terms of plankton abundance and diversity. More intensive studies of the plankton species in Indian lakes will lead to the documentations of other species and wider distribution of many others than those that were recorded in the current study. This will lead to greater understanding of the factor that controls the distribution of these species.

Keywords: Plankton, Species, Diversity, Index, Powai lake.

INTRODUCTION

Powai Lake, situated 55 meters above mean sea level (msl) and located just outside Sanjay Gandhi National Park, was created by British India in 1891 at an initial cost of Rs 6.5 lakh, as an emergency measure to augment the drinking water supply for the city by recharging the area's underground water table and by constructing two stone dams of 10 metres high across two hillocks. The spread of the water body thus achieved was about 370 acres or 2.10 Sq kilometres (210 hectares) and the depth varied from about 3.05 m (off periphery) to 12.19 m at its deepest which has been reduced to 0.69 m from 6.90 m now due to constant siltation. Powai lake supplied two million gallons of water to Bombay.

However, after Tansa Lake became a more viable option, in 1892, Powai was turned over for angling and sport fisheries. Average rainfall at Powai is about 2540 mm per year which makes the lake to overflow for about 60 days each year. The watershed area of the lake is 688 hectares. The volume of minimum water in summer is 440 lakh liters and in monsoon the maximum water is 528 lakh liters. Total silted area is 420859 sq. meters. It supports a very rich ecosystem with a wide variety of flora and fauna. Over the years, indiscriminate use of the lake as an outlet for storm sewers, waste water drains, domestic sewage, wash water and a wide variety of pollutants have rendered the lake's water highly polluted particularly during pre and post monsoon seasons. Siltation, shallowness, pollution, reclamation, weed-infestation, quarrying and blasting, industrial activities within the catchment area, ecosystem degradation, encroachments along the lake, vehicular pollution, loss of aesthetic and recreational value are also some other reasons for degradation of its water quality.

Successful management of aquatic ecosystem such as Powai lake requires fundamental knowledge of dynamic interactions among its various components. Thus, monitoring the physio-chemical and biological characteristics of the lake in time and space is vital for both short term and long term sustainable exploitation of the aquatic resource. It will provide an early warning signal for decisions to be made and action taken to minimize impending deleterious effects on the water quality, and any other purpose the water might be intended to serve. In the long-term, it can provide greater insight into why problems occur, help to discern trends and assess potential remedies (Nwankwo, 1990; Usman *et al*., 2014; Biswas, 2015; Dede and Deshmukh, 2015; Indur *et al*., 2015; Acharya 2016; Bhavan *et al*., 2016).

Phytoplankton form the base of most of the lake food-webs and fish production is linked to phytoplankton production. Moreover, the number and species of phytoplankters serve to determine the quality of a water body (Ryder *et al.,* 1974; Goswami and Mankodi, 2012; Raut *et al*., 2015; Sharma *et al*., 2015a; Smruti, 2016; Sree and Shameem, 2017). The physico-chemical, geomorphological and sedimentary natures are always correlated with the density of plankton (Yeragi and Yeragi, 2003). The study of plankton also serves as an index of water quality in respect of industrial, municipal and domestic sewage pollution (Pati and Sahu, 1993; Acharjee *et al.,* 1995; Baruah *et al.,* 1997; Kumar and Kiran., 2015; Dey *et al*., 2015; Manickam *et al*., 2015; Sharma *et al*., 2015b; Pawar, 2016; Ramesh and Majagi, 2016; Shukla and Solanki, 2016; Sivalingam *et al*., 2016). Study of plankton is a very useful tool for assessment of water quality in any type of water body and also contributes to the understanding of the basic nature and general economy of the lake (Pawar *et al*., 2006). Lehman (2000) determined the direct role of climate variation on phytoplankton community bio-volume. Hambright and Tamar (2000) concluded that disturbances can enhance phytoplankton species diversity. Goldman and Horne (1983) have reported that the dynamic features of lakes such as colour, clarity, trophic state, zooplankton and fish production depend to a large degree on the phytoplankton. The phytoplankton community on which whole aquatic population depends is largely influenced by the interaction of a number of physico-chemical factors. Davis, (1955); Raut *et al*., (2015); and Acharya (2016), showed that a number of physical, chemical and biological factors acting simultaneously must be taken into consideration in understanding the fluctuations of phytoplankton population.

Several workers have studied plankton dynamics in lakes and reservoirs. Sugunan (1980, 1995) indicated the seasonal fluctuation of plankton in Nagarjuna Sagar reservoir. Sreenivasan (1969) reported the dominance of blue green algae and diatoms in the South Indian reservoirs. Jepachandramohan *et al.,* (2009) showed the influence of spatial and temporal variations on phytoplankton community structure in Pechiparai reservoir. Other workers like Sreenivasan, 1964; Govind, 1969; Ganapati and Pathak, 1969; Fernando and Kanduru, 1984; Salim and Ahmed, 1985; Khan, 1986; Saha, 1990; Rao and Choubey, 1990; and Deorari 1993, reported about plankton communities of Indian reservoirs. Tilzer *et al.,* 1977; Duncan and Gulati, 1981; Krzanowski, 1986; Pollingher, 1986; Hanzato and Yasuno, 1987; James and Forszh, 1990; Vasconcelos, 1990; Melao and Rocha, 2000; Ariyadej *et al.,* 2004; Sendacz *et al.*, 2006; Sebetich, 2009; Ghosh and Biswas, 2015; Kather *et al*., 2015; Mahesh *et al*., 2015; and Mruthyunjaya *et al*. 2016, have studied plankton and productivity of various lakes around the world.

The variation in abundance, biomass (Torres-Orozco and Zanatta, 1998), communities (Deevey *et al.,* 1980; Haberyan *et al.,* 1995), and vertical distribution (Cervantes-Martínez *et al.,* 2005) of zooplankton in tropical systems during annual cycles has been described. However, the causes of these changes remain vague (Crisman and Streever, 1996; Manivelu *et al*., 2016). Similarly the zooplankton communities in small, tropical lakes (such as the sinkholes of the Yucatan Peninsula) and the factors related to their dynamics, have received limited attention (Lewis, 1990; Crisman and Streever, 1996; Kapoor, 2015; Watkar and Barbate, 2015; Das and Kar, 2016; and Shiv *et al*., 2017). Therefore, this study is necessary to update information on the species diversity index in Powai lake, Mumbai, India. In view of this, the objective of this study is to assess and to compare the plankton diversity indices in Powai lake in relation to its richness and evenness index.

MATERIALS AND METHODS

Study area

Powai lake is located between latitude 19^0 7' N and longitude 72^0 54' E with total surface area of 2.10 km^2 and 35 meters above the mean sea level. It is a man-made lake built in 1891 and known as 'Anglers Paradise' with catchment area of 6.61 km^2, maximum depth of 12m and surface elevation of 58.5m. It is meant exclusively for angling and sports and is located about 27 Km away in the north- east of Mumbai city. This lake was built in the year 1891, when Mumbai Municipality got constructed a monsonary dam of 10 meter height between two hillocks across Powai basin to conserve the rain water for drinking purpose, which is commonly known as Powai lake, since it impounded in Powai area (Kohil *et al*., 1998). However, the water in the lake was found in potable because of indiscriminate use of the lake for various purposes by the local people and also due to the addition of domestic sewage. This lake was open for the general utilization of the natives and it is leased out Maharashtra State Angling Association, Mumbai for angling in addition to conservation. The conservation of Powai Lake is in the interest of man because of its ecological, aquacultural and tourist value. One of the most important steps in the conservation of the lake is to restore the water quality by controlling the pollution through different remedial measures (Fig. 1).

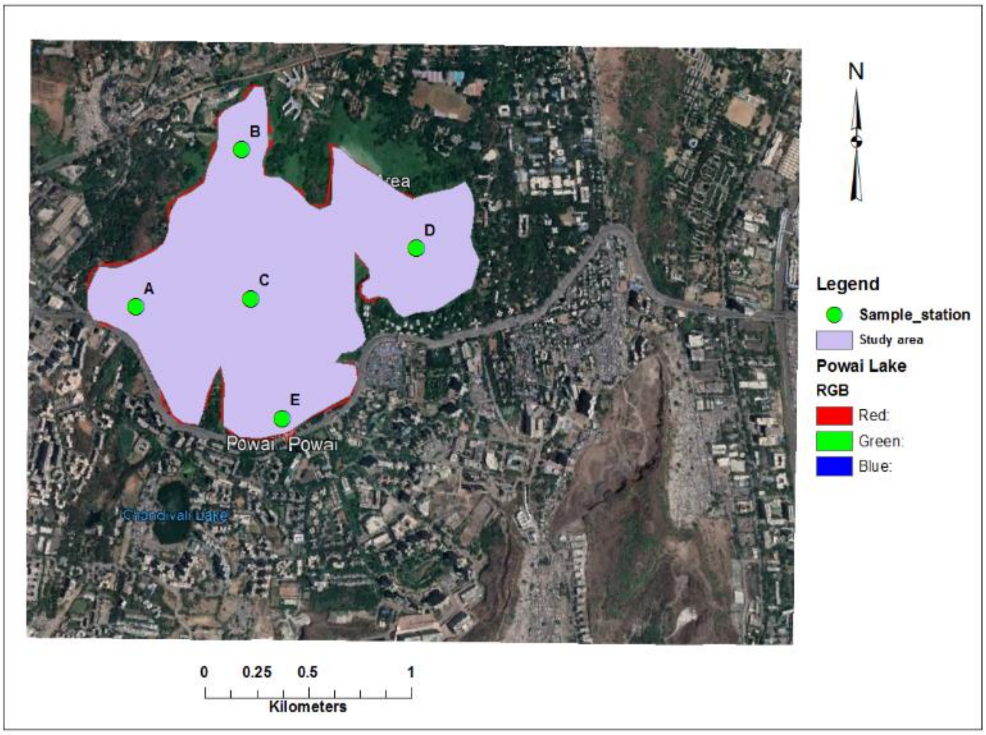

Fig 1: Map of Powai lake showing the sampling stations
Source: Google map 2016

Sampling stations

Five sampling stations were chosen based on preliminary surveys of the lake and factors such as average depth, volume of water, accessibility, security and various activities taking place in and around the lake. GPS was used to locate the coordinates of the Station A (19.1259 and 72.8979), Station B (19.1330 and 72.9030), Station C (19.1263 and 72.9032), Station D (19.1285 and 72.9108) and Station E (19.1213 and 72.9047) respectively.

Sampling frequency and duration of study

Pour- through method was used to collect the samples in triplicate. A 10-liter graduated plastic bucked was used to collect water at a depth of about 30cm below the water surface, and pour into a plankton net of mesh size 150µm for zooplankton and 60µm for phytoplankton, these were done 10 times to make a total of 100 litres of filtered water concentrated into 100 ml. These were then transferred into labeled collecting bottles and preserve in 5% formalin. The samples were taken to the Plankton laboratory of the Division of Aquatic Environment and Health Management of ICAR-CIFE for further analysis.

After they were taken to laboratory, each preserved plankton sample was poured into a graduated centrifuge tube and centrifuged using a 'Gallen Kamp- Medico' model (90) centrifuged for 10 minutes at low speed (14,000 rpm) this was allowed to settle and the Supernatant decanted. After decanting the concentrated plankton was analyzed. A dropping pipette was used to place the concentrated plankton on a glass slide with a cover slip and then viewed under a wild binocular microscope model BH2 and a wild Olympus microscope model AH2 Vanox 7. The plankton were thereafter counted (quantitative analysis) and then identified (qualitative analysis) using standard identification keys and chart were identified them to species level with aided by the taxonomic guide according to Pennak, (1978) Jeje and Fernando (1986). The above processes were repeated four times, in order to determine the abundance and diversity of plankton at the five stations.

Statistical and computational analysis

The data were statistically analysed using one-way analysis of variance (ANOVA-IBM SPSS version 22), and the significant differences between the means were determined by Duncan's Multiple Range Test (DMRT). The significant level was made at $P<0.05$. Data are as mean ± standard error of the mean.

The estimation of species abundance and diversity of planktons was done using Margalef's Diversity Index (D), Shannon-Wiener Diversity Index(H^I) and Simpson's Index(D) methods (1949).

The faunal similarities at different sites based on nominal data, were analyzed using indices of Jackson (1989). The relative abundance of taxa that were common among the tributaries was calculated using Renkonen similarity (1975). Simpson index (d) and Jackknife Estimator (S) were employed to evaluate species richness. The Shannon-Weiner index (H) and evenness index (E) of Shan Weiner (1963) were used to evaluate species diversity. Jackknife index (S) estimate was employed to account for the probability of missing some of the actual total number of species present in any count based on a sample population.

RESULTS

Table 1 show the monthly plankton diversity index of Powai lake for the months studied. The monthly trend of Shannon-Weiner index for the lake can be depicted as month of March had the highest, other higher indices were observed in the month of August > July = September = October > June > April > May > November > January > December and least in February. The maximum number (3337551) of plankton species was recorded in October whereas the minimum (4204) was observed for January. The concentration of dominance was highest in March > August > July=September=October > June > November > May > April > January > December > February. The species richness index ranged from 0.632 (October) to 1.095 (January). The equitability or evenness index was highest in March (0.327) and lowest (0.143) in December. Species heterogeneity was in descending order as February > December > January > November > April > May > July > June = September = October > August > March.

Table 1: Monthly diversity indices of plankton species of Powai Lake (November, 2016 to October, 2017)

Month	No. of sp.	No. of Individual per litre	Diversity indices				
			Species Richness Index (*d*)	Shannon-Weiner Index (H')	Equitability Index (*J*)	Simpson's Index (*D*)	Species Heterogeneity (1 – *D*)
November	10	5050	1.074	0.616	0.267	0.227	0.772
December	10	10636	0.994	0.329	0.143	0.108	0.891
January	9	4204	1.095	0.474	0.216	0.177	0.822
February	8	7850	1.025	0.307	0.148	0.105	0.894
March	11	32568	0.895	0.782	0.327	0.350	0.649
April	11	60309	0.848	0.655	0.274	0.262	0.737
May	11	115569	0.803	0.654	0.273	0.264	0.735
June	11	220502	0.763	0.665	0.278	0.270	0.729
July	11	436799	0.726	0.666	0.279	0.271	0.728
August	11	865749	0.692	0.669	0.280	0.273	0.726
September	11	1698931	0.660	0.666	0.278	0.271	0.728
October	11	3337551	0.632	0.666	0.279	0.271	0.728

The trend of Shannon-Weiner index for sampling stations in Powai lake (table 2) can be depicted in descending order as station A > D > C > B > E. The minimum number (15001) of plankton species was recorded in station B whereas the maximum number (26320) was observed for station C. The concentration of dominance was highest in station A > D > C > B = E. The species richness index ranged from 0.983 (station B) to 1.040 (station C). The Equitability or evenness index was highest in station A (0.167) and least (0.153) in station B, C and E. Species heterogeneity was in the descending order station E > B > C > D > A.

Table 2: Diversity indices of plankton at different stations in Powai Lake (November, 2016 to October, 2017)

Station	No. of sp.	No. of Individual per litre	Diversity indices				
			Species Richness Index (*d*)	Shannon-Weiner Index (H')	Equitability Index (*J*)	Simpson's Index (*D*)	Species Heterogeneity (1 – *D*)
A	11	21575	1.003	0.400	0.167	0.134	0.865
B	11	26320	0.983	0.366	0.153	0.121	0.878
C	11	15001	1.040	0.367	0.153	0.122	0.877
D	11	15649	1.033	0.376	0.157	0.124	0.875
E	10	17743	1.022	0.353	0.153	0.115	0.884

Relative abundance

The species abundance data was plotted as a rank abundance curve following Whittaker (1965). Each species is represented by a point on the line graph proportional to its abundance. Fig. 2 shows the rank abundance plot. The long tail depicts rarer species, hence the plankton community of Powai lake can be said to have high to moderate evenness.

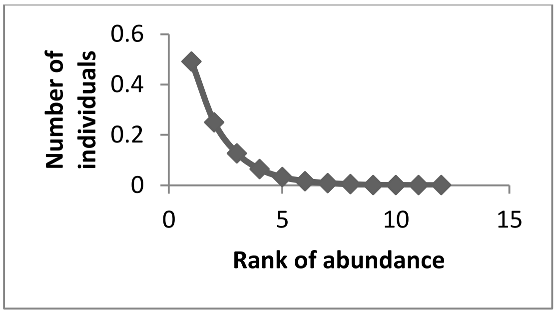

Fig. 2: Rank-abundance curve for the plankton community of Powai lake India

DISCUSSION

The taxonomic dominance of *Microcystaceae* as reported in this study has been observed in several other water bodies. This pattern is common in tropical and subtropical fresh water, whether in lakes, ponds, reservoirs, rivers or streams (Green, 1960; Jeje and Fernando, 1986; Cavlli *et al.*, 2001; Nugueira, 2001; Sampaio *et al.*, 2002; Neves *et al.*, 2003; Kudari *et al.*, 2005; Imoobe and Akoma, 2008, 2009; Armoro and Oganah, 2010; Parikh and Mankodi, 2012; Manjare, 2015; Das and Kar, 2016; Sultana and Balamurugan, 2016). The species composition of plankton with dominance of *Microcystaceae* was also observed by Olaifa and Leilei (2007) in Ekole River and Paramita (2012) in the same Powai lake. Mathivanan *et al.,* (2007) also reported dominance of *Microcystaceae* in Cauvery River, with the predominance genus usually being *Microcystis aeruginosa*. In this study a total of eleven (11) plankton species were identified belonging to nine (9) families. Ganapati and Pathak (1969) reported that under normal conditions, *Microcystis aeruginosa* occurred throughout the year with a bloom in summer, in enclosed water bodies. Sugunan (1995), Sinha and Singh (2016), and Adhikari *et al*. (2017) also reported the overwhelming presence of *Microcystis aeruginosa* in Indian reservoirs. The dominance of *Microcystis* throughout the year in Powai lake is similar to the findings of Paramita, (2012). An analysis of the family wise representation of recorded species depicted the relative quantitative sequence to be *Microcystaceae* > *Naviculaceae* > *Brachionidae* > *Moinidae* > *Volvocaceae* > *Acartiidae* > *Hydrodictyaceae* > *Bacillariaceae* > *Zygnemataceae*.

Abundance of plankton is influenced by the seasonal variations in water quality parameters of a water body (Fig. 2). Plankton diversity has been studied in relation to these parameters by Hedge, 1985; Pollinger *et al.,* 1988; Kulshreshtha *et al.*, 1989; and Adholia, 1991. Byars, 1960; Hutchinson, 1967; Rao, 1975; Patil *et al*., 2012; Shaikh, 2015; Kar and Kar, 2016a; Manikandan *et al*., 2016; Rao *et al*., 2017, reported that temperature plays an important role in the periodicity of phytoplankton. In the present investigation, peak population of phytoplankton recorded during the post-monsoon months (July to October). In present study, direct relationship of phytoplankton was observed with specific conductivity of water and organic carbon of soil; and an inverse relationship for phytoplankton was observed with reactive phosphorus, nitrate nitrogen, which are supported by the works of Round, 1957; Singh, 1960; Vollenweider, 1968; Lund, 1965; and Das and Singh, 1993; Majumder *et al*., 2015; Kadam, 2016; Kar and Kar, 2016b; and Rao, 2017. Phytoplankton is inversely related to phosphorus, less phosphorus in post-monsoon correlates with a peak in phytoplankton density. It is a notable that increased deposition of organic wastes in station E due to immersion of idols, dry flowers and clay pots used in religious rituals during August to September. Ammonia nitrogen, phosphate phosphorus, nitrate nitrogen and silica also registered higher values bringing in domestic wastes and leakage from sewerage lines has also contributed.

Pediastrum sp., *Volvox sp.* and *Eudorina sp.* were most commonly occurring green algae. From the study of phytoplankters, it can be concluded the total number of individuals (density) was quite high in Powai lake as compared to the number of species (diversity). This conforms with report of Romo and Villena, 2005, who stated that high nutrient levels and fish stocks decreased phytoplankton diversity and species richness, with a trend towards the establishment of an assemblage dominated mainly by cyanobacteria in a warm shallow lake. The lake has mostly pollution tolerant species giving an indication of the polluted nature of the lake. It is reported that the study of plankton serves as an index of water quality in respect of industrial pollution, and municipal and domestic sewage pollution (Pati and Sahu, 1993; Acharjee *et al.*, 1995; Baruah *et al.*, 1997; Pal *et al*., 2015; Imran *et al*., 2016; Maibam *et al*., 2016; and Reddy *et al*., 2016). Pollution load in Powai lake was confirmed by the presence of pollution indicator species as per Palmer (1969) comprising different groups like *Microcystis*, *Spirogyra*, *Navicula*,and *Nitzschia* etc. in considerably higher numbers in Powai lake. The plankton biomass studies are also important for gaining insight into fish production (Lenz, 1973). Rich biomass of plankton indicates high fish production. Maximum phytoplankton biomass can be correlated to the influence of warm temperature of water and nutrient enrichment of the lake through surface runoff from monsoon rains which mature during post-monsoon to increase primary productivity in pre-monsoon. The high phytoplankton biomass indicated good potential of the lake for fish production.

The richness of the plankton within Powai lake is low compared with what was obtained in some southern Nigeria lakes, and this may be attributed to influences such as climate change, aridity, physical, chemical and biological factors within each station and may also be associated with tropic state as well as geographical factors observed by Arora and Narish (2003) in Yamuna River. Egborge (1981) recorded 78 species in Asejire Lake, Jeje and Fernando (1986) recorded 65 species in Adada, Bonny and Oguta lakes.

The average plankton species per station in Powai lake is higher when compared with previous studies in northern Nigeria lakes. For example, Abdullahi (1982) observed 18 species from Tiga lake in Kano, Ovie (1993) recorded 13 species in Kainji Lake. This is especially notable given that the sampling assessed was from the arid lake with very low rain, as well as surface water sampled. A higher number would be expected if greater sampling frequency at a deeper depth was employed. Also low rain with reduced vegetation had a greater effect on the qualitative and quantitative level of plankton species.

The highest species recorded by Egborge, 1981; Arora and Naresh, 2003; and Vasanthkumar *et al*., 2015 were associated with high vegetation which provides anchorage to the resting eggs and larva stage of zooplankton in those water bodies studied. Species abundance of plankton varies widely between stations within study. It is difficult to make a definite conclusion on the causes of the species pattern but we can suggest that the depth significantly contribute, even though flow of water from the source through all other stations as well as homogeneity of the stations may be one of the factors to be considered.

Results show that the distribution of plankton varied among depths, some species recorded here are likely to be limited in their distributions by their tolerance to environmental conditions and their preferences for food quality and quantity. Not all the identified species were present in all the five stations and months. For instance, *Navicula sp.* was totally absent in station E, also in the month of January and February. *Nitzschia sp.* absent in February, while *Spirogyra sp.* absent in November, December, January and February. These findings agree with the reports of Idowu *et al.*, (2008) who stated that for the determinant species (concentration) was depth played a vital role. Idowu, 2004; Rai, 2016; and Rathod *et al*., 2016 observed that majority of zooplankton were found to be sensitive to low, medium or high levels of illumination, and as transparency changes, their positions in the water column also changed.

In the previous investigation of Powai lake by Paramita (2012), a total of 25 species under 20 genera of plankton were recorded. Rawat (1991) also recorded 21 species of zooplankton from Tumaria reservoir of Uttarakhand. Dumount and Tundisi, 1984; and Vijverberg *et al*., 1987, reported that zooplankton species diversity (especially limnetic copepods and cladocerans) decrease progressively towards the equator. Fernando (1980) also reported that the number of species occurring in temperate regions of Britain and Canada were approximately 50% higher than in tropical Sri lanka. Thus the plankton species spectrum of Powai lake matched with the species spectrum of tropical lakes. Plankton species diversity expressed as the number of species or combined abundance and number of species in Shannon-index was very low compared with what was obtained in Oguta lake. But it was higher in Powai lake compared with what was obtained in Tiga lake (Abdullahi, 1982), Man-made wetland (Sarkar *et al*. 2016) and Urpod Beel lake (Kalita *et al*. 2016). Ovie (1993), Malik and Panwar (2016) and Fathibi *et al*. (2017), also suggest that flow velocity may be particularly important as a determining factor of composition and diversity of plankton assemblage. Vertical migration with suspect to change in temperature can also be considered as limiting factor for zooplankton occurrence in Powai lake for the variation in their distribution in relation to depth and stations. More intensive study of the pelagic plankton in Indian lakes will lead to the documentations of other species and wider distribution many others than those that were recorded in the current study. This will lead to greater understanding of the factors that controls the distribution of these species.

CONCLUSION

The presence of typical plankton species, notwithstanding other limnological features strongly suggests that the water body is maintaining an eutrophic status. Powai lake is fairly rich in terms of plankton abundance and diversity.

Settlement around Powai lake should be encouraged to adopt environmentally friendly low and non-waste technologies (LNWT) at all stages of product life. Monitoring of the lake should be encouraged as part of environmental management policy, so as to control the effluents that enters each station, through canals, washing, etc and hence maintains acceptable limits of metal concentration, such as phosphate-phosphorus that encourages eutrophication of lake which will adversely affect the plankton community as well as the whole ecosystem. Substantial Limnological research information has occurred from a relatively short period of research work, long period oriented study becomes increasingly vital and desirable. In doing so, further prolong research would provide a broader understanding of this very economically and scientifically important water body in the tropic. In addition, the knowledge derived could be used as an index for other man-made lakes in tropic zones. More intensive study of the plankton in Indian lakes will lead to the documentations of other species and wider distribution of many others than those that were recorded in the current study. This will lead to greater understanding of the factor that controls the distribution of these species.

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