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Impact of Water Quality on Production and Productivity in BellandurLake, Karnataka

Prabhudeva K N[1], Chethan N[2], Rajanna K B[1] and Adarsha H S[3]

[1]Fisheries Research and Information Centre, KVAFSU, Hebbal, Bengaluru, Karnataka
[2]ICAR-KVK, Dakshina Kannada
[3]ICAR-BIRDS KVK, Belagavi-1

ABSTRACT

Bellandur lake is considered to be the largest water body in Bengaluru city with catchment area of 287sqm and water storing capacity of 17.66 million cubic feet. Water quality of this lake has been a major issue for a long time with foam appearance and accidental burning of the same has become national news in recent times. Eleven parameters from three different location of the lake were monitored from March, 2014 to December, 2017. Majority of the physico- chemical parameters were beyond the optimal range for surface waters and biological parameters also above the desirable limits. Heavy metals concentrations were also high with major source from untreated sewage, industrial effluents, solid waste etc. Dissolved oxygen was nil in many seasons at various location with high BOD concentrations indicated that this lake was containing copious amount of organic load which was utilizing dissolved oxygen for decomposition by microbes and making the water body anaerobic at times. There is a need for proper management measure to rejuvenate this water body by stopping all the illegal entry of pollutants.

Key Words: Bellandur lake, Heavy metal, Pollution, Water quality.

INTRODUCTION

Water is one of the most important natural resource available to mankind. Realizing the importance of water for sustenance of life, concerted efforts are going in different parts of the world to conserve water bodies especially the fresh water bodies. Lakes are not only the source of precious water but provide valuable habitats to plants and animals, moderate hydrological cycles, influence microclimate, enhance the aesthetic beauty of the landscape and extend many recreational opportunities to humankind. Bangalore city has numerous lakes but there are no rivers close by. Around 35 per cent of the water bodies in the city have been lost in the past 20 years and now majority of lakes are on the verge of extinction, as all are filled with solid wastes and untreated sewage.

The Bellandur lake, located at latitude of 12°58' N and Longitude of 77°35' E at an altitude of 921 m above mean sea level, is the largest lake in Bangalore city spreads across an area of 892 acres. The lake has a catchment area of 287 km^2 and its water storing capacity is of 17.66 million cubic feet. Its length is 3 km while width is 2.75 km. It is one of the largest man-made lakes in Southeast Asia and represents what was once a beautiful and wholesome source of water for the city of Bengaluru. Off late, the Bellandur Lake catchment has been subjected to extreme anthropogenic stress mainly due to the rampant unplanned developmental activities in recent years. The lake bed has also been subjected to ad-hoc development approaches and the functional ability of the ecosystem is impaired due to structural changes in the ecosystem. This is evident from poor water quality, breeding of disease vectors, contamination of ground water in the catchment, frequent flooding in the catchment due to topography alteration, decline in ground

Corresponding Author's Email:

water table, erosion in lake bed, etc. Hence, a study was taken up to understand the health condition of this lake by way of monitoring the water quality.

MATERIALS AND METHODS

The status of various physical, chemical and biological water quality parameters of Bellandurlake was monitored from March, 2014 to December 2017. The samples were collected and analysed as per the standard procedures APHA (1985). Two out flows of the lake namely station 1 and station 2 along with station 2 between the two outflows were selected for the study. The water samples were collected at all the three locations of the lake and totally eleven water quality parameters were monitored to check the health condition of the lake. These parameters included water temperature, pH, dissolved oxygen, Biochemical Oxygen Demand (BOD), nitrate nitrogen, phosphate phosphorous, heavy metals like lead and mercury, bacterial loads like Total *Coliforms* (total plate count) and *E. coli* counts.

RESULTS AND DISCUSSION

Water temperature and pH

The surface water temperature at all the three locations exhibited a uniform trend without much spatial variation from 25.10°C during March 2014 to 29.11°C during September 2017. The seasonal variation during September, 2017 reported a maximum of 31.9°C with gradual increasing trend due to shortage of rainfall during the year 2017.

The surface water pH has gradually decreased over the period of time towards acidic condition, which was evident by 7.2 and 7.3 at initial period of monitoring (March, 2014) and 6.7, 6.9 and 6.8 at station 1, 2 and 3, respectively during December 2017.The decreased pH may lead to collapse of primary productivity in the lake. In the seasonal variation, the rainy months had an impact on the variation with reducing the concentration while summer and winter seasons the pH has increased to a neutral condition. The statistical analysis of the data also showed that there was a significant difference between the stations and also the seasons. Neutral pH condition in the same location has been reported by Pattusamy *et al*(2013) and Helen and Paneerselvam (2008) during their respective studies and it was essential to have a pH concentration range of 6.0 to 8.5 for the productive nature of any water body (Garg *et al,* 2010).

Dissolved oxygen

The depletion of dissolved oxygen was observed at all the stations and in all the seasons except in the month of July, 2014 with 7.23 mg/l concentration as a result of peak rainfall in the locality. The presence of high organic load derived from untreated sewage, industrial effluents etc. in the lakes has resulted in depletion of dissolved oxygen with minimum being zero in the surface water during majority of the sampling periods and below the optimal levels throughout the study period. This depletion of dissolved oxygen has a direct impact on the aquatic biota and this was a serious issue to be tackled for avoiding the water body to be unfit for biotic components to prevail. This depleted condition was also supported by increased BOD concentration in the lake which was beyond the permissible limits with a concern to the aquatic biota.

The biochemical oxygen demand (BOD) concentration has been found to be of increasing trend in Bellandur lake with minimum of 9.12, 8.77 and 9.72 mg/l at station 1, 2 and 3, respectively during initial period of the study to a maximum of 22.34, 24.68 and 20.44 mg/l at the end of the study period, which was way beyond the optimal limits for surface waters indicating the chemical pollution in the lake.. The two outflows have been reported with highest concentration compared to the station situated between the two, and the summer months with highest concentration. The seasonal and spatial variation along with the increasing trend of this parameter was of a critical importance as the addition of organic load to the water body was increasing day by day and impact on the oxygen concentration, essential for survival of all the

aquatic organisms was evident. Similar results have been reported by Ramesh and Krishnaiah (2014).

Carbon-dioxide

The concentration of carbon-dioxide varied at all the stations with maximum mean concentration of 33.909 mg/l being at station two, where the presence of aquatic vegetation was enormous indicating the spatial variation. Winter months reported high concentration compared to any other season with maximum concentration of 49 mg/l during December 2014.The statistical analysis of all the dissolved gases exhibited a significant variation between the stations and seasons. There was external influence to all these gases in the water body, which may be of domestic sewage, industrial waste or any sold waste with organic matter.

Nitrate nitrogen concentration

The nitrate nitrogen concentration in Bellandur lake was found to be beyond optimal range in most of the study duration with maximum concentration being in the year 2017. The concentration levels increased over the period of time, with minimum of 0.04 mg/l during July, 2014 and maximum of 0.97 mg/l in March, 2017. This increasing trend was a result of addition of nitrogenous waste into the water body through untreated sewage, industrial effluents or solid waste with maximum organic matter etc. The spatial variation was observed with maximum concentrations at the two outflows compared to the station situated in between. The mean concentration at all the stations was reported to be 0.41, 0.40 and 0.45 mg/l at station 1, 2 and 3 respectively. The seasonal variation was reported to be in increasing trend with maximum in summer months were the decomposition of organic load results in release of nitrogenous waste. Statistical analysis of the nitrate nitrogen values indicated the significant variation between the stations and seasons during the study period. The higher concentration of nitrate nitrogen in the same water body was reported by earlier workers.

Phosphate concentration

The phosphate concentration in Bellandur lake, essential for the primary productivity was beyond the optimal range and maximum concentrations were reported in two out flows of the lake compared to the station located in between. The mean concentration at all the three locations was found to be of 0.955, 0.905 and 0.928 mg/l at station 1, 2 and 3 respectively. Apart from the spatial variation, it was clear from the data that monsoon months exhibited the highest concentration of phosphate, which may be due to the inflow of water carrying phosphate components during the rainfall. The seasonal variation and spatial variation was also significant with the statistical analysis of the collected data. The formation of foam caused by the increased phosphate concentration in this water body has been the national news from a very long time.

The heavy metal lead concentrated in Bellandur lake was well within the desirable limit except in July, 2014 where its concentration was up to 0.198 mg/l at station 2 where the disposal of solid waste from the public was evident. Presence of high concentration at station 2, compared to outflows of the water body clearly indicated the spatial variation with mean concentrations of 0.064, 0.083, 0.0576 mg/l at station 1, 2 and 3 respectively. The seasonal variation was found to be with uniform range except in July and December of 2014, where the lead concentrations were high, which may be due to the addition through inflow during the rains. Helen and Paneerselvam (2008) reported lead concentration of 0.13mg/l in the Bellandur village bore well water and opined that the village has fallen prey for this chronic poison.

Mercury concentrations

The mercury concentrations in the lake were beyond the desirable limits at all the stations with maximum of 1.171 mg/l at station 1, the main out flow of the lake. The two outflows had the highest concentration of mercury compared to the

station located in between with mean concentration of 0.749, 0.702 and 0.769mg/l at station 1, 2 and 3, respectively. The seasonal variation also revealed that summer months contained higher concentrations, as the rate of inflow was minimal during these months. The statistical analysis of both lead and mercury exhibited a significant difference between the stations and seasons, making them crucial parameters in understanding the health of an ecosystem.

The presence of high fecal coliforms and total coliforms counts in Bellandur lake was evident for high organic load existing in the water body causing pollution. The *E. coli* counts were high during the monsoon season, which could be due to the organic load entered in large quantity into the lake during the rains. Presence of high counts at both the out flows (station 1 and 2) with 614 and 644 MPN/100 ml indicates the clear spatial variation existing. The Total Plate counts were also high throughout the study period and the counts were as high as 17,746 CFU/100ml at station 2 during March, 2014. The outflows station 1 and 2 were with 13,267 CFU/100ml during June 2016 and 15,743 CFU/100ml during March 2015 respectively. Spatially, station 2 had the highest mean counts of 12,509 CFU/100ml compared to the out flows, which may be due to the organic waste disposal at this place was evident. Due to the deficit of rain water during the summer months, the counts were in higher numbers compared to other seasons indicating he seasonal variation. The statistical analysis of both fecal coliforms and total coliforms counts revealed significant difference between the stations and seasons during the entire study period.

Statistical analysis

The Pearson's correlation between physico chemical and biological parameters showed that pH has a moderate correlation with dissolved oxygen, carbon-dioxide, lead and *E. coli* counts, while moderately negative correlation with BOD, nitrate nitrogen, phosphate phosphorous, mercury and total plate counts. Dissolved oxygen has strong correlation with BOD, carbon dioxide, phosphate phosphorous, lead, mercury and *E. coli* count while, moderately negative correlation with nitrate and total plate counts. BOD has positive correlation with nitrate, and total plate counts while negative correlation to all other parameters. Carbon dioxide was having moderate positive correlation with phosphate, dissolved oxygen and mercury with negative weak correlation with nitrate, *E. coli* and total plate count. Nitrate nitrogen was having strong positive correlation with total plate counts and BOD while strong negative correlation with phosphate, lead and mercury. Phosphate phosphorous was having strong positive correlation with dissolved oxygen and strong negative correlation with mercury and total plate counts. Lead has a strong positive correlation with dissolved oxygen, phosphate and *E. coli* counts while moderate negative correlation with BOD, Nitrate, and total plate count. Mercury has got moderate positive correlation with lead, dissolved oxygen while moderate negative correlation with BOD and phosphate. E. coli counts had moderate positive correlation with pH, dissolved oxygen, phosphate and lead while moderate negative correlation with total plate count. The total plate count was having strong positive correlation with nitrate and strong negative correlation with phosphate content. For analysis of variance, the months falling under different seasons were separated and put to test. The analysis of variation without replication resulted in significant variation between the parameters and less significant variation between the seasons (Table 3).

CONCLUSION

Bellandur lake was facing the severe pollution with chemicals and organic load addition every day and this lake with minimal dissolved oxygen was not providing a good habitat for aquatic organisms to survive. The presence of high levels of heavy metals was not only contaminating the lake ecosystem but also the underground water in the vicinity. There is

Table 1a: Water quality parameters of Bellandurlake from March, 2014 to December, 2017

Particulars	Mar 14	Jul 14	Dec14	Mar 15	Mar 16	Jun 16	Sep 16	Dec 16	Mar 17	Sep 17	Dec 17	Mean
Water Temperature (^{0}C)												
Station 1	25.5	28.5	28.1	28.5	26.1	27.5	26.5	24.9	28.1	31.5	26.1	**27.391**
Station 2	25.1	28.5	28.2	28.3	26.8	27.8	26.4	25.3	26.5	31.9	26.3	**27.373**
Station 3	25.6	28.3	28.15	28.2	26.7	27.5	26.4	25.1	27.7	31.9	25.9	**27.405**
pH												
Station 1	7.2	6.85	7.28	7.1	6.7	6.96	7.04	7.45	6.53	7	6.71	**6.984**
Station 2	7.3	6.76	6.44	7	6.9	7.01	7.15	7.19	6.62	7.12	6.99	**6.953**
Station 3	7.3	6.71	6.89	6.9	7.1	6.96	7.11	7.26	6.91	6.68	6.8	**6.965**
Dissolved oxygen (mg/l)												
Station 1	0.1	6.4	0.1	0	0.34	0	0	2.2	0	1.25	0	**0.945**
Station 2	0.6	7.12	0.1	2.62	1.24	0	1.06	2.36	0.67	2.16	1.66	**1.781**
Station 3	0.4	8.18	0.51	1.87	1.04	1.98	0	2.66	0	1.01	0.57	**1.656**
BOD(mg/l)												
Station 1	9.12	6.13	10.35	9.97	9.9	14.28	13.2	12.28	24.67	16.37	22.34	**13.510**
Station 2	8.77	5.81	10.45	7.54	8.56	12.3	11.05	10.96	20.09	18.64	24.68	**12.623**
Station 3	9.72	4.37	9.67	8.29	8.34	10.09	13.26	11.03	26.48	21.26	20.44	**12.995**
Carbon-dioxide(mg/l)												
Station 1	36	32	49	32	44	38	24	22	24	28	32	**32.818**
Station 2	32	32	45	38	32	42	48	20	28	24	32	**33.909**
Station 3	32	28	38	38	28	29	44	28	20	24	28	**30.636**

Table 1b: Water quality parameters of Bellandurlake from March, 2014 to December, 2017.

Particulars	Mar 14	Jul 14	Dec14	Mar 15	Mar 16	Jun 16	Sep 16	Dec 16	Mar 17	Sep 17	Dec 17	Mean
Nitrate Nitrogen (mg/l)												
Station 1	0.216	0.048	0.275	0.418	0.501	0.638	0.5631	0.4867	0.497	0.5413	0.4015	**0.417**
Station 2	0.193	0.05	0.306	0.341	0.401	0.511	0.4966	0.3966	0.646	0.695	0.4596	**0.409**
Station 3	0.203	0.049	0.199	0.219	0.357	0.421	0.561	0.487	0.972	0.8974	0.6654	**0.457**
Phosphate Phosphorous (mg/l)												
Station 1	0.125	2.648	2.845	0.216	0.317	0.399	0.2964	0.3106	1.081	1.2164	1.0579	**0.956**
Station 2	0.21	2.59	2.827	0.357	0.397	0.424	0.3265	0.2981	0.697	0.9647	0.8794	**0.906**
Station 3	0.091	2.62	2.328	0.385	0.401	0.36	0.3016	0.2644	1.114	1.2447	1.1002	**0.928**
Lead												
Station 1	0.04	0.197	0.088	0.063	0.046	0.031	0.0963	0.0645	0.027	0.0332	0.0266	**0.065**
Station 2	0.056	0.198	0.219	0.095	0.084	0.062	0.0846	0.0687	0.012	0.0218	0.0114	**0.083**
Station 3	0.046	0.19	0.086	0.067	0.052	0.04	0.0463	0.0545	0.011	0.0197	0.0211	**0.058**
Mercury												
Station 1	1.171	1.076	0.177	1.049	1.064	0.921	0.8436	0.5988	0.346	0.4578	0.5448	**0.750**
Station 2	1.091	0.945	0.783	1.125	0.459	0.631	0.8016	0.6554	0.235	0.6541	0.3478	**0.702**
Station 3	1.075	0.874	0.273	1.114	0.965	0.541	1.0145	0.6487	0.649	0.7471	0.5644	**0.770**
E. coli (MPN/100ml)												
Station 1	453	842	768	389	468	631	864	854	387	654	465	**616**
Station 2	231	717	715	310	645	412	496	646	749	844	658	**584**
Station 3	691	916	502	517	659	610	864	961	409	509	455	**645**
Total Plate Count (CFU/100ml)												
Station 1	11721	8747	6896	10967	12658	13267	11234	12494	10678	10364	11245	**10934**
Station 2	17746	8371	7341	12348	15267	11559	12045	9648	16790	15248	11245	**12510**
Station 3	10197	8294	6966	15743	12498	13567	10687	13467	9648	11879	11334	**11298**

Table 2: Analysis of variation of physico chemical and biological parameters.

Station 1: Source of Variation	SS	df	MS	F	P-value	F crit
Between parameters	1.18E+09	10	1.18E+08	386.1423	3.66E-75	1.926692
Between months	2846202	10	284620.2	0.928346	0.510748	1.926692
Error	30658859	100	306588.6			
Total	1.22E+09	120				
Station 2: Source of Variation	SS	df	MS	F	P-value	F crit
Between parameters	1.55E+09	10	1.55E+08	146.7241	4.28E-55	1.926692
Between months	10254426	10	1025443	0.96972	0.474516	1.926692
Error	1.06E+08	100	1057463			
Total	1.67E+09	120				
Station 3: Source of Variation	SS	df	MS	F	P-value	F crit
Between parameters	1.26E+09	10	1.26E+08	217.7066	3.59E-63	1.926692
Between months	5795016	10	579501.6	0.998005	0.450488	1.926692
Error	58066002	100	580660			
Total	1.33E+09	120				

Table 3: Pearson's correlation coefficient between Physico Chemical and biological Parameters.

Parameters	**WT**	**pH**	**DO**	**BOD**	**CO_2**	**NO_3**	**PO_4**	**Pb**	**Hg**	**E. coli**	**TPC**
WT	1.0000										
pH	-0.1910	1.0000									
DO	0.1725	0.0275	1.0000								
BOD	0.0980	-0.5363	0.4388	1.0000							
CO_2	-0.0027	0.0347	0.1778	-0.4063	1.0000						
NO_3	0.0220	-0.1152	-0.6105	0.4973	-0.2641	1.0000					
PO_4	0.4447	-0.0591	0.5133	-0.1143	0.3347	-0.5993	1.0000				
Pb	0.1017	0.1370	0.8236	-0.6167	0.0110	-0.6675	0.5861	1.0000			
Hg	-0.2906	-0.0121	0.2249	-0.5972	0.0660	-0.2054	-0.4605	0.2494	1.0000		
E. coli	-0.0049	0.5051	0.5273	-0.3881	-0.1493	-0.1203	0.3813	0.6375	-0.1444	1.0000	
TPC	-0.4686	-0.1021	-0.3117	0.1660	-0.2877	0.6146	-0.8963	-0.5375	0.4665	-0.2940	1.0000

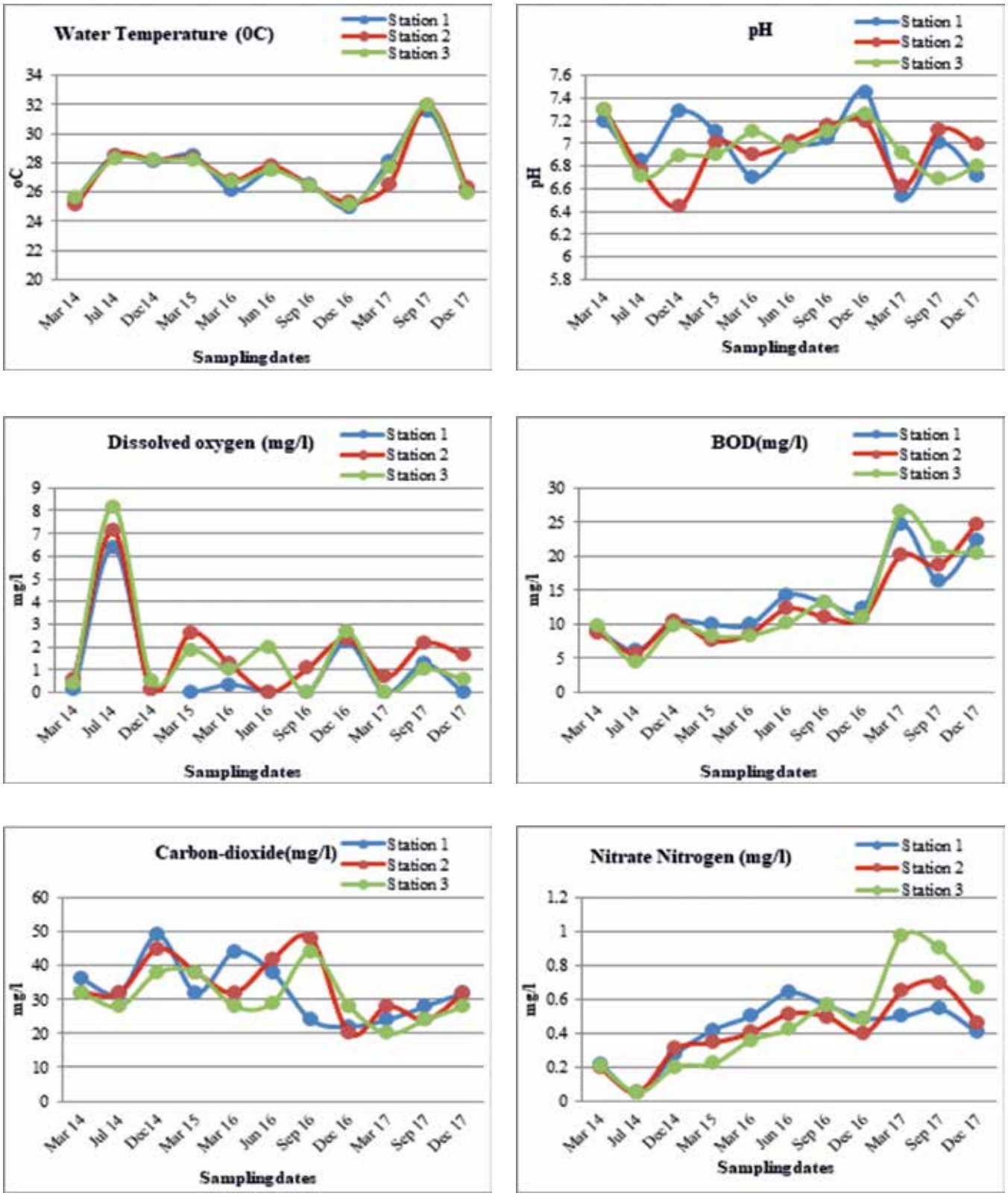

Fig. 1a: Water quality parameters of Bellandurlake from March, 2014 to December, 2017

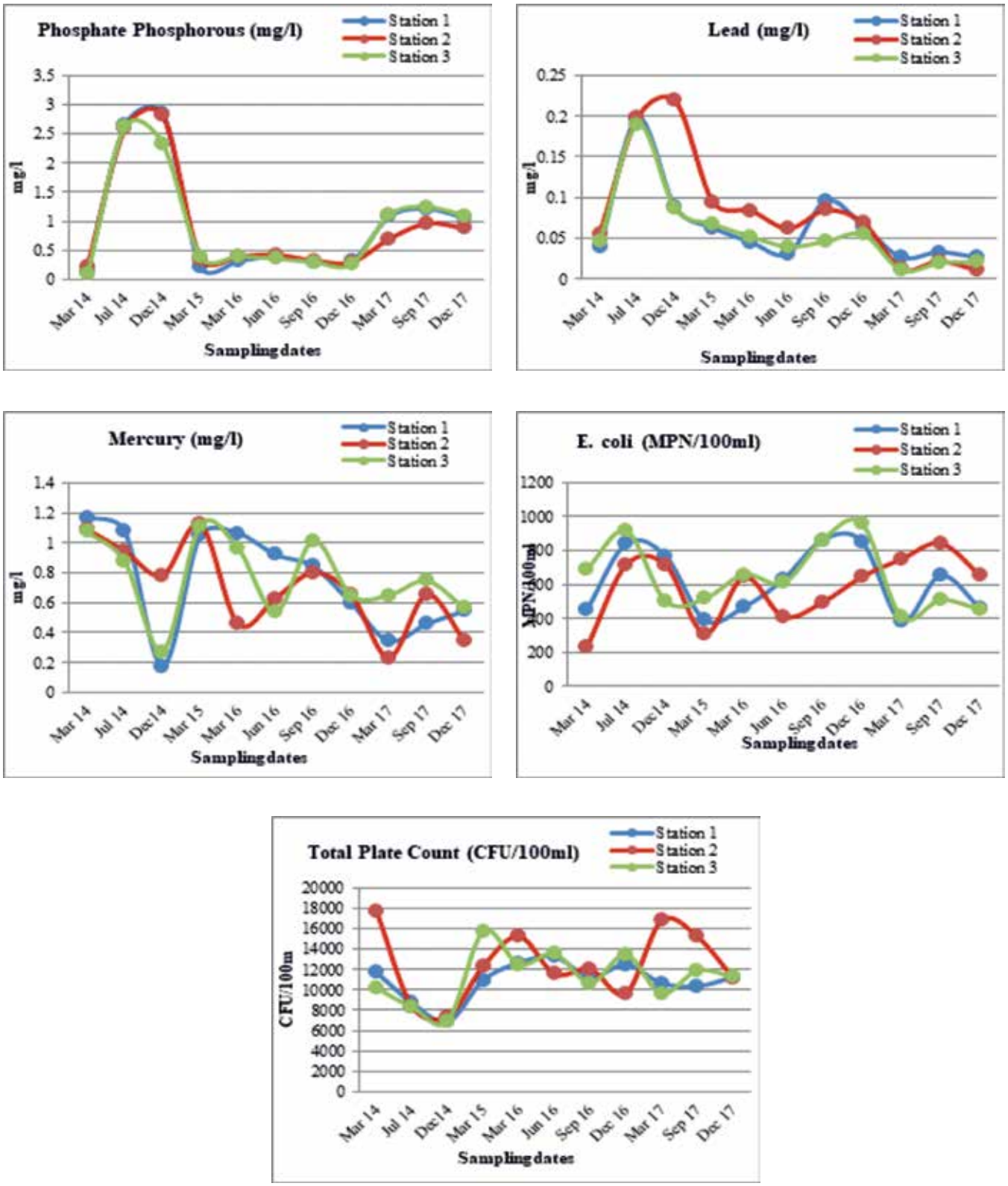

Fig. 1b: Water quality parameters of Bellandurlake from March, 2014 to December, 2017

a critical need of management measures to retain this lake from pollution and also to provide suitable habitat for the organisms associated with this lake ecosystem.

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