Appl Water Sci (2017) 7:1791–1798
DOI 10.1007/s13201-015-0352-5

ORIGINAL ARTICLE

Impact of physicochemical parameters on phytoplankton compositions and abundances in Selameko Manmade Reservoir, Debre Tabor, South Gondar, Ethiopia

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Received: 20 April 2015 / Accepted: 5 October 2015 / Published online: 9 December 2015

Abstract Impact of physicochemical parameters on phytoplankton compositions and abundances in Selameko Reservoir, Debre Tabor, South Gondar from August 2009 to May 2010 was assessed. Water quality parameters, such as temperature, water transparency, water depth, dissolved oxygen, pH, total dissolved solids, phosphate, nitrate, and silicate were measured in situ from two sites (littoral and open water zone) of the reservoir. Phytoplankton compositions and abundances were analyzed in Tana fisheries and other aquatic organisms' research center. ANOVA result of the physicochemical parameters included chlorophyll-a showed the presence of significance difference among seasons and between sites ($P < 0.05$). A total of seven families, 36 genera from three groups (Diatom, Blue green algae and Green algae) of phytoplankton were identified during the study period. From all groups, diatoms were the most abundant at both sites and Blue green algae were the least abundant. ANOVA of all phytoplankton showed highly significant difference among seasons and between sites ($P < 0.05$). ANOVA of all phytoplankton showed highly significant difference among seasons and between sites ($P < 0.05$). Based on the stepwise regression, a total number of phytoplanktons had positive correlation with some of the physicochemical parameters (R2 = 0.99, $P < 0.001$, $N = 16$). The study concluded that some of physicochemical parameters (NO_3-N and PO_4-P) indicated the presence of reservoir water pollution. This is supported by the presence of pollution-resistant phytoplankton species such as *Melosira* and *Microcystis*. The reservoir water was eutrophic (productive) throughout the year. To avoid such pollution, basin and reservoir management are recommended.

Keywords Physico-chemical parameters · Phytoplankton composition · Abundance

Introduction

Phytoplankton are free-floating uni-cells and colonies that grow photoautotrophically in aquatic environments. Phytoplankton play a key role in the primary production and global nutrient cycles of the Earth (Daniel 2001) by making up the main producers in any given water body (Biddanda and Benner 1997). It colonizes the upper part of the water column, down to the limit of penetration of light. The structure and abundance of the phytoplankton populations are mainly controlled by inorganic nutrients such as nitrogen, phosphorus, and silica (Daniel 2001) and mainly available nitrogen as nitrate, nitrite and ammonia, phosphorus as soluble orthophosphate (USEPA 2000) and silicone as silicate forms.

Phytoplankton communities are sensitive to changes in their environment and therefore phytoplankton total biomass and many phytoplankton species are used as indicators of water quality (Reynolds et al. 2002; Brettum and Andersen 2005).

Wholly, the use of living organisms to determine the presence, amounts, changes in and effects of physical,

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chemical, and biotic factors in the environment are termed biological monitoring (Baker 1976). Therefore, the water quality has to be monitored by measuring the phytoplankton content in order to come up with preventive measures such as aeration to prevent fish kills during the decay of the phytoplankton biomass, and the sustainable use of drinking water supply and recreational activities (Imhoff and Alberrecht 1975) and other uses of the water bodies. This work was aimed to determine the impacts of physicochemical parameters on the phytoplankton compositions and abundances in Selameko manmade reservoir, Debre Tabor, South Gondar, Ethiopia.

Materials and methods

Description of the study area

This study was conducted at Selameko manmade reservoir, south-west of Debre tabor town, Ethiopia. This manmade reservoir is found 2513 meter above sea level (masl), specifically located at 38°05′E and 11°53′24″N (Fig. 1). The reservoir was constructed in 2007 with a total of 11.6 hectares (ha) with 20 m depth to irrigate nearly 63 ha. The catchments of the reservoir are extended from 2513 to 2726 masl with 879.25 ha of total area.

Hydrology and climate

Based on the National Metrology Agency of Bahir Dar Branch Office, the mean annual temperature of the study area is 16.23 °C (ranges from 9.2 to 23.26 °C) (from 1997 to 2009 years) and its mean annual rainfall is 1371.2 mm (ranges from 1096.7 to 1645.7 mm). The climate of reservoir is characterized roughly by four seasons: (1) A main-rainy season (MRS) with heavy rains during July–September, (2) a post-rainy season (PORS) between October and November, (3) a dry season (DS) between December and April and (4) a pre-rainy season (PRS) from May to June (Tamiru 2006; Ayalew et al. 2007).

Measurements of physicochemical parameters

Samples of physicochemical parameters were collected from August 2009 to May 2010 in the four seasons, i.e., main rainy/MRS/, post-rainy/PORS/, dry/DS/, and pre-

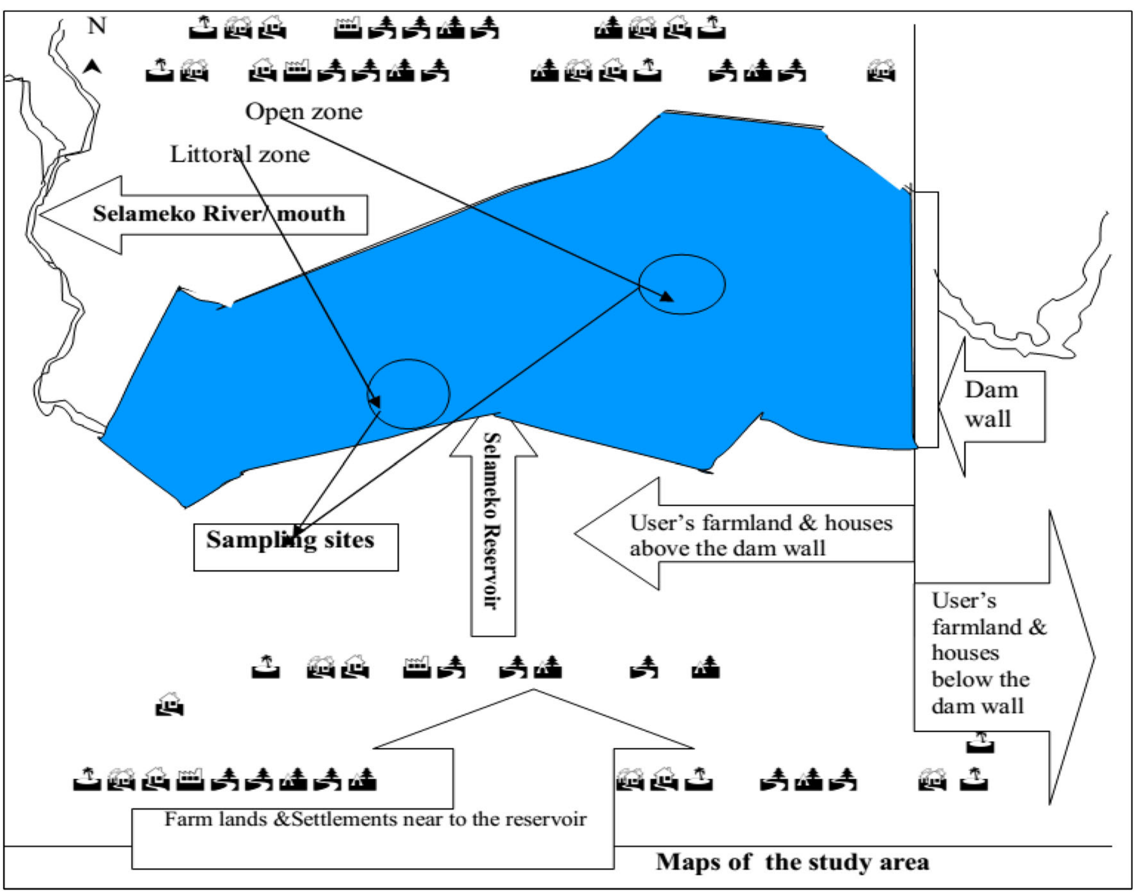

Fig. 1 Map and location of the study area (Selameko Manmade Reservoir)

rainy/PRS/seasons. The water samples were taken only from littoral (SI) and open water zone (SII) two times from each for each parameter (Fig. 1).

Water temperature and pH, dissolved oxygen (DO), total dissolved substances (TDSs), and water transparency were determined in situ. Water temperature and pH were measured with coupled pH/TDS/CON Meter (Model Tochpro II); DO was determined by portable oxygen analyzer (JPB-607); TDSs were measured by cond/TDS meter (Model CE 470 Cond. Meter 01189); water depth was measured by standardized meter (the calibrated meter that had metal tip part was dipped into the reservoirs water until it touched the bottom of the reservoir three times at the central and the average recorded depth was taken) and transparency was measured by standardized Secchi disk. The physico-chemical parameter measurements were taken after the probes dipping down from the surface water to 50 cm down in the reservoir water. Major nutrients, nitrate (NO_3-N), phosphate (PO_4-P), and silicate (SiO_2), were measured in situ immediately by using a portable water analyzer kit (Wagtech international, Palintest transmittance display photometer 5000, Palintest Ltd., and UK) (Palintest Ltd 1989). The collected water samples from the two sites were first filtrate by Whatman GF/C, 0.6–0.7 µm pore size membrane filter to avoid unnecessary large-sized particulate materials (debris) that cause further nutrient release before nutrient analysis was made.

Measurement of phytoplankton community

Phytoplankton

Integrated phytoplankton samples were collected two times for each from littoral (SI) and open water zone (SII) using Van Dorn water sampler. The collected samples were concentrated in 100 mL using 55 µm (mesh opening) phytoplankton net and preserved with Lugol's solutions. Again, 100 mL was allowed to settle in graduate cylinder overnight and the supernatant was siphoned off till 10 mL remained. Of this concentrated sample, 1 mL was used in a Sedgwick-Rafter Cell, of which 100 microscopic field were counted for major species according to Wetzel and Likens (2000). Identification and counting were made under Olympus (CH-2) compound microscope (200X) based on a key guideline of Yamaguchi and Gould (2007) and Blomqvist and Olsen (1981), and abundance of each species of phytoplankton was calculated based on Lind (1979). Chlorophyll-a (Chl-a) was calculated based on monochromatic methods (Lorenzen 1967 in Wetzel and Likens 2000).

Data analyses

Analysis of variance (ANOVA) was used to test significant differences between those like spatial and temporal variations of physico-chemical and phytoplankton ($P < 0.05$). Tukey (Honestly Significantly Differently Test) test was used to determine significance in mean catches and estimates. Stepwise regression was used to test the relationship between the physico-chemical parameters and biological variables; the observed (r) values were then compared to the table values at $P < 0.05$ level of significance, whereas abundance of phytoplankton was analyzed using percentage. Two-way ANOVA was applied for both physico-chemical and phytoplankton. In general, data were calculated and organized using appropriate statistical software, such as the SPSS (2007) version 16 and SAS (2003).

Results and discussion

Physicochemical measurements (in seasons and sites)

Most of the physicochemical parameters are very suitable for phytoplankton growth. The ANOVA result showed that there were highly significant differences in temperature, pH, DO, WTD, TDS, NO_3-N, PO_4-P, SiO_2 and chl-a among seasons and between sites (Table 1). The Tukey test also showed similar scenario (Table 1). Specifically, temperature of the reservoir water ranged from 18.7 °C (PORS, SI) to 24.2 °C (DS, SI and SII, PRS, SII). This registered temperature is good for planktons but not optimum for the growth of fish as suggested by Korai et al. (2008) which is between 22 and 31 °C. pH of the reservoir extended from 7.01 (SII) to 8.01 (SI). These pH values are good for aquatic life including fish and fall (Oso and Fagbuaro, 2008) within the EPA Redbook recommended range for fresh water (6.5–9.0) (Schmirz 1996) and recommended by others (Chapman 1996; Goldman and Horne 1983). DO was ranged from 5.0 (DS) to 6.15 mg/L (MRS). The obtained DO concentration satisfied the minimum recommended standard (>5 ppm) set by EPA Redbook and others (USEPA 2008; Yajurvedi 2008) and good for fishing and planktons. The transparency depth was ranged from 32 (MRS, SI) to 97 cm (PORS, SII) and is eutrophic (Horne and Goldman 1994). The lowest was due to the presence of high suspended matter (sands, silts) that increased water turbidity in the MRS (Meesukko et al. 2007; Rafique et al. 2002), and the presence of large numbers phytoplankton that favored by high nutrient loads in rain season (Musta-

Table 1 Physico-chemical parameters of Selameko reservoir from 2009 to 2010 respect to seasons and locations

Physico-chemical parameters	SI					SII				
	Seasons					Seasons				
	MRS	PROS	DS	PRS	Av ± SD	MRS	PROS	DS	PRS	Av ± SD
T °C	20.0^{d}	18.7^{e}	24.2^{a}	23.1^{b}	21.5 ± 1.28	19.7^{d}	20.8^{c}	24.2^{a}	24.1^{a}	22.2 ± 1.16
pH	$7.72^{a,b}$	8.01^{a}	$7.42^{b,c}$	7.59^{b}	7.69 ± 0.12	$7.42^{b,c}$	7.39^{bc}	7.01^{d}	$7.22^{c,d}$	7.26 ± 0.094
DO (mg/L)	$5.59^{b,c}$	$5.9^{a,b}$	5.1^{d}	$5.3^{c,d}$	5.47 ± 0.17	6.15^{a}	$5.9^{a,b}$	5.0^{d}	$5.2^{c,d}$	5.56 ± 0.27
WTD (cm)	32^{f}	67^{c}	$62^{c,d}$	40^{e}	50.25 ± 8.46	42^{e}	97^{a}	89^{b}	60^{d}	72 ± 12.72
TDSs (ppm)	98.4^{c}	67.1^{f}	74.3^{e}	87.4^{d}	81.8 ± 6.94	137.2^{a}	67.1^{f}	90.43^{d}	114.3^{b}	102.26 ± 15.11
NO_3-N (mg/L)	1.85^{b}	$0.21^{e,f}$	0.25^{e}	0.53^{d}	0.71 ± 0.34	2.0^{a}	0.22^{e}	0.10^{f}	0.71^{a}	0.758 ± 0.43
PO_4-P mg/L)	0.83^{a}	$0.12^{c,d}$	0.44^{b}	$0.16^{c,d}$	0.388 ± 0.26	0.45^{b}	0.24^{c}	0.24^{c}	0.08^{d}	0.253 ± 0.075
SiO_2 (mg/L)	22.5^{a}	6.81^{c}	2.24^{d}	0.66^{e}	8.05 ± 4.98	22.5^{a}	10.06^{b}	2.08^{d}	0.09^{f}	8.68 ± 5.08
pH	$7.72^{a,b}$	8.01^{a}	$7.42^{b,c}$	7.59^{b}	7.69 ± 0.12	$7.42^{b,c}$	$7.39^{b,c}$	7.01^{d}	$7.22^{c,d}$	7.26 ± 0.094

The table included the mean differences of (Tukey Test) "physico-chemical" parameters. Means of the two columns of a particular parameter followed by the same letter (s) are not significantly different from each other ($P < 0.05$, Tukey HSD). (average ± SD)

Av average, *SD* standard deviation, *WTD* water transparency depth

pha and Omotosho 2005). Similarly, the TDSs of the reservoir were between 67.1 (in PORS, SI, SII) and 137.2 ppm (in MRS, SII). This registered value is very conducive for the growth of aquatic organisms including fish (Mohamed et al. 2009) (Table 1).

The concentration of NO_3-N was between 0.1 and 2 mg/L, for PO_4-P was between 0.08 and 0.83 mg/L, and for silicate was between 0.09 and 22.5 mg/L. All nutrients, the highest values were recorded in MRS due to surface water inflow that brought nutrients from the surrounding agricultural areas (Meesukko et al. 2007; Stanley et al. 2003) and the leachates of municipal wastes from waste disposal sites and sanitary landfills (Bennett 1998). Additionally, PO_4-P concentration was due to washing and bathing with phosphate-based detergents and soaps (Davies et al. 2009), and silicate was due to the presence of high rate of rock and soil weathering in the water body (Little 2004). All these high concentrations of nutrients abnormally increased plankton abundances and composition in rainy time than other seasons. Generally, the obtained nitrate concentration is tolerable by fish and other aquatic organism and satisfies surface water quality standards (<5 mg/L) (PCD 1997 in Chattopadhyay and Banerjee 2007) and fulfills the minimum level of nitrate in lake to be productive (Yajurvedi 2008). The registered silicate concentration is good for plankton growth and satisfies freshwater ranges from 1 to 30 mg/L (Wetzel 2001 in Meesukko et al. 2007; Chapman 1996). However, the obtained concentration of PO_4-P is greater than other standards (0.005–0.020 mg/L PO_4-P, Chapman 1996; 0.01–0.03 ppm phosphorus, Yajurvedi 2008) and an indication of the presence of pollution.

Phytoplankton compositions and abundances (in season and sites)

A total of 36 genera from seven taxonomic families and three groups were recorded during the study period.

The ANOVA result showed that there were highly significant differences in zygnemaphyceae, bacillariophyceae, chlorophyceae, cryptophyceae, cyanophyceae, euglenenophyceae, and dinophyceae among seasons and between sites (Tables 2 and 3). According to stepwise regression, total number of phytoplankton had positive relationship with physicochemical parameters ($R2 = 0.99$, $P < 0.001$, $N = 16$). Grand total of phytoplanktons = +2.6 × e + 6 NO_3-N, +4.5 × e + 6 PO_4-P, +1.8 × e + 5 SiO_2, +1 × e + 5 chl-a.

From the total numbers of phytoplankton, the MRS was higher than the other seasons and PORS was the least abundance. The highest record was due to the presence of excess nutrients that come from human sources such as waste and agricultural runoffs (Osondu 2008) mainly attributed to the increase in nitrates, phosphates, and silicates (Kobbia et al. 1991) (Table 1). These alternative nutrients became food sources of various phytoplankton types. The lowest abundance in PORS was probably due to the presence of small amounts of nutrients like phosphates and nitrates. From all seasons, Bacillariophyceae was the most abundance family due to majorly the presence the high concentration and most favorite food alternative, silicate (Radwan 2005; Little 2004) and to some extant nitrate (Khenari 2007). Among Bacillariophyceae, *Melosira* and in Cyanophyceae, *Microcystis* were some of the dominant genera and were indicators of the presence of pollution

Table 2 Seasonal and temporal abundance (ind/L) and distribution of phytoplankton in Selameko manmade reservoir during the four seasons in two locations, South Gondar, Debre Tabor

Phytoplankton genera	MRS			PORS			DS			PRS					Total
	sSI	sSII	TTotal	sSI	sSII	TTotal	sSI	sSII	TTotal	sSI	sSII	TTotal	sSI	sSII	
Diatom															
Bacillariophyceae															
Cyclotella	11633	15863	27496	697	6502	7199	9288	3483	12771	13003	11378	24381	34621	37226	71847
Cymatpleura	–	–	–	–	–	–	–	464	464	10	–	10	10	464	474
Cymbella	–	–	–	–	10	–	10	10	–	–	–	–	10	20	30
Pinnularia	–	–	–	12	–	–	–	–	–	–	464	464	12	464	476
Fragilaria	–	–	–	–	10	–	10	10	–	–	–	–	10	20	30
Navicula	–	100	100	232	1393	1625	3947	1393	5340	1858	464	2322	6037	3350	9387
Melosira	1E+7	8.2E+6	1.8E+7	59792	345049	404841	12074	10217	22291	20666	16951	37617	1.0E+6	8.5E+6	1.9E+7
Synedra	–	100	100	–	–	–	–	–	–	10	–	10	10	100	110
Suririella	–	–	–	10	–	10	–	–	–	–	–	10	10	10	20
Nitzstcha.	–	–	–	–	20434	20434	3483	–	3483	1161	1393	2554	4644	21827	26471
Gyrosigma	–	–	–	–	–	–	232	–	232	–	–	–	232	–	232
Tabularia	–	–	–	–	–	–	232	–	232	–	–	–	232	–	–
Total	1E+7	8.2E+6	18452519	60743	373398	434141	29276	15577	44853	36708	30660	67368	1E+7	8.6E+6	1.9+7
% Bacillariophyceae													94.8	93.1	94
Green algae's															
Zygnemaphyceae															
Cosmarium.	100	–	100	17531	61301	78832	145357	91022	236379	2090	1625	3715	165078	153948	3.2E+5
Staurastrum	–	–		12	1393	1405	232	232	464	–	–		244	1625	1869
Total	100	–	100	17543	62694	80237	145589	91254	236843	2090	1625	3715	165322	155573	3.2E+5
% Zygnemaphyceae													1.5	17	1.6
Chlorophyceae															
Ankistrodesmus	–	–		1277	1161	2438	1858	–	1858	10	–	10	3145	1161	4306
Piiiastrum	–	–		232	232	464	6734	7430	14164	1161	3947	5108	8127	11609	19736
Sieimiasmui	2215	5288	7503	348	3483	3831	5341	10449	15790	9056	7895	16951	16960	27115	44075
Oocytis	25380	22208	47588	104	1393	1497	3019	2786	5805	10	1858	1868	28513	28245	56758
Closterium	–	3173		348	232	–	232	–	–	10	464	474	590	3869	4459
Chlamydomonas	–	–		2786	2089	4875	5108	4179	9287	–	–	–	7894	6268	14162
Pandorina	–	–		–	–	–	–	–	–	10	–	10	10	–	10
Kirchnelriella	–	–		348	1858	2206	–	464	464	10	–	10	358	2322	2680
Staurastrum	–	–		5	5	10	1393	10	1403	–	–	–	1398	15	1413
Chodatella	–	–		–	10		78716	18344	–	929	464	1393	79645	18818	98463
Crucigenia	28553	25380	53933	1393	6037	7430	13003	13932	26935	22059	20201	42260	65008	65550	130558

Table 2 continued

Phytoplankton genera	MRS			PORS			DS			PRS					Total
	sSI	sSII	TTotal	sSI	sSII	TTotal	sSI	sSII	TTotal	sSI	sSII	TTotal	sSI	sSII	
Sphaerocysis	7403	15863	–	–	–	–	–	–	–	10	10	20	7413	15873	23286
Monoraphidium	–	–		–	1161	1161	3715	1161	4876	–	10	10	3715	2332	6047
Coelastrum	20093	14805	34898	813	464	1277	–	10	10	–	–	–	20906	15279	36185
Total	83644	86717	170361	7654	18125	25779	119119	58765	177884	33265	34849	68114	243682	198456	442138
% Chlorophyceae													2.2	2.1	2.2
Cryptophyceae															
Cryptomonas	–	–	–	–	2089		3483	7663					3483	9752	13235
Euglenophyceae															
Euglena	100	100	–	–	–	–	–	–	–	–	–	–	100	100	200
Phacus	200	2115		10	232	–	–	–	–	–	–	–	210	2347	2557
Total	300	2215		10	232	–	–	–	–	–	–	–	310	2447	2757
% Euglenophyceae	–	–	–	–	–	–	–	–	–	–	–	–	0.01	0.01	
Dinophyceae															
Peredinium	100	–		464	4644		7663	3367		64319	94041	158360	72546	1E+5	174597
% Dinophyceae													0.7	1.1	0.9
Blue green algae															
Cyanophyceae															
Oscillatoria	–	–	–	–	–	–	–	–	–	10	–	10	10	–	10
Anabaena	–	–	–	8127	17415	25542	10	1393	1403	464	697	1161	8601	19505	28106
Microcystis	46530	92003	13853333	2322	4876	7198	11610	36455	48065	14861	16951	31812	75323	1502855	225608
Planktosphaneria	–	–	–	464	–	–	–	–	–	–	–	–	464	–	464
Total	46530	92003	138533	10913	22291	33204	11620	37848	49468	15335	17648	32983	84398	1697900	254188
% Cyanophyceae													0.8	1.8	1.3
Grand total (ind/1)	1E+7	8.4E+7	1.9e+7	97327	483473	580800	316750	214474	531224	151717	178823	330540	10956334 334	9250357	2E+7
T/no of genera	12	13		22	25		24	22		21	18				
% abundance	94.84	90.5		0.89	5.2		2.89	2.32		1.38	1.93		100	100	100

SI site one (littoral), *SII* site two (open); Most abundance > 201,000 Less abundance = between 200,000 and 50,000; Common = between 49,999 and 2000; Rare < 1999; dash represents implied absence

Table 3 The mean differences of (Tukey Test) biological parameters (phytoplankton) of Selameko manmade reservoir, South Gondar (Debre Tabor) from 2009 to 2010

Biological parameters	Seasons	Locations	
		SI	SII
Zygnemaphyceae	Main rainy	100.0[g]	0.0[f]
	Post-rainy	17543[d]	62,694.0[c]
	Dry	1.5e + 5[a]	91,254.0[b]
	Pre-rainy	2090.0[e]	1625[f]
Bacillariophyceae	Main rainy	1.0 + e+7[a]	8192653[b]
	Post-rainy	60743[d]	373398[c]
	Dry	29276[g]	15577[h]
	Pre-rainy	36708[e]	30660[f]
Chlorophyceae	Main rainy	83644[c]	86717[b]
	Post-rainy	7654[h]	18125[g]
	Dry	1.2e + 5[a]	58765[d]
	Pre-rainy	33265[f]	34849[e]
Cryptophyceae	Main rainy	0.0[d]	0.0[d]
	Post-rainy	0.0[d]	2089[c]
	Dry	3483[b]	7663[a]
	Pre-rainy	0.0[d]	0.0[d]
Cyanophyceae	Main rainy	46530[b]	92003[a]
	Post-rainy	10913[h]	22291[d]
	Dry	11620[g]	37848[c]
	Pre-rainy	1.5e + 5[f]	17648[e]
Euglenenophyceae	Main rainy	300.0[b]	2215[a]
	Post-rainy	10.0[d]	232[c]
	Dry	0.0[d]	0.0[d]
	Pre-rainy	0.0[d]	0.0[d]
Dinophyceae	Main rainy	100[g]	0.0[g]
	Post-rainy	464[f]	4644[d]
	Dry	7663[c]	3367[e]
	Pre-rainy	6.4e + 5[b]	94041[a]
Chlorophyll-a	Main rainy	39.29[a]	31.23[b]
	Post-rainy	11.02[e]	23.03[c]
	Dry	21.33[c]	15.65[d,e]
	Pre-rainy	17.88[c,d]	12.43[e]

Means of the two columns of a particular parameter followed by the small letter(s) are not significantly different from each other ($P = 0.05$, Tukey HSD)

(Heiskary and Markus 2001) and the alkaline nature of the reservoir water (Onyema 2007). Totally, very large numbers of phytoplankton were recorded. The total numbers of phytoplankton had positive correlation with NO_3-N, PO_4-P, and SiO_2 as well as chl-a. When the concentrations of nutrients increased, the phytoplankton abundances increased and vices verse (Onyema 2007). Being these, very large concentrations of chl-a (39.29 μg/L) were recorded in MRS than any other seasons (Meesukko et al. 2007; Radwan 2005). Based on this registered chl-a concentration, reservoir water is productive (eutrophic) because its value is between 10 and 40 μg/L (ADEQ 2008), and 3.0–78.0 μg/L (Wetzel 1983).

Conclusions

Based on the present observation, Selameko manmade reservoir is rich in species diversity and composition and the nutrient status is high enough to support the plankton community. However, the high concentration of PO_4-P indicates the presence of strong anthropogenic pressure. To solve such big pressure, both basin and reservoir management are recommended to solve such acute problems.

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