Phytoplankton assemblage of a small, shallow, tropical African reservoir

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Abstract: I measured physico-chemical properties and phytoplankton in the small, shallow tropical reservoir of Oyun (Offa, Nigeria) between January 2002 and December 2003. I identified 25 phytoplankton genera in three sampling stations. Bacillariophyceae dominated (75.3%), followed by Chlorophyceae (12.2%), Cyanobacteria (11.1%) and Desmidiaceae (0.73%). The high amount of nutrients (e.g. nitrate, phosphate, sulphate and silica) explain phytoplankton heterogeneity ($p<0.05$). Phytoplankton was abundant during the rainy season, but the transition period had the richest assemblage and abundance. Fluctuations in phytoplankton density were a result of seasonal changes in concentration of nutrients, grazing pressure and reservoir hydrology. The reservoir is eutrophic with excellent water quality and a diverse phytoplankton assemblage: fish production would be high. These conditions resulted from strategies such as watershed best management practices (BMPs) to control eutrophication and sedimentation, and priorities for water usage established through legislation. Additional measures are recommended to prevent oligotrophy, hypereutrophy, excessive phytoplankton bloom, toxic cyanobacteria, and run-off of organic waste and salts. Rev. Biol. Trop. 57 (4): 1009-1025. Epub 2009 December 01.

Key words: Freshwater reservoir, hydrology, phytoplankton assemblage, nutrients, water quality.

Phytoplankton are usually at the base of aquatic food web and are the most important factor for production of organic matter in aquatic ecosystem. Most reservoirs will require significant amount of phytoplankton to have productive and sustainable fisheries. The interplay of physical, chemical and biological properties of water most often lead to the production of phytoplankton, while their assemblage (composition, distribution, diversity and abundance) is also structured by these factors. Thus any perturbations in these factors may affect the phytoplankton assemblage which could have a significant impact on water quality and fisheries of reservoirs. The importance of phytoplankton in tropical reservoir ecosystems include its use in estimating potential fish yield (Hecky & Kling 1981), productivity (Park *et al.* 2003), water quality (Walsh *et al.* 2003), energy flow (Simciv 2005), trophic status (Reynolds 1999) and management (Beyruth 2000). Weiss & Stockner (1993) observed that energy in pelagic ecosystems flows from phytoplankton, the primary producers to zooplankton, the consumers through the classical food chains and microbial food webs. Models that use phytoplankton primary production as the main controlling variable for predicting fish yield in lakes and reservoirs have resulted in more successful predictions than many other methods (Knosche & Barthelmes 1998).

Phytoplankton studies of small, shallow, tropical African reservoirs such as Oyun reservoir could provide management guide to the reservoir water quality and its fisheries, since most of these reservoirs are constructed solely for drinking water supply, but, with fish production often superimposed on them. Such study could reveal information on phytoplankton that could impact unpleasant tastes and odours to the water (Muller *et al.* 1982), produce toxins that could affect fish when consumed (Codd

1995), and affect the physico-chemistry of the water. According to Bucka (1998), there is currently great interest in preventing or reducing the growth of planktonic algae and cyanobacteria in water supply reservoir.

The aim of this paper is to look at the species composition and relative abundance of the phytoplankton of Oyun reservoir, Offa, Nigeria to various physico-chemical variables; this is with a view to managing the reservoir for sustainable water and fish production.

MATERIALS AND METHODS

Study site description: Oyun reservoir is located in Offa, Kwara State, Nigeria (8°30'05" N and 8°15'55" E) (Fig. 1). It is a dam reservoir on Oyun River, created in 1964 (expanded in 1983 and 1995 with further expansions proposed) by damming the Oyun River. The reservoir is eutrophic (Mustapha 2008) with diverse species of littoral plant occupying the shoreline length.

The reservoir was created to supply potable water for domestic and industrial uses to an estimated population of about 300 000 people. Subsistence and commercial fishing activities is also carried out on the reservoir. The reservoir has a maximum length of 128m, maximum width of 50m and maximum depth of 8.0m, mean depth of 2.6m. The surface area is $6.9x10^5m^2$ while the water volume

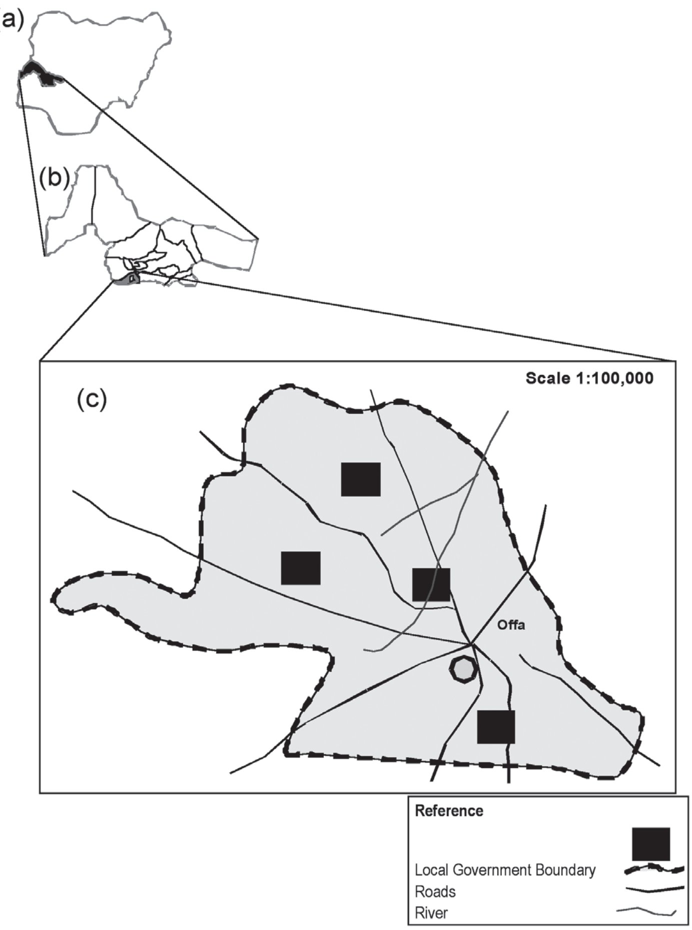

Fig. 1. Reservoir location in Offa (b), Kwara State (b), Nigeria (a).

is $3.50x10^6 m^3$. The net storage capacity is $2.9x10^6 m^3$. The reservoir is subjected to temporal fluctuations in water volume with high water volume in the rainy season and less water in the dry season due to high evaporation. The water retention time is between 4-5 months in the rainy season (April-October), with an average precipitation between 1 000mm and 1 200m, while the water residence time in the dry season (November-March) is between 1-2 months with average rainfall of about 100mm and 200mm. The morphometric characteristics of the reservoir are listed in Table 1.

Samplings: Physico-chemical variables of the water body selected as water quality parameters were sampled monthly from three stations between January 2002 and December 2003. Station 1 was at the dam axis where a lot of human activities such as washing, bathing, fish landing and cassava fermentation take place. It is the highest point of human and animal contact with the reservoir and also the deepest part close to run-offs from farm lands and outflow. Station 2 was at the mid-section of the reservoir which represented the area of lentic water, it is the transition zone between the riverine and lentic sections of the reservoir. Station 3 was at the head water of the reservoir which represented the lotic section and inflow of the reservoir. Duplicate surface water samples were collected from 10cm depth into 50ml plastic water bottles that have been acid-washed prior to water analyses. Surface water temperature,

TABLE 1
Morphometric characteristics of Oyun Reservoir, Offa, Nigeria

Elevation (m)	15
Surface area (m^2)	13.4 x 10^5
Volume (m^3)	3.50 x 106
Mean depth (m)	2.6
Maximum depth (m)	8.0
Mean depth to maximum depth ratio	0.325
Hydraulic residence time (days)	12
Length of Shoreline (km)	10
Shoreline Development	2.43

pH, electrical conductivity and total dissolved solids were measured *in situ* using Hanna portable pH/EC/TDS/Temperature combined water proof tester model HI 98129. Transparency was determined by extinction method using the secchi disc by measuring the mean of the depths at which the secchi disc disappears and at which it reappears, dissolved oxygen was determined by Azide modification of the Winkler method, chemical oxygen demand was measured using the dichromate reaction method (Hach 2003), carbon dioxide and alkalinity were determined by titration (APHA 1995). Nitrate-Nitrogen (NO_3-N), Phosphate (PO_4-P), Sulphate (SO_4^{2-}), Calcium Ca^{2+}, Magnesium Mg^{2+}, total hardness and Silica (SiO_2) were measured according to APHA (1995) standard procedures using Hach spectrophotometer model DR-EL/2. All the chemical analyses were done at the water quality laboratory of Kwara State Utility Board, Ilorin, Nigeria, immediately after the sample collection.

Phytoplankton sampling: Phytoplankton samples were collected with 1- litre plastic bottles (Wetzel 1999). The samples were fixed on the field with Lugol solution to arrest cell activity, for sedimentation and better staining (Sherr *et al.* 1989). The sample was stored in a dark compartment in the laboratory for overnight sedimentation. In the morning, the upper 900ml was siphoned out and the remaining 100ml homogenized samples were retained from which 1ml subsample was collected for phytoplankton identification and counting under a microscope (100X). The phytoplankton was identified to generic level using keys compiled by Edmonson (1959) and Withford & Schumacher (1973). Numerical estimations of the phytoplankton were done using the drop method of Margalef (1976). The relative abundance of the various taxa was then calculated.

Data analyses were done using the GLM procedure of statistical analysis system 9.1.3 (SAS Institute 2003). Monthly mean differences in stations, seasons and years were assessed by LSD using two-way ANOVA with test of significance at $p<0.05$. Analysis of co-variance was used to investigate the correlation and level of dependence between the total phytoplankton and the phytoplankton classes with the physico-chemical variables. The test variables were stations, seasons and years. Statistical differences were considered at $p<0.05$

RESULTS

Physico-chemical factors: Seasonal fluctuations were recorded among the physico-chemical factors. The driving forces for theses fluctuations were the rainy and dry seasons. The mean monthly variations in the surface water temperature of the three stations are presented in Fig. 2. The temperature ranged between the lowest value of 23.1±0.5°C obtained in September and highest of 29.6 ±0.1°C obtained in March, 2003. Dry season temperature was significantly higher ($p<0.05$) than the wet season. Secchi disc transparency was highest at 1.62±0.32m obtained in the dry season of 2002 and lowest at 0.62±0.8m in the rainy season of 2003 (Fig. 3). Significant higher

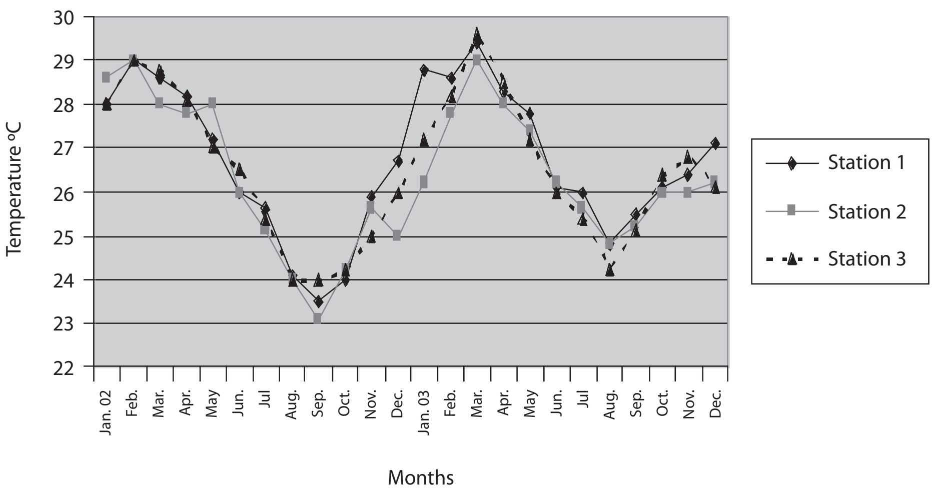

Fig. 2. Monthly mean variations in surface water temperature of Oyun Reservoir.

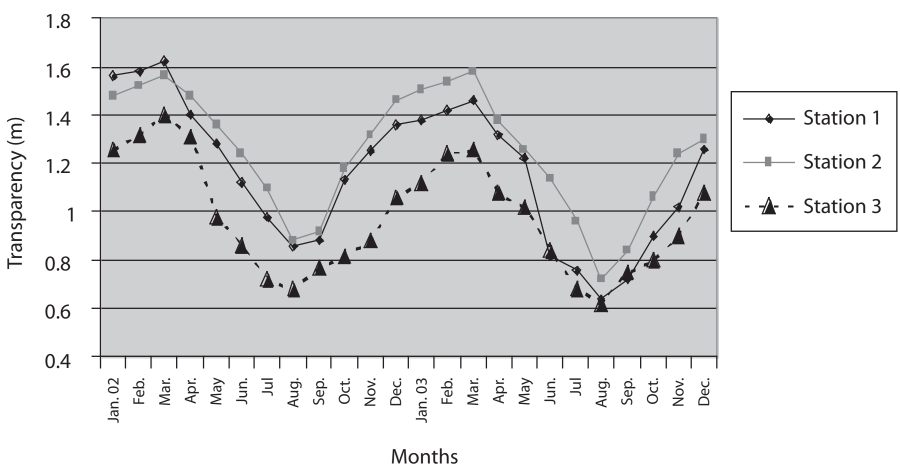

Fig. 3. Monthly mean variations in Secchi disc transparency of Oyun Reservoir.

transparency ($p<0.05$) were obtained in the dry season, Station 2 and year 2002. Dissolved oxygen fluctuated between lowest monthly mean of 4.8±0.25mg/L obtained in February and March 2003 and highest monthly mean of 8.2±0.31mg/L recorded in June 2002 (Fig. 4). Dissolved oxygen values in the wet season, Station 2 and year 2002 were significantly higher ($p<0.05$). Chemical Oxygen Demand (COD) varied between 1.2±0.1 mg/lL and 2.6±0.2mg/L COD was significantly higher in the dry season and in Station 1 (Fig. 5). Carbon dioxide and total alkalinity showed similar pattern with COD in their concentrations among the stations and in the seasons. Carbon dioxide ranged between monthly mean of 1.6±0.2mg/L to 3.0±0.6mg/L (Fig. 6) while total alkalinity fluctuated between monthly mean of 30 ±2.6mg/L and 55±3.4mg/L (Fig. 7). The total hardness value in the reservoir which is the sum

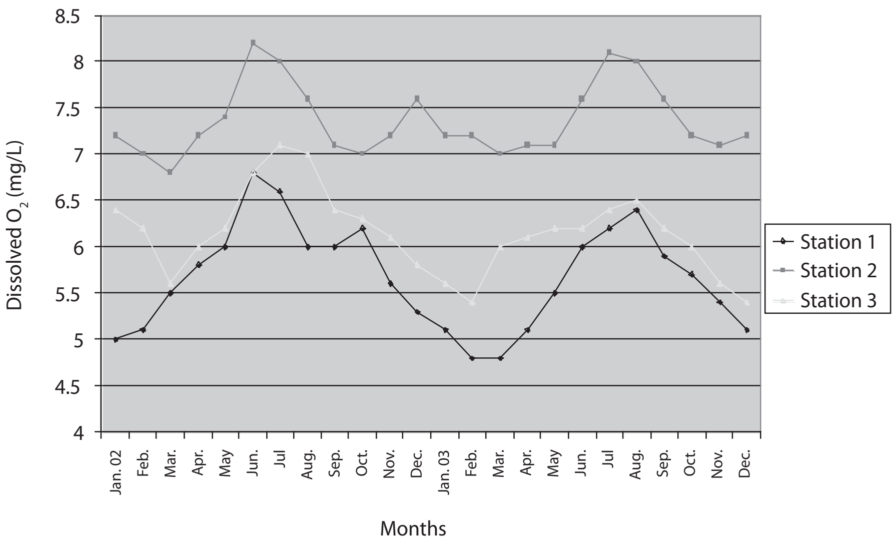

Fig. 4. Monthly mean variations in dissolved oxygen concentrations of Oyun Reservoir.

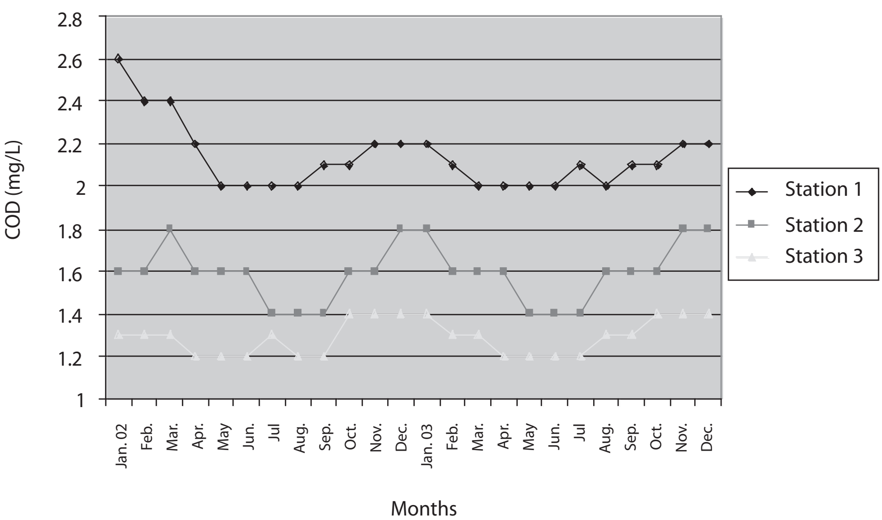

Fig. 5. Monthly mean variations in COD of Oyun Reservoir.

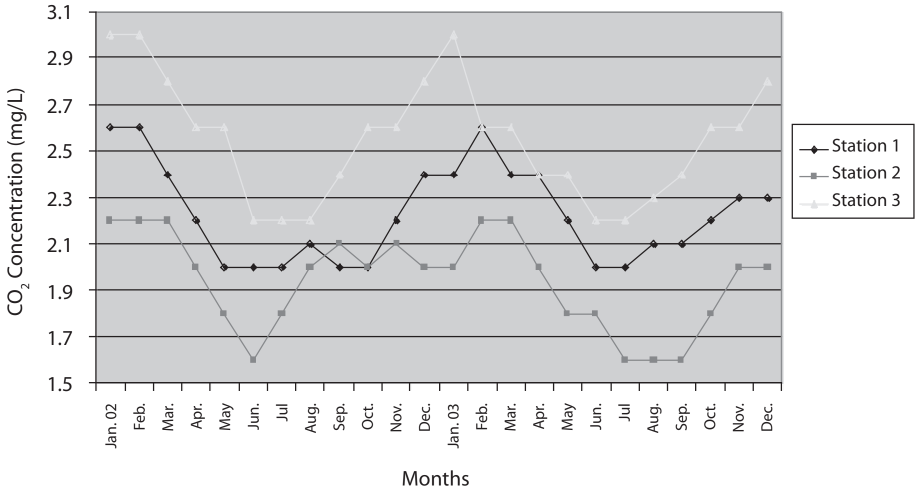

Fig. 6. Monthly mean variations in carbon dioxide concentration of Oyun Reservoir.

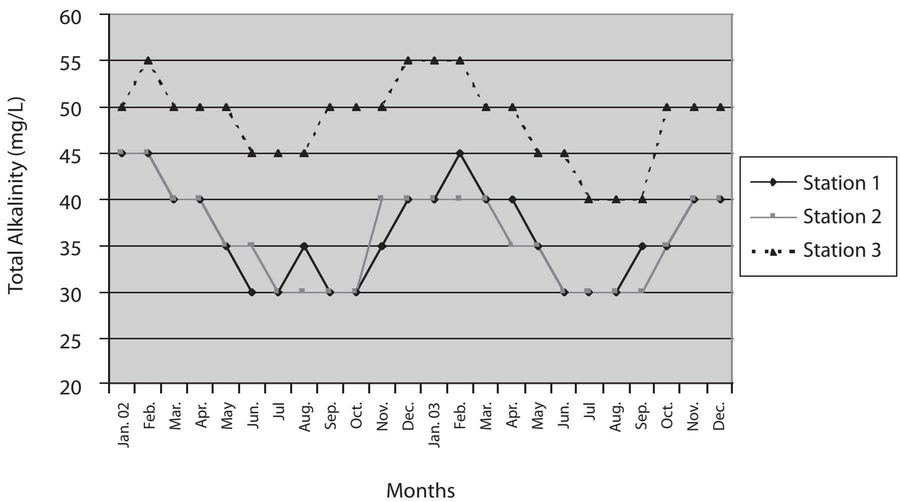

Fig. 7. Monthly mean variations in total alkalinity of Oyun Reservoir.

of calcium and magnesium hardness concentrations was found to be significantly higher in the wet season. This was the same for calcium and magnesium ions. Station 3 showed significantly higher concentration of total, calcium and magnesium hardness. The mean monthly range of the total hardness (32±0.5-68±1.4mg/L), calcium hardness (20±0.1-44±1.8mg/L) and magnesium hardness (10±0.4-28±0.6mg/L) are presented in figures 8, 9 and 10 respectively. The highest monthly mean concentration of nitrate recorded was 6.4mg/L ±0.3 obtained from Station 1 at the peak of the rains in August 2003. A decrease was observed in the dry season with the lowest concentration of 1.4±0.1mg/L recorded from Station 3 in October 2003 (Fig. 11). Nitrate was significantly higher in the raining season and the order of magnitude in the concentration among the stations was Stations 1>2>3. Phosphate had

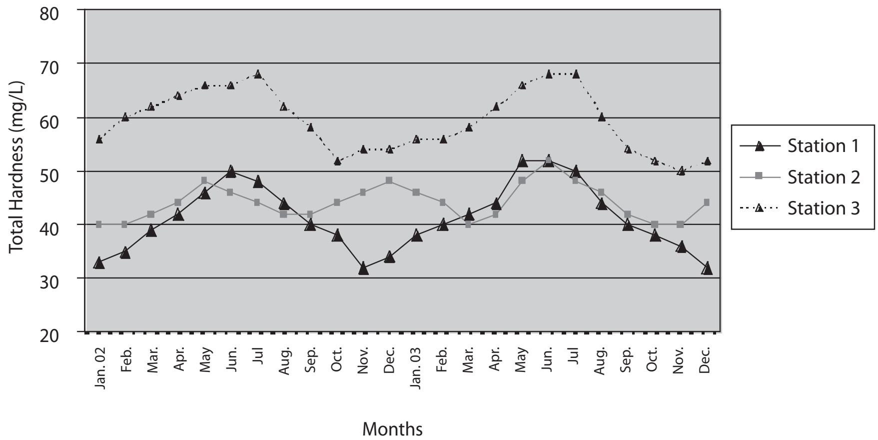

Fig. 8. Monthly mean variations in total hardness concentrations of Oyun Reservoir.

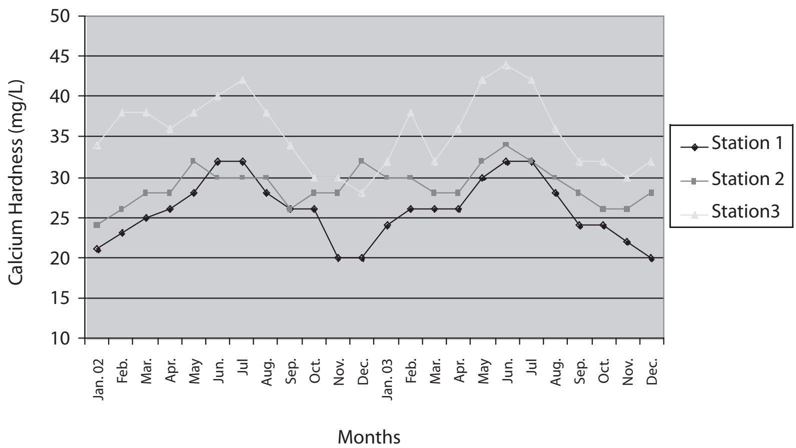

Fig. 9. Monthly mean variations in calcium hardness of Oyun Reservoir.

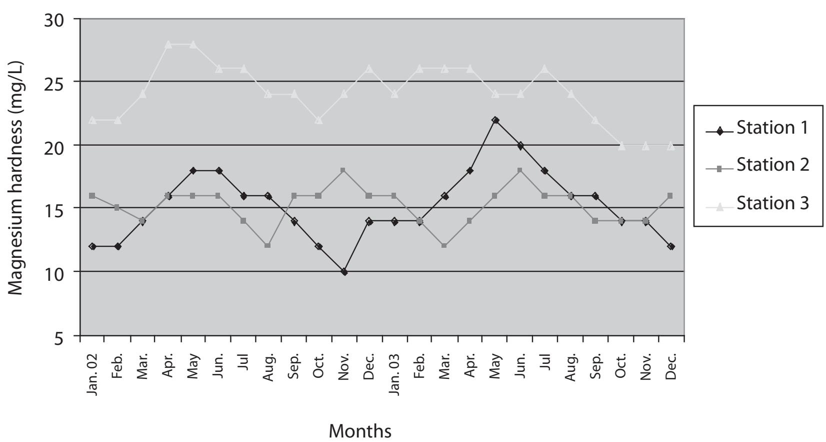

Fig. 10. Monthly mean variations of magnesium hardness in Oyun Reservoir.

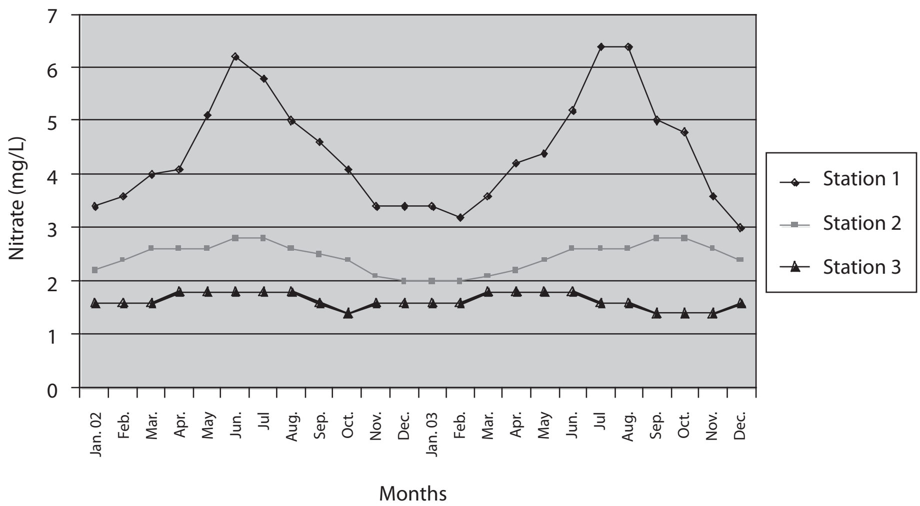

Fig. 11. Monthly mean variations in nitrate concentration of Oyun Reservoir.

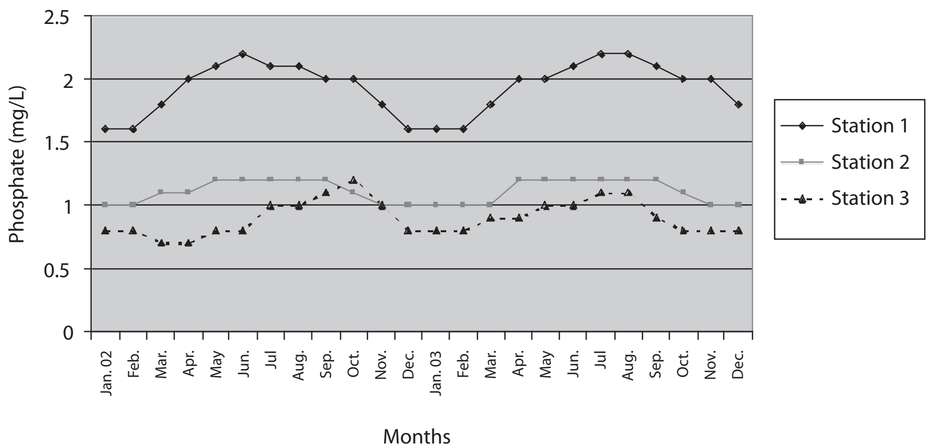

Fig. 12. Monthly mean variations in phosphate concentration of Oyun Reservoir.

the least concentration among the ions. It ranged between 0.7±0.0mg/L to 2.2±0.2 mg/L (Fig. 12). Like Nitrate, phosphate concentration was significantly higher in raining season and in Station 1 ($p<0.05$). Sulphate concentration was lowest at 9±0.2mg/L; it gradually increased until a maximum concentration of 16.9±0.45mg/L (Fig. 13). Sulphate was significantly higher in the wet season while the order of higher concentration among the stations was Stations 3>2>1.The minimum and maximum monthly mean concentration of silica was from 30±0.2mg/L to 60±0.6mg/L (Fig. 14). Silica was significantly higher ($p<0.05$) in the rainy season and Station 3 recorded the highest concentration among the stations. The surface water pH fluctuated between slight acidity and moderate alkalinity. The lowest monthly mean pH was 6.8±0.05 obtained during the dry season in January 2002, while the highest was 8.2±0.2 obtained in the wet season of August and September of 2003 (Fig. 15). pH was significantly

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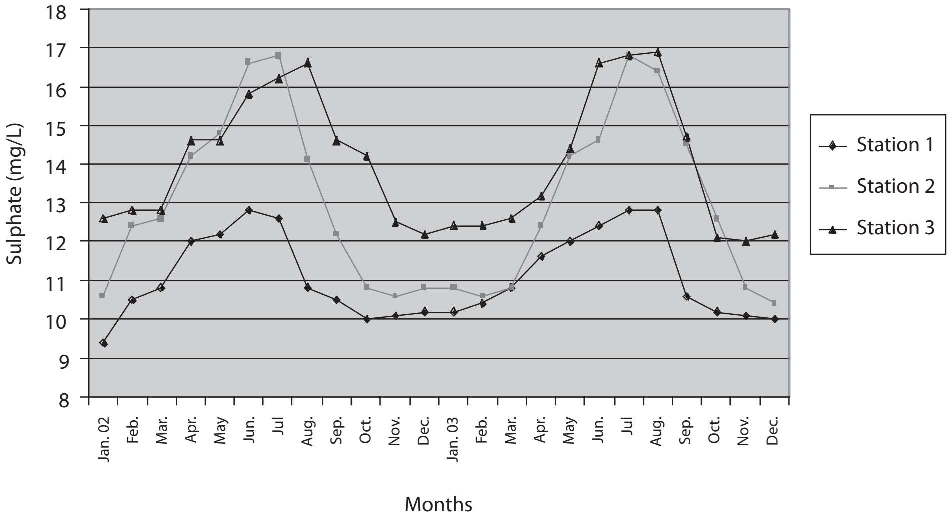

Fig. 13. Monthly mean variations of sulphate concentration in Oyun Reservoir.

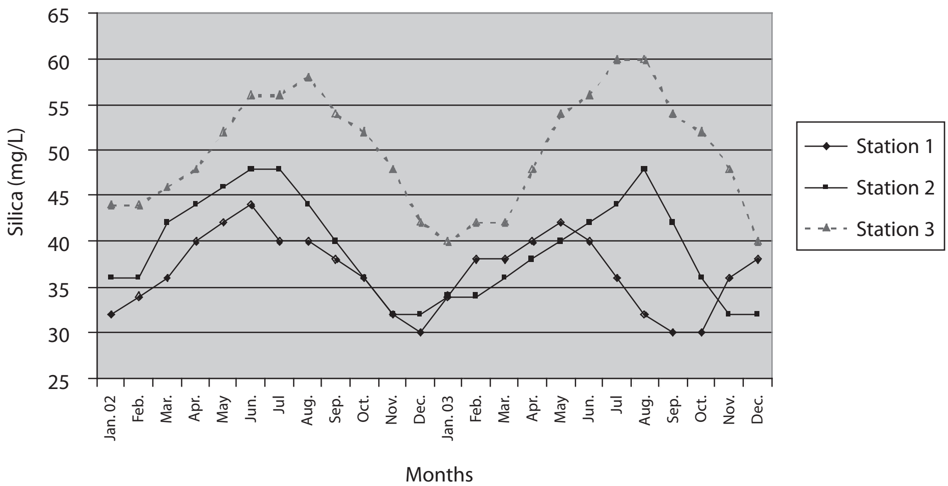

Fig. 14. Monthly mean variations of silica in Oyun Reservoir.

($p<0.05$) higher during the wet season and in Station 2. The monthly mean variations in electrical conductivity and total dissolved solids (TDS) were similar. The lowest conductivity (80.4±0.8µs/cm) and TDS (53.9±0.8mg/L) values were recorded in December 2002 and the highest (178.8±2.0µs/cm) and TDS (119.8 ±2.0mg/L) were obtained in July 2002 (Figs. 16 and 17). The two factors were statistically higher ($p<0.05$) during the rainy season while the order of significant difference between the stations was Stations 3>2>1.

Phytoplankton species composition and abundance: Four classes of phytoplankton namely Bacillariophyceae (diatoms), Chlorophyceae (green algae), Cyanobacteria (blue-green algae), and Desmidiaceae (desmids) were recorded in the reservoir. A total of 25 genera were found in the phytoplankton

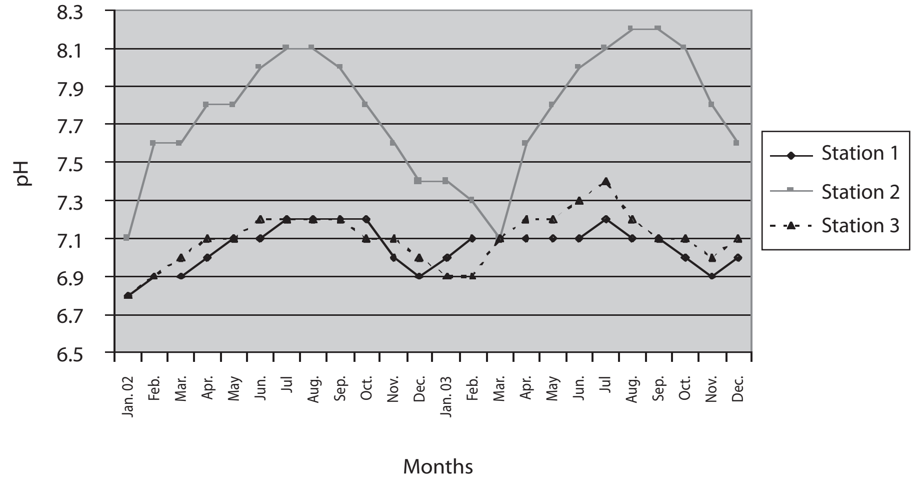

Fig. 15. Monthly mean variations in pH of Oyun Reservoir.

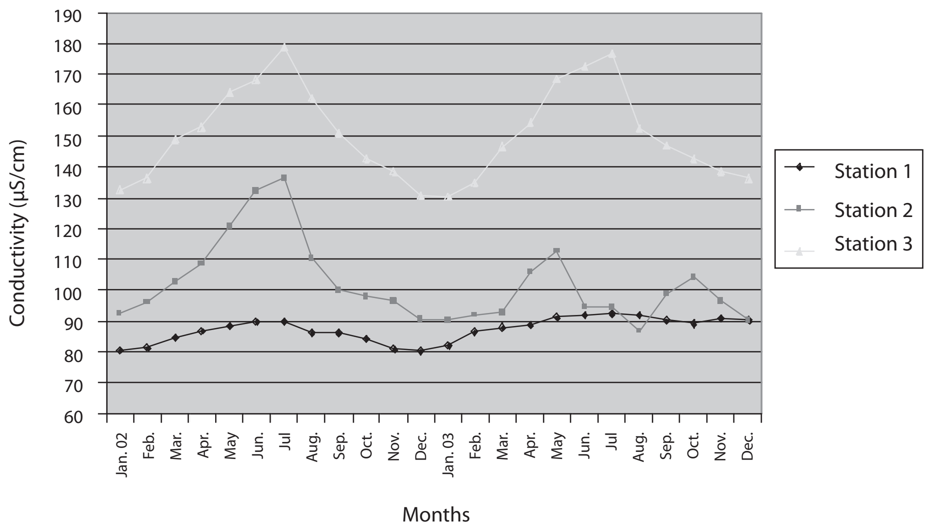

Fig. 16. Monthly mean variations in conductivity of Oyun Reservoir.

classes with Bacillariophyceae and Chlorophyceae having the highest of eight genera each, while Cyanobacteria and Desmidiaceae had six and three genera respectively (Table 2). A total phytoplankton biomass of 13 594x10^3cells per millilitre was recorded in the reservoir. Bacillariophyceae (180x10^3 to 460x10^3cells/ml) dominated the phytoplankton classes in terms of individual cells/ml and abundance with a total of 10 320x10^3cells/ml constituting 75.93% of the phytoplankton. This was distantly followed by the Chlorophyceae (37 to 569x10^3cells/ml) dominated by *Pediastrum*, and making up 12.22% , while Cyanobacteria (114 to 449x10^3cells/ml) dominated by *Anabaena* and Desmidiaceae (13 to 65x10^3cells/ml) dominated by *Closterium* made 11.12% and 0.73% respectively of the phytoplankton population. Among phytoplankton genera, *Melosira* was the most abundant constituting

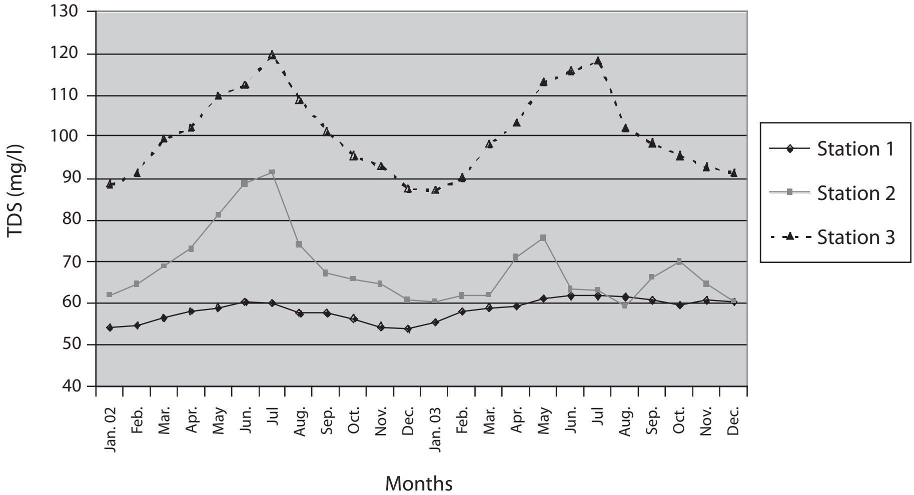

Fig. 17. Monthly mean variations of TDS in Oyun Reservoir.

TABLE 2

Phytoplankton composition and abundance of Oyun reservoir

Class	Genus	Total number of cells x1000/l	Species % in class	Species % in population	Class % in population
Cyanobacteria	*Anabaena*	449	29.68	3.3	11.12
	Oscillatoria	320	21.15	2.35	
	Coelosphaerium	210	13.88	1.54	
	Nostoc	265	17.52	1.95	
	Spirulina	155	10.24	1.14	
	Polycystis	114	7.53	0.84	
Total		1513	100	11.12	
Desmidiaceae	*Closterium*	65	65	0.48	0.73
	Netrium	13	13	0.09	
	Cosmarium	22	22	0.16	
Total		100	100	0.73	
Chlorophyceae	*Pediastrum*	569	34.26	4.19	12.22
	Scenesdemus	254	15.29	1.87	
	Botryococcus	223	13.43	1.64	
	Ankistrodesmus	97	5.84	0.71	
	Ulothrix	202	12.16	1.49	
	Dictyosphaerium	37	2.22	0.27	
	Selenastrum	147	8.55	1.08	
	Spirogyra	132	7.95	0.97	
Total		1661	100	12.22	
Bacillariophyceae	*Melosira*	3180	30.81	23.39	75.93
	Navicula	2150	20.83	15.82	
	Synedra	1870	18.12	13.76	
	Fragillaria	855	8.29	6.29	
	Gyrosigma	555	5.38	4.08	
	Nitzschia	696	6.74	5.12	
	Cyclotella	554	5.34	4.08	
	Diatoma	460	4.46	3.39	
Total		10320	100	75.93	
Grand total		13594			

25.81% of the total phytoplankton and was also the predominant in the class Bacillariophyceae while *Netrium*, a desmid had the least biomass of $13x10^3$cells/ml which was 0.09% of the total phytoplankton population. ANOVA ($p<0.05$) showed significant difference in total phytoplankton count among the seasons, stations and the years. Phytoplankton was significantly abundant in the wet season than the dry season with Station 3 having higher phytoplankton cell number than Station 2 and Station 1 in that order, while year 2002 recorded a higher abundance of phytoplankton than 2003.

Phytoplankton community assemblage: The phytoplankton classes were present in all the three stations and highly abundant in the rains especially between May and October with peaks in June and July while in the dry season the phytoplankton density was significantly reduced. Station 2 had a higher genera diversity with 23 genera recorded, Station 1 recorded 22 genera, while 20 genera were observed from Station 3 (Tables 3, 4 and 5). ANOVA ($p<0.05$) also revealed that all the phytoplankton classes were significantly higher in the rains, Chlorophyceae, Cyanobacteria and Desmidiceae were significantly abundant ($p<0.05$) in Station 2, while Bacillariophyceae was more abundant in Station 3. Bacillariophyceae and Chlorophyceae had a higher cell count in 2002, while Cyanobacteria and Desmidiaceae recorded significant higher biomass in 2003.

Correlations matrix: The correlation coefficient (r) values shows the total phytoplankton and all the classes to be positively correlated ($p<0.05$) with phosphate, nitrate, dissolved oxygen, sulphate, silica, carbon dioxide, total alkalinity, pH, conductivity and total

TABLE 3

Phytoplankton composition and abundance in Station 1 of Oyun reservoir

Class	Genus	Total number of cells x1000/l	Species % in class	Species % in population	Class % in population
Cyanobacteria	*Anabaena*	204	34.99	5.03	14.39
	Oscillatoria	145	24.88	3.58	
	Coelosphaerium	100	17.15	2.47	
	Nostoc	84	14.4	2.07	
	Spirulina	25	4.29	0.62	
	Polycystis	25	4.29	0.62	
Total		583	100	14.39	
Desmidiaceae	*Closterium*	12	63.16	0.29	0.48
	Cosmarium	7	36.84	0.17	
Total		19	100	0.48	
Chlorophyceae	*Pediastrum*	212	32.32	5.24	16.21
	Scenesdemus	123	18.75	3.04	
	Botryococcus	58	8.84	1.43	
	Ankistrodesmus	28	4.26	0.69	
	Ulothrix	57	8.69	1.41	
	Selenastrum	46	7.01	1.14	
	Spirogyra	132	20.13	3.26	
Total		656	100	16.21	
Bacillariophyceae	*Melosira*	1020	36.55	25.19	68.93
	Navicula	770	27.59	19.01	
	Synedra	380	13.62	9.39	
	Fragillaria	142	5.09	3.51	
	Gyrosigma	109	3.9	2.69	
	Nitzschia	114	4.09	2.82	
	Cyclotella	256	9.16	6.32	
Total		2791	100	68.93	
Grand total		4049		100	100

TABLE 4
Phytoplankton composition and abundance in Station 2 of Oyun reservoir

Class	Genus	Total number of cells x1000/l	Species % in class	Species % in population	Class % in population
Cyanobacteria	*Anabaena*	194	25.97	4.07	15.67
	Oscillatoria	119	15.93	2.49	
	Coelosphaerium	110	14.73	2.31	
	Nostoc	156	20.75	3.25	
	Spirulina	80	10.71	1.68	
	Polycystis	89	11.91	1.87	
Total		747	100	15.67	
Desmidiaceae	*Closterium*	47	65.28	0.99	1.51
	Netrium	13	18.06	0.27	
	Cosmarium	12	16.66	0.25	
Total		72	100	1.51	
Chlorophyceae	*Pediastrum*	297	35.36	6.24	17.64
	Scenesdemus	111	13.21	2.33	
	Botryococcus	131	15.6	2.75	
	Ankistrodesmus	54	6.43	1.13	
	Ulothrix	117	13.93	2.46	
	Selenastrum	101	12.02	2.12	
	Dictyosphaerium	29	3.45	0.61	
Total		840	100	17.64	
Bacillariophyceae	*Melosira*	1020	32.86	21.42	65.18
	Navicula	640	20.62	13.44	
	Synedra	720	23.2	15.12	
	Fragillaria	283	9.11	5.94	
	Gyrosigma	156	5.03	3.28	
	Cyclotella	130	4.19	2.73	
	Nitzschia	155	4.99	3.25	
Total		3104	100	65.18	
Grand total		4763			

dissolved solids. Only transparency and temperature showed negative correlation with the phytoplankton (Table 6).

DISCUSSION

Phytoplankton assemblage: The phytoplankton assemblage of Oyun reservoir was highly diversed, heterogenous and abundant. This was due to the presence of large amount of nutrients especially nitrate, phosphate, silica and sulphate as well as the shallow nature of the reservoir, which greatly exposes the surface to light for algal productivity. This is reflected in the positive correlation of the nutrients with all the classes of phytoplankton found in the reservoir. Gasse *et al.* (1983) correlated phytoplankton species composition of lakes with a number of water quality parameters including temperature, alkalinity, concentration and pH. The phytoplankton were highly abundant during the rains which corresponded to the period when the ions were highly concentrated in the reservoir. Thomas *et al.* (2000) has reported that high primary productivity in tropical reservoir is usually rain induced.

The dominance of Bacilariophyceae was attributed to the high concentration of silica, while the high amount of nitrate phosphate and sulphate caused the abundance of Chlorophyceae, Cyanobacteria and Desmidiaceae. The nutrients have been known to be limiting

TABLE 5

Phytoplankton composition and abundance in Station 3 of Oyun reservoir

Class	Genus	Total number of cells x1000/l	Species % in class	Species % in population	Class % in population
Cyanobacteria	*Anabaena*	51	27.87	1.07	3.83
	Oscillatoria	56	30.6	1.17	
	Nostoc	26	14.21	0.54	
	Spirulina	50	27.32	1.05	
Total		183	100	3.83	
Desmidiaceae	*Closterium*	6	66.67	0.13	0.19
	Cosmarium	3	33.33	0.06	
Total		9	100	0.19	
Chlorophyceae	*Pediastrum*	60	36.36	1.25	3.45
	Scenesdemus	20	12.12	0.42	
	Botryococcus	34	20.61	0.71	
	Ankistrodesmus	15	9.09	0.31	
	Ulothrix	28	16.97	0.59	
	Dictyosphaerium	9	4.85	0.17	
Total		165	100	3.45	
Bacillariophyceae	*Melosira*	1140	25.76	23.84	92.53
	Navicula	740	16.72	15.48	
	Synedra	770	17.4	16.1	
	Fragillaria	430	9.72	8.99	
	Gyrosigma	290	6.55	6.06	
	Cyclotella	310	7.01	6.48	
	Nitzschia	285	6.44	5.96	
	Diatoma	460	10.4	9.62	
Total		4425	100	92.53	
Grand total		4782			100

TABLE 6

Correlation Coefficient Values (r) between the physico-chemical factors with total phytoplankton and the phytoplankton classes

Parameters	Total phytoplankton	Bacillariophyceae	Chlorophyceae	Cyanobacteria	Desmidiaceae
Phosphate	0.92^{+}	0.90^{+}	0.94^{+}	0.92^{+}	0.88^{+}
Nitrate	0.92^{+}	0.90^{+}	0.94^{+}	0.92^{+}	0.88^{+}
Transparency	-0.88	-0.88	-0.84	-0.82	-0.80
Temperature	-0.88	-0.88	-0.84	-0.82	-0.80
Dissolved O_2	0.92^{+}	0.86	0.92^{+}	0.90	0.88
Carbon dioxide	0.90^{+}	0.86^{+}	0.92^{+}	0.88	0.90^{+}
Sulphate	0.95^{+}	0.92^{+}	0.96^{+}	0.90^{+}	0.88^{+}
Silica	0.92^{+}	0.96^{+}	0.90^{+}	0.86	0.94
PH	0.88^{+}	0.86^{+}	0.84^{+}	0.90^{+}	0.86^{+}
Conductivity	0.94^{+}	0.94^{+}	0.94^{+}	0.90^{+}	0.90^{+}
TDS	0.94^{+}	0.94^{+}	0.94^{+}	0.90^{+}	0.90^{+}
Total Alkalinity	0.90^{+}	0.86	0.92^{+}	0.88	0.90^{+}

+ = significant at $p<0.05$.

in phytoplankton growth (Talling & Lemoalle 1998). This is evident from the reduction seen in concentration of these nutrients with the phytoplankton growth and abundance. Harris *et al.* (1989) described this scenario has bottle effect. The dominance of Bacillariophyceae is typical of tropical reservoirs (Wood & Talling 1988). Alfred-Ockiya & Otobo (1990) also reported the dominance of diatoms in Ofoniturobo Lake in Nigeria. The absence of many species of desmids could be due to their preference for brackish or high saline waters. Opute (2000) reported that Desmidiaceae are often not significantly abundant in Nigerian freshwater reservoir. The order of abundance and assemblage of the phytoplankton of Oyun reservoir Bacillariophyceae >Chlorophyceae>Cyanobacteria >Desmidiaceae was similar to the observations of Brooklemma (1995) on a tropical lake in Ethiopia. The dominace of Chlorophyceae, Cyanobacteria and Desmidiaceae in Station 2 (transition zone) was due to the station's high nutrients; transparency and water residence time. Higher total phytoplankton biomass and density especially Bacillariophyceae in Station 3 was linked to higher inputs of nutrients in the station coming from rocks and sediments, with the station located in the riverine zone of the reservoir. The low density of the phytoplankton in Station 1 was attributed to factors such as high level of organic decomposition, low transparency, patchiness and low concentration of dissolved salts. The dominance of *Melosira* was due to the high concentration of silica and sulphate which were abundant in the rains. The preponderance of *Anabaena, Pediastrum* and *Closterium* in their respective classes might have occurred in response to the availability and utilization of nitrate and phosphate ions.

Correlation of physico-chemical factors with phytoplankton assemblage: The high species of phytoplankton diversity in the reservoir could also be due to its 'old age' since older reservoirs usually display higher species richness (Rocha *et al.* 1999) and its assemblages were similar to other tropical reservoirs. Factors such as high temperature in short water residence time, high flushing rate of nutrients in the dry season and grazing effects by zooplankton and fishes could have caused the reductions in numbers of the phytoplankton in the dry season. The negative correlation of temperature and transparency with all the classes of the phytoplankton was an indication that the phytoplankton were depleted during higher temperature and higher transparency (which occurs in the dry season). High transparency could have allowed grazers such as zooplankton and fishes to effectively predate on them.

Water quality parameters and phytoplankton assemblage: The phytoplankton assemblage of Oyun reservoir shows the reservoir to be eutrophic and its fluctuation is in response to seasonal concentration of nutrients, grazing pressure by biotic organisms and the reservoir hydrology. Nuisance conditions associated with high phytoplankton diversity and productivity were absent from the reservoir probably due to its shallow depth and high mixing volume. This made the water quality to be good in relation to phytoplankton composition. The water quality of Oyun reservoir as assessed from the physico-chemical properties compared well with the ranges found in other Nigerian reservoirs (Kemdirim 1990, Akinbuwa 1992). It also fell within the range of allowable limits recognized by WHO (1997) and NIS (2007).

Phytoplankton and fish yield: The heterogeneity of the phytoplankton of the reservoir will support a high fish production. The phytoplankton community composition diversity and abundance of this reservoir could be used as the main controlling variable for predicting fish yields in the reservoir. Knosche & Barthemes (1998) have used this model of phytoplankton primary production to predict fish yields in lakes and reservoirs and reported this model resulted in more successful predictions than many other methods. Cushing (1982) also observed a strong relationship between primary production and fish production and concluded that a long term fluctuation in fish stocks was due to this relationship.

Reservoir management: The diverse assemblage of the phytoplankton was due to the strategies being employed in the management of the reservoir. This include the use of watershed best management practices (BMPs) to control eutrophication and sedimentation, and the establishment of important priorities through legislations for water usage by space and time. Other measures that prevent oligotrophy, hypereutrophy, excessive phytoplankton bloom, establishment and proliferation of toxic cyanobacteria, run-off of organic wastes and high dissolved salts were also been used to maintain the water quality and this made the phytoplankton assemblage and productivity of the reservoir to be high.

RESUMEN

Investigué las propiedades físico-químicas y el fitoplancton del pequeño embalse tropical Oyun (Offa, Nigeria) entre enero de 2002 y diciembre de 2003, para determinar el efecto de las propiedades físico-químicas en el fitoplancton y la producción de peces. En las tres estaciones estudiadas identifiqué 25 géneros de fitoplancton pertenecientes a cuatro clases. Bacillariophyceae dominó (75.3%), seguida de Chlorophyceae (12.2%), Desmidiaceae (11.1%) y Cianobacteria (0.73%). La gran cantidad de nutrientes (e.g. nitrato, fosfato, sulfato y sílice) explica la heterogeneidad del fitoplancton ($p<0.05$), el cual fue abundante durante la época de lluvias. La zona de transición de la reserva tuvo el conjunto más rico y abundante. Las fluctuaciones en la densidad del fitoplancton fueron resultado de la concentración estacional de los nutrientes, la presión del forrajeo y la hidrología. El embalse es eutrófico con agua excelente y fitoplancton diverso, y por tanto su producción pesquera sería alta. Estas condiciones son consecuencia de estrategias como mejores prácticas de gestión de cuencas (BPM) para controlar la eutroficación y la sedimentación, y el establecimiento de prioridades legales para un buen uso del agua. Recomiendo medidas adicionales contra la oligotrofía, la hipereutrofia, el exceso de fitoplancton, las cianobacterias tóxicas, las escorrentías de residuos orgánicos y el exceso de sales disueltas.

Palabras clave: Embalse de agua dulce, hidrología, conjunto de fitoplancton, nutrientes, calidad de agua.

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