Assessment of limnological variables and algal diversity of Shagari Reservoir, Sokoto, Nigeria

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Abstract

Shagari Reservoir is the second man-made lake in Sokoto, impounded in 2007 to improve irrigation activities, provide drinking water and control flood. The study was conducted from June to October 2014. The aim was to determine the level of limnological variables at two depths (0.5m and 1m) and to survey diversity of algal species in the reservoir. Among the physicochemical variables studied, temperature was slightly higher at 0.5 m than at 1 metre depth. Phosphate concentration tends to be higher at 1 meter depth. Nineteen (19) species of algae belonging to five divisions were identified, in which *Euglena viridis* accounted for 20.57%. The algal assemblage was found to comprise of Euglenophyta (30.03%) > Chlorophyta (27.43%) > Bacillariophyta (22.27%) > Dinophyta (12.06%) > Cyanophyta (7.8%). July seem to have equal (Equitability Index) distribution of these algal species compared to other months of study and the months varied in terms of richness and evenness. Status of the lake suggests that the nutrient load was low, though enough to promote the growth of algal species and little anthropogenic activities/influences were observed within the reservoir. Proper monitoring and management is required to protect the reservoir from excessive input of nutrients that could lead to eutrophication.

Keywords: Algae, *Euglena viridis;* limnological; variables; Shagari Reservoir.

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Introduction

In Nigeria, as in many parts of the globe, man-made lakes or reservoirs are of great importance, by providing water for drinking, irrigation, aquaculture, etc. They also constitute a very important part of our heritage and have been widely utilized by mankind over the centuries (Araoye, 2002). Generally, these lakes are characterized by instability due to changes in status from riverine to lacustrine conditions. The fluctuations of these lakes appear to be seasonal or depending on other factors (Seda *et al* 2000; Saito *et al* 2001; Johnson *et al* 2002). The effect of these fluctuations in reservoirs does not only affect their socio-economic functions negatively, but also contributes to a loss of their structural biodiversity. Changes in physicochemical characteristics usually provide valuable informa-tion on water quality of a reservoir (Mustapha, 2008).

Residential development of lakeshores brings about changes in a variety of key lake features that include nutrient loading, among others (Schindler *et al* 2000). Nutrients are essential for primary production and their sources may include; regeneration from decomposition of aquatic plants and animals in the water column and other substrates, mixing processes between sediments and overlying waters, terrestrial sources such as domestic activities, fertilizer-leached soils or precipitation of particulate matter (Wetzel, 2001). Movement of these nutrients from the sediment to water column is an important process whose significance depends upon the efficiency of the mixing mechanism (Sithik *et al* 2009).

Algae have immense value as they play a vital role in aquatic ecosystems; they form the major part of primary producers. As the most sensitive organisms, they serve as indicators of water quality with their ability to detect even the subtle changes taking place in their ambient environment (Sithik *et al* 2009). It has been established that about 90% of the photosynthetic activities on this earth is carried out by green algae. Algae does not only oxygenate the surrounding but they are also solely responsible for the production of energy which is consumed by the organisms on higher trophic levels (Guru *et al* 2013). To benefit from the algae of lakes, ponds and reservoirs, it is necessary to study their diversity (Atici, 2002). This study was undertaken to evaluate variation of limnological variables within the littoral zone depths and to provide a checklist of present algal diversity in Shagari Lake within the months of rainy season.

Materials and methods

Study area

Shagari Reservoir is located in Shagari Local Government

Area of Sokoto State, Nigeria. It was commissioned on the 20th of March, 2007. The reservoir is located between Latitude 12° 35´N to 12°45´N, and Longitudes 5°00´E to 5°30´E. It is situated across River Gawon Gulbe which originates partly from River Rima in the northern part of Shagari, and flows through Illela, downstream to Jabaka. The reservoir has many farmlands at the lakeshore, and there are few human activities (washing, fetching water, bathing, etc.) on daily basis. It was constructed for the purpose of providing drinking water, irrigation and with the aim of improving fishing activities in the area (SHSL, 2007), Figure 1.

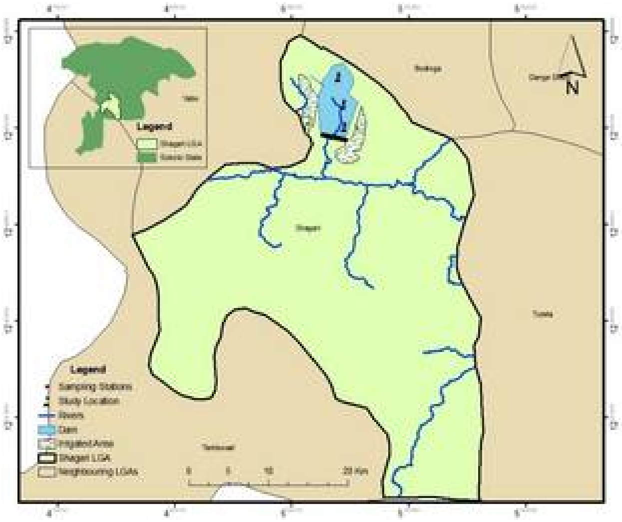

Figure 1. Map of the study-area, Showing Shagari Reservoir.

Sample collection

Samples were collected within the littoral zone at 0.5 m and 1 meter depths, each at three different locations for the period of five months from June to October 2014 (raining season period in Sokoto). The samples were taken to laboratory for analysis, while temperature was measured *in situ*. Phytoplankton samples were collected by horizontal towing with standard plankton net of 25 μm mesh size. The collected samples (50 ml) was preserved immediately with 4% formaldehyde prior to identification (Verlencar and Desai, 2004).

Determination of limnological variables

Standard methods were adopted for determination of limnological variables. Temperature was determined according to Panday *et al* (2005), while pH, DO, BOD_5, NO_3^-, NH_4^+, PO_4^{3-}, Ca^{2+}, K^+, Na^+, Mg^{2+}, HCO_3^-, Cl^-, TDS and Chl-*a* were all determined according to the methods of UNEP (2004).

Phytoplankton identification

Phytoplankton were identified by pipeting 1 ml from the sample on a slide, which was mounted on a light microscope. Counting of the phytoplankton was done by counting each cell as individual (Tash, 1971). Identification was done by comparing the specimens with the phytoplankton identification charts (Hotzel and Croome, 1999; Botes, 2003; Perry, 2003; Janse Van Vuuren *et al* 2006; Yamaguchi and Gould, 2007) before recording.

Statistical analyses

Data obtained from both field and laboratory was statistically analyzed using Prism Graph Statistical Package. One-way Analysis of Variance (ANOVA) was employed at 5% probability to compare the monthly means and results obtained were interpreted and presented on Tables 1-3 (Motulsky, 2007).

Results

Physicochemical variables

Most of the physicochemical parameters studied namely; temperature, pH, dissolved oxygen, nitrate, ammonia, phosphate, calcium, magnesium, bicarbonate, etc. were observed to vary slightly within the months of study, their means and standard error, Table 1. Surface water temperature varied significantly (p<0.05). The mean range of 0.5 m depth was 22.00-32.00°C, while at 1 m depth was 21.63-30.00°C. The pH level in the reservoir range from 5.60-6.08 at both depth which was more or less acidic, this fluctuates throughout the period of study. The level of calcium and magnesium salts were generally low, indicating the reservoir have soft water. Nutrients essential for primary productivity (growth nutrients) were observed to range as follows; nitrate 1.00-1.30 mg/L at both 0.5 m and 1 m depths, while phosphate range from 0.87-1.10 mg/L which were considered low but enough to promote growth of algal cells.

Algal diversity

The total number of algal species were identified during the study, belonging to five taxa and 14 genera. June recorded the highest number individual cells of 152 (Table 2). Bacillariophyta (diatoms) species were more distributed compared to other taxa. Chlorophyta (green algae) were observed to have the highest percentage species distribution (27.43%), while cyanophyta have the least percentage distribution (7.80%).

Results of diversity indices indicates in summary how the reservoir varied within the months of study in terms of species diversity and distribution of these species. Taxa-S and Cha-1 indices all indicated the number of species encountered during the study in which both indicated that June and September has the more number of species identified (11 each) than other months that recorded 10 species each (Table 3). Dominance index recorded 0.29 in June as the highest compared to July to September, which suggest that dominant species are more encountered in June than other months. Margalef, Shannon and Simpson indices operates in similar

Table 1. Physicochemical variables at 0-10 cm and 1 metre depths of Shagari Reservoir (June-October 2014).

Variables	Depth	June	July	August	September	October
Temp (^{o}C)	0.5meter	22.40±0.31	23.00±0.12	22.00±0.15	32.00±1.20	30.00±0.92
	1 meter	22.00±0.27	22.97±0.03	21.63±0.32	30.00±0.58	28.47±0.81
pH	0.5meter	5.70±0.10	5.60±0.15	5.80±0.10	6.00±0.10	5.90±0.15
	1 meter	6.03±0.10	6.03±0.02	6.08±0.02	6.05±0.03	5.96±0.09
DO (mg/L)	0.5meter	5.30±0.41	5.40±0.23	5.40±0.41	5.30±0.38	5.70±0.10
	1 meter	5.30±0.41	6.10±0.08	5.80±0.21	5.40±0.38	5.90±0.09
BOD_5(mg/L)	0.5meter	20.00±0.59	19.00±0.24	20.00±0.62	20.00±0.20	20.00±0.09
	1 meter	19.00±0.13	19.00±0.23	20.00±0.20	20.00±0.19	20.00±0.10
NO_3^- (mg/L)	0.5meter	1.10±0.06	1.00±0.06	1.10±0.07	1.20±0.09	1.30±0.07
	1 meter	1.30±0.06	1.20±0.09	1.30±0.07	1.30±0.03	1.40±0.06
NH_4^+ (mg/L)	0.5meter	0.90±0.06	0.93±0.07	0.93±0.07	1.00±0.09	1.00±0.04
	1 meter	0.90±0.24	0.97±0.03	0.87±0.07	1.10±0.08	1.10±0.03
PO_4^{3-} (mg/L)	0.5meter	0.10±0.00	0.11±0.00	0.11±0.00	0.11±0.00	0.12±0.00
	1 meter	0.10±0.00	0.14±0.00	0.15±0.00	0.12±0.00	0.13±0.00
Ca^{+2} (mg/L)	0.5meter	0.60±0.00	0.65±0.01	0.77±0.12	0.67±0.03	0.63±0.01
	1 meter	0.80±0.00	0.97±0.03	0.70±0.03	0.70±0.06	0.70±0.02
K^+ (mg/L)	0.5meter	2.00±0.12	2.30±0.06	2.50±0.03	2.50±0.07	2.40±0.03
	1 meter	2.00±0.12	2.40±0.03	2.80±0.03	2.60±0.12	2.40±0.03
Na^+ (mg/L)	0.5meter	0.30±0.00	0.30±0.00	0.30±0.00	0.35±0.02	0.35±0.03
	1 meter	0.30±0.00	0.33±0.03	0.33±0.03	0.37±0.03	0.36±0.03
Mg^{+2} (mg/L)	0.5meter	1.90±0.03	0.71±0.02	2.00±0.03	1.90±0.03	1.80±0.09
	1 meter	1.90±0.03	1.05±0.01	2.57±0.03	2.01±0.05	1.86±0.09
HCO_3^- (mg/L)	0.5meter	1.30±0.03	1.20±0.09	1.40±0.03	1.30±0.13	1.30±0.03
	1 meter	1.30±0.03	1.20±0.03	1.20±0.03	1.40±0.07	1.40±0.04
Cl^- (mg/L)	0.5meter	0.47±0.03	0.50±0.06	0.53±0.03	0.44±0.03	0.48±0.04
	1 meter	0.47±0.03	0.40±0.00	0.43±0.03	0.45±0.07	0.50±0.04
TDS (mg/L)	0.5meter	2.00±0.00	2.00±0.09	2.00±0.00	2.00±0.06	2.00±0.00
	1 meter	2.00±0.00	1.90±0.03	1.30±0.33	2.00±0.00	2.00±0.00
Chl-*a* (mg/L)	0.5meter	0.53±0.03	0.94±0.03	0.99±0.11	0.52±0.10	0.58±0.20
	1 meter	0.53±0.03	0.17±0.32	0.20±0.03	0.58±0.20	0.12±0.01

Footnote: 0.5 metre: Samples collected within that range depth, 1 meter: Samples at that depth.

Table 2. Checklist of algal species in Shagari Lake, Nigeria (June-October 2014).

Division /Species	Jun	Jul	Aug	Sept	Oct	Total	%
Bacillariophyta							
Aulacoseira granulata	3	-	-	-	-	3	0.71
Asterionellaformosa	3	6	8	16	10	43	10.17
Cymbella timida	4	-	-	2	-	6	1.42
Cosnodiscus centralis	-	12	2	-	13	27	6.38
Melosira granulata	4	-	-	7	-	11	2.60
Synedra ulna	6	-	-	-	-	6	1.42
Chlorophyta							
Spirogyra gracilis	12	10	12	12	8	54	12.77
Spirogyra cummis	18	13	5	3	20	59	13.95
Chlorella eupsoidea	-	3	-	-	-	3	0.71
Cyanophyta							
Anabaena wisconsenese	-	-	2	2	-	4	0.95
Aphanocapsa elachista	-	2	-	-	-	2	0.47
Oscillatoria ornata	2	-	2	2	2	8	1.89
Spirulina albida	-	-	-	-	2	2	0.47
Oscillatoria limimosa	-	9	8	-	-	17	4.02
Dinophyta							
Ceratium hirundinella	8	9	8	6	6	37	8.75
Peridinium cinctum	-	-	-	-	2	2	0.47
Ceratium tiredenella	-	6	-	6	-	12	2.84
Euglenophyta							
Euglena rubra	16	5	5	2	12	40	9.46
Euglena viridis	76	-	4	4	3	87	20.57
Total	**152**	**75**	**56**	**62**	**78**	**423**	
Mean	**14.00**	**7.00**	**6.00**	**6.00**	**8.00**		
Std. Deviation	**21.00**	**4.00**	**3.30**	**5.00**	**6.01**		
Std. Error	**6.40**	**1.20**	**1.10**	**1.40**	**2.00**		

Footnote: Indicates not present.

direction by taking into account number of individuals and how they are distributed. June has the highest number of individuals of 152 but because the 11 species were not equally distributed compared to other months June has lower value of 0.71, 0.72 and 1.99 for Simson, Shannon and Margalef respectively (Table 3).

Table 3. Values of diversity indices of algal species identified at Shagari Reservoir (June-October 2014).

Index	Jun.	Jul	Aug	Sept	Oct
Taxa_S	11	10	10	11	10
Chao-1	11	10	10	11	10
Dominance_D	0.29	0.12	0.13	0.15	0.15
Simpson_1-D	0.71	0.88	0.87	0.85	0.85
Shannon_H	1.72	2.19	2.14	2.13	2.04
Evenness_e^H/S	0.51	0.89	0.85	0.77	0.77
Brillouin	1.61	1.98	1.89	1.88	1.85

Discussion

Physicochemical variables

Eutrophication of lake ecosystems caused by excess concentrations of nitrogen and phosphorus may have harmful consequences for biodiversity and poses a health risk to humans via water supplies (Audet *et al* 2014). On the average, significant difference in physicochemical variables was observed in some parameters between the depths (0.5 m and 1 metre). Temperature varied significantly (p<0.5) with a mean range of 22.00-32.00ºC which was observed in June (beginning of raining season) and September, at the peak of raining season. The low temperature recorded at 1 meter depth in Shagari Reservoir could be due to decrease of incident light radiation that penetrates into the water column, which decreases as the depth increases, as reported by Larson *et al* (2007).

Hydrogen ion level was more or less uniform at both depths, i.e. 0-10 cm and 1 metre (Table 1). The highest pH at 0.5 m was 6.0 (i.e. acidic) while at 1 metre was 6.08 in August, therefore the means suggest that the water is acidic at both depths and quite suitable for fish production and fit for domestic uses (Adakole *et al* 2003).

Dissolved oxygen at 0.5 m tends to be uniform, but in October 5.70 mg/l was recorded as the highest, while at 1 metre depth 6.30 mg/l was obtained as the highest in June. Sufficient dissolved oxygen is important for high-quality water, for the survival of fish and other aquatic life forms (Adakole *et al* 2003). The dissolved oxygen may likely decrease from photic to aphotic zones, down to sediment layer (Larson *et al* 2007). There was slight variation at the two depths for BOD, though 19.00±0.24 mg/l was only recorded in July, while the values were more or less uniform at 0.5 m (Table 1), but at 1 meter 20.00 mg/l was measured from August to October (Table 1). High BOD values indicate the extent of organic pollution in an aquatic system, which will adversely affect the water quality (Jonnalagadda and Mhere, 2001).

Nitrogen compounds in this study i.e., NO_3^- and NH_4^+, were not significant between the months of study. Although nitrate was observed to be higher with a maximum mean of 1.30±0.07 mg/L, 1.40±0.06 mg/L both in October at 0.5 m and 1 meter respectively (Table 1). The values of phosphate did not indicate any significant difference between the months at 0.5 m depth. At 1 meter depth, concentration phosphate varied between the months, which was significant between the months (Table 1). Low level of phosphate at the surface may likely be due to decomposed organic matter which is permanently fixed in the sediment or recycles back in overlying water as available nutrients, thus, the concentration may tend to increase as the depth increases (Goldeman and Horne, 1994).

Chlorophyll-*a* concentration was low in this study, in which 0.99±0.11 mg/L was the maximum mean recorded at 0-10 cm in August (Table 1). This indicates minimal availability of nutrients in this lake and low chlorophyll may suggest the lake is oligotrophic, since lakes with 0-2.6 mg/l chlorophyll-*a* are considered oligotrophic (Carlson and Simpson, 1996). Calcium, potassium, sodium and magnesium were observed to vary slightly between the depths and within the months of study, with maximum means of 0.97 mg/L, 2.80 mg/L, 0.37 mg/L, and 2.57 mg/L respectively (Table 1), which indicates the values did not exceed recommended limits for aquatic life (WHO, 2004). Bicarbonate, chloride and total dissolved solids recorded a range values of 1.20-1.40 mg/L, 0.40-0.53 mg/L and 1.30-2.00 mg/L respectively (Table 1) therefore were found to be within the limit to support life in aquatic systems (UNEP, 2004; WHO, 2004; Weiner, 2007).

Algal diversity

The reservoir reveals less diverse algal individuals with only 19 species, belonging to five divisions were identified The few species identified may be related to low chlorophyll-*a* measured in the reservoir, which usually indicate level of productivity as reported by Carlson and Simpson (1996) as well as Jenkerson and Hickman (2007). So the less diverse plankton identified may be due to the influence of prevailing physicochemical parameters, which determine their abundance, occurrence and seasonal variations according to Rothhaupt (2000). Therefore, the low nutrient of nitrate and phosphate in the present work may be attributed to less number of algal species, as reported by Rothhaupt (2000) earlier. The findings were contrary to Ajuzie (2012) who identified 22 species in Lamingo Reservoir in Jos Nigeria, so also with Tanimu *et al* (2012) whom identified 32 species along Hadeja-Nguru wetland.

Reservoirs are considered favourable environments for developments of phytoplankton communities, which may establish diverse assemblages in relatively short periods of time after impoundment (Rocha *et al* 1999). The algal assemblage in this study comprised of Euglenophyta (30.03%)> Chlorophyta (27.43%)> Bacillariophyta (22.27%)> Dinophyta (12.06%)> Cyanophyta (7.8%) (Figure 1). The emergence of more Chlorophyta over Bacillariophyta may be attributed to a common trend in some parts of West Africa (Kadiri, 1999a, b; Alika and Akoma, 2012). The low level of nutrients was reported to largely affects diversity of phytoplankton species (Hobara *et al* 2001; Ligêza and Smal, 2003; Hobara *et al* 2005; Osono *et al* 2006; Breuning-Madsen *et al* 2010), and may consequently trigger when in excess the availability of food to other organisms, being the base of aquatic food chains (Hebert *et al* 2005). Biological indices are usually used to describe diversity features of communities which can allow comparison and also estimate species diversity (Morris *et al* 2014).

In this study, June and September had 11 species present in each case, while July, August and October recorded 10 species each. Simpson, Shannon-Weiner, Evenness, Brillouin, Menhinick, Margalef and Equitability were evaluated for homogeneity of abundance in Shagari Reservoir. These indices express a bulk data with single figure that give meaning to the community of species surveyed (Morris *et al* 2014). The study reveals how months were different on richness and evenness from the values of indices used. July seems to have more equal (equitability) distribution of different species than other months. July had the following 0.89, 0.95, 0.88, 2.19, 1.16 values for Evenness, Equitability, Simpson, Shannon and Margalef respectively. This indicates that July had the highest equal distribution of algal species identified and the findings therefore conformed to the reports of Neelamegam *et al* (2015) as well as that of Anchonitis *et al* (2016).

Conclusion

Shagari Lake undergoes slight fluctuation in physicochemical variables within the period of study. There were also little anthropogenic influences at lakeshore and within the lake (such washing, bathing, etc.) and the chemistry of the lake suggests medium nutrient level, but this may increase with time.

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