A First Survey of Phytoplankton Community Richness in Lamingo Reservoir, Jos, Nigeria: A Wake-up Call for the Continuous Monitoring of Microalgae in surface waters serving as drinking water sources in Nigeria.

Cyril C. Ajuzie

Applied Fisheries and Hydrobiology Unit, Department of Zoology, University of Jos, Nigeria
E-mail: efulecy@yahoo.com

Abstract: Lamingo reservoir was investigated twice (one week apart) during the month of May 2011 in order to document a preliminary inventory of phytoplankton occurring in the system. Physico-chemical parameters (i.e. temperature, dissolved oxygen, pH, nitrate-nitrogen and phosphate-phosphorus) were equally monitored. 22 species of diatoms, 18 species of green algae, 9 species of blue-green algae, and 5 species of dinoflagellates were recorded in samples collected from the reservoir. The cyanobacteria group included the potentially harmful genus *Microcystis*. A suggestion is made for the continuous monitoring of surface drinking water sources in Nigeria if a good-status water body is desired for the systems.
[Cyril C. Ajuzie. A First Survey of Phytoplankton Community Richness in Lamingo Reservoir, Jos, Nigeria: A Wake-up Call for the Continuous Monitoring of Microalgae in surface waters serving as drinking water sources in Nigeria. New York Science Journal 2012;5(2):1-8]. (ISSN: 1554-0200). http://www.sciencepub.net/newyork. 1

Key words: Lamingo Reservoir, Jos, Nigeria, Phytoplankton, potentially harmful *Microcystis* species

1. Introduction

Dams are built to 'store' water. The resultant reservoirs are important in the realization of water-related projects such as hydroelectric power generation, municipal water supply, field irrigation and creation of fishing basins. They can be used, also, to control flooding and land erosion. Lamingo reservoir facilitates the distribution of pipe-borne water to the Jos University Teaching Hospital (JUTH) and to some areas of the Jos metropolis.

In Lamingo reservoir, like in other water bodies, communities of phytoplankton constitute the basis of the aquatic food chain. This is because they are primary producers, which sustain populations of primary consumers that include zooplankton, some macroinvertebrates and phytoplanktivorous fish. The composition and abundance of phytoplankton communities may provide a hint on the health status of a reservoir. Presently, our knowledge on the microalgal communities of Lamingo reservoir is shallow. We do not know the present composition of these organisms in the reservoir. We do not also know anything about the dynamics of different algal populations, or much about their ecology and biology within the system. This may have a lot to do with the choices made by yesteryears limnologists with respect to waterbody types they were interested in. Until (relatively) recently, limnological studies of smaller water bodies in Nigeria and West Africa were scarce. Most of the early researchers focused mainly on large water bodies such as River Sokoto (Holden and Green, 1960), River Senegal (Van de Velde, 1978), River Jong (Wright, 1982), and lakes such as the West Cameroonian Crater lakes (Green, 1972), Lake Kainji (Bidwell and Clark, 1977), and Lake Sonfon (Green, 1979). However, nowadays limnologists are showing continuous interest in smaller freshwater bodies (e.g. Adeniji, 1983; Khan and Ejike, 1984; Anadu et al. 1990; Kemdirim, 1990; Akin-Oriola, 2003; Achionye-Nzeh and Isimaikayi, 2010; Edward and Ugwumba, (2010).

Studies of small freshwater bodies (streams, ponds, and reservoirs) are relevant because of their importance to mankind, and because they are easily impacted by man (also see Ajuzie, 2012). Lamingo reservoir is not far from human settlements and activities. Since this reservoir serves as a source of municipal water supply to some parts of Jos town, it is highly advisable to regularly monitor and keep records of organisms, particularly microalgae, that occur in the water and which may affect the water quality. This work was designed to provide a preliminary list of phytoplankton species in Lamingo reservoir.

2. Materials and Methods

2.1. The study site

Jos is located in Plateau State, in the central region of Nigeria (Figure 1). Plateau State lies approximately between latitudes 9^0 and 11^0 North and longitudes 9^0 and 11^0 East. The state occupies an area of about 26,899 km^2 and possesses the most conspicuous features in the Northern part of the country. Jos has a sharp division between the rainy season that lasts from April-September or May-October and the dry season, which lasts from November-April. The mean minimum temperature is 18 ^{0}C and the mean maximum temperature is 22 ^{0}C. During the Harmattan months (December to February) mean temperatures could drop to between

8 and 10 ^{0}C. This bestows on the city a temperate climate feeling (Balogun, 2007). Lamigo reservoir, the study site for this project, is located within the Shere Hills area of Jos North Local Government Area (Ita et al., 1985). The reservoir is directly exposed to sunlight since no trees are found on its banks or within the water body. Traces of cattle hooves and their droppings litter the land surrounding the reservoir, indicating that cattle are driving there to drink. There are no farming activities within the immediate surroundings of the reservoir. Some local residents fish in the reservoir, though clandestinely.

2.2. Sampling

Sampling was done twice during the month of May 2011. The first sampling was on the 19th and second on the 26th. At the site both air and water temperatures were measured using a mercury-in-glass thermometer. Water temperature was measured by placing the thermometer a few centimetres below the water surface, horizontally. Water samples were collected in plastic bottles and taken to the laboratory for pH, nitrate, and phosphorous tests. For the determination of dissolved oxygen concentration in the water, a 250 ml stopper bottle was used to collect water sample. The bottle was filled and capped under water with no air bubbles inside. When the filled bottle was taken out of the water, 2 ml of manganese sulphate ($MnSO_4$) and 2 ml of alkaline iodide sodium-azide solutions were added to the sample to fix it. This caused precipitates to form in the bottle. The bottle was then re-stoppered and taken to the laboratory for further analysis. In order to determine the composition of phytoplanktons in the reservoir, water samples were collected with a bucket and flittered through a 20 µm mesh sieve. Materials retained by the sieve were stored in small (200 ml) screw-cap plastic bottles. Formaldehyde (10%) was added to the water sample to preserve the algae. Each sample was properly labelled.

Figure 1. Map of Nigeria showing the location of Jos (source: http://en.wikipedia.org/wiki/Jos)

2.3. Laboratory studies

The pH of the water was determined using a pH meter. Nitrate and phosphate contents were determined spectrophotometrically (AOAC, 1980). Dissolved oxygen was determined by the Winkler titration method (APHA, 1992). In order to identify phytoplankton species in the water samples collected, a drop of water sample was placed on a microscope slide, covered with a cover slip and viewed under the light microscope. The organisms were identified to the species level, using taxonomic guides by Bourrelly (1966), Belcher and Swale (1978), Durand and Leveque (1980), Pentecost (1984), Anagnostidis and Komarek (1988), Baker and Fabbro (1999), and Lawton et al. (1999).

3. Results

3.1. Physico-chemical parameters

Results of the physico-chemical analyses are presented in Table I. Air temperatures were slightly higher than those of water for the two dates. But temperatures were comparatively higher on the first sampling date than on the second. Dissolved oxygen was comparatively higher on the second sampling date than on the first. pH was on the alkaline side of the pH scale. The concentration of nitrate-nitrogen was higher on the first day of sampling than on the second; but phosphate-phosphorus was higher on the second sampling date than on the first. Dissolved oxygen concentration was almost the same for the two sampling dates.

Table 1. Observed physico-chemical parameters in Lamingo reservoir

Parameters	Diss. O_2 [ppm]	NO_3 [µg/l]	PO_4 [µg/l]	pH	Air temp. (°C)	H_2O temp. (°C)
Date 19/05/11	8.3	844	217	8.45	33	32
26/05/11	8.5	662	269	7.74	28	26
Mean	8.4	753	243	8.09	30.05	29

Table 2. Diatoms of Lamingo reservoir observed during this study

Division:	Bacillariophyta
Class:	Bacillariophyceae
Order:	Achnanthales
Family:	Achnanthaceae
Genus:	*Achnanthes* Bory
Species:	*A. exiguoides Grunow*
Order:	Bacillariales
Family:	Bacillariaceae
Genus:	*Cylindrotheca* Rabenhorst
Species:	*C. closterium* (Ehrenberg) Reimann
Genus:	*Nitzschia* Hassall
Species 1:	*N. cf. acicularis* (Kutzing) Smith
Species 2:	*N. cf. palea* (Kutzing) Smith
Order:	Centrales
Family:	Melosiraceae
Genus:	*Melosira* Agardh
Species:	*Melosira* sp.
Order:	Cymbelalles
Family1:	Cymbellaceae
Genus:	*Cymbella* Agardh
Species 1:	*C. kappii* (Cholnoky) Cholnoky
Species 2:	*C. ventricosa* Kutzing
Species 3:	*C. turgida* Gregory
Family 2:	Gomphonemataceae
Genus:	*Gomphonema* Ehrenberg
Species:	*G. parvulum* Kutzing
Family 3:	Thalassiosiraceae
Genus:	*Gomphoneis* Cleve
Species:	*Gomphoneis* sp.
Order:	Fragilariales
Family:	Fragilariaceae
Genus:	*Diatoma* Bory
Species:	*Diatoma* sp.
Genus:	*Fragilaria* Williams & Round
Species:	*F. capucina* Desmazieres
Genus:	*Synedra* Ehrenberg
Species:	*S. ulna* (Nitzschia) Ehrenberg
Order:	Naviculales
Family 1:	Amphipleuraceae
Genus:	*Frustulia* Rabenhorst
Species:	*F. rhomboides* (Ehrenberg) de Toni
Family 2:	Naviculaceae
Genus:	*Navicula* Bory
Species 1:	*N, cuspidata* (Kutzing) Kutzing
Species 2:	*N. cf. margalithii* Lange-Bertalot
Species 3:	*N. radiosa* Kutzing
Family 3:	Pinnulariaceae
Genus:	*Diatomella* Greville
Species:	*D. balfouriana* (Smith) Greville
Order:	Rhopalodiales
Family:	Scolioneidaceae
Genus:	*Epithemia* Brebisson
Species:	*E. zebra* (Ehrenberg) Kutzing
Order:	Surirellales
Family:	Surirellaceae
Genus:	*Surirella* Turpin
Species:	*S. linearis* Kutzing
Order:	Thalassiosirales
Family:	Stephanodiscaceae
Genus:	*Stephanodiscus* Ehrenberg
Species:	*S. hantzschii* Grunow

3.2. Phytoplankton divisions and species

Phytoplankton species were recorded in the following divisions: Bacillariophyta, Chlorophyta, Cyanophyta, and Dinophyta. In the division Bacillariophyta, 22 species of diatoms (under 16 genera, 12 families and 9 Orders) were recorded. The species included *Achnanthes exiguoides, Achnanthes microcephala, Cymbella kappii, Cymbella ventricosa*, *Cymbella turgid, Cylindrotheca closterium, Diatomella balfouriana, Diatoma* sp, *Epithemia zebra, Fragilaria capucina, Frustulia rhombodes, Gomphonema parvulum, Gomphoneis* sp, *Melosira* sp, *Navicula cuspidate, Navicula cf. Margalithii, Navicula radiosa, Nitzschia cf. acicularis*, *Nitzschia cf. palea, Surirella linearis, Stephanodiscus hantzschii* and *Synedra ulna* (Table 2). In the Chlorophyta division a total of 18 species (under 13 genera, 7 families and 4 Orders) were recorded. The green algal species included *Staurastrum subcruciatus, Staurastrum trifidum, Staurastrum teliferum, Staurastrum arachne, Staurastrum validus*, *Scenedesmus quadricauda, Scenedesmus perforates, Oocystis lacustris, Cosmarium circulare, Spondylosium planum, Botryococccus braunii, Coelastrum microporum, Coccomyxa dispar, Eremosphaerus viridis, Dictyosphaerium* sp, *Closterium* sp, *Ulothrix* sp *and Xanthidium* sp (Table 3). In the cyanophyta division, 9 species of blue-green algae were recorded under eight genera, four families and two Orders. They cyanobacterial species included: *Calothrix parietina, Coelosphaerium confeitum, Dermocarpa aquae-dulcis, Gloeocapsa sanguinea, Gomphosphaeria aponina, Microcystis aeruginosa f. aeruginosa, Microcystis aeruginosa* f. *flos–aquae, Nostoc sp.* and *Synechocystis aquatilis* (Table 4). And for the dynophytes, 5 species of dinoflagellates (under two genera, two families and two Orders) were recorded. The species included *Gymnodinium aeruginosum*, *Gymnodinium inversum*, *Peridinium cinctum*, *Peridinium inconspicuum* and *Peridinium willei* (Table 5).

Table 3. Green algae of Lamingo reservoir observed during this study

Division:	Chlorophyta
Class:	Chlorophyceae
Order:	Chlorococcales
Family 1:	Coccomyxacceae
Genus:	*Coccomyxa* Schmidle
Species:	*C. dispar* Schmidle
Family 2:	Dictyosphariaceae
Genus:	*Botryococcus* Kutzing
Species:	*B. braunii* Kutzing
Genus:	*Dictyosphaerium* Nageli
Species:	*Dictyosphaerium* sp
Family 3:	Oocystaceae
Genus:	*Eremosphaera* de Bary
Species:	*E. viridis* de Bary
Genus:	*Oocystis* Nagali ex A. Braun
Species:	*O. lacustris* Chodat
Family 4:	Scenedesmaceae
Genus:	*Coelostrum* Nageli
Species:	*C. microporum* Nageli
Genus:	*Scenedesmus*
Species 1:	*S. perforatus* Bourelly
Species 2:	*S. quadricauda* (Turp.) Brebisson
Order:	Desmidiale
Family:	Closteriaceae
Genus:	*Closterium* Ralfs
Species:	*Closterium* sp
Order:	Ulotrichales
Family:	Ulothrichaeceae
Genus:	*Ulothrix* Kutzing
Species:	*Ulothrix* sp
Order:	Zygnematales
Family:	Desmidiaceae
Genus:	*Cosmarium* Ralfs
Species:	*C. circulare* Reinch
Genus:	*Spondylosium* Brebisson ex Kutzing
Species:	*S. planum* Wolle
Genus:	*Staurastrum* (Meyen) Ralfs
Species 1:	*S. subcruciatus* Cooke & Wills
Species 2:	*S. teliferum* Ralfs
Species 3:	*S. trifidum* Haekel
Species 4:	*S. arachne* Ralfs
Species 5:	*S. validus* Thomason
Genus:	*Xanthidium* Ehrenberg ex Ralfs
Species:	*Xanthidiums* sp.

4. Discussion

Monitoring of freshwater habitats is essential for assessing the long term ecological status and trends in species diversity and water quality. For this purpose records must be kept and guarded. This study provides a preliminary inventory of the physical, chemical and biological characteristics of Lamingo reservoir. The results of pH tests indicated that Lamingo reservoir is not acidic but slightly neutral to basic, making it a good source for drinking water supplies, and hospitable for aquatic biota to live and thrive. The reservoir is adequately oxygenized. Dissolved oxygen in a water body is judged normal when concentrations are greater than 3.0 mg/L, potentially stressful between 2.0 and 3.0 mg/L and hypoxic at concentrations less than 2.0 mg/L (see Sabo et al. 1999; Rutherford et al. 2001).

There was a correlation between water temperature and dissolved oxygen. On the first sampling date, when the water temperature was higher, the concentration of dissolved oxygen was relatively lower. This is in agreement with the views of Limnologists who postulate that dissolved oxygen is dependent on water temperature, and that it decreases as the water temperature increases (e.g. Uzunov et al., 2006). The variation in temperature recordings between the two sampling dates is attributed to solar radiation and cloud-cover. The first sampling day was sunny and warm, while the second was cloudy. Additionally, it had rained the night before the second sampling date. The difference between air and water temperatures could have something to do with the well known phenomenon of light backscattering - as light impinges on the water surface some of the solar energy hitting the water surface is reflected back into the atmosphere. The position of the sun (i.e. the sun angle) also plays a role in the backscattering of solar radiation (see http://www.theweatherprediction.com/habyhints2/532/). When the sun is low on the horizon (e.g. at dusk) more radiation will be reflected off water because of the low angle the sun assumes. For this reason a low sun angle does not allow for adequate water warming. This dramatically changes, though, as the sun climbs higher in the sky (e.g. at noon). When the sun is directly overhead the liquid water will absorb just about all the solar radiation striking it. This adds an enormous amount of heat energy to tropical waters. Yet, surface waters in shallow water bodies or overlying continental shelves can show significant scattering from phytoplankton (Vaillancourt et al., 2004), as well as re-suspended silts, clays and other inorganic particles that are brought to the surface by the action of internal waves, tidal and coastal currents, and winds (Chang and Dickey, 2001). And when appreciable air injection occurs, air bubbles may also contribute significantly to light scattering (Terrill et al., 2001).

Table 4. Cyanobacteria of Lamingo reservoir observed during this study

Division:	Cyanophyta
Class:	Cyanophyceae
Order:	Chroococcales
Family 1:	Chroococcaceae
Genus:	*Coelosphaerium* Nägeli
Species:	*C. confertum* (In Ref. nr. 15)
Genus:	*Synechocystis* Sauvageau
Species:	*S. aquatilis* Sauvageau
Genus:	*Gloeocapsa* Kutzing
Species:	*G. sanguine* (Agardh) Kutzing
Genus:	*Gomphosphaeria* Kutzing
Species:	*G. aponina* Kutzing
Family 2:	Dermocarpellaceae
Genus:	*Dermocarpa* Crouan et Crouan
Species:	*D. aquae-dulcis* (Reinsch) Geitler
Family 3:	Microcystaceae
Genus:	*Microcystis* Kutzing
Species 1:	*M. aeruginosa* f. *aeruginosa* Kutzing
Species 2:	*M. aeruginosa* f. *flos*-aquae (Wittr.) Elenkin
Order:	Nostocales
Family:	Nostocaceae
Genus :	*Calothrix* Agardh ex Born. et Flah.
Species:	*C. parietina* (Nägeli) Thuret
Genus:	*Nostoc* Vaucher ex Born. et Flah.
Species:	*Nostoc* sp.

The concentrations of the nutrients nitrogen and phosphorus fluctuated in the reservoir and were high. The high concentrations of these nutrients may be attributed to the fact that the sampling period coincided with the onset of the rainy season, which caused allochthonous materials (particularly leached soil and associated organic particles, including cow dung and human faeces) to enter the water body as runoffs emptied into it. The short sampling period, however, made it difficult for one to ascertain any possible correlation between the concentrations of these nutrients and the occurrence and population dynamics of the observed phytoplankton species. A longer sampling period, which is currently being planned, should reveal a correlation between nutrient dynamics and phytoplankton species dynamics in the reservoir.

Table 5. Dinoflagellates of Lamingo reservoir observed during this study

Division:	Dinophyta		
Class:	Dinophyceae		
		Order:	Peridiniales
Order:	Gymnodiales	Family:	Peridiniaceae
Family:	Gymnodiniaceae	Genus:	*Peridinium* Ehrenberg
Genus:	*Gymnodinium* Stein	Species 1:	*P. cinctum* Muller
Species 1:	*G. aeruginosum* Stein	Species 2:	*P. inconspicuum* Lemmermann
Species 2:	*G. inversum* Nygaard	Species 3:	*P. willei* Huitfeld-Kaas

Table 6. A comparison of phytoplankton taxa in Lamingo reservoir with three other reservoirs in Nigeria

Ecosystem	Microalgal group	Species	Genera	Families	Orders
Lamingo Dam[1]	Cyanobacteria	9	8	4	2
	Diatom	22	16	12	9
	Dinoflagellates	5	2	2	2
	Green algae	18	13	7	4
Awba Reservoir[2]	Cyanobacteria	3	3		
	Diatom	3	3		
	Dinoflagellates	1	1	1	1
	Green algae	7	7		
U. Ilorin Reservoir[3]	Cyanobacteria	3	3		
	Diatom	4	4		
	Dinoflagellates	0	0		
	Green algae	7	7		
Egbe Reservoir[4]	Cyanobacteria	8	6		
	Diatom	15	10		
	Dinoflagellates	1	1	1	1
	Green algae	4	4		

N/B: 1: represents data from this study
2: represents data from Akin-Oriola (2003)
3: represents data from Achionye-Nzeh and Isimaikaiye (2010)
4: represents data from Edward and Ugwumba (2010)
U. Ilorin Reservoir: represents University of Ilorin Reservoir

This very short research period witnessed the presence of a highly diversified community of phytoplankton in Lamingo reservoir. When this work is compared with studies carried out in other smaller freshwater bodies in Nigeria, and the sampling period of which lasted over two months (e.g. Akin-Oriola, 2003; Achionye-Nzeh and Isimaikaiye, 2010; Edward and Ugwumba, 2010), the species richness in the reservoir will be most appreciated. In Table 6 the taxonomic richness of phytoplankton in Lamingo reservoir is compared with that of some freshwater bodies that were recently studied in Nigeria. From these observations, one may be tempted to rule that Lamingo reservoir is richer in phytoplankton species than the other referred small water bodies investigated in Nigeria. At any rate, the mesh size of nets used in phytoplankton sampling may have caused the low number of species recorded by the other authors mentioned. Whereas this study employed a 20 µm mesh sieve, Edward and Ugwumba (2010) employed a 60 µm mesh sieve, while Akin-Oriola (2003) employed a 64 µm mesh sieve. The larger mesh sizes used by these workers must have let some of the phytoplankton species to pass through the collecting nets.

Special attention was drawn to the paucity of dinoflagellate species in the reservoir. But this was not considered a surprise, since some past studies show that dinoflagellates have few representatives in freshwater ecosystems (e.g. Pentecost, 1984). But one surprise was that no *Ceratium* species was recorded. *Ceratium,* particularly C. hirundinella, is believed to be a common freshwater bloom-forming organism (see Pentecost, 1984).

Since Lamingo reservoir is used chiefly for municipal water supplies, special attention must be paid to it. Regular monitoring of microalgal species in the reservoir is recommended. This will help, among others, for the early detection of potentially toxic species. According to Fleming et al. (2002) surface water drinking supplies are particularly vulnerable to the growth of toxic cyanobacteria. This study observed the presence of potentially toxic cyanobacterial organisms (the *Microcystis* species) in the reservoir. Toxic *Microcystis* species produce potent phycotoxins (in this case cyanotoxins) like the microcystins, which are responsible for a variety of illnesses in persons and animals drinking from waters infested by members of this toxic genus. Microcystins have been associated with acute liver damage and possibly liver cancer in laboratory animals (Yu, 1995; Ueno et al, 1996; Ito et al, 1997). And a study by Yu (1995) found an association between primary liver cancer and surface water in humans. Cyanotoxins in surface drinking waters, to my knowledge, are currently not monitored in Nigeria. I just hope I am wrong! But if this is the real situation, how can Public Utilities and Public Health officials in Nigeria ascertain that the World Health Organization's admissible levels for cyanotoxins in drinking water are met? Although cyanotoxins are not totally eliminated in surface drinking waters by any known water treatment method (Chorus and Bartram, 1999), early detection of cyanobacterial blooms in surface waters that serve as sources of drinking water will help reservoir managers implement measures, and promptly, that will help reduce their biomass, and possibly their overall toxic potentials in affected waters.

Acknowledgements:

C. Barki helped during the field work, and T. Ojobe analysed the nutrient contents of the water.

References

1. Achionye-Nzeh CG and Isimaikaiye A. Fauna and Flora composition and water quality of a reservoir in Ilorin in Nigeria. International Journal of Lakes and Rivers 2010; 3(1):7-15.
2. Adeniji HA. A pre-impoundment fisheries study of the River Niger in the proposed Jebba Lake area. Kainji Lake Research Institute Annual Report 1983: pp. 45-50.
3. Ajuzie CC. Aspects of biodiversity studies in a small rural tropical reservoir (Lamingo Reservoir) in Jos, Nigeria. World Rural Observations 2012; 4(1):23-33.
4. Akin-Oriola GA. On the phytoplankton of Awba Reservoir, Ibadan, Nigeria. Revista De Biologia Tropical 2003; 51(1):99-106.
5. Anadu DA, Obioha A and Ejike C. Water quality and plankton periodicity in two contrasting mine lakes in Jos, Nigeria. Hydrobiologia 1990; 208:17-25.
6. Anagnostidis K and Komarek J. (1988). Modern approach to the classication system of cyanophytes. Archiv für Hydrobiologie Supplement 80, Algological Studies1988; 50-53: 327-472.
7. AOAC. Standard Official Methods of Analysis. 13th Edn., Association of Official Analytical Chemists, Washington, DC. 1980.
8. APHA. Standard methods for the examination of water and wastewater. 18^{th} ed. American Public Health Association, Washington, DC. 1992.
9. Baker PD and Fabbro LD. A guide to the identification of common blue–green algae (Cyanoprokaryotes) in Australian freshwaters. Co-operative Research Centre for Freshwater Ecology Identification Guide 1999; No. 25: 23 pp.
10. Balogun T. The Changing Landscape of Jos, Nigeria. Escape From America Magazine 9 (11) Nov/Dec 2007. http://www.escapeartist.com/efam/97/changing_landscape_of_Jos.html

11. Belcher H and Swale E. A beginner's guide to freshwater algae. Natural Environment Research Council, London. 1978: 47 pp.
12. Bidwell A and Clarke NV. The invertebrate fauna of Lake Kainji, Nigeria. Nigeria Field 1977; 42: 104–110.
13. Bourrelly P. *Les Algues d'Eau Douce*. Tome I: Les.**Algues** Vertes. Editions N. Boubée et Cie., Paris. 1966: 511 pp.
14. Chang GC and Dickey TD. Optical and physical variability on timescales from minutes to the seasonal cycle on the New England shelf: July 1996 to June 1997. Journal of Geophysical Research 2001; 106: 9435–9453.
15. Chorus I and Bartram J, eds. Toxic cyanobacteria in water: a guide to their public health consequences, monitoring and management. E and FN Spoon, London. 1999.
16. Durand JR and Leveque C. Flore et faune aquatiques de l'Afrique Sahelo-Soudanienne. 2 Vol. Ed. de l'Office de la Recherche Scientifique et Technique Outre-Mer. Doc. Techn. n° 44. Paris. 1980.
17. Edward JB and Ugwumba AA. Physico-chemical parameters and plankton community of Egbe Reservoir, Ekiti State, Nigeria. Research Journal of Biological Sciences 2010; 5(5): 356-367.
18. Fleming LE, Rivero C, Burns J, Williams C, Bean JA, Shea KA and Stinn J. Blue green algal (cyanobacterial) toxins, surface drinking water, and liver cancer in Florida. Harmful Algae 2002; 1:157-168.
19. Green J. Ecological studies on crater lakes in West Cameroon. Zooplankton of Barombi Mbo, Mboandong, Lake Kotto and Lake Soden. Journal of Zoology (London) 1972; 166:283–301.
20. Green J. The fauna of Lake Sonfon, Sierra Leone. Journal of Zoology (London) 1979; 187:113-133.
21. Holden MJ and Green J. The hydrology and plankton of the River Sokoto. Journal of Animal Ecology 1960; 29(1):65–84.
22. Ita EO, Sado EK, Balogun JK, Pandogari A and Ibitoye B. A preliminary checklist of inland water bodies in Nigeria with special reference to lakes and reservoirs. Kainji Lake Research Institute Technical Report Series. 1985: No. 14
23. Ito E, Kondo F, Terao K and Harada K-I. Neoplastic nodular formation in mouse liver induced by repeated intraperitoneal injections of microcystin L.R. Toxicon 1997; 35(9):1453-1457.
24. Kemdirim EC. Periodicity and succession of phytoplankton in an upland and lowland impoundment in plateau state (Nigeria) in relation to nutrient levels and physical characteristics. Journal of Aquatic Science 1990; 5:43-52.
25. Khan MA and Ejike C. Limnology and plankton periodicity of Jos Plateau water reservoir, Nigeria, West Africa. Hydrobiologia 1984; 114:189-199.
26. Lawton L, Masalek B, Padisak J and Chorus I. Determination of cyanobacteria in the laboratory. In I. Chorus, and J. Batram, eds. Toxic cyanobacteria in water: A guide to their public health consequences, monitoring and management. WHO Publications. 1999.
27. Pentecost A. Introduction to Freshwater Algae. Kingprint Limited, Richmond, Surrey. 1984: 247 pp.
28. Rutherford DA, Gelwicks KR and Kelso WE. Physicochemical effects of the flood pulse on fishes in the Atchafalaya River Basin, Louisiana. Transactions of the American Fisheries Society 2001; 130:276-288
29. Sabo MJ, Bryan CF, Kelso WE and Rutherford DA. Hydrology and aquatic habitat characteristics of a riverine swamp: II. Hydrology and the occurrence of chronic hypoxia. Regulated Rivers: Research and Management 1999; 15:525-542
30. Terrill EJ, Melville WK. and Stramski D. Bubble entrainment by breaking waves and their influence on optical scattering in the upper ocean. Journal of Geophysical Research 2001; 106:16815–16823.
31. Ueno Y, Nagata S, Tsutsumi T, Hasegawa A, Watanabe MF, Park H-D, Chen G-C, Chen G and Yu S-Z. Detection of microcystins, a blue green algal hepatotoxin, in drinking water sampled in Hiamen and Fusui, endemic areas of primary liver cancer in China, by highly sensitive immunoassay. Carcinogenesis 1996; 17:1317-1321.
32. Uzunov Y, Nuttle T, Nakova E and Varadinova E. Dissolved oxygen in the River Mesta (Bulgaria): a case study for qualitative modeling of sustainable development. Proceedings of the 20th International Workshop on Qualitative Reasoning (QR 2006), Hanover/New Hampshire. 2006.
33. Vaillancourt RD, Browni CW, Robert RL, Guillard RRL and Balch WM. Light backscattering properties of marine phytoplankton: relationships to cell size, chemical composition and taxonomy. Journal of Plankton Research 2004; 26(2): 191–212.
34. Van de Velde I. Cladocera and Copepoda from the valley of the river Senegal. Biologisch Jaarboek Dodonaea 1978; 46: 192-201.
35. Wright R. Seasonal variations in water quality of a West African river (R. Jong in Sierra Leone) Revista Hydrobiologia Tropical 1982; 15: 193–199.
36. Yu S-J. Primary prevention of hepatocellular carcinoma. Journal of Gastroenterology and Hepatology 1995; 10: 674-682.

12/25/2011