Effects of bottom-up and top-down interactions on the productivity of Iyieke Lake, Afikpo North, Ebonyi State, south-east Nigeria

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Abstract

The bottom-up and top-down interactions of the abiotic and biotic components of Iyieke Lake were studied for eleven months covering a pre-flood, flood and post-flood periods. During the study, some water quality parameters were measured while plankton samples were collected for identification in the laboratory using standard method. The results of the water quality parameters measured showed that water temperature was highest (35.00R″C) in February. pH (7.10) and transparency (0.98 m) were highest in August. Highest TDS (28.0 mg/L) and conductivity (56.00 µS/cm) were recorded in March (pre-flood period) while dissolved oxygen level was lowest (4.00 mg/L) in the pre-flood period (February and March). Nitrate (0.18 mg/L) was highest in August (flood period) and phosphate (0.25 mg/L) at the two extreme periods (pre-flood and post flood). The depth of the lake was highest (3.2 m) in August which was the period of inundation. The phytoplankton (Bacillariophyta, Chlorophyta, Cyanobacteria) and zooplankton (Rotifera, Cladocera, Copepoda) of the lake were made of three divisions and taxa each, respectively. Bacillariophyta dominated among the phytoplankton while Rotifera was the most abundant among the zooplankton. The study revealed that nutrients and zooplankton grazing were the major factors that affected phytoplankton abundance and biomass during the study.

Keywords: Flood; phytoplankton; Iyieke; water quality; zooplankton.

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Introduction

Phytoplankton play key roles in lake productivity by fixing energy through photosynthetic activities (Akin-Oriola, 2003). They occupy mainly the euphotic zone of aquatic ecosystem, where they utilize energy derived from the sun to build up small inorganic molecules into complex organic compounds that are stored in their tissue, hence are found at the base of aquatic food chain. Phytoplankton serve as food for numerous aquatic fauna including zooplankton, herbivorous fish fingerlings and ensure the stability of trophic interaction in aquatic ecosystem. Hence, the productivity of any aquatic ecosystem depend largely on the inert capacity of the phytoplankton to fix energy by utilizing inorganic materials within such ecosystem. Therefore, the abundance, diversity and biomass production of phytoplankton in a lentic system depend largely on the interaction with the physico-chemical variables of the ecosystem, predation by zooplankton and other carnivorous animals that may be feeding on the zooplankton and herbivorous fishes (Reynolds, 1988; Reynolds, 2006; Salmaso and Braioni, 2008; Okogwu and Ugwumba, 2013).

Zooplankton grazing have been reported among the factors that affect the species composition, abundance, diversity and biomass of phytoplankton in lentic ecosystem (Reynolds, 1998). Zooplankton play a vital role in energy flow in aquatic food web, serving both as consumer of most phytoplankton, bacteria and as prey for macro crustaceans, insects and fishes (Infante and Abella, 1985). Phytoplankton species, *Senedesmus acuminatus*, *Ankistrodesmus* have been reported to serve as suitable diet for *Moina micrura* and have been used as feed stock in the maintenance of some zooplankton species, *Anuraeopsis fissa* and *Daphnia* (Goulden *et al* 1982; Dumont *et al* 1995). Zooplankton also help to regulate phytoplankton and microbial productivities by enhancing clear water phase production due to its filtering activities (Mathivanan *et al* 2007). However, the trophic interactions between phytoplankton and zooplankton are regulated majorly by environmental and biological factors which affect the growth of the communities (Abdel-Aziz *et al* 2006). Hence, high flow rate, discharge, residence time, transparency, water temperature, nutrient concentrations, and suspended solids have been listed as the major regulatory factors of phytoplankton species composition, abundance, diversity and biomass in lentic and lotic ecosystems (Reynolds, 2006; Okogwu and Ugwumba, 2013). Also, zooplankton grazing and selective predation have been reported to have direct influence on the biomass and species composition of phytoplankton in lentic system

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(Sterner, 1989; Sommer *et al* 2001; Kagami *et al* 2002). Therefore, this research is designed to assess the effects of bottom-up and top-down interactions on the abundance and biomass accumulation of phytoplankton in Iyieke Lake within the study period.

Methodology

Study area

Iyieke Lake is a natural shallow floodplain lake (05° 502 33.49 N, 007° 562 40.88 E) located 50 m away from the Cross River channel (Okogwu and Ugwumba, 2012), near Ndibe beach. It is one of the numerous lakes within the drainage basin of the Cross River system (Nwonumara and Okogwu, 2013). Seasonal flooding of the lake by the Cross River divided the hydrology into three distinct periods which include the pre-flood period (January-May), when the lake remains completely separated from the river; the flood period (June-August), when the lake is inundated; and the post-flood period (September-December), when the flood recedes (Nwonumara and Okogwu, 2013).These periods cover both dry (November-April) and wet or rainy season (May-October). Major anthropogenic activities in and around the lake are fishing and farming.

Sample collection and field determinations

Water samples for physico-chemical and plankton analyses were collected monthly from the littoral and pelagic zones of the lake for eleven months, which covered the pre-flood (February-May), flood (June-August), and the post-flood (September-December) periods. Samples were pooled from different locations from each zone. Water temperature, dissolved oxygen (DO) and pH were measured *in situ* using Hanna digital thermometer, DO meter (Model HI 9142), and pH meter (Model HI 77700P), respectively. Total dissolved solids (TDS) and conductivity were also measured at the study site using Hanna TDS (Model HI 98108) and conductivity (Model HI 98303) metres, respectively. Depth was measured from calibrated poles permanently mounted in the lake while transparency was determined using a Secchi disc. Phosphate (PO_4-P) and nitrate (NO_3-N) were measured using standard procedures (APHA 2005). Plankton samples were collected from the same zones as in the physico-chemical variables using plankton net, pooled into a I litre plastic container holding 400 ml of buffered formalin (4 %) until the 1 litre mark is reached.

Laboratory and data analyses

Morphological identification of plankton was done to the species level with standard keys and guides of Gebrüder (1978), Prescott (1978), Jeje and Fernando (1986), Williams (1991), WRC, 2002 and Nwankwo (2004), using Olympus binocular microscope at x400 magnification (Model BHTU BH-2). The quantitative assessment of plankton abundance was carried out by identifying/counting individuals of each species deposited in Utermohl chambers and presented as the number of individuals per litre (ind/L). Plankton biovolume (mm^3) was estimated by measuring individual cells and their volumes were calculated according to geometrical solids (Ruttner-Kolisko, 1977; Hillebrand *et al* (1999). Biovolume (mm^3) was, then, obtained by multiplication of the density of each species by the average volume of its cells. Specific biomass was expressed in µg (fresh weight)/L, assuming the specific density of a phytoplankter of 1 g/cm^3 (Edler, 1979).

Variations in physico-chemical parameters, plankton abundance and biomass among pre-flood, flood and post-flood periods during the study were tested statistically using one sample t-test and one way analysis of variance (ANOVA). Values were considered significant at $p < 0.05$ levels. All statistical analyses were performed using statistical package for social science (SPSS) version 20.

Results

Physico-chemical variables

Water temperature was highest (35^{o}C) in February, the pre-flood period and the water pH ranged from 6.50 to 7.10 (Figure 1). Both TDS and conductivity were highest in March (pre-flood period) with 28.0 mg/L and 56.0 µS/cm, respectively. Dissolved oxygen was lowest (4.00 mg/L) in the pre-flood period (February and March) and highest (1.00 mg/L) in June (flood period) (Figure 1). Nitrate (0.18 mg/L) was highest in August and phosphate (0.75 mg/L) in February and November. The depth of the lake (3.2 m) and transparency (0.98 m) were highest in August, the period of inunctation (Figure 2). Temporal variation in the physico-chemical variables measured were not significant ($p > 0.05$) while water temperature, pH, transparency, conductivity and DO varied significantly ($p < 0.05$) between the study periods (Table 1).

Phytoplankton and zooplankton species composition

Three phytoplankton divisions were identified during the study (Table 2). The divisions are Chlorophyta, Bacillariophyta and Cyanobacteria with Bacillariophyta (309 ind/L) as the most abundant and the post-flood period (Table 2). Species with the highest frequency of occurrence among the Bacillariophyta were *Achnanthes* and *Gryosigma* spp. (Table 2). ANOVA result showed that difference in the abundance and biomass production of Cyanobacteria was significant ($p < 0.05$) during the study period.

The zooplankton species identified during the study were comprised of three broad taxonomic groups, namely Rotifera, Cladocera and Copepoda (Table 3). Copepoda (496 ind/L) was the most abundant while Rotifera (12 ind/L) was the least all in the post-flood period. *Collotheca spp* (16.66 %), *Diaphanosoma spp* (28.58 %) and *Thermocyclops oithonoides* (23.53 %) were the highest in percentage relative abundance and in the pre-flood and flood periods (Table 3). There was no significant difference ($p > 0.05$) in the abundance of the zooplankton taxa identified during the study period.

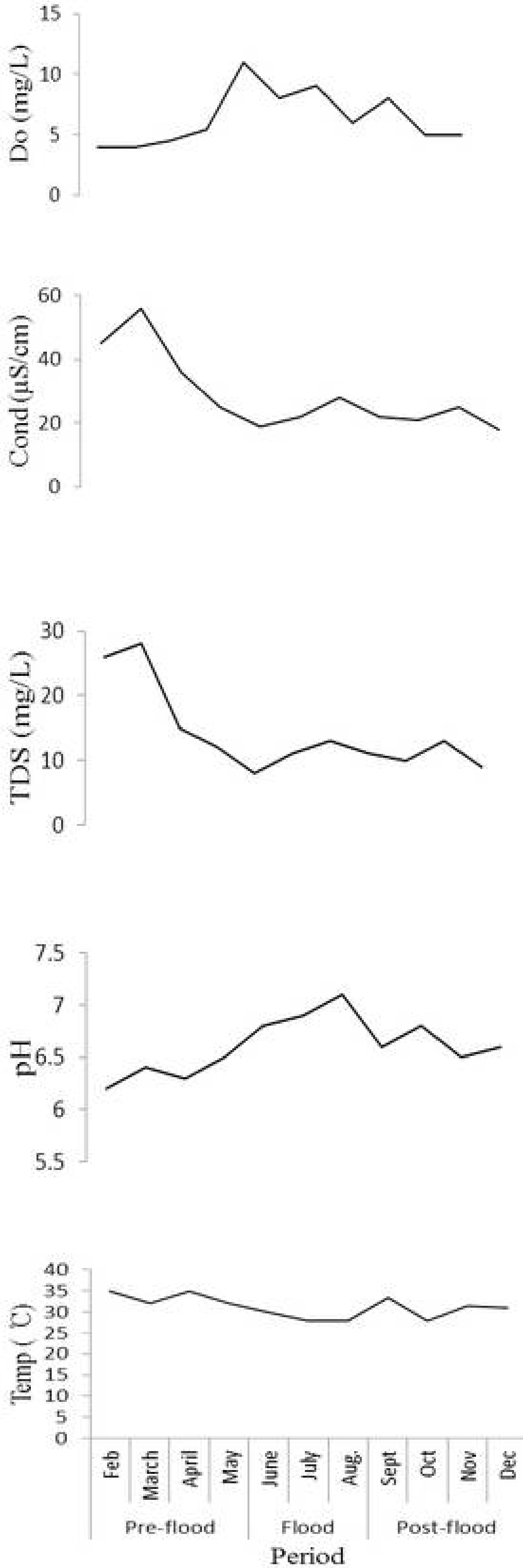

Figure 1: Temperature, pH, TDS, Conductivity and DO of the study site.

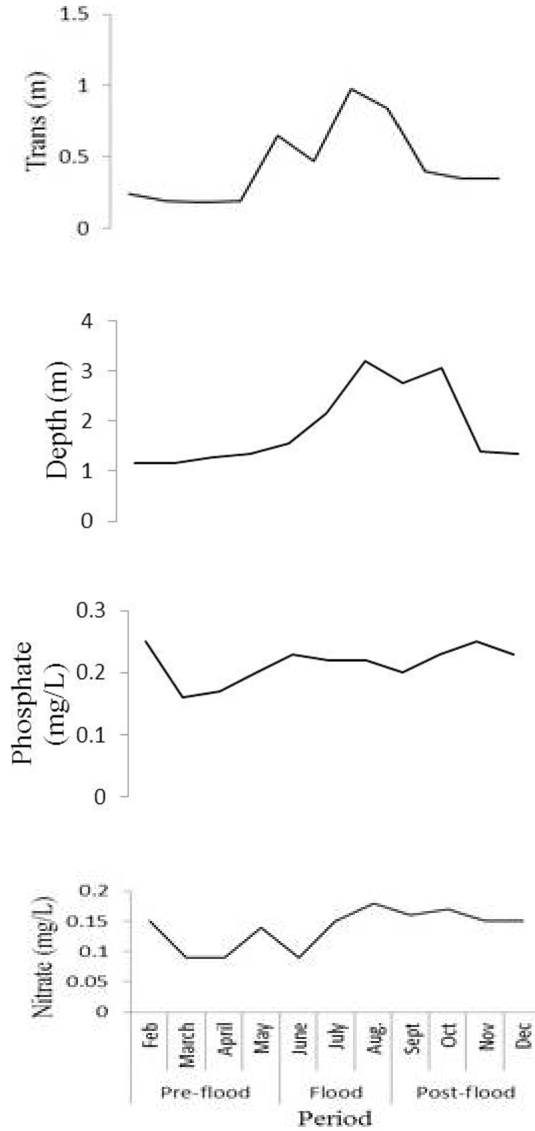

Figure 2: Nitrate, Phosphate, Depth and Transparency of the study site.

Phytoplankton biomass-zooplankton abundance relation

Total phytoplankton biomass had negative correlation (-0.21, $r = 0.53$) with total zooplankton abundance though not significant, thus indicating the negative effect of zooplankton grazing on phytoplankton biomass. At lower zooplankton abundance, phytoplankton biomass was observed to increase. However, when zooplankton abundance increased in August and November, phytoplankton biomass declined (Figure 10).

Principal coordinate (PC) analysis showed that dissolved oxygen (DO) was influenced by depth while temperature influenced conductivity and TDS (Figure 11). Nitrate, phosphate and zooplankton interactions affected phytoplankton biomass most (Figure 11).

Table 1: Statistical description of spatial and temporal variations in physico-chemical variables of Iyieke Lake during the study.

Parameter	Pre – flood	Flood	Post - flood		Monthly				
	Mean±SD	Mean±SD	Mean±SD	*p* - value	Mean±SD	*N*	Range	*P*- value	*t* -statistic
Temperature (^oC)	33.50±1.73	28.67±1.15	31.00±2.27	0.026	31.27±2.60	11	7.00	1.00	0.003
pH	6.35±0.13	6.93±0.15	6.63±0.13	0.002	6.61±0.27	11	0.90	0.99	-0.01
Transparency (m)	0.20±0.03	0.70±0.26	0.49±0.24	0.028	0.44±0.27	11	0.80	1.00	0.00
TDS (mg/L)	20.25±7.93	10.67±2.52	10.75±1.71	0.051	14.18±6.65	11	20.00	0.99	0.001
Conductivity (µS/cm)	40.50±13.18	23.00±4.58	21.50±2.89	0.027	28.82±12.04	11	38.00	1.00	-0.001
Dissolved oxygen (mg/L)	4.50±0.71	9.33±1.53	6.00±1.41	0.003	6.36±2.30	11	7.00	0.99	0.005
Nitrate (mg/L)	0.12±0.03	0.14±0.05	0.16±0.01	0.242	0.14±0.03	11	0.09	0.86	-1.84
Phosphate (mg/L)	0.20±0.04	0.22±0.01	0.23±0.02	0.268	0.21±0,03	11	0.09	0.62	0.51
Depth (m)	1.23±0.10	2.30±0.84	2.13±0.89	0.135	1.85±0.79	11	2.05	0.99	0.01

Table 2: Percentage relative abundance of phytoplankton species of Iyieke lake during the study period (February-December, 2011).

Phytoplankton Division	Pre-flood	Flood	Post-flood
Chlorophyta	**12 (4.32)**		**74 (12.84)**
Ankistrodesmus spp.	0.36	*	*
Pithophora sp.	1.44	*	*
Schizomeris spp.	1.80	*	0.17
Sticococcus sp.	0.72	*	*
Strauastrum laptocladium	*	*	0.17
Spirogyra sp.	*	*	12.50
Bacillariophyta	**247 (88.85)**	**235 (97.11)**	**309 (53.65)**
Achnanthes sp	5.04	20.66	15.23
Aulacoseira granulate	7.91	0.83	2.60
Bacillaria spp	0.72	*	*
Bacteriastrum hyalinum	0.36	*	*
Cocconeis spp.	21.58	2.89	2.95
Coscinodiscus spp.	2.52	3.31	1.04
Gryosigma balticum	46.40	69.01	30.03
Hemidiscus hardimaniamus	0.36	*	*
Hyalodiscus sp.	0.36	*	*
Nitzschia spp.	2.16	*	2.08
Skeletonema spp.	0.72	*	*
Surirella linearis	0.36	*	*
Tabellaria sp.	0.36	0.41	*
Cyanobacteria	**19 (6.83)**	**7 (2.89)**	**193 (33.51)**
Aphanizomenon flos-aquae	6.83	2.89	13.02
Glocotrichia sp**.**	*	*	20.49

Key: * indicate absence of species.

Table 3: Percentage relative abundance of zooplankton species of Iyieke Lake during the study period (February-December, 2011)

Zooplankton species	Study period		
	Pre-flood	Flood	Post-flood
Rotifera	**72 (43.57)**	**14 (4.82)**	**12 (2.11)**
Anuraeopsis sp.	*	0.32	0.60
Brachionus spp.	1.92	0.49	0.30
Keratella cochlearis varrobusta	0.64	*	*
Notholca spp.	1.93	0.32	0.15
Collotheca spp.	16.66	2.56	0.15
Colurella spp.	1.92	0.16	*
Lepadella sp.	0.64	0.16	*
Proales sp.	3.20	*	*
Euchlanis deflexa deflexa	0.64	*	0.15

Table 3: Percentage relative abundance of zooplankton species of Iyieke lake during the study period (February-December, 2011) continued.

Zooplankton species	Study period		
	Pre-flood	Flood	Post-flood
Hexarthra spp.	1.28	*	*
Lecane spp.	1.28	0.16	*
Testudinella species	*	0.16	0.61
Macrochaetus sp.	0.64	*	0.15
Trichocerca spp.	12.82	0.49	*
Cladocera	**64 (41.03)**	**223 (36.62)**	**149 (22.68)**
Diaphanosoma sp.	12.82	28.58	11.85
Pseudosida bidentata	2.56	2.43	2.43
Ceriodaphnia cornuta	*	0.16	1.24
Daphnia longispina	5.77	0.16	*
Scapholeberi kingi	*	*	0.46
Simocephalus spp.	2.56	2.13	5.62
Moina micrura	7.35	*	0.46
Moinodaphnia macleayi	1.92	0.99	0.30
Bosmina longirostris	0.64	*	*
Bosminopsis deisteri	0.64	0.33	*
Echinisca sp.	*	0.49	0.30
Grimaldina brazzai	0.64	*	*
Guernella raphaelis	*	0.16	*
Ilyocryptus spinifer	0.64	*	*
Macrothrix geoldi	0.64	*	*
Alona spp.	3.94	0.82	*
Chydorus spp.	*	0.32	*
Leyidigia acanthocercoides	0.64	*	*
Pleuroxus hamatus hamatus	0.64	*	*
Copepoda	**21 (13.46)**	**372 (61.08)**	**496 (75.49)**
Cryptocyclops bicolor	*	1.32	1.22
Ectocyclop sphaleratus	0.64	*	0.15
Eucyclops serrulatus	0.64	0.49	0.15
Halicyclops troglodytes	0.64	*	0.30
Mesocyclops leuckarti	*	0.16	0.15
Metacyclops minutus	*	0.49	5.78
Microcyclops varicans	1.92	13.90	18.69
Thermocyclops neglectus	0.64	*	*
Thermocyclops oithonodes	7.06	23.53	16.72

Key: * indicate absence of species.
(Adopted and modified from Nwonumara and Okogwu, 2013).

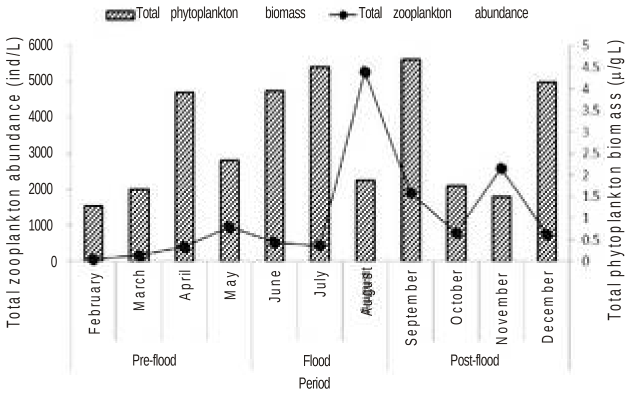

Figure 10: Phytoplankton biomass – zooplankton abundance relation.

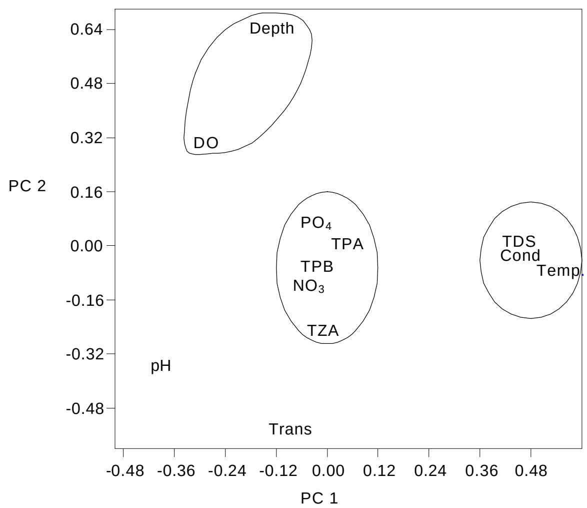

Figure 11: Principal coordinate of factors interaction in Iyieke Lake during the study.

Discussion

Iyieke Lake is one of the floodplain lakes along the Cross River Floodplain. The lake provides numerous services which include provision of water for irrigation farming, habitat for several aquatic flora and fauna, temperature moderation, regulation of river flow, flood control and recharging of ground water aquifer. Most importantly, it serves as spawning ground for different fish species (Nwonumara, 2012). Hence, study of the bottom-up and top-down interactions of the lake will provide basic knowledge of the functionality of the important ecosystem.

The study therefore revealed that water temperature, pH, transparency and DO varied significantly during the study period. Temperature variation could be linked to the influence of season on the variable. The pH of the lake was slightly acidic throughout the study period except in the flood period when it reached neutral point. Lower pH recorded in the pre-flood and post-flood periods could be linked to higher water temperature which enhanced microbial activity at the benthic zone (Atobatele and Olutona, 2013) that released more organic acid from decomposition of organic matter at these periods. It could also be due to the decomposition of submerged plants which released more organic acids into the water in the post-flood period. Transparency of the lake was at the peak during flood period which, could be due to the lake sill height and the indirect connectedness of Cross River, preventing direct inflow of flood water. These according to Squires and Lesack, 2002, increase the progressive decantation of sediments as the distance from the connection point with the main river channel increases. Meanwhile, Okogwu *et al* (2009) have reported high transparency at the flood period in floodplain lakes. Inflow of flood water from Cross River increased the depth and volume of the lake. Thus, might have contributed to the higher dissolved oxygen (DO) concentration recorded in the flood period through water turbulence which facilitated air-water mixing and consequent increase in dissolved oxygen level (Nwonumara and Okogwu, 2013). Gautam *et al* (1993) as well as Sivakumar and Karuppasamy (2004) have also reported increase in DO level during flood period in lakes which they attributed to respiration from inundated vegetation. Phosphate concentration was low in the pre-flood period. This could be attributed to utilization by phytoplankton and aquatic plants (Wani and Subla, 1990; Sivakumar and Karuppasamy, 2004). However, higher values recorded in the flood and post-flood period could be due to the inflow of phosphate fertilizer from riparian farmland (Nwonumara and Okogwu, 2013) and decomposed plants submerged in water during flood (Lauridsen *et al* 1998).

The phytoplankton of the lake was represented by similar divisions that have been recorded in tropical waters such as Paranapanema River reservoirs (Nogueira *et al* 2010), Ikot Okpora, Obubra and Ejagham Lakes (Offem *et al* 2011a), Ikwori Lake (Offem *et al* 2011b), Nguru Lake (Mohammad *et al* 2012), Cross and Asu Rivers (Okogwu and Ugwumba, 2013), Shagari Reservoir (Magami *et al* 2014), Bhoj wetland (Bhat *et al* 2015), Khami River (Dzinomwa and Ndagurwa, 2017) and so on. However, the phytoplankton divisions at Iyeke Lake were fewer compared to some of the tropical waters mentioned above. This could be due to the nutrient status of the lake which may not have supported the proliferation of the phytoplankton divisions that are not recorded during the study. Bacillariophyta was the most frequently encountered among the three divisions recorded especially in the pre-flood period. This could be due to its exceptional ability to utilize silicate, an advantage that might have made it proliferate more than the other divisions (Akpan, 1997). However, low abundance of the Chlorophyta could be due to higher predation by zooplankton as some species (*Scenedesmus* spp.) among the division have been reported to serve as food for zooplankton (*Moina micrura*, *Anuraeopsis fissa*) (Dumont *et al* 1995). These zooplankton species were among the ones recorded during the study and could have been responsible for the low abundance of Chlorophyta due to their predatory characteristics. On the other hand, low abundance of the

Cyanobacteria may have been caused by the nutrient status of the water during the study period since most species of the group do not grow and proliferate in nutrient poor waters (Ambasht and Ambasht, 2005).

The limnological structure of Iyieke Lake during the study had positive effect on zooplankton production compared to phytoplankton. Among the factors that boosted zooplankton proliferation could be temperature at the pre-flood period and increased water level at the flood period. Increased temperature has been reported to be favourable to the parthenogenetic reproductive pattern of Rotifers and the attainment of peak reproductive period in fewer days (Akin-Oriola, 2003; Imoobe and Adeyinka, 2010). Similarly, increased water level to the littoral zone of the lake enhanced the hatching of resting Cladoceran eggs lying dormant in flooded areas (Okogwu, 2010). Increased water level also enhanced the influx of species from other water bodies which include Bob Eric Lake, Ehoma Lake, Egwebe Lake and Cross River which, connect to Iyieke lake during inundation (Okogwu, 2010; Nwonumara and Okogwu, 2013).

However, the negative correlation between the phytoplankton biomass and zooplankton abundance of the lake during the study could be attributed to grazing or massive predation by zooplankton and herbivorous fishes. The grazers exerted a top down effect on the phytoplankton, which reduced the proliferation and directly affected the biomass production.

In conclusion, the study revealed that phytoplankton abundance and biomass production were mainly controlled by eutrophic factor (bottom-up) and grazing by zooplankton (top-down) influence.

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