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Ecology and diversity of phytoplankton in River kashimbila Takum, Taraba state, Nigeria

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Abstract
The ecology of river Kashimbila has been predisposed to pollution due to the construction of the dam and other anthropogenic activities around the river. This study explored the effects of the physicochemical parameters on the phytoplankton diversity and abundance. A total of thirty seven (37) species of phytoplankton were identified, which was dominated by Chlorophyta (94.92%), followed by Bacillariophyta (2.19%) and the least being Euglenophyta (0.27%). The result revealed significant difference ($P<0.05$) among number of species between raining and dry season. Phytoplankton diversity and abundance were influenced by seasons and sites while species composition varied significantly with season at ($P<0.05$).

Keywords: diversity, phytoplankton, River Kashimbila, species

Introduction

Phytoplankton is free floating unicellular, filamentous and colonial organisms that grow phyto – autotrophically in aquatic environments. They are the basis of food chains and food webs which directly provide food for zooplankton, fishes and some aquatic animals (Millman *et al.*, 2005) [28].

According to Paul (2003) [31] phytoplankton is a microscopic drifting plant that live in aquatic environments, and are not restricted to the oceans. However, phytoplankton is not merely one homogeneous group of organisms. They represent a rich diversity of shapes, colours and varieties ranging from single –celled photosynthetic bacteria such as cyanobacteria, to plant-like diatoms and armor-plated coccolithophores. Phytoplankton which evolved over 2.8 billion years ago plays an essential role in shaping the earth's carbon, oxygen and nitrogen cycles over sweeping expanses of time and leading to the biogeochemical conditions of the present. These organisms are all –important and ever-present, yet remain virtually imperceptible to all other living beings.

Changes in the growth of phytoplankton may affect atmospheric carbon dioxide concentrations which would feed back to global surface temperatures. These miniscule beings, through a series of chemical processes, regulate key global activities in the biosphere such as the climate system, which affect all other living organisms in marine and terrestrial ecosystems (Rebecca and Simmon, 2010) [34].

Phytoplankton populations growth is dependent on light levels and nutrient availability and these factors of growth varies from region to region in the world's oceans,seas, rivers and lakes. On a broad scale, growth of phytoplankton in the oligotrophic tropical and subtropical gyres is generally limited by nutrient supply, while light often limits phytoplankton growth in subarctic gyres. (Steinacher, 2010) [34].

Materials and Methods

Study Area

River Kashimbila took its source from the Bamenda highlands in northwestern Cameroon and as the tributary of Benue River.

The dam is located in the Guinea Savannah Zone of North Eastern Nigeria. It consists of undulating landscape dotted with a few mountainous features and few scattered trees along the river, on the Latitude 06° 52′N and Longitude 09^0 45′E which is between the towns of Kashimbila and Gamovo in Takum, Taraba State, Nigeria (Figure 1). The area has two distinct seasons (wet and dry). The rainy season period lasts from May to October while the dry season lasts from November to April.

The ethnic tribes in Takum are Jukun, Chamba, Kuteb, Ichen, Hausa, Tiv. They are predominantly farmers therefore cultivate crops like: cassava, guinea corn, maize, millet, groundnut, soyabean, benniseed, rice, melon, and other vegetable crops and some migrant Fulani who rear animals along the river.

Takum Local Government is bordered to the north by Donga Local Government Area, to the west and south west by Benue State, to the east by Ussa LGA and Republic of Cameroon. The Kashimbila Dam is 50km south west of Takum (Oruonye, 2015) [29].

There are growing communities along the river (Bamenda) which relies on the river for household chores, irrigation and source of public water supply thereby creating unnecessary disturbance of the aquatic environment (Tita *et al*., 2012) [43].

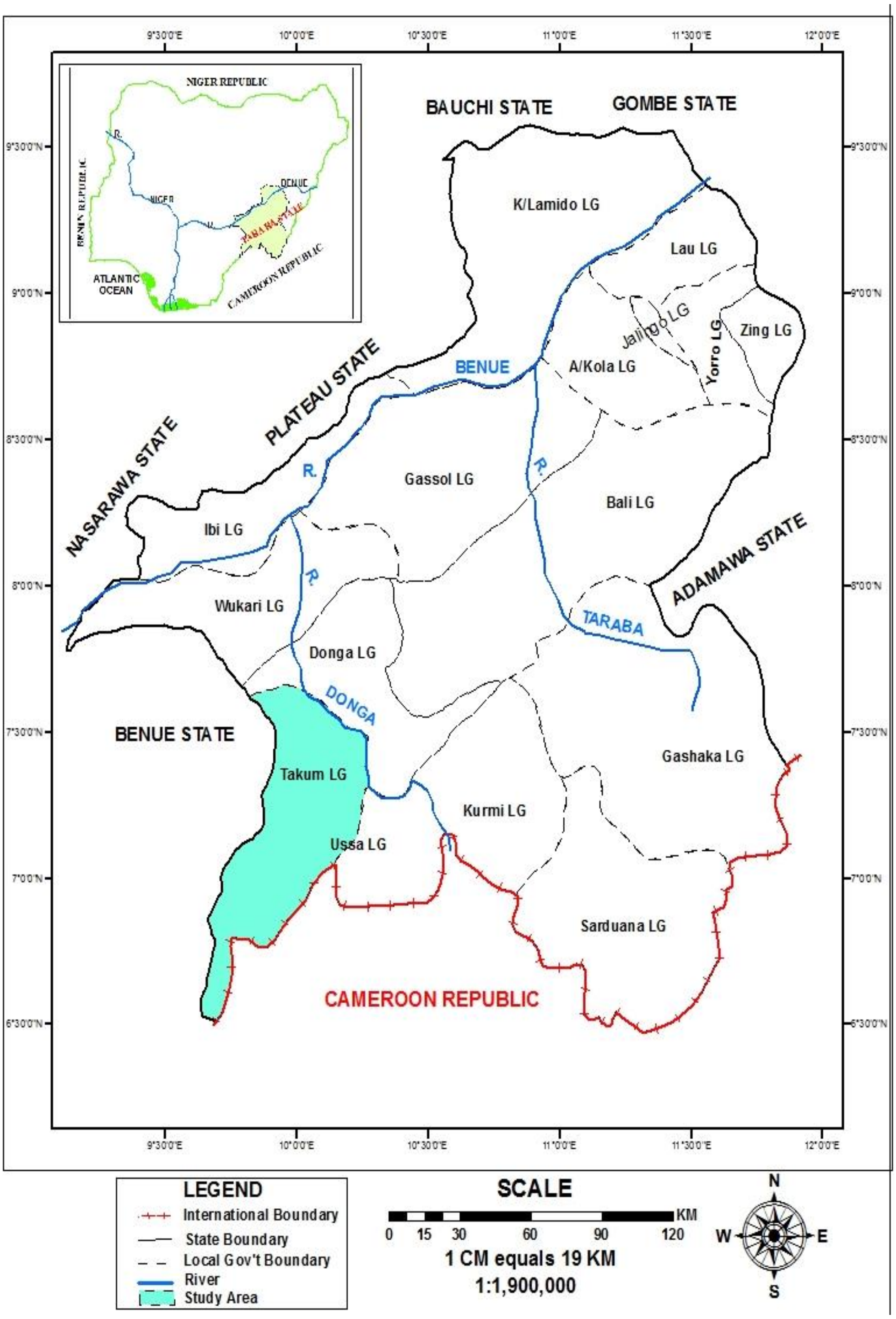

Fig 1

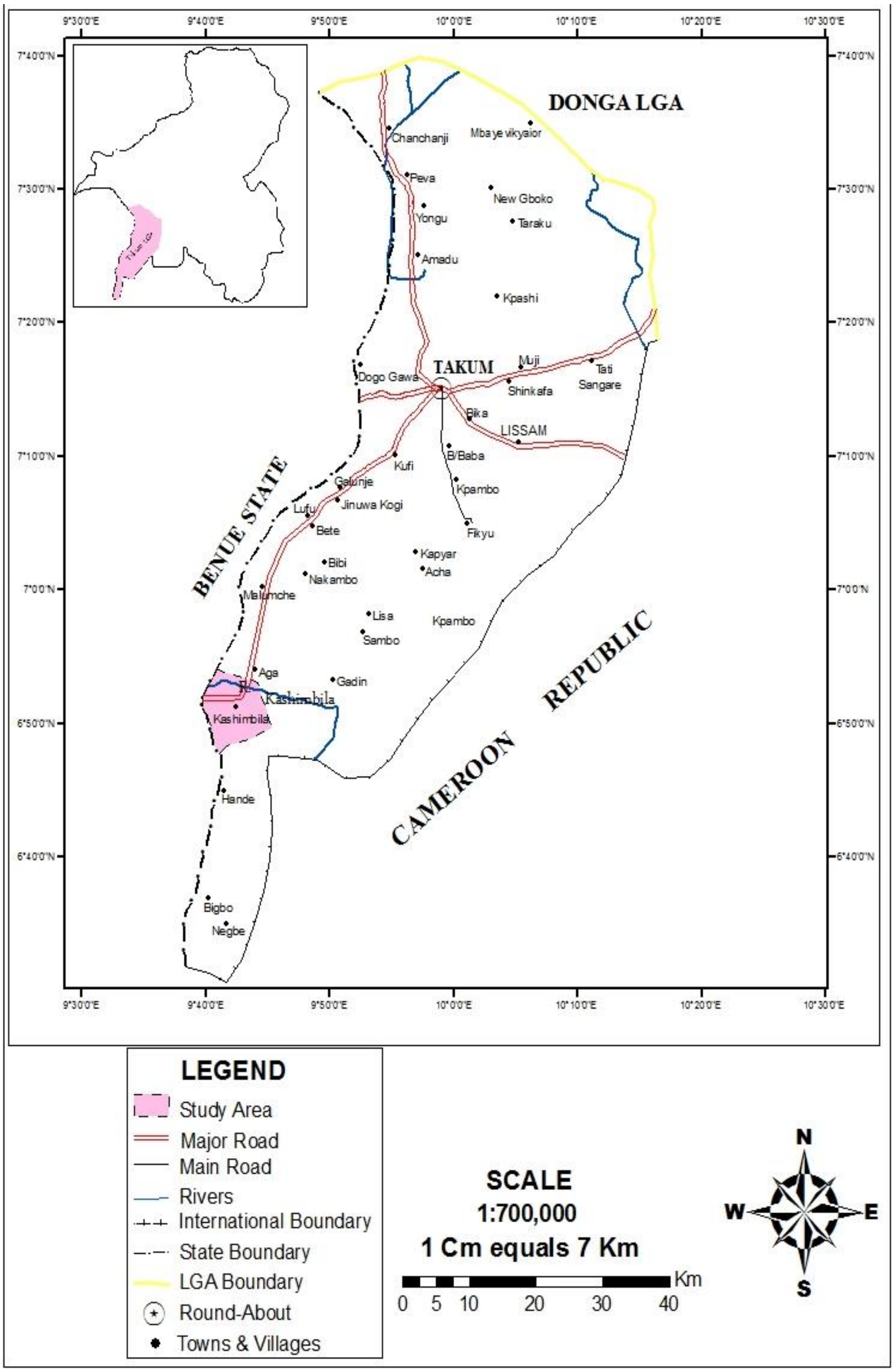

Fig 2

Sample Location

The samples were collected in three stations namely: Station A before the dam where fishing activities, farming, bathing and washing of clothes occur; Station B where the dam is built and Station C where irrigation, farming and cattle rearing were carried out.

Sample Collection and Analysis

Samples were collected once in a month for eight (8) Months (August 2016 - March 2017) Samples were collected from each station using plankton net of mesh size 55um by hauling the sampler horizontally, a distance of five (5) meters according to the method of Anene (2003). The resultant concentrated plankton samples were transferred into a plastic container and were fixed using 4% formalin and three drops of Lugol's solution was added according to the method of Boney (1983). The Lugol's solution was added for sedimentation of the organisms; this was leftover night for complete sedimentation to take place according to Li-li *et al.* (2014). Plankton was analysed in the Laboratory by pippetting 1ml of the sample and placing on a sedge-wick rafter-counting chamber with a cover slip and observed directly by the use of Olympus Microscope, a method described by APHA (2005) [6].

Phytoplankton population were estimated based on the number in each species. Phytoplankton consisting of individual cells, filaments and colonies were counted as individual cell in the sedge-wick rafter-counting chamber from the total count obtained and the count of species observed per specimen and the relative abundance of each taxa per sample were calculated.

Species Composition and Abundance

Species composition (%) was calculated as according to Eyo *et al.* (2013) follows: % SC = n (100)/N,

Where;

N = the total number of phytoplankton species in each taxonomic group.

N = the total number of phytoplankton species in all taxonomic group.

Shannon - Weiner Index

The (H) of the phytoplankton species within the different sites was determined using $H^1 = \Sigma$ (Pi) (Log_nP) (Magauran, 1988).

Where H^1 = Index of species, Pi = proportional of total sample belonging to the ith species and the i = the number of species.

Margalef index is by D = (S - 1)/Log_eN where: D = species richness index, S = number species in the samples and N = number of individuals in the sample.

Species Evenness

Evenness is given as: E = H/lnS where H = Shannon – Weiner's index and S = Number of species in sample (Pielou, 1966) [32].

Results

Thirty seven (37) species of phytoplankton were identified. Total abundance of n = 12,425 phytoplankton were recorded with six (6) phyla: Bacillariophyta, Chlorophyta, Cyanophyta, Pyrrhophyta, Euglenophyta and Chrysophyta. Phylum Bacillariophyta (n = 15) was the most dominant in terms of number of species followed by Chlorophyta (n = 14) then Pyrrophyta (n = 4) and the least were Chrysophyta and Cyanophyta recording (n = 1) each.

In terms of percentage abundance, Chlorophyta (n = 11793; 94.92%) was the most dominant, followed by Bacillariophyta (n = 273; 2.19%) and the least were Euglenophyta (n = 34; 0.27%), Pyrrhophyta (n = 41; 0.33%) and Chrysophyta (n = 45; 0.36%); Also *Spirogyra sp* (n = 3281; 26.41%) of phylum Chlorophyta was the most abundant followed by *Closterium sp* (n = 2,779; 22.3%) and *Volvox sp* (n = 2,519; 20.27%) then *Pediastrum sp* (n = 1,429; 11.50%) and the least was *Netrium sp* (n = 6; 0.05%). Bacillariophyta, *Bacillaria sp* (n = 89; 0.72%) was the most abundant followed by *Gyrosigma sp* (n = 51; 0.4%) and Pyrrhophyta, *Protoperidinium obtusum* was the most dominant and the least abundant species in among phytoplankton species were *Rhizosolenia imbricata* (n = 2; 0.02%) *Rhizosolenia sp* (n = 2; 0.02%), *Asterionella gracilis* (n = 2; 0.02%), *Procentrum micans* (n = 2; 0.02%) (Pyrrhophyta), *Leptomedusa sp* (n = 2; 0.02%) (Pyrrhophyta) and *Navicula sp* (n = 2; 0.02%) (Bacillariophyta).

Values recorded for Shannon Weiner Index, Margalef Index and Pielou Index (Evenness) at sites A, B and C were (1.28; 2.09; 1.69), (4.34; 4.53; 4.17) and (0.35; 0.58; 0.47) respectively.

Table 1: Phytoplankton Species Composition and Abundance in River Kashimbila

	Phytoplankton Taxa/Species	Site A	Site B	Site C	Total	%	Average
	(A)BACILLARIOPHYTA (Diatoms)						
1	*Synedra sp*	+	-	+	+	0.15%	6.33
2	*Bacillaria sp*	+	+	+	+	0.72%	29.66
3	*Asterionella sp*	+	+	+	+	0.12%	5.00
4	*Meridion sp*	+	-	-	+	0.02%	1.00
5	*Rhizosoleniaimbricata*	+	-	-	+	0.02%	0.66
6	*Surirella sp*	+	+	+	+	0.29%	13.00
7	*Fragillaria sp*	-	+	+	+	0.16%	6.66
8	*Asterionella gracialis*	+	-	-	+	0.02%	0.66
9	*Rhizosolenia sp*	+	-	-	+	0.02%	0.66
10	*Guinardia sp*	-	-	+	+	0.06%	2.66
11	*Tabelleria sp*	-	-	+	+	0.03%	1.33
12	*Gyrosigma sp*	+	+	+	+	0.41%	17.00
13	*Guinardia strata*	-	-	+	+	0.11%	4.66
14	*Licmorphora enrenbergil*	-	-	+	+	0.04%	1.66
15	*Navicula sp*	+	-	-	+	0.02%	1.00
	Total	+	+	+	+	2.19%	91
	(B) CHLOROPHYTA (Green algae)						
16	*Spirogyra rhizobrachialis*	+	+	+	+	26.41%	1093.66
17	*Pediastrum sp*	+	+	+	+	11.50%	476.33
18	*Hydrodictyon sp*	+	+	+	+	2.71%	112.33
19	*Volvox sp*	+	+	+	+	20.27%	839.66
20	*Netrium sp*	+	-	+	+	0.05%	2.00
21	*Rhizodonium sp*	+	-	+	+	0.18%	7.33
22	*Ulothrix sp*	+	+	+	+	0.20%	8.33
23	*Bulbochaete sp*	+	+	+	+	0.40%	16.66
24	*Oedogonium sp*	+	+	+	+	0.35%	14.33
25	*Scenedesmus quadricauda*	+	+	+	+	4.23%	175.33
26	*Micrasterias sp*	+	+	+	+	1.03%	42.66
27	*Cosmarium sp*	+	+	+	+	1.03%	46.00

28	*Closterium sp*	+	+	+	+	22.37%	926.33
29	*Zygnema sp*	+	+	+	+	4.19%	173.33
	Total	+	+	+	+	94.92%	3934.33
	(C) CYANOPHYTA (Blue -green)						
30	*Microcystis aeruginosa*	+	+	+	+	1.92%	79.66
	Total	+	+	+	+	1.92%	79.67
	(D) PYRRHOPHYTA (Dinoflagellates)						
31	*Protoperidinium obtusum*	+	+	+	+	0.27%	11.00
32	*Procentrum micans*	+	-	-	+	0.02%	0.66
32	*Protoperidinium excentrium*	-	+	-	+	0.03%	1.33
34	*Leptomedusa sp*	-	-	+	+	0.02%	0.66
	Total	+	+	+	+	0.33%	13.66
	(E) EUGLENOPHYTA (Euglenoids)						
35	*Euglena sp*	+	+	+	+	0.14%	6.00
36	*Euglena gracilis*	-	-	+	+	0.13%	5.33
	Total	+	+	+	+	0.27%	11.33
	(F) CHRYSOPHYTA (Yellow-green algae)						
37	*Vaucheria sp*	+	+	+	+	0.36%	15.00
	Total	+	+	+	+	0.36%	15.00
	Total Abundance	**3971**	**2824**	**5643**	**12425**	**100%**	
	Shannon Weinner index	**1.28**	**2.09**	**1.69**			
	Margalef index	**4.34**	**4.53**	**4.17**			
	Pielou index (Evenness)	**0.35**	**0.58**	**0.47**			

+ indicates presence, – indicates absence

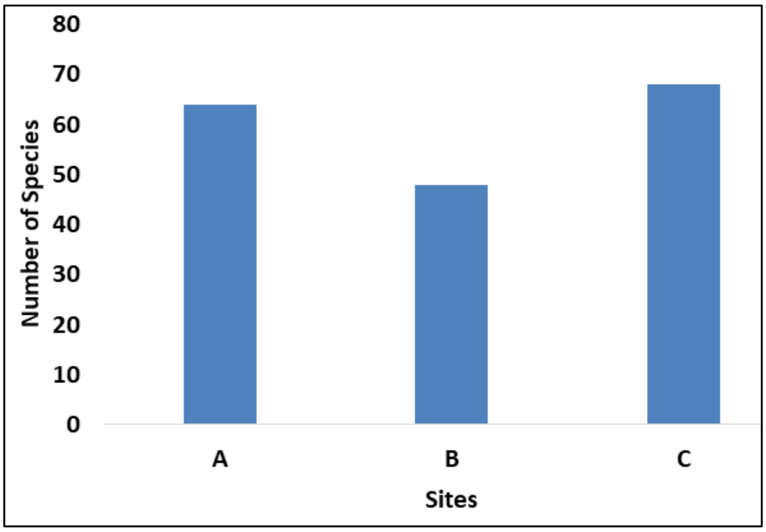

Fig 3: Abundance of Phytoplankton in River Kashimbila based on sites

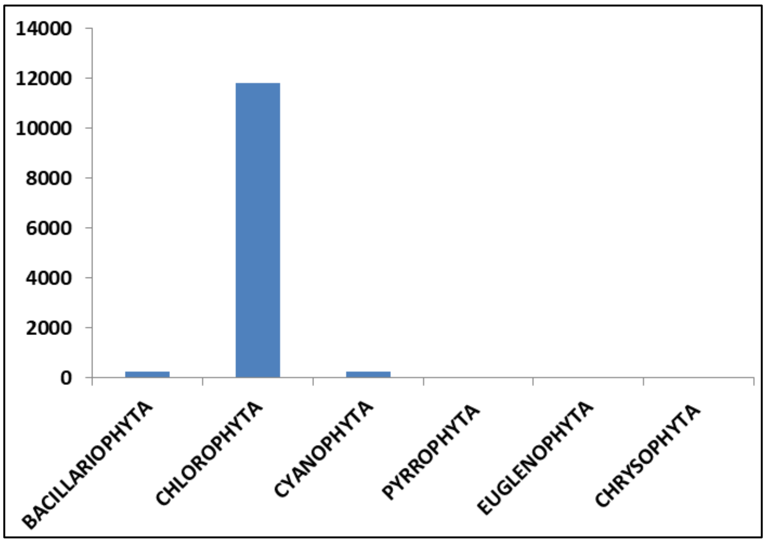

Fig 4: Abundance of Phytoplankton taxa in River Kashimbila based on phylum

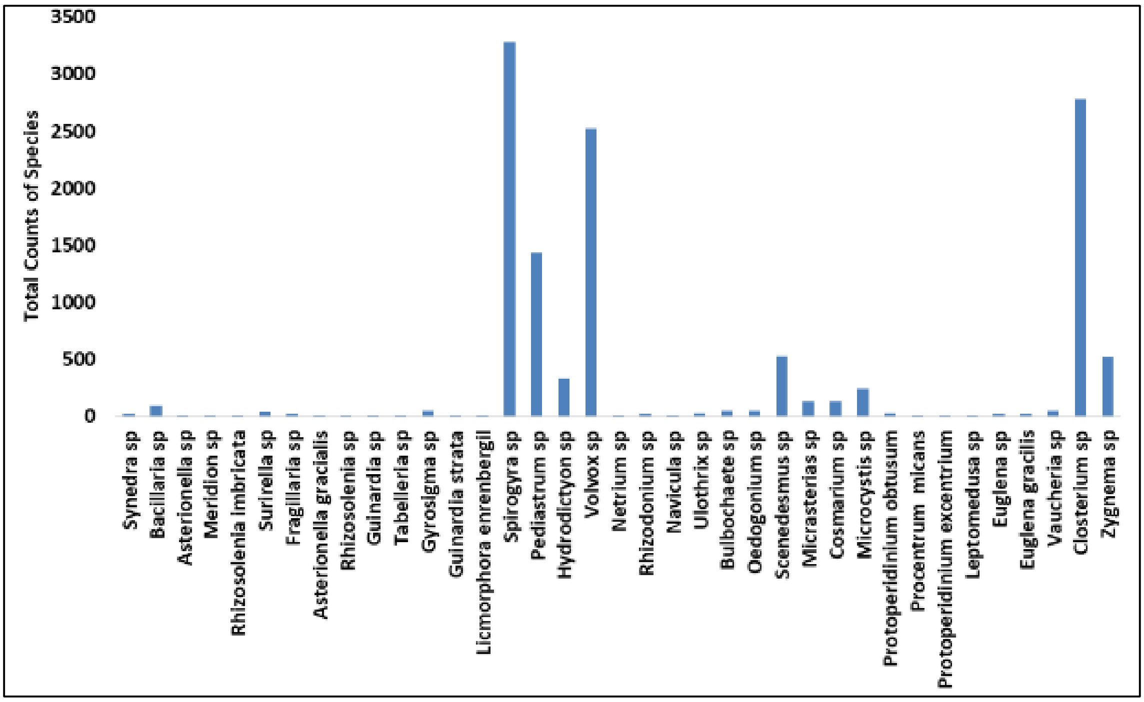

Fig 5: Abundance of phytoplankton Species in River Kashimbila

Table 2: Mean square of metals (Ca, Cu, Mg, Ma and Zn) for sites

Site	Means of Metals				
	Ca(mg/l)	**Cu(mg/l)**	**Mg(mg/l)**	**Mn(mg/l)**	**Zn(mg/l)**
A	0.11916^{a}	11.141^{a}	0.9453^{a}	4.9540^{a}	0.4583^{a}
B	0.6365^{a}	11.189^{a}	0.9655^{a}	2.4774^{a}	0.31879^{b}
C	0.3917^{a}	11.168^{a}	1.0585^{a}	2.5004^{a}	0.2149^{b}
WHO	75	2	0.5	0.5	3.00
BIS	75-200	0.05-1.5	30-100	0.1-0.3	5.0-15
USEPA	-	1.3	-	0.05	5.0
SE±	0.1228	0.0702	0.0443	2.4176	0.0777

*abcd values with the same letters in the column did not differ significantly at P<0.05
*WHO: World Health Organization (2006) *BIS: Bureau of Indian Standards Drinking Water Specifications (2012)
*USEPA: United States Environmental Protection Agency (2003)

Table 3: Mean square differences of metals (Ca,Cu,Mg,Mn and Zn) for the months of August 2016 to March, 2017

Months	Mean of Metals				
	Ca(mg/l)	**Cu(mg/l)**	**Mg(mg/l)**	**Mn(mg/l)**	**Zn(mg/l)**
Aug	0.0817^{c}	0.0000^{b}	0.3448^{e}	0.0607^{b}	0.0437^{c}
Sept	0.0553^{c}	0.000^{b}	0.3400^{e}	0.0810^{b}	0.0743^{c}
Oct	0.4720^{bc}	0.2063^{b}	0.8447^{h}	0.000^{b}	0.2593^{bc}
Nov	0.7390^{ab}	0.2503^{b}	1.2160^{c}	0.000^{b}	0.2423^{bc}
Dec	0.5493^{ab}	22.257^{a}	1.4593^{b}	0.9180^{ab}	0.7477^{a}
Jan	1.1260^{a}	22.003^{a}	1.6797^{a}	12.339^{a}	0.5343^{ab}
Feb	0.4753^{bc}	22.360^{a}	0.9750^{d}	6.5377^{ab}	0.2813^{bc}
March	0.5543^{ab}	22.220^{a}	1.0587^{cd}	6.5487^{ab}	0.4620^{ab}
WHO	75	2	0.5	0.5	3.00
BIS	75-200	0.05-1.5	30-100	0.1-0.3	5.0-15
USEPA	-	1.3	-	0.05	5.0
SE±	0.2006	0.1147	0.0723	3.9480	0.1268

*abcd values with the same letters in the column did not differ significantly at P<0.05
*WHO: World Health Organization (2006) *BIS: Bureau of Indian Standards Drinking Water Specifications (2012)
*USEPA: United States Environmental Protection Agency (2017)

Table 4: Mean square difference of physicochemical parameters (Alkalinity, Ammonia, CO_2, D.O, pH, Temp, Transparency and Conductivity) for sites

Means of Physicochemicals								
	Alkalinity (mg/l)	**Ammonia (mg/l)**	**CO_2 (mg/l)**	**D.O (mg/l)**	**pH**	**Temp. ^{O}C**	**Trans (NTU)**	**Conductivity µS/cm**
A	566.3^{a}	0.0203^{a}	4.02^{a}	3.9625^{a}	6.2275^{a}	25.375^{a}	0.9050^{a}	504.79^{a}
B	571.8^{a}	0.0320^{a}	5.20^{a}	3.7875^{a}	5.9187^{a}	25.625^{a}	0.3900^{b}	438.84^{a}
C	689.6^{a}	0.0339^{a}	9.24^{a}	3.8250^{a}	5.9012^{a}	25.625^{a}	0.7300^{ab}	429.63^{a}
WHO		-		5.00	6.5-8.5	25	5.00	50-1500
BIS	200-600	0.5	-	-	6.5-8.5	-	5-10	-
USEPA	-	-	-	-	6.5-8.5	-	-	300
SE±	86.02	7.359	4.054	0.2087	0.2062	0.5428	0.1654	52.561

Mmmm m*abcd values with the same letters in the column did not differ significantly at P<0.05
*WHO: World Health Organization (2006) *BIS: Bureau of Indian Standard Drinking Water Specifications (2012) *USEPA: United States Environmental Protection Agency (2017)

Table 5: Mean square differences of physicochemical parameters (Alkalinity, Ammonia CO_2, D.O, pH, Temp, Transp and Conductivity) for the Months of August 2016 to March 2017

Means of Physicochemical parameters for months								
	Alk (Mg/l)	**Ammo (mg/l)**	**CO_2 (mg/l)**	**D.O (mg/l)**	**pH**	**Temp ^{O}C**	**Trans (NTU)**	**Conductivity µS/cm)**
August	283.7^{d}	0.016^{b}	0.0012^{b}	4.0667^{ab}	5.5900^{b}	23.000^{c}	0.2400^{c}	502.00^{ab}
Sept	743.3^{bc}	0.026^{b}	0.0235^{a}	4.1333^{ab}	5.8367^{ab}	25.667^{bc}	0.2567^{ab}	677.20^{a}
Oct	400.0^{cd}	0.023^{b}	0.0011^{b}	2.9000^{d}	5.8333^{ab}	24.667^{bc}	0.4867^{ab}	360.00^{b}
Nov	406.7^{cd}	0.027^{b}	0.0018^{b}	2.5800^{d}	5.5000^{b}	24.000^{c}	0.6100^{ab}	476.00^{ab}
Dec	506.7^{cd}	0.026^{d}	0.0015^{b}	5.6000^{bc}	6.4000^{ab}	24.000^{c}	1.0667^{ab}	310.00^{b}
Jan	596.7^{cd}	0.029^{b}	0.0054^{ab}	4.8333^{a}	6.6667^{a}	28.000^{a}	0.6533^{ab}	340.99^{ab}
Feb	886.7^{ab}	0.065^{a}	0.0089^{ab}	4.0333^{ab}	6.3667^{ab}	27.000^{ab}	1.0967^{a}	497.50^{ab}
Mar	1050.0^{a}	0.0097^{b}	0.0060^{ab}	4.2667^{ab}	5.9333^{ab}	28.000^{a}	0.9900^{ab}	497.50^{ab}
WHO	-	-		5.00	6.5-8.5	25	5.00	50-1500
BIS	200-600	0.5	-	-	6.5-8.5	-	5-10	-
USEPA	-	-	-	-	6.5-8.5	-	-	300
SE±	140.80	0.0120	0.621	0.3408	0.3367	0.8864	0.2702	85.831

*abcd values with the same letters in the column did not differ significantly at P<0.05
*WHO: World Health Organization (2006) *BIS: Bureau of Indian Standard for Drinking Water Specifications (2012) *USEPA: United States Environmental Protection Agency (2017)

Discussions

Phytoplankton Species Composition and Abundance

Bacillariophyceae was the dominant species in terms of species composition and abundance. This could be as a result of its ability to survive and adopt wide range of ecological conditions and physicochemical parameters. The dominance of Bacillariophyceae could also be an indication of water quality and eutrophic environment. This agrees with the work of Aneni and Hassan (2003) [4] who reported that Bacillariophyceae can adapt to a wide range of physicochemical parameters. This also agrees with the finding of Arimoro *et al.* (2008) [8] who reported that Bacillariophyceae and Chlorophyceae were the most abundant phytoplankton in Orogodo River in Nigeria. Bellinger and Siegee (2010) reported that diatom (Bacillariophyta) abundance is a characteristic feature of a eutrophic environment. Wackstrom *et al.* (1997) [46], Kelly (1998) [25] and Ajuonu *et al.* (2011) [5] also reported that the qualitative and quantitative dominance of diatoms in an aquatic ecosystem is a major indicator of water quality and environmental condition as they are adapted to a wide range of physicochemical parameters.

Chlorophyceae was the second in dominance due to the high light intensity especially from the months of November to March which is the characteristics of the tropics, the isotherm of lake stratification, nutrient availability and adaptation to wide range of physico-chemical parameters. This also agrees with finding of Ajounu *et al.* (2011) who recorded the abundance of Chlorophyceae in Bonny River. Fonge *et al.* (2012) [20] reported on abundance of Chlorophyceae in Ndop wetland plain as a result of their adaptation to a wide range of physicochemical parameters. Asha *et al.* (2015) recorded abundance of Chlorophyceae in Silva (2005) [38] related that abundance of Chlorophyceae were due to high light intensity characteristic of the tropics and the isotherm of water column which favour the development of Chlorophyta.

In terms of species abundance, *Spirogyra sp* leads followed by *Closterium sp*, then *Volvox sp*.The abundance of spirogyra is due to availability of nutrient and indication of unpolluted water. This is agrees with Ariyadej *et al.* (2004) [9] who reported that spirogyra abundance was related to increase in nutrient concentration of the water. This also agrees with Jose *et al.* (2008) [23] who revealed that the occurrence of some desmid like Closterium indicate a better water quality of the water bodies.

The predominance phytoplankton in dry season (between December, February and March) than the raining season (between August and November) could be due to the effects caused by high velocity of the river as the water current was high during the raining season which inhibited plankton development as well as the effect of water dilution (less nutrient concentration). In January, it could be as a result of the cold harmattan winds. The abundance, quality of life and species richness are influenced by current velocity as stated by Crayton and Sommerfields (1979) [16] in tributaries of Colorada Rivers. Abundance of plankton during the dry season is attributed to bright sunshine, isothermal water column and extensive catchment area (Adeniyi, 1978) [3].

River Kashimbila is rich in phytoplankton based on the value obtained from Shannon Weinner diversity index which ranged from 1.28 to 2.09 indicating that phytoplankton communities are heterogeneous and the water is moderately clean. Values of less than 1 (< 1) are interpreted as heavily polluted, (1-3) as moderately polluted and greater than 3 (> 3) as clean water (Whitton, 1975). The report from the present study is similar to Dewan *et al.* (2012) [18] who reported on heterogeneous plankton community in Rivers of Bangladesh. The values obtained for eveness or Pielou Diversity Index (Eveness) which ranged from 0.35 to 0.58 suggests that phytoplankton communities were not even. Values greater than or equal to 0.8 are usually considered as indicator of equitability in communities (Dagets, 1976) [17].

Composition and Abundance of Plankton in Relation to Physico-chemical Parameters.

Table 4, showed the mean square differences of physicochemical parameters identified from the three different sites (A, B & C). The means of physicochemical did not differ for the three (3) sites except for transparency, where there was significant (P<0.05) differences between sites A (0.9050) and B (0.3900). This could be due to human activities such logging, transportation of farm produce, fishing, laundry, irrigation and bathing which may have added to the turbidity experienced in sites A and B. The results obtained indicate that the values were above WHO measured standard of 5NTU but fell within range of FAO irrigation water quality guideline value of 35 NTU. Therefore, the present study suggests that the water is not safe for drinking but could be used for irrigation purposes (WHO, 2006 and Ayers and Wescot, 1985) [10].

The physicochemical parameters based on months revealed that alkalinity was dominant in the month of March but least in August. It means alkalinity increase with decrease in quantity of water; it could be as a result of the carbonate rich soil and rock and anthropogenic activities. Alkalinity also neutralizes high concentration of acid; regulate pH range so as not to be lethal to aquatic life. The acceptable limit of alkalinity is 200 mg/l and in the absence of alternate water source, alkalinity of up to 600 mg/l is acceptable for drinking (Patil *et al.*, 2012) [30]. On the contrary, Boyd and Lichtkoppler (1979) [14] suggested that water with total alkalinities of 20 to 150 mg/ L contain suitable quantities of carbon dioxide to permit plankton production for fish culture.

The presence of ammonia was highly significant in the dry season ($P<0.05$) in February (0.065) compared to the rest of the months. This could be one of the reasons why there was high production of plankton in this season and months probably due to the fast ammonia uptake by phytoplankton, particularly Bacillariophyceae species. The relatively low ammonia concentrations from August to January may be attributed to high biological activities as nitrogen presence stimulates plankton communities. This agrees with Turano *et al*. (2008) [45] on high affinity ammonium uptake by Cyanobacteria.

The presence of ammonia could be an indication of pollution. In the present study, ammonia ranged from 0.0097 to 0.065mg/l which was below 0.5mg/l (BIS-1991). It was suggested that pollution level of ammonia in the water was very low therefore aquatic life would be supported.

Free carbon dioxide was significantly high in September (0.0235), this could be due to respiration, and the free CO_2 released during respiration reacts with water, producing carbonic acid (H_2CO_3). It could become more acidic which some species of plankton might not survive it. On the contrary Hinga (2002) [22] reported that high pH leads to high phytoplankton production and low oxygen concentration. The rise in carbon dioxide makes it more difficult for fish to use the limited amount of oxygen present. William and Robert (1992) [50] reported that high CO_2 concentrations are almost always accompanied by low dissolved oxygen concentrations.

In the present study there was low concentration of dissolved oxygen in the months of October and November, which could be due to run-offs from farm fields containing phosphates and nitrates and this affects, the growth of many aquatic lives. This agrees with Wetzel (1983) [47] who reported on the importance of DO to water quality assessment, and physico-chemical and biological processes prevailing in water which also affects the solubility and availability of many nutrients and, thus, has impact on the productivity of an aquatic ecosystem. However, the significant difference in the months of February, March, August and September was due to photosynthetic activities of phytoplankton.

Bais and Agarwal (1990) [11] reported that DO concentrations within a water body can experience large daily fluctuations. Aquatic plants and algae produce oxygen as a by-product of photosynthesis by day, but at night, they consume oxygen through respiration.

The high concentration of pH in the months of August – November was due to lack of high alkalinity concentration which is effective as a buffer to fluctuating of pH which might be caused by introduction of waste water and other metabolic processes. Tanimu *et al*. (2011) [42] reported that alkalinity concentration is an effective buffer for pH. Thus, the pH range obtained in this study was from 5.50 - 6.66 which was not higher than the recommended level of 6.5 -8.5 but within the range which is good for drinking water (WHO, 2006). Fluctuations of pH affect reproduction and cause death in many aquatic organisms (Boyd, 1979) [14]. The change of pH could be due to the inflow of chemical from the dam construction site, disposal of domestic and farm wastes, run-off from agricultural fields and cattle dung. This agrees with Abel (1996) who reported that even though the pH of 5–9 is not directly harmful to aquatic life, such changes can make many common pollutants more toxic. Satpathy *et al.* (2009) [37] also recorded that pH of water also depends upon relative contents of free CO_2, carbonates, bicarbonates and calcium. The water tends to be more alkaline when it possesses carbonates, but lesser alkaline when it supports more bicarbonates, free CO_2 and calcium. The high concentration favoured high phytoplankton production between January - March. This agrees with Hinga (2002) [22] who reported that high pH leads to high phytoplankton production and low oxygen concentration.

The mean temperature range of the present study was between 23- 28°C for months while mean square for sites was 25.625°C therefore, it is good for plankton production. This is in agreement with Effendi (2003) who reported that optimum temperature for phytoplankton growth ranged from 20 – 30°C. The significant variations in temperature between the wet and dry seasons were the reasons for plankton abundance in the water as shown by the high significance during the dry season. According to Kagalou *et al*. (2001) [24], chlorophytes increase under high temperature. Therefore, water temperature increases the rate of molting, brooding and reproduction in water (Wetzel, 1983) [47].

The temperature in the month of March ranged between 28-30°C which favoured high reproduction of *Volvox sp*, *Spirogyra sp* and C*osmarium sp.* This agrees with the different species that showed varied tolerances to increases or reductions in temperature ranges, and particularly sensitive individuals are eliminated by them (Andrulewicz *et al*., 2008; Tunowski, 2009) [7, 44].

On the contrary, the temperature obtained for three sites are within the natural background level of 22-30°C for water in the tropics (Stumm and Morgan, 1981) [41] but slightly above the limit of 25°C allowed for WHO drinking water standard.

The turbidity in August (0.2400) was significantly higher than other months, this could be due to the high velocity of water transporting debris or suspended particles, but the water became more transparent (less turbid) from December to March therefore, there was relatively equal reception of sun light and this could be the reason for the abundance of plankton in the dry season. Increase in water turbidity, increases water temperature because suspended particles absorb more heat. This in turn reduces the concentration of dissolved oxygen because warm water holds less dissolved oxygen than cold water (Abubakar, 2006) [1]. Suspended materials can clog fish gills reducing resistance to disease, lowers growth rates and affects egg and larva development (Sterling, 1985) [40]. However, the water may not be safe for drinking as the values obtained exceeded the WHO standard for drinking water (5NTU) but could be used for irrigation as the values obtained in the present study is within the range FAO recommended 35 NTU (Nephelometric Turbidity Unit) guidelines for irrigation.

Conductivity (µs/cm) is referred to as ability of liquid to transmit heat, electrical charges and also the measurement of ionic strength. Conductivity measurement of this present study ranged from 310 – 677.20 µS/cm and the analysis of variance showed significant difference between the months. However, most streams conductivity range between 50 to 1500 µS/cm. Freshwater streams ideally should have conductivity between 150 to 500 µS/cm to support diverse aquatic life (Abowei, 2010) [2]. The high values in August and September were (502.00 and 677.20) which could be due to high contamination from domestic activities such as bathing, washing, deposit of refuse and agricultural run-off. On the contrary, there were no significant effects of conductivity on phytoplankton abundance and diversity despite high mean value in September. This could be that some strains of phytoplankton are resistant to conductivity changes and tolerant to increase in conductivity. Flöder *et al.* (2010) [19] reported resistance of some phytoplankton to saltwater and sensitive to conductivity changes.

Composition and Abundance of phytoplankton in relation to metals

The concentration of Calcium ranged from 0.0472 to 1.1260mg/l which is below the mean value of WHO permissible limit for drinking water of 75.0mg/l but with significant concentrations in November, December, January, February and March, it means concentration of Ca become stronger with water level. Porter, 1983 [33], Hessen *et al.* (2000) [21] and Rukke (2002) [36] reported that calcium (Ca) concentrations are influence by anthropogenic activities such as forest harvesting and, removal of timber followed by several cycles of regrowth of forests results in a decline of calcium (Ca) in soils and, consequently, a decline in the amount of calcium (Ca) that reaches the river via run-off process.

The mean concentration of copper (Cu) ranged from 0.000 to 22.360mg/l in this present study. For August and September it was beyond detection limit but from November to March above WHO permissible limit of 2.0mg/l (WHO-2006). This could be as a result of dilution and may be heavy leaching of pipes and other activities from the construction site or the dam. Ingesting large amount of copper can cause death and kidney and liver failure. High levels of copper in drinking water can cause vomiting, abdominal pain, nausea, diarrhoea, high blood pressure and chronic anaemia. However, low concentration of copper in water is not inimical to the growth of the phytoplankton. Riley (1939) [35] reported that at low concentrations copper is beneficial to phytoplankton growth, while at high concentrations copper is toxic and can affect the abundance of plankton.

The significance presence of Magnesium all through the months could be as a result of its relevance of being an essential component. It ranged from 0.344mg/l to 12.339mg/l above WHO permissible limit of 0.5mg/l, the content of magnesium in drinking water in various countries was found to range between 0 and 111 mg/l Maheswaran *et al.* (1999) [27]. Therefore, it suggests that the concentration of magnesium may not be dangerous to health and safe for irrigation.

Manganese is one of the basic limiting nutrients for phytoplankton growth and development. On the contrary, Dawes (1998) observed that the iron and manganese are thought to be in low demand to limit growth of plankton. The mean concentration of Manganese in this study ranged from 0.000 – 12.339mg/l higher than the WHO (0.5mg/l) permissible limit suggesting high concentration which have little limiting effect on plankton growth and abundance.

Zinc ranged from 0.2423 – 0.7477 lower than the WHO permissible limit of 5.0 – 15mg/l which were negligible and of no significance in the present study except for their presence in dry season. However, the presence of Zinc in high concentration inhibits daphnia uptake of calcium resulting in reduced total calcium body content of the organisms. When calcium reduction is severe the organisms die of hypocalcaemia (Brita *et al*. 2016) [15].

Conclusion

Phytoplanktons are also an important source of pollutant transfer from water to upper tropic levels and to humans, affect global temperature and formed the base of food pyramid.

The study showed that spirogyra is the most dominant species; diversity, abundance and distribution of species were greatly influenced by season and sites as well as the physico-chemical parameters.

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