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Original article

Phytoplankton diversity as index of water quality in the Umuaja Watershed of Ethiope River, Delta state, Nigeria

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ABSTRACT

Phytoplankton composition, abundance, diversity indices and water quality parameters were monitored for twenty-four months to assess the health status of River Ethiope at the source in the Umuja watershed following standard methods. The physicochemical parameters indicated an oligotrophic system. The phytoplankton structure was composed of Chlorophyta with 55 species constituting 34.16%, Bacillariophyta 48 species (29.81%), Cyanophyta 45 species (28.0 %), Euglenophyta 7 species (4.35 %), Rhodophyta (2.48 %), Xanthophyta and Chrysophyta had 0.62 % each different from numerical structure (Cyanophyta accounting for 45.0% of 711 individuals, Bacillariophyta (41.63%), Chlorophyta (11.25%), Centrales (1.12%) and Euglenophyta (0.98%)). The phytoplankton taxa were diverse and quantitatively low. The coefficient factors and factor analysis of phytoplankton abundance indicated the influence of air and water temperatures, total solids, TSS and TDS, nitrate, sulphate and phosphate ($p < 0.05$) on its composition and abundance. Low diversity indices (0.00 - 1.277) and the abundance of organic loving and toxins producing organisms are signatories to organically polluted water body. However, the presence of freshwater species despite biological signs of pollution indicates the system's resilience and possible recovery with adequate sanitary awareness or sensitization.

Keywords: Phytoplankton composition, abundance, Ethiope River and Diversity indices.

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INTRODUCTION

Phytoplankton diversity indices have been employed in assessing the health integrity of aquatic ecosystems following the hypothesis that phytoplankton species richness, composition, structure and abundance are influenced by the predominant environmental factors. This is due to the promptitude response of phytoplankton to changes in aquatic ecosystems, favouring the prevalence of certain species than others (Silva and Costa 2015). According to Rostamian *et al.*, (2015), this habitat (ecological)

influence on phytoplankton characterization is due to different adaptability and tolerance to different prevailing environmental conditions.

Nditurú *et al*., (2003) and Holmes and Taylor, 2015) also noted that phytoplankton characterization will not only infer water quality but health impairment, threatened aquatic ecosystem as well as identify problem - causing algae (Gulecal and Temel 2014; Riediger, 2015; Silva *et al*., 2015, Chen *et al*., 2016). Thus Qu *et al*., (2016) opined that the use of species diversity, composition, abundance, interdependence with one another and environmental variables is a better tool for assessing ecosystem health than any other technologist's tool. In other words, assessing the changes in phytoplankton composition, abundance and biomass infers the degree of impact of natural and human activities on the altered aquatic ecosystem (Silva and Costa 2015; El Otify and Iskaros, 2015; Sharma *et al*., 2016). Therefore, the exposure of plankter communities to any deleterious environmental condition will either increase or decrease their composition and abundance and possibly lead to deleterious health hazard in man once the water quality is compromised (Holmes and Taylor, 2015).

Umuaja watershed has been under intensive traditional threat for a long time arising from its importance in the community's traditional religion and worship (Iloba, 2012). Umuaja watershed is considered sacred and attracts traditional worshippers from the neighbouring communities as this section of the river is considered the citadel of power of the river's goddess "*Onuku*". Materials for such rites such as dead animals, cowries, white chalk and blood of the animals offered to the river goddess "*Onuku*" are thrown into the river for acceptance (Iloba, 2012). This study area also attracts spectators and also has been proposed a tourist/ recreational spot because of the belief that the river issues from under tree.

In this study, phytoplankton composition, abundance and diversity indices will be used as an index to assess this section of the river's water quality.

MATERIALS AND METHODS

Study Area

Umuaja watershed is the source of Ethiope River in Delta State and is believed to drain from a rock underlying a "sacred tree". The study area is located at approximately latitude 5˚57' and longitude 6˚14' which is about 150 feet away from the Umutu – Nsukwa express road, Ukwuani LGA (Fig. 1) with the terrain gently sloping towards the river. This section of river Ethiope is very shallow with less than 1 meter depth and about 1.5m wide. The bottom is exposed with varying pebble units. The study area is covered with trees, forming canopies over the water body. Routinely sacrifices are performed by the river goddess faithful who believe in her powers for protection, fruitfulness and the likes. These activities give the study area a filthy look as items such as dead animals, white chalk, calabashes etc are dumped indiscriminately in and around the river (Iloba, 2012). These materials eventually find their way into the river particularly during the rains. During the rains, the river receives large runoff from the terrain which gently slopes into the river. The area experiences two climatically distinct seasons annually; a rainy season from April to October and a dry season from November to March (Odum and Oradiwe 1997).

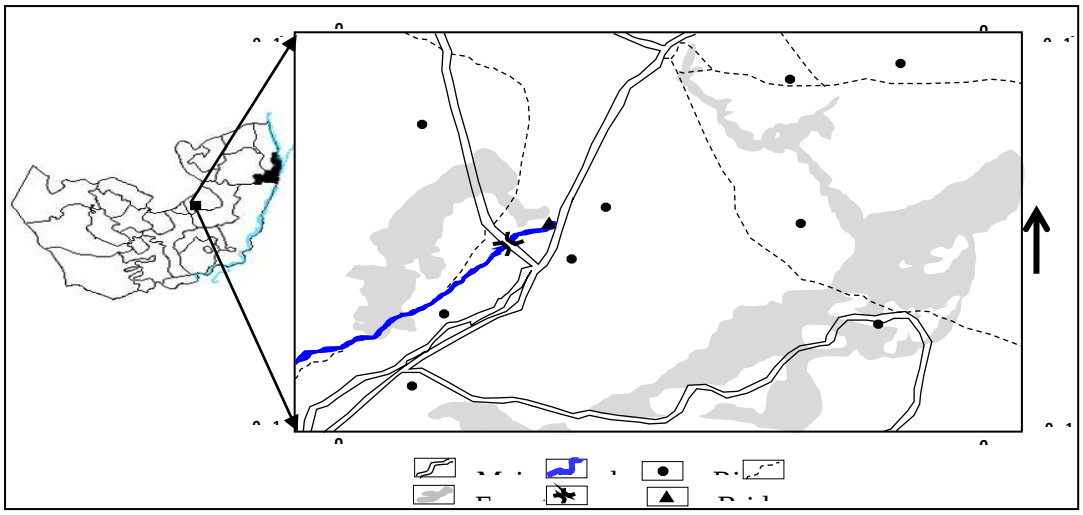

Fig 1: Map of study area (index map of Delta State)

Sampling and Analysis

The source of Ethiope River at Umuaja is the sampling station of this study (Fig, 1). Water samples were collected and analyzed monthly for twenty-four consecutive months from February 2003 to January 2005.

Limnological parameters such as Total solids, Total SS, and TDS, Alkalinity, Chloride, Sulphate , Phosphate, Nitrate, Nitrite, Potassium, Sodium, Calcium , Magnesium , Total iron, Lead , Chromium, Copper(mg/l) were analyzed in the laboratory according to APHA (1990) while air and water temperatures, transparency, depth conductivity, pH were determined on site using mercury in glass thermometer (0-110C), black and white Secchi disc (25cm diameter), graduated pole (meters), conductivity(model DDB/303A) and pH meters (Hanna hand pH meter) respectively. Samples for dissolved oxygen were collected using 100ml glass bottles as described by Winkler's method in APHA (1990).

Composite qualitatively phytoplankton samples were collected using 25µm Hydrobios plankton tow net, towing from a large cross sectional area of the river source due to the small dimension to determine phytoplankton composition while the quantitative samples were obtained by filtering 100 litres of water with the same net size to determine the number of phytoplankton in a known water volume. All algological samples were preserved with 5% formaldehyde and taken to the laboratory. In the laboratory, the samples were concentrated and viewed under Olympus binocular microscope and all phytoplankton species encountered were routinely identified using relevant standard literatures (Wehr and Sheath, 2003) and counted. Phytoplankton quantitative counts were carried out on a grid with three repetitions for each sample; the values were presented in number per ml of sample.

Data Analysis

Some physicochemical parameters were log transformed to normalize differences in values, units and allow comparison. Data with zero and negatives values cannot be transformed and as such were removed. The Descriptive statistics (mean standard error and coefficient of variations) and Pearson correlation between the phytoplankton abundance and physico-chemical parameters was calculated with using Statistix 8.

PAST statistical software was used to calculate the eight diversity indices used in this study. These indices include species richness, abundance (Individuals), dominance_D, Simpson's_1-D, Shannon_H, Evenness_e^H/S, Margalef, Menhinicks and equitability_J. The Phytoplankton data were first log transformed to dampen the effect of the most occurring species. The Principal component analysis was applied to identify the underlying evaluative limnological dimensions of the water parameters in the study section and also the interconnectedness between the physicochemical parameters and the phytoplankton group using the scattered plots which were done using the PAST statistical software (Hammer *et al.*, 2001). The Euglenophytes were eliminated due to predominant zero occurrence.

ESULTS

Physicochemical Variables

The means of the investigated physiochemical variables with quartile box plots and associated median during the twenty-four months study period are presented in Fig. 2. Figure 2 also presents temporal changes in these parameters. Limnological and biological changes were evident particularly sulphate, nitrate, phosphate and phytoplankton during the study from February 2003 – January 2005 (Fig. 2). Other variables were generally low in concentration

The range, mean and coefficient of variation (significant at 40%) of the physicochemical variables are given in Table 1. The temporal monthly values of all limnological parameters (Fig 2) were significantly different ($p < 0.05$) except calcium ($P = 0.3929$) and magnesium ($p = 0.1245$) despite the generally low values of other variables recorded. The pH of the study varied within the acidic range (4.9 – 6.9)

Species composition and Abundance

The study revealed different community structure in relation to numerical abundance and species composition.

A total of 157 phytoplankton species belonging to seven taxonomic classes were recorded at the study site. The largest community in terms of species composition (qualitatively) was Chlorophyta with 52 species constituting 33.12% of the total phytoplankton species. Bacillariophyta 51 species (32.48%), Cyanophyta 41 species (26.11%), Euglenophyta 8 species (5.10%), Rhodophyta 3 species (1.91%), Xanthophyta and Chrysophyta were rare with one species (0.64%) each (Table 2). The study site revealed diverse phytoplankton species composition but were quantitatively low (Fig.3). The phytoplankton counts varied between 1 – 4 organisms per ml except on few occasions as shown in Fig.3.

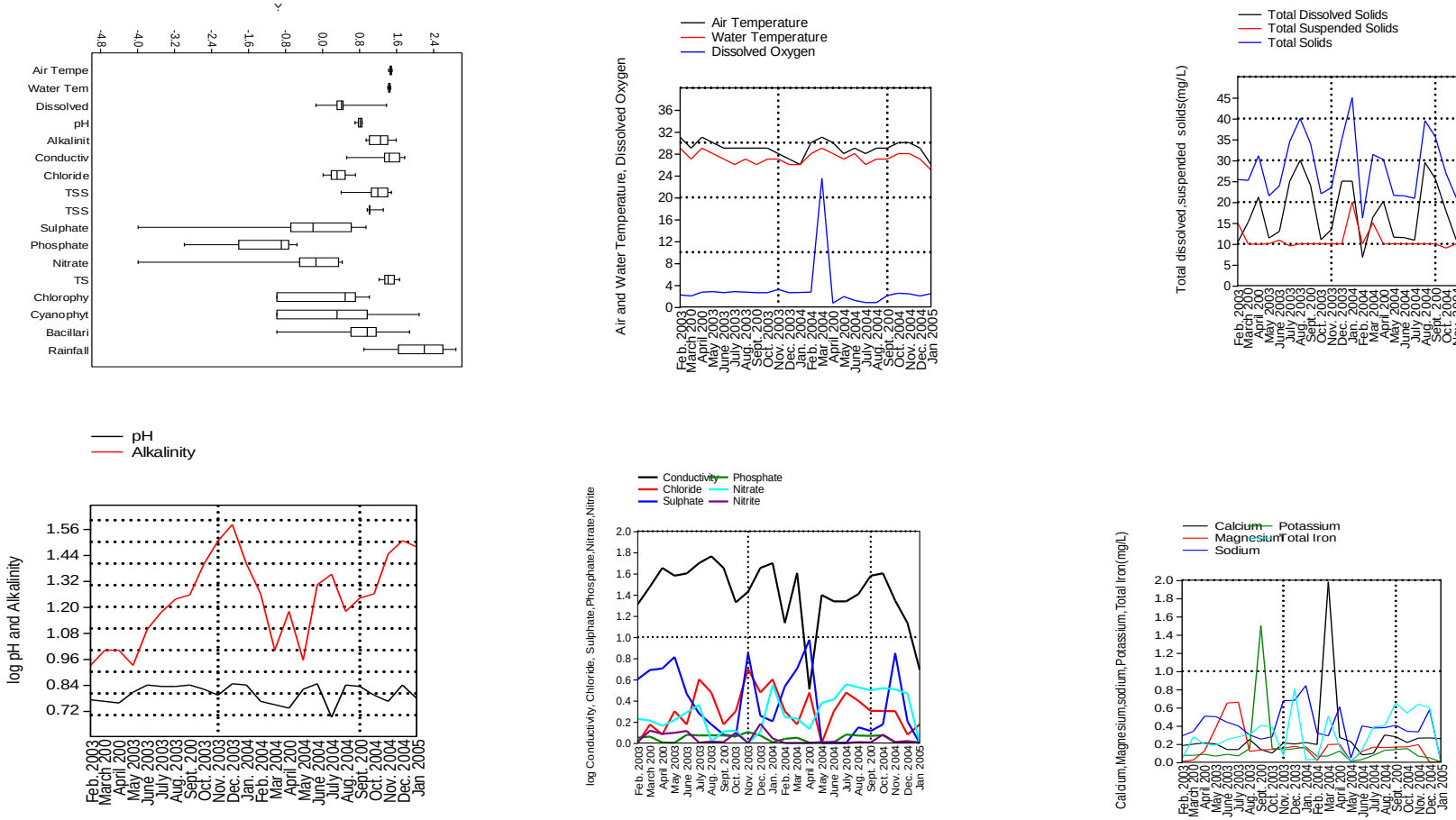

Fig. 2: Bar Charts of means with quartile box plot with median of physiochemical variables and temporal variation of the studied limnological parameters investigated during the study from February 2003 – January 2005.

Table 1: Range, mean values of physicochemical variables investigated during Umuaja Watershed during the investigated period

Parameters	Range of Variation	Mean	Coefficient of Variation
Air temperature ^{o}C	26 – 31	29.5	4.7
Water temperature ^{o}C	25 – 29	27.2	3.9
Transparency m	0.00	0.0	0.000
Depth m	<0.5	0.3	0.000
Conductivity µS/cm	3.22 – 58	30.8	47.6*
Hydrogen-ion concentration	4.9 – 6.9	6.3	9.5
Total solids mg/l	16.8 – 4.5	28.1	27
Total suspended solids mg/l	9.0 – 20.0	11.0	23.1
Total dissolved solids mg/l	2.46 –30.0	17.0	43.7*
Dissolved oxygen mg/l	0.7 – 23.5	3.1	41.7*
Alkalinity mg/$CaCO_3$	8.5 – 38.0	46.7	612.1*
Chloride mg/l	1.0 – 5.01	2.2	46.5*
Sulphate mg/l	0.0 – 8.46	2.1	117.1*
Phosphate mg/l	0.0 – 0.27	0.11	75.8*
Nitrate mg/l	0.0 – 2.592	1.1	80.4*
Nitrite mg/l	0.0 – 0.52	0.1	140.4*
Potassium mg/l	0.003 – 1.5	0.2	192.2*
Sodium mg/l	0.012 - 0.843	0.4	47.0*
Magnesium mg/l	0.0 - 0.66	0.2	99.9*
Calcium mg/l	0.1 - 2.0	0.3	134.0*
Total iron mg/l	0.0 - 0.805	0.3	76.1*

The monthly variations in the abundance of the five major taxa of phytoplankton in this study are represented in Figure 3.

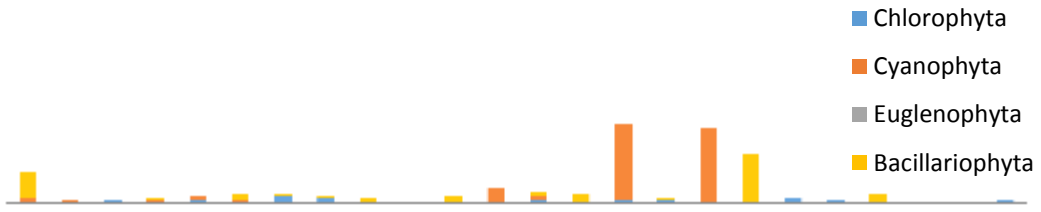

Fig 3: Temporal variation of the Major phytoplankton during the study from February 2003 – January 2005.

Quantitatively, the class cyanophyta recorded the highest numerical abundance accounting for 44.87% of the total phytoplankton counts (711 individuals) followed by Bacillariophyta (42.76%), Chlorophyta (11.25%), and Euglenophyta (1.13%). The monthly occurrences of the major phytoplankton groups are presented in Fig. 3. The Cyanophytes were the most abundant and were represented by seven families comprising of 23 genera. The genus Dactylococcus (*Dactylococcopsis mucicola, Dactylococcopsis raphidioides*) contributed 72.8% of the total Cyanophyta (320). Others are; Rhadoderma, *Chroococcus, Synechoccus, Spirulina, Clastidium, Phormidium, Geitherrinema, Rivularia,*

Anabaena and *Oscillatoria* accounted for 27.2%.

The class Baccillariophyta was recorded in all months except in November 2003. Bacillariophyta was the second dominant (42.76%), formed by 14 genera which were categorized into five major sub groupings; araphid forming 66.89%, symmetrical naviculoid (14.9%), eunotoid and asymmetrical (11.15%), keeled (6.76%) and monoaraphid (1.01%). The araphid was the dominant group constituting 66.89% (*Tabellaria* species forming 54.1% while others; *Asterionella japonica, Diatoma enlongatum*, *Fragillaria construens, Meridion* sp., and Synedra acus, naviculoid (Navicula; *Navicula cryptotenella, Navicula halophila, and Navicula monmonthiana, Navicula* sp*. 1, 2, &3)* and *Pinullaria (Pinnularia acrosphaeria, P. braunii, P. rivularis, and P. subcapitata)* and Eunotia accounted for the rest.

The eunotoid and asysmetrical diatoms were represented by Eunotia *(*83.4%), *Cymbella* (10%), and *Gomphonema* (6.7%). The appearance of the eunotoids were few in nature particularly in the first phase of sampling where it appeared five times; February, May, September, December, 2003 and January 2004.

The abundance of the keeled and cannelled group of diatoms was significantly low and not exceeding 1ind. per ml in virtually all appearances. These were represented by the *Epithemia, Rhopalodia (Rhopalodia gibberula), Denticula* (*Denticula elegans, Denticula* sp*, Nitzchia and Surirella* (*Surirella biseriata, Surirella elegan and Surirella* sp*).*The monoraphid diatoms were rare and were represented sporadically by *Acanthes exiguodes* in August, September and October 2003 by one/ml organism each. The monoraphids did not make any appearance in the 2003 to January 2005.

Table 2: Taxa Checklist and Composition of phytoplankton in Umuaja Watershed during the investigated period (February 2003 - January 2005)

Chlorophyta	Bacillariophyta	Cyanophyta	Euglenophyta
Actinastrum sp	Achnanthes exigua	*Anabaena alatospora*	
Actinotaenium globosum	*Bacteriastrum hyalinum*	*Anabaena oryzae*	*Euglena acus*
Ankistrodesmus nannoselone	*Chaetoceros decipiens*	*Aphanocapsa sescianensis*	*Euglena* sp 1
Ankyra schroederia	*Coscinodiscus* sp	*Calothrix sp*	*Euglena* sp2
Bulbochaete nigerica	*Cyclotella glomerata*	*Camptylonemopsis lahrensis*	*Gyropaigne lefferei*
Chara sp	*Cyclotella kuetzingiana*	*Chamaesiphon curvatus*	*Lepocinclis ovum*
Characium sieboldii	*Cymbella affinis*	*Chroococcus minor*	*Strombomonas fluviatilis*
Chlamydomonas angulosa	*Cymbella cuspidata*	*Chroococcus minutus*	*Strombomonas verrucosa*
Chlamydomonas platystigma	*Denticula elegans*	*Chroococcus varius*	*Trachelomonas zingeri*
	Denticula sp	*Clastidium stigenum*	Rhodophyta
Chlorococcum hypnosporum	*Diatoma enlogatum*	*Clastidium* sp	*Hildenbrandia angolensis*
	Epithemia alpestris		
Chlorogibba ostreata	*Eunotia flexuosa*	*Dactylococcopsis mucicola*	*Monosiga varians*
Closterium aciculare	*Eunotia garusica*	*Dactylococcopsis pectinatellophila*	*Porphyridium* sp
Closterium Cynthia	*Eunotia lunaris*	*Dactyloccopsis raphidioides*	*Rhododraparnaldi a oregonica*
Closterium lanceolatum	*Eunotia monodon*	*Epigloeosphaera glebulenta*	Xanthophyta
Closterium lunula v. maximum	*Eunotia monodon 1*	*Geitlerinema earlei*	*Tribonema utriculosum*
Closterium pronum	*Eunotia serra*	*Homoeothrix crustaceae*	Chrysophyta
Closteriun pseudolunula	*Eunotia sudetica*	*Komvophoron constrictum*	*Tetrachrysis dendroides*
Closterium sigmoideum	*Fragilaria* sp 1	*Komvophoron minutum*	
Cosmarium depressum	*Fragilaria construens*	*Lyngbya limnetica*	
Cosmarium lubatum	*Fragilaria lapponica*	*Merismopedia elegans*	
Cosmarium ralfsii	*Gomphonema parvulum*	*Microcystis aeruginosa*	
Cosmarium subturgidium	*Mesodictyon* sp	*Microcystis pseudofilamentosa*	
	Melosira nyassensis		
	Navicula bottnica		

Table 2: Cont

Chlorophyta	Bacillariophyta	Cyanophyta
Desmococcus viridis	Navicula capitata	Nostoc zetterstedtii
Echicocoleum elegans	Navicula dystrophica	Oscillatoria amphibian
Enteromorpha flexuosa	Navicula halophila	Oscillatoria brevis
	Navicula militeris	Oscillatoria laetevirens v. minimus
Eudorina elegans	Navicula monmonthiana	Oscillatoria sp1
Gomontia aegagropila	Navicula submollesta	Phormidium foveolarum
Gonatozygon aculeatum	Navicula tenelloides	Phormidium mucicola
Gonatozygon kinahani	Navicula sp 1	Phormidium sp1
Gonotozygon sp	Navicula sp 2	Planktothrix suspensa
Hematococcus lucastris	Navicula sp 3	
Hydrodictyon reticulatum	Nitzchia sp 1	Rivularia sp
Kirchineriella sp	Nitzchia sp 2	Schizothrix lacustris
Microspora ulothrix	Pinnularia acrosphaeria	Spirulina sp 1
Monoraphidium contortum	Pinnularia sp1	Spirulina weissi
Oedogonium grassum	Rhopalodia gibberula	Synechococcus elongates
	Rhopalodia gibberulav.producta	Synechococcus cedrorum
Oedogonium suecica	Surirella elegans	Trichodesmium sp
Oedogonium undulatum	Surirella engleri	Trichormus fertilissimus
Oedogonium sp 2	Surirella sp	Vahlkampfia limax
Oedogonium landsboroughii	Synedra acus	
Oedogonium reinschii	Tabellaria fenestrata	
Palmellococcus protothecoides	Tabellaria flocculosa	
Pedinomonas minor	Tabellaria janvanica	
Pleurotaenium trabecula	Tabellaria sp1	
Spirogyra insignis	Tabelleria double sp2	
Staurastrum fuellebornei		
Staurastrum trihedrate		
Scenedesmus bijuga		
Ulothrix tenerrima		
Volvox dissipathrix		
Volvox perglobator		
Zoochlorella parasitica		

Although the Class Chlorophyta was encountered in all months but was low in abundance (11.5%) while Euglenophytes were rare contributing

only 1.0% of the total phytoplankton counts. The Euglenophytes made sporadic appearances in February and September 2003 and in March 2004 by two genera namely *Euglena* (57.14%), *Strobomonas* (42.86 %).

Factor Analysis

The principal component analysis was performed to determine the underlying limnological dimensions of the water quality variables on the phytoplankton and also the interconnectedness between the physicochemical parameters. Six principal components were extracted (Fig. 4) of which the first three components gave sharp distinctness (Fig. 4F). The scattered plot diagrams of the six PCA members and loadings of each parameter are presented in Table 3, revealing loadings that define climate, organic load, nutrient and season as factors affecting water quality and phytoplankton abundance (Bacillariophyta, Cyanophyta, Chlorophyta) in the study area. The factors implicated include air and water temperatures, total solids, TSS and TDS, nutrients (nitrate, sulphate and phosphate) as climate, season, organic load and nutrient.

Diversity Indices

Significant low diversity indices (≤ 1.277) were recorded all through the study period.

The monthly variations of the various indices shown in Table 4 , revealed similar pattern of fluctuations indicating weak stability of the water quality.
Simpson diversity index was the lowest and varied from 0 to 0.694, Shannon varied from 0.0 to 1.277, Menhinick's (0.179 – 1.155) and Margalef (0.0 – 1.17). In 2003, three indices were near zero except Menhinick. Dominance index (D) varied between 0.31 and 1.00.

Correlation Analysis

The Pearson correlation implicated major parameters that influenced the abundance of phytoplankton abundance during this study (Table 5). The greens (chlorophyta) correlated positively with conductivity, rainfall, total solids white cyanophyta were influenced strongly positively by nutrient parameters particularly nitrate ($r = 0.9871$, $p = 0.0000$) which was close to perfect but negatively with conductivity as shown in Table 3. Bacillariophyta had a negative association with pH only($r = -0.5227$; $p = 0.0181$). The euglenoids associated positively with calcium($r = 0.5727$; $p = 0.0083$), dissolved oxygen($r = 0.6143$; $p = 0.0040$) and total solids ($r = 0.4503$; $p = 0.0463$)

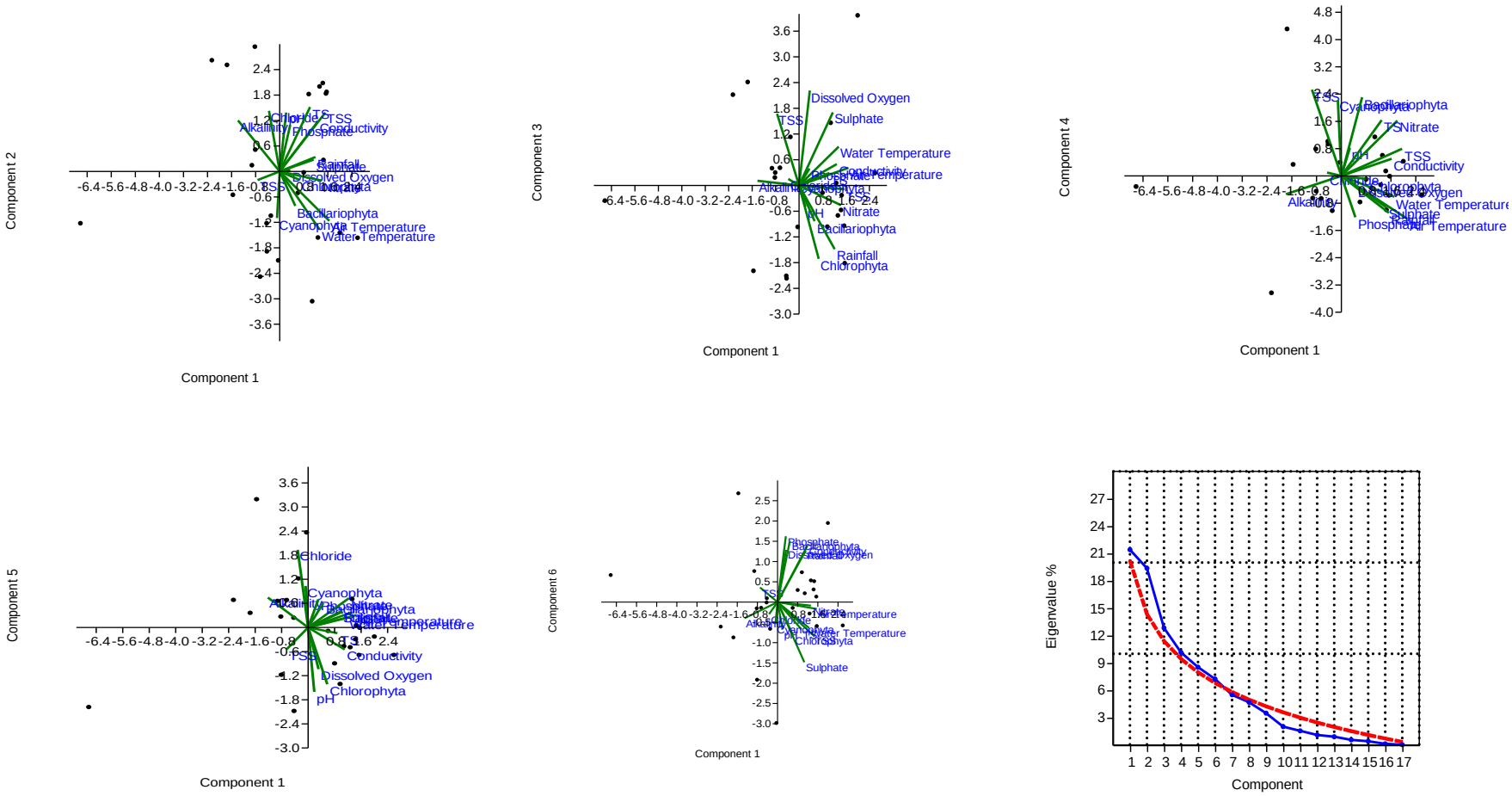

Fig.4: Principal component analysis (axes 1 and 2, 3, 4, 5 and 6) on environmental variables on phytoplankton groups and the scree plots of the components

Table 3: Principal component analysis, loadings and eigen values on the correlation matrix

Parameters	PCA 1	PCA 2	PCA 3	PCA 4	PCA 5	PCA 6
Air Temperature	0.7495	-0.5034	0.1419	-0.305	0.1003	-0.04729
Water Temperature	0.6015	-0.591	0.3117	-0.1477	0.07773	-0.1779
Dissolved Oxygen	0.1627	0.01297	0.7621	-0.06574	-0.3389	0.3608
pH	0.09679	0.6	-0.1711	0.2003	-0.5232	-0.1879
Alkalinity	-0.6299	0.5197	0.03751	-0.13	0.2435	-0.1112
Conductivity	0.5719	0.505	0.1719	0.122	-0.1794	0.3908
Chloride	-0.1626	0.6178	0.05246	0.02349	0.631	-0.08305
TSS	0.69	0.5999	-0.03036	0.193	0.1233	-0.2307
TSS	-0.3342	-0.08729	0.576	0.6134	-0.1766	0.1008
Sulphate	0.5127	0.1201	0.5866	-0.2232	0.1308	-0.4149
Phosphate	0.1592	0.4745	0.1361	-0.2942	0.2283	0.4544
Nitrate	0.6368	-0.09308	-0.1584	0.3932	0.2381	-0.02398
TS	0.4583	0.6566	0.09991	0.3967	-0.04652	-0.1882
Chlorophyta	0.2993	-0.08538	-0.5896	-0.02237	-0.4612	-0.2303
Cyanophyta	-0.04008	-0.4743	0.02811	0.5379	0.3378	-0.1485
Bacillariophyta	0.236	-0.3516	-0.2865	0.5593	0.1982	0.4234
Rainfall	0.5399	0.1466	-0.5113	-0.2629	0.1285	0.3568
Eigenvalue	3.63989	3.29399	2.18338			
% variance	21.411	19.376				
Cum variance	21.411					

Table 4: Monthly variation in diversity indices during the study

Indices	Feb 03	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec03	Jan 04	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan 05
Sp	5	3	4	3	3	3	4	3	2	1	4	3	2	4	3	3	2	4	3	2	2	2	2	3
TNI	61	8	14	14	19	23	25	19	10	1	13	35	30	26	133	14	125	80	17	10	17	5	3	10
D	0.59	0.38	0.31	0.43	0.39	0.46	0.40	0.42	0.68	1	0.52	0.52	0.52	0.39	0.81	0.48	0.83	0.81	0.45	0.52	0.71	0.52	0.56	0.42
1-D	0.41	0.63	0.69	0.57	0.61	0.54	0.60	0.58	0.32	0	0.49	0.48	0.48	0.60	0.19	0.52	0.17	0.19	0.55	0.48	0.29	0.48	0.44	0.58
H	0.82	1.04	1.28	0.96	1.02	0.92	1.05	0.94	0.50	0	0.94	0.83	0.67	1.13	0.40	0.89	0.32	0.43	0.88	0.67	0.47	0.67	0.64	0.94
e^H/S	0.46	0.94	0.90	0.87	0.93	0.84	0.71	0.86	0.83	1	0.64	0.76	0.98	0.78	0.50	0.81	0.69	0.38	0.80	0.98	0.80	0.98	0.94	0.86
Men	0.64	1.06	1.07	0.80	0.69	0.63	0.80	0.69	0.63	1	1.11	0.51	0.37	0.79	0.26	0.8	0.18	0.45	0.73	0.63	0.49	0.89	1.15	0.95
Mg	0.97	0.96	1.14	0.76	0.68	0.64	0.93	0.68	0.43	0	1.17	0.56	0.29	0.92	0.41	0.76	0.21	0.68	0.71	0.43	0.35	0.62	0.91	0.87

* Sp = Species richness; TNI = Total number of individuals; D = Dominance; 1-D = Simpson; H = Shannon; e^H/S= Evenness; Men = Menhinick and Mg = Margalef*Index except Dominance :> 4 clean water, 3-4= mildly polluted, 2-3= moderately polluted water, <2= heavily polluted water

Table 5: Pearson correlation between the major phytoplankton and physico- chemicalparameters in this study * = significant, P< 0.05

Parameters;	Baccillariophyta	Chlorophyta	Cyanophyta	Euglenophyta
pH; P- value	- 0.5227*; 0.0181	0.1873; 0.4291	- 0.3164; 0.1742	- 0.1553;0.5133
Calcium	- 0.0457; 0.8448	0.1657; 0.4851	- 0.0128; 0.9574	0.5727*; 0.0083
Conductivity	- 0.1915; 0.4187	0.5004*; 0.0247	- 0.4372*; 0.0539	0.0490; 0.8373
Dissolved oxygen	- 0.0370; 0.8769	0.0887; 0.7099	- 0.1277; 0.5917	0.6143*; 0.0040
Rainfall	0.2524;0.2831	0.6425*; 0.0022	- 0.2221; 0.3466	- 0.1537; 0.5177
Total solids	- 0.2758; 0.2393	0.6953*; 0.0007	0.0672; 0.7784	0.0210; 0.9298
Sulphate	- 0.2628; 0.2629	- 0.2545; 0.2789	0.5342*; 0.0152	0.0332; 0.8894
Nitrate	0.2053; 0.3853	0.1267; 0.5946	0.9871*; 0.0000	- 0.2942; 0.2080
Total SS	0.1275; 0.5923	0.0496; 0.8355	0.0894; 0.7078	0.4503*; 0.0463
Bacillariophyta	-			
Chlorophyta	0.0384;0.8724	-		
Cyanophyta	- 0.0229; 0.9236	0.0171; 0.9429	-	0.1428; 0.5482
Euglenophyta	0.3027; 0.1946	0.1428; 0.5482	- 0.0827; 0.7289	-

DISCUSSION

In this study, we demonstrated differences in species composition qualitatively; Chlorophyta > Bacillariophyta> Cyanophyta> Euglenophyta> Rhodophyta> Xanthophyta = Chrysophyta and species numerical abundance quantitatively followed this order; Cyanophyta> Bacillariophyta > Chlorophyta >Euglenophyta. Dominance of cyanophytes quantitatively reflects an unhealthy water body (Mohamed, 2016; Sasikala *et al*., 2017). Difference in species composition and abundance may be related to difference in volume of water filtered in each method. This indicates the volume of water filtered determines the number of organisms per ml of sample. A large surface area sampling applies to the estimation of compositional presence (quality) in the system than in the quantified (numerical abundance) (Iloba, 2012). The compositional structure of the phytoplankton community in this study is typical of freshwater water body (Kadiri, 2006; Buchberger and Stockenreiter, 2018). However, the dominance of Chlorophytes was not quantitatively significant probably due to prevailing unfavourable conditions induced by accumulated substances or materials from anthropogenic pressure. The positive correlation of rainfall, total solids and conductivity with the Chlorophytes suggest dilution, due reduction in ionic contents of the system thereby influencing the development of desmids. The occurrences of low and nutrient-rich preferring desmids (*Volvox, Eudorina, Chlamydomonas*) could be nutrient associated due to their efficient survival strategies hence the high species compositions (El- Otify and Iskaros, 2015; Riediger, et al., 2015).

The number of orgs/mL and the diversity indices throughout our study period were relatively low compared to other water bodies within the same geographical region(Kadiri 2006 in survey of 24 locations in Western Niger Delta; Davis *et al*., 2009 in Elechi Creek; Okogwu and Ugwumba 2013 in Asu River and Cross

River;. Temporal variability in Phytoplankton variability may be driven by change in environmental factors thereby resulting in the recruitment of the fittest or opportunistic species (Callieri, 2007, Chen *et al*., 2016).This is confirmed by both positive (conductivity, dissolved oxygen, total suspended solids, sulphate) and negative (pH, calcium) correlation of some environmental variables with the phytoplankton groups and the principal component ordinates but no significant correlation amongst the groups. This may be part of the factors responsible for the low diversity indices observed throughout the twenty – four months of this study. Judging from diversity index category, the low diversity values (0 – 1.277) recorded all through the present study revealed that the study site is unstable and grossly polluted (Shekhar *et al*., 2008; Zabbey *et al*., 2008; Ogbuagu and Ayoade, 2012). This cannot be abstracted from the addition of organic wastes from the intensive spiritual rituals; cultural and religious rites throw or exported by flood into the water body. Other inherent events such as extensive loading of leaf litter, rainfall (flood), could also act antagonistically against the abundance of these organisms particularly the freshwater components (*Closterium* species) to produce the pattern of organically polluted indicator phytoplankton species and diversity (*Dactylococcopsis, Navicula, Synedra, Euglena, Oscillatoria, Nitzchia, Gomphonema, Microcystis, Phormidium, Chrococcus, Synechoccus, Spirulina, Nostoc, Anabaena, Oscillatoria, Phormidium, Planthorix, Aphanocapsa* and *Calothrix*) observed in this study (Viner, 1987; Shekhar *et al*., 2008; Kurmayer and Christiansen 2009; Jindal *et al*., 2014). The decomposition of the introduced leaf litter will strongly impact on the acidic nature of the river which is contrary to the best pH range for the growth of algae. The near zero indices in November 2003 could be exaggerative effects of season: no rain, no flood, drastically reduced water depth, coupled with incessant introduction of organic waste, leaf litter on the quality and quantity of the organisms (Mainstone and Clarke, 2012, Arimoro *et al*. 2018).

The prevalence of Cyanophyta in the quantified samples is an indication that this group of phytoplankton is an important component of phytoplankton in this system and must play a decisive role in determining the health status and utility of this system. The presence of the toxins producing Cyanophytes such as *Chrococcus, Synechoccus, Nostoc, Anabaena, Oscillatoria, Phormidium*, and *Planthorix* in this study will have negative impact on water quality in terms of tourism and creativity due to the threat to human and livestock health. Their development in this site could be naturally enhanced by high water resilience created by the spring like head water nature in here, resulting in the reduction of water flow and also the reduced availability of light due to extensive tree cover (Gulecal and Temel, 2014; Dembowska and Pul, 2015; Liyanage *et al*., 2016).

The spate in the blue-green algae abundance during April and June 2003 may be due to their response to favourable changing environment which subjected those (Dactylococcopsis) to dominance since they could be the fittest available species (Callieri, 2007). Besides the provision of favourable environment, this group of phytoplankton is endowed with adaptation qualities or features making them competitively superior to

other phytoplankton (Pridmore and Etheredge, 1987; Kurmayer and Christiansen 2009, Chen *et al*., 2016).

The class Bacillariophyta was the second abundant compositionally and quantitatively. The most occurring and abundant diatom is the genus *Tabellaria* which indicates an ecologically conducive environment. The acidic nature of the studied site (4.9 – 6.9) could be one of the major reasons for the preponderance of *Tabellaria fenestrata*, *T. flocculosa*, *Eunotia gracilis, E. lunaris*, *E. pectinalis* var. *minor*, *E. praerupta* var. *bidens*, *E. sudetica*, *Frustulia rhomboides*, *Gomphonema angustatum,* evident from the extraction of pH as an influencing parameter in this study (Law, 2011; Kelly 2011; Silva and Costa, 2015). The halophobic nature of *Tabellaria fenestrata* and *T. flocculosa* which prefer very low mineralization (up to 0.02 g l-1) as recorded in this study also contributed to their preponderance. Another possible reason for the preponderance of *Tabellaria* is attributed to favourable habitat in relation to depth. Tabellaria, a phytobenthos will be positively fitted to a shallow system by associating with the sediment (Law, 2011; Riediger *et al*., 2015).

The euglenoids were quantitatively rare in this study and their abundances were negatively influenced by rainfall, attributed to dilution factor since the identified species flourish well in an uninterrupted nutrient- rich and flow reduced system (Iloba, 2012). Calcium, dissolved oxygen, and total suspended solids played an important significant role in the structuring and abundance of the euglenoids as noted experimentally by Moss 1973 and Juran, 2016.

The high species composition recorded in this study despite the opposition records from the abundance of organically loving and toxin producing phytoplankton species, low diversity indices (mixed stresses) all through the entire study show the resiliency of the system and thus could easily be recovered (Reynolds, 2002; Mainstone and Clarke 2008; Mathooko *et al*., 2009). The source of River Ethiope could be transformed into a recreational resource otherwise will soon lose its quality and jeopardize this economic potentials if the government does not put a sanitary programme in place.

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