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Bio-monitoring and diversity of phytoplankton in a tropical estuarine mangrove swamp in Akwa Ibom State, South-South, Nigeria

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Abstract
Bio-monitoring and Diversity of Phytoplankton in a Tropical Estuarine Mangrove Swamp in Akwa Ibom State, South-South, Nigeria were conducted between May 2015 and April 2016. Water and plankton samples were collected monthly in three stations and analyzed using standard procedures. Water quality index value computed from the obtain parameters during the study indicated that the water quality from Qua Iboe River Estuary is unsuitable for domestic usages. A total of 5,279 (2,411 and 2,868 for wet and dry season respectively) phytoplankton individuals which was made up of 38 species and belonging to 5 classes were encountered through-out the study. Bacillariophyceae constituted the bulk of the phytoplankton group during the study. This followed the pattern: Bacillariophycea>Cyanophyceae>Dinophyceae>Chlorophyceae>xanthophyceae. Species dominance ranged between 0.07 and 0.50, Shannon-Wiener index ranged between 0.69 – 2.70 while Simpson index ranged between 0.50 – 0.93 and species evenness ranged between 0.88 – 0.99 indicating that the phytoplankton were evenly distributed throughout the study. Relationship of physico-chemical parameters and phytoplankton classes were established using principal component analysis which suggested that environmental factors plays vital role in phytoplankton dynamics. Based on findings, this study further vindicates the call for proper monitoring and management of our indigenous water bodies.

Keywords: bio-monitoring, diversity, phytoplankton, tropical mangrove swamp,

1. Introduction
In Nigeria, increase human activities have successfully resulted in sufficient food and energy to meet the growing population. However, these activities together with poor waste management have led to considerably waste loses from land to aquatic ecosystem, causing water pollution and habitat alteration in the structure and composition of aquatic flora. This problem will likely worsen in the future due to continuously growing population and economy.
Once water is contaminated, its quality cannot be restored by stopping the pollutants from the source. It therefore becomes imperative to regularly monitor the quality of surface water and to device ways and means to protect it in the event of pollution. The allotment, abundance and diversity of phytoplankton reveal the environmental state of aquatic ecosystems in broad-spectrum and its nutrient status in particular (Anene, 2003) [2]. The state of any water body can easily be predictable based on the plankton community of such water (Olasehinde and Abeke, 2012) [24].
Water quality index is one of the most valuable tools to communicate information on the status of water to the concerned populace and policy makers. Hence, it has become an important index for evaluation and management of coastal water.
Phytoplankton form a diverse group of marine and freshwater plants ranging from unicellular planktonic species which lack true roots, stems and leaves and do not produce flowers or seeds (Mann, 2000) [19]. They are eukaryotic or prokaryotic photosynthetic species that contain chlorophyll and also utilize solar energy to generate their chemical energy (Ali *et al*., 2003) [2]. They are present throughout the lighted regions of all aquatic ecosystems (Mudflats, ponds, lakes, streams, rivers, seas and Oceans) (Castro and Huber, 2005) [8].
Phytoplankton's are responsible for more than 95% of the photosynthetic activities in the oceans and other aquatic bodies (Prasad, 2000) [27]. This amounts to nearly ¾ of the world's primary production and nearly half of the oxygen in our atmosphere (Naz & Turkmen, 2005; Mann, 2000) [20, 19].
The objective of this study is to assess the suitability of Qua Iboe River Estuary for domestic purposes and other usages based on computed water quality index values and also assess the diversity and abundance of phytoplankton species.

2. Materials and Methods
2.1 Description of study area
Qua Iboe River estuary (Fig. 1) is located on the South Eastern coast in the Niger Delta region of Nigeria where it empties into the Atlantic Ocean. It lies within latitude 4º 40´30´´N and longitude 7º 57´0´´E on the south Eastern Nigeria Coastline. The geomorphology of the lower reaches of Qua Iboe River Estuary consist of sandy coastal beach, small mixohaline lagoons, wetlands, tidal creeks; notable among them is Stubbs creek and Douglas creek, and tributaries fringed with mangrove vegetation made up of species of *Avicennia*, *Rhizophora* and *Nypa*. The coastal vegetation of the area is mainly thick mangrove swamp. The Estuary is also rich with abundance of edible aquatic biota.
The climate of the area is characterized by a long wet season usually lasting from May to November and a short period of dry weather from December to April. Human perturbations in the area include, dredging, indiscriminate disposal of sewage and domestic waste, run-off from storm city drains empties

into the adjoining rivers which finally empties into the estuary, artisanal fishermen employing the use of paddle canoes and motorized engine boats, also big ships use in industrial fishing with possible spill of oil from these engines.

2.2 Sampling Stations

Three sampling stations, namely Iwuokpom, Mkpanak and Iwochang were mapped out in the mangrove swamp of the Qua Iboe River Estuary (Fig.1).

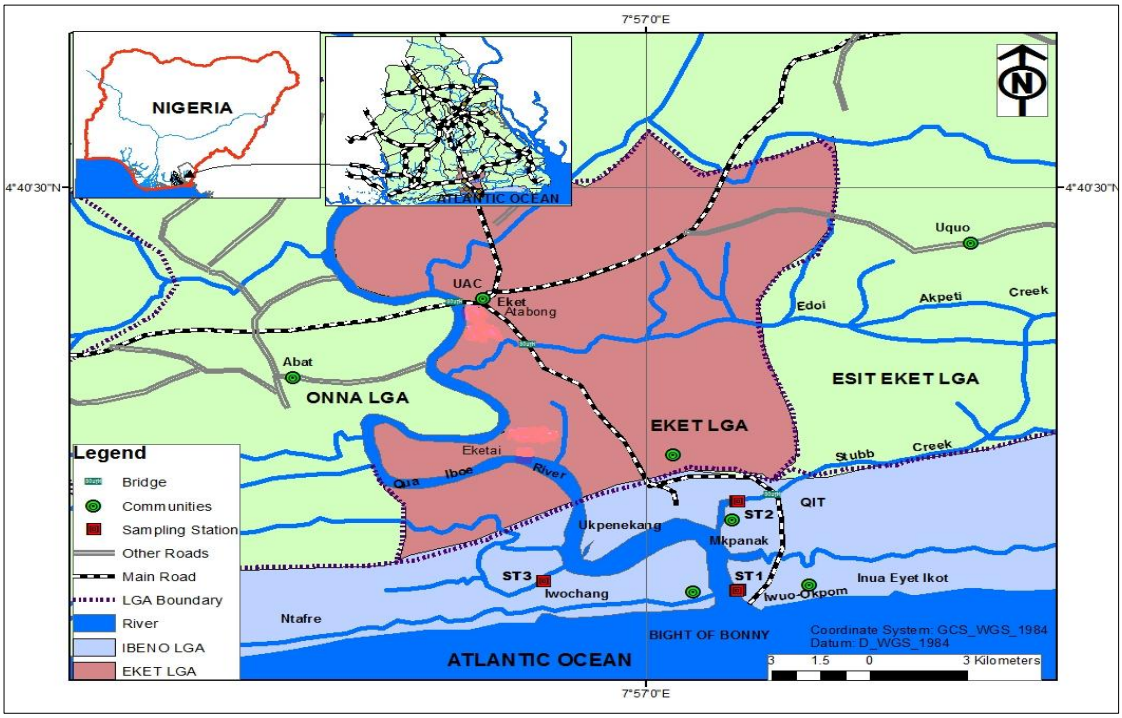

Fig 1: Map of Study area showing sampling location

2.3 Collection and analysis of water samples

Water samples were collected in each of the sampling stations from May 2015 to April 2016. At all times sampling was carried out between 800 hours and 1200 hours each sampling day. Water samples for Temperature, pH, Dissolved oxygen, Electrical conductivity and Turbidity were measured at *in situ* according to Standard Methods for Examination of Water and Waste water (USEPA, 2007) [32]. Water sample for biological oxygen demand, chemical oxygen demand, phosphate, nitrate sulphate and ammonia were collected using 250 ml glass bottle. The sample bottle was filled with water and stoppered under water, ensuring that no air bubble was trap in it. After collection, all samples were stored in ice-packed coolers at 4°C to inactivate microbes and preserve the integrity of the samples and transported to the laboratory prior to analysis. In the laboratory samples were analysed using standard methods for examination of water and waste water (APHA, 1998; AOAC, 2000) [3].

2.4 Collection of samples and identification of phytoplankton species

Phytoplankton samples were collected monthly for 12 months (between May 2015 and April 2016)in three stations along the estuary at a depth of about 60cm below the water surface following Sverdrup *et al* (2006)[31] using a standard plankton net of 55 µm mesh of 18.0 cm diameter. The net was towed for 300 seconds (5 minutes; at a speed, of about I800ms^{-1} (I8 kmhr^{-1}) (0.5 knots) at each sample station.

The content of the tube attached to the end of the plankton net was emptied into well-labeled plastic sample bottles and made to 100ml. The samples were preserved in 10 % formaldehyde solution following Newell and Newell (1977) [21], and Sverdrup *et al.*, (2006) [31]. All samples were transported at the end of each sampling month to the laboratory for identification.

In the laboratory, the samples were allowed to stand for at least 24 hours for the phytoplankton to settle before the supernatant pipetted to concentrate the samples. Few drops of the concentrate were investigated at different magnifications under a light microscope (LM) using the Drop Count Method by (Lackey, 1938) [17]. Phytoplankton classes were identified using identification schemes of Newell and Newell (1977) [21] and Sverdrup *et al.*, (2006) [31].

2.5 Determination of water quality index

For the calculation of water quality index, ten (10) important parameters namely, pH, temperature, electrical conductivity, dissolved oxygen, turbidity, biological oxygen demand, nitrate, sulphate, phosphate and ammonia were chosen. The water quality index was calculated using standards of drinking water quality recommended by the World Health Organization WHO (2011) [33]. The weighted Arithmetic index method (Brown *et al.*, 1972) [7] was used for the calculation of WQI in this study. For computing WQI, three steps were followed. In the first step, each of the 10 parameters was assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. In the second step, the relative weight (W_r) was computed from the following equation:

$$W_r = \frac{w_i}{n}$$

Where;

W_r = relative weight

w_i =weight of each parameter
n = number of parameters.

In the third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the WHO (2011)[33] and the result multiplied by 100.

$$q_i = \frac{C_i}{S_i} \times 100$$

Where;
q_i= quality rating
C_i = concentration of each chemical parameter in each water sample in mg/l
Si = WHO drinking water standards for each parameter.
For computing the WQI, the Si is first determined for each chemical parameter, which was then used to determine the WQI as per the following equations

$$Si = W_i \times q_i$$

$$WQI = \sum SI$$

Where;
Si = sub index of each parameter
q_i = rating based on the concentration of each parameter
WQI = Water Quality Index
The rating of the water quality values are shown in the table 1 below

Table 1: Water quality index and quality of water

Water quality index level	Water quality status	Grading
0-25	Excellent water quality	A
25-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
>100	Unsuitable for drinking	E

Source: Asuquo and Etim, (2012)[6]

2.6 Determination of relative abundance (%)
Phytoplankton species were identified, sorted and counted individually. The sum of each individual Phytoplankton species from each sampling station for the twelve (12) sampling months were added together in order to determine the numerical abundance of each species in each of the season. The Relative abundance (%) of Phytoplankton species was calculated according to Ali *et al*. (2003) [2] as follows:

$$\% Ra = n/N \times 100$$

Where;
n = the total number of individuals in each phytoplankton taxonomic group.
N = the total number of individuals in the entire phytoplankton taxonomic.

2.7 Ecological diversity Indices
The occurrence and relative numerical abundance of phytoplankton species was calculated using biotic indices such as Shannon and Weiner's index, Dominance, species evenness and Simpson index in order to determine distribution, abundance and diversity of species.

2.7.1 Shannon and Weiner's index (H): is a measure of species abundance and evenness and was expressed as:

$$H = \sum_{i=1}^{s} - (P_i * \ln P_i)$$ (Shannon and Weiner, 1949)

Where:
H = the Shannon diversity index
P_i = fraction of the entire population made up of species i
In = natural logarithm
S = numbers of species encountered
$\sum$ = sum from species 1 to species S

2.7.2 Species evenness (E) was determined by using the equation:

$$E_H = \frac{H}{H_{max}} = \frac{H}{\ln S}$$ (Pielou, 1966)

Where:
H = Shannon and Wieners index.
S = Number of species in samples

2.7.3 Dominance (D) was determined using the equation:

$$(n/N)^2$$

Where:
n = total number of organisms of a particular species within the population
N = total number of organisms of all species

2.7.4 Simpson index was expressed as:

$$1- D$$

Where:
$D = (n/N)^2$
n = total number of organisms of a particular species within the population
N = total number of organisms of all species

2.8 Statistical analysis
Data obtained was subjected to paired sample t-test to compare seasonal difference. The probability level was set at p = 0.05. Principal component analysis (Greig-smith, 1980) was employed to ordinate environmental variables into factor components. Biological indices, such as Margalef, Equitability (E), Simpson index, Dominance and Shannon-wiener's diversity indices was computed using paleontological statistics software (PAST) (version 3.0).

3. Results
3.1 Water quality
The result of physico-chemical parameters is presented in Table 2. The pH range between 8.00 – 8.70 with a mean of 8.2

± 0.11, temperature range between 25.00 – 26.90 with a mean of 26.17 ± 0.26 ^{o}C, electrical conductivity range between 47920.00 - 51610.00 with a mean of 49993.33 ± 634.09 µs/cm, dissolved oxygen range between 5.70 – 6.50 with a mean of 6.12 ± 0.10 mg/l, turbidity range between 23.30 - 38.00 with a mean of 25.55 ± 4.63 NTU, biological oxygen demand range between 2.00 - 2.60 with a mean of 2.28 ± 0.11 mg/l, nitrate range between 31.30 - 54.00 with a mean of 37.93 ± 3.34 mg/l, sulphate range between 3190.00 - 3540.00 with a mean of 3321.67 ± 63.95 mg/l, phosphate range between 8.00 – 8.60 with a mean of 8.24 ± 0.09 mg/l and ammonia range between 20.40 - 27.90 with a mean of 22.62 ± 1.12 respectively. Significant seasonal variation at p = 0.05 was observed for all the parameters except nitrate. Water quality index (WQI) value calculated from the mean of physico-chemical parameters obtained during the study had a value of 678.92 which makes the status of Qua Iboe River Estuary unfit for domestic purposes and other usage (Table 3).

3.2 Phytoplankton composition

A checklist of the different Phytoplankton classes and species is given in Table 4. Five (5) Phytoplankton classes were recorded with each containing varied number of species.These were Bacillariophyceae, Chlorophyceae, Cya nophyceae, Dinophyceae and Xanthophyceae. A total of 1109 and 1336 individuals of Bacillariophyceae forming (45.99 % and 46.58 %) which was made up of 15 spe cies (39.47 %) with 194 and 219 individuals of Chlorophyceae (8.05 % and 7.64 %) which was made up of 5 species (13.16 %), 824 and 956 individuals of Cyanophyceae (34.18 % and 33.33 %) which was made up of 12 species (31.58 %), 227 and 294 individuals of Dinophyceae (9.42 % and 10.25 %) which was made up of 4 species (10. 53 %) and 57 and 63 individuals of xanthophyceae forming (2.36 % and 2.20 %) which was made up of 2 species (5.26 %) were recorded for wet and dry season respectively (Table 5).

Phytoplankton species was more abundant in the dry season than in the wet season (Table 5). In terms of abundance Bacillariophyceae constituted the bulk of the phytoplankton group during the study. This was followed by Cyanophyceae, Dinophyceae, Chlorophyceae and xanthophyceae in the following pattern: Bacillariophycea>Cya nophyceae> Dinophyceae> Chlorophyceae> Xanthophyceae (Table 6). In regards to species diversity in each of the classes during the study, Bacillariophyceae had the highest number of species. This was followed by Cyanophyceae, Chlorophyceae, Dinophyceae and Xanthophyceae in the following pattern: Bacillariophycea> Cyanophyceae> Chlorophyceae> Dinophyceae> Xanthophyceae (Table 6).

Seasonal distribution of the major phytoplankton classes recorded during the study and relative abundance of the major phytoplankton classes are illustrated in Figure 2 and 3 respectively.

Species dominance ranged between 0.07 and 0.50, Shannon-Wiener index ranged between 0.69 – 2.70 while Simpson index ranged between 0.50 – 0.93 and species evenness ranged between 0.88 – 0.99 indicating that the phytoplankton were evenly distributed (Table 6).

3.3 Ordination of Physico-chemical Parameters and and phytoplankton abundance of the Study Area

Ordination of physico-chemical parameters in water and phytoplankton abundance by principal component analysis with varimax rotation distinguished 5 components with the sizes as shown on Table 7. The first component account for 48.68 % of the variations due to physico-chemical parameters in water and phytoplankton abundance, component 2 had 24.59 %, component 3 had 13.54 % while component 4 and 5 explained 8.94 % and 4.24 % respectively of the variations in the data set. The first component therefore bear vital information required for explaining most of the variations due to physico-chemical parameters in water and phytoplankton abundance in this estuary.

On the principal component (PC_1) 11 variables were spotted with characteristic high loadings. These were: pH (-0.744) BOD (0.937), Cyanophyceae (0.901), Turbidity (0.900), Dinophyceae (0.870), Chlorophyceae (0.57), Phosphate (0.728), Xanthophceae (0.704), Nitrate (0.689), Bacciliarophyceae (0.687) and Ammonia (0.593). Also On principal component (PC_2) 5 variables were spotted with characteristic high loadings. These parameters were Temperature (0.961), Electrical Conductivity (0.726), Dissolved Oxygen (-0.689), Nitrate (0.581), Sulphate (-0.746) and Ammonia (0.546) while on principal component (PC_3) 3 variables were spotted with characteristic high loadings. These were pH (0.622), Electrical conductivity (0.643) and Bacciliarophyceae (-0.593) and on principal component (PC_4) only Phosphate was spotted with significant high loading. There was no significant high loading for principal component (PC_5) (Table 8). The ordination diagram for PCA assortment of variables is shown as Figure 4.

Table 2: Mean physico-chemical parameters of the study area (May, 2015 – April, 2016).

Parameters	Minimum	Maximum	Mean ± S.E
pH	8.00	8.70	8.2 ±0.11
Temp. (^{O}C)	25.20	26.90	26.17 ±0.26
EC(µs/cm)	47920.00	51610.00	49993.33 ±634.09
DO (mg/l)	5.70	6.50	6.12 ±0.10
Turbidity (NTU)	23.30	38.00	25.55 ±4.63
BOD (mg/l)	2.00	2.60	2.28 ±0.11
NO_3^- (mg/l)	31.30	54.00	37.93 ±3.34
SO_4^{2-} (mg/l)	3190.00	3540.00	3321.67 ± 63.95
PO_4^{3-} (mg/l)	8.00	8.60	8.24 ± 0.09
NH_3 (mg/l)	20.40	27.90	22.62 ± 1.12

Table 3: Water quality index for Qua Iboe River Estuary during the study period (May, 2015 – April, 2016).

Parameters	Mean values	Standard permissible value (WHO, 2011)[33]	Weight (w_i)	Relative Weight (W_r)	Quality rating (q_i)	Sub Index value ($S.I = W_r \times q_i$)
pH	8.2	6.5 – 9.2	4	0.118	104.4586	12.32611
Temp. (ºC)	26.17	20 – 30	4	0.118	104.68	12.35224
EC (µs/cm)	49993.33	1500	4	0.118	3332.889	393.2809
DO (mg/l)	6.12	5	4	0.118	122.4	14.4432
BOD (mg/l)	25.55	10	4	0.118	255.5	30.149
NO_3^- (mg/l)	2.28	50	5	0.147	4.56	0.67032
PO_4^{3-} (mg/l)	37.93	5.00	4	0.118	758.6	89.5148
SO_4^{2-} (mg/l)	3321.67	500	4	0.118	664.334	78.39141
NH_3(mg/l)	8.24	0.5	1	0.029	1648	47.792
			$\sum w_i = 34$			WQI = 678.92

Table 4: Taxonomic checklist of phytoplankton species recorded during the different months of study within the Qua Iboe River Estuary (May, 2015 – April, 2016).

Phytoplankton classes / Species		Wet season							Dry season							Grand total
		May	Jun	Jul	Aug	Sept	Oct	Total	Nov	Dec	Jan	Feb	Mar	Apr	Total	
(A) Bacillariophyceae																
1	*Asterionella formosa*	17	19	15	-	14	11	76	15	19	25	-	19	8	86	
2	*Biddulphia favus*	15	13	21	19	-	18	86	11	14	19	13	15	23	95	
3	*Coscinodiscus granii*	13	11	-	15	17	11	67	18	16	-	15	14	11	74	
4	*Coscinodiscus lacustris*	11	15	11	-	13	14	64	21	23	15	17	21	16	113	
5	*Epithermia zebra*	16	-	17	14	19	15	81	11	14	21	-	19	18	83	
6	*Flagillaria construens*	11	13	-	16	13	10	63	16	-	17	18	11	25	87	
7	*Flagilaria striatula*	13	18	17	-	15	-	63	15	15	-	15	14	18	77	
8	*Nitzschia obtustata*	19	21	15	13	17	15	100	18	11	21	18	23	22	113	
9	*Nitzschia paradoxa*	-	18	15	10	25	-	68	21	-	13	19	-	18	71	
10	*Pleurosigma directum*	16	-	-	13	10	17	56	12	18	18	-	25	-	73	
11	*Striatella unipunctata*	21	17	18	15	-	-	71	14	18	18	21	15	13	99	
12	*Synedra affinis*	17	11	13	13	11	14	79	15	11	21	19	18	16	100	
13	*Skeletonema costatum*	13	-	11	21	13	19	77	-	14	16	23	17	18	88	
14	*Tabellaria fenestrata*	15	17	-	19	21	23	95	-	21	25	13	15	17	91	
15	*Tabellaria flocculosa*	16	19	-	13	-	15	63	15	-	11	8	23	29	86	
	Total abundance (N)	213	192	153	181	188	182	1109	202	194	240	199	249	252	1336	2,445
(B) Chlorophyceae																
1	*Closterium sp*	14	16	-	16	14	18	78	18	17	16	17	13	16	97	
2	*Gonatozygon aculeatum*	7	5	5	6	9	4	36	-	9	2	5	4	7	27	
3	*Micrasterias foliacea*	8	3	7	5	-	-	23	6	-	3	8	5	8	30	
4	*Stigeocloniumsp*	-	5	9	2	8	8	32	-	3	4	9	11	5	32	
5	*Xanthridium sp*	5	9	-	2	6	3	25	-	8	11	6	8	-	33	
	Total abundance (N)	34	38	21	31	37	33	194	24	37	36	45	41	36	219	413
(C) Cyanophyceae																
1	*Aphanothece clathrata*	15	14	11	15	-	13	68	16	14	17	-	19	14	80	
2	*Aphanothece stagnina*	19	17	6	15	8	11	76	18	19	16	14	10	12	89	
3	*Aphanizomenon flos-aquae*	11	17	14	9	13	11	75	-	11	13	19	11	19	73	
4	*Dactylococcopsis acicularis*	-	19	16	10	18	11	74	19	18	-	13	14	11	75	
5	*Dactylococcopsis irregularis*	13	14	11	12	9	8	67	13	11	16	11	14	11	76	
6	*Gloeocapsa minima*	16	17	-	19	11	16	79	18	-	19	16	18	15	86	
7	*Gloeotrichiae chinulata*	11	12	9	17	13	11	73	14	16	11	18	13	17	89	
8	*Merismopedia punctata*	15	12	8	14	13	11	73	17	12	12	14	16	14	85	
9	*Microcystis aeruginosa*	14	9	6	11	4	7	51	14	11	9	13	11	14	72	
10	*Microcystis Grevillei Hass*	9	11	7	14	8	-	49	13	16	12	11	14	9	75	
11	*Oscillatoria tenuis*	8	11	12	16	9	11	67	8	11	12	16	9	11	67	
12	*Phormidium sp*	16	15	11	9	13	8	72	18	14	16	12	15	14	89	
	Total abundance (N)	147	168	111	161	119	118	824	168	153	153	157	164	161	956	1,780
(D) Dnophyceae																
1	*Dinophysis rotundata*	16	14	12	13	11	9	75	18	20	16	18	14	11	97	
2	*Ceratium tripos*	9	7	8	11	-	6	41	11	14	9	11	9	-	54	
3	Gonyaulax *sp*	10	8	11	8	13	-	50	16	18	16	12	-	8	70	

4	*Gymnodinium sp*	11	7	13	16	14	-	61	14	18	16	14	11	-	73	
	Total abundance (N)	46	36	44	48	38	15	227	59	70	57	55	34	19	294	521
E	(E) Xanthophyceae															
1	*Tribonema viride*	4	5	-	4	4	8	25	9	-	7	5	3	5	29	
2	*Tribonema minus*	8	6	4	-	6	8	32	9	4	6	4	5	6	34	
	Total abundance (N)	12	11	4	4	10	16	57	18	4	13	9	8	11	63	120

Table 5: Summary of the phytoplankton classes, their total counts (Numerical) and relative abundance in the study area during wet and dry season

S/n	**Phytoplankton** classes	No. of species	Species composition	Numerical abundance		Relative abundance (%)	
				Wet season	Dry season	Wet season	Dry season
1	Bacillariophyceae	15	39.47	1109	1336	45.99	46.58
2	Chlorophyceae	5	13.16	194	219	8.05	7.64
3	Cyanophyceae	12	31.58	824	956	34.18	33.33
4	Dinophyceae	4	10.53	227	294	9.42	10.25
5	Xanthopyceae	2	5.26	57	63	2.36	2.20
	Total abundance (N)	38	100.00	2,411	2,868	100.00	100.00

Table 6: Diversity indices of the major phytoplankton classes in the study area in both season (May, 2015 – April, 2016).

S/n	**Phytoplankton** classes	Numerical abundance	Number of species	D	H	1-D	E_H = H/In S
1	Bacillariophyceae	2,445	15	0.07	2.70	0.93	0.99
2	Chlorophyceae	413	5	0.26	1.48	0.74	0.88
3	Cyanophyceae	1,780	12	0.08	2.48	0.92	0.99
4	Dinophyceae	521	4	0.26	1.36	0.74	0.98
5	Xanthopyceae	120	2	0.50	0.69	0.50	0.99
	Totalabundance (N)	5,279	38	1.17	8.71	3.83	4.83

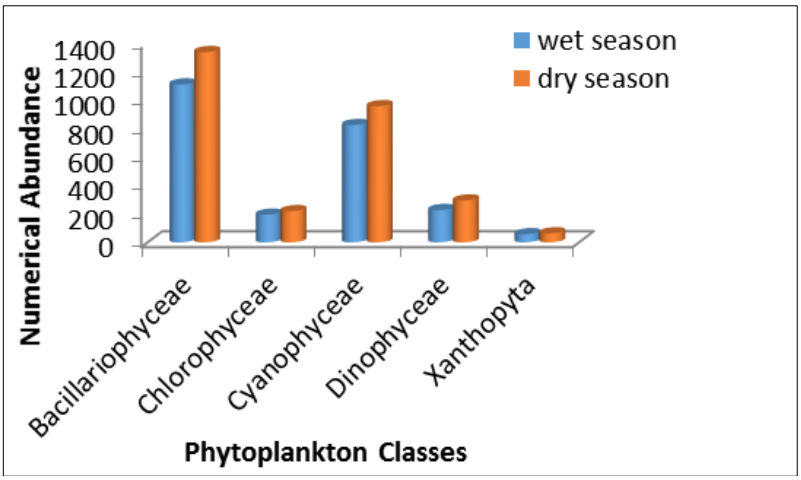

Fig 2: Seasonal distribution of the major phytoplankton classes recorded within Qua Iboe River Estuary during the study

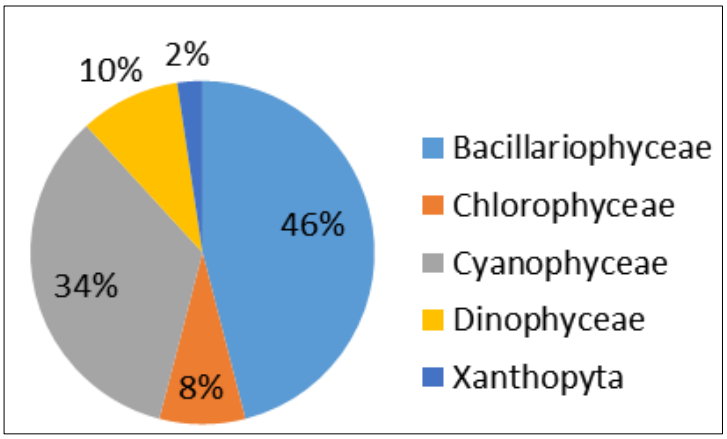

Fig 3: Relative abundance of the major Phytoplankton classes recorded within Qua Iboe River Estuary during the study

Table 7: Size, Percentage total variation and cumulative percentage of correlation matrix of five components in the original data set of phytoplankton classes and physico-chemical parameters of Qua Iboe River Estuary

Component	Eigen Values	Total % of Variance	Total Cumula-tive %
1	7.303	48.684	48.684
2	3.690	24.599	73.282
3	2.032	13.544	86.827
4	1.341	8.938	95.765
5	.635	4.235	100.000

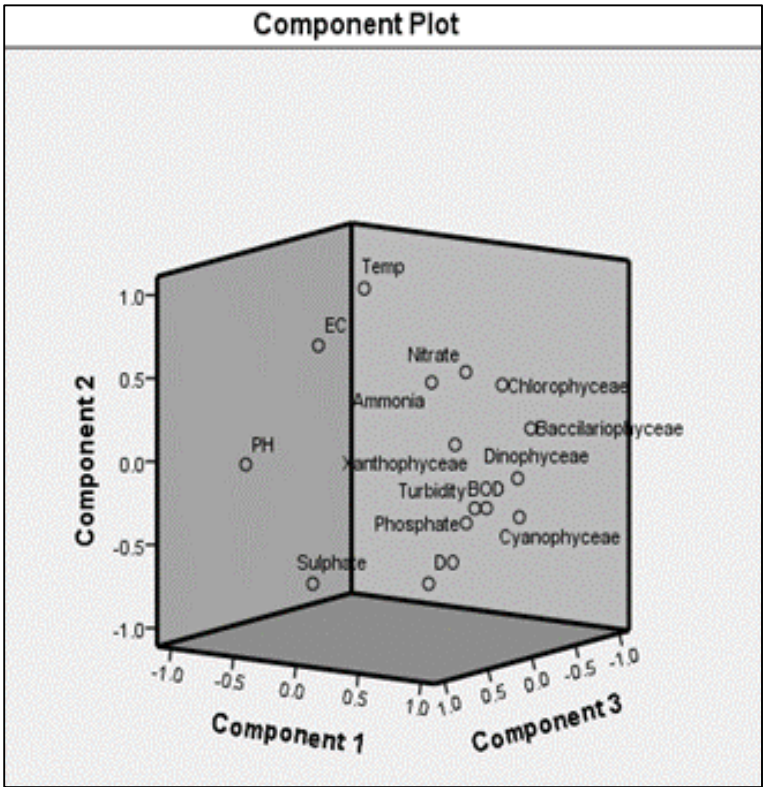

Fig 4: Principal component analysis plot for phytoplankton classes and physico-chemical parameters of Qua Iboe River Estuary

Table 8: Rotated component matrix of phytoplankton classes and physico-chemical parameters of Qua Iboe River Estuary during the study (May, 2015 – April, 2016).

Parameters	Component				
	1	2	3	4	5
Zscore:pH	-.744	-.051	.622	-.041	-.235
Zscore:Temp	-.256	.961	-.036	.048	-.091
Zscore:EC	-.149	.726	.643	-.120	.152
Zscore:DO	.493	-.689	.298	.438	-.032
Zscore:Turbidity	.900	-.188	.351	-.176	.009
Zscore:BOD	.937	-.194	.271	-.057	.090
Zscore:NO_3^-	.689	.581	.153	.403	.037
Zscore:PO_4^{3-}	.728	-.315	.204	-.524	.234
Zscore:SO_4^{2-}	-.317	-.746	.466	.279	.218
Zscore:NH_3	.593	.546	.407	.375	.210
Zscore:Baccilariophyceae	.687	.133	-.593	-.077	.391
Zscore:Chlorophyceae	.857	.496	-.022	.084	-.105
Zscore:Cyanophyceae	.901	-.314	-.156	.025	-.253
Zscore:Dinophyceae	.870	-.087	-.180	.327	-.309
Zscore:Xanthophyceae	.704	.167	.296	-.565	-.263

4. Discussion

The mean values of water quality were analyzed to assess the trophic status of Qua Iboe River Estuary. Physico-chemical parameters (electrical conductivity, turbidity, biological oxygen demand, phosphate, sulphate and ammonia) exceeded the permissible standard as recommended by WHO. Paired sample t-test revealed significant (p=0.05) seasonal variations for all parameters except nitrate. The elevation in these parameters were attributed to human perturbations and run-off from agricultural activities and adjoining land carrying massive load of nutrients into the estuary. This finding is consistent with the report of (Chindah and Braide, 2001 and Chindah and Nduaguide, 2003)[10, 9] that attributed deterioration in water quality to impacts of human induced activities.

The results obtained from this study revealed that WQI of Qua Iboe river estuary water is not within the permissible limits (100) from the entire samples taken. The computed overall WQI was 678.92 and can therefore be categorized as "water unsuitable for drinking and other usages". The high value of WQI has been found mainly from higher value of electrical conductivity, BOD, phosphate, sulphate and ammonia in the water sample. This could be attributed to coastal activities like: improper disposal of wastes, agricultural run-off from farmland, urban run-off, open defecation and sewage and domestic wastes from homes. This finding synchronizes with the findings of Ramakrishnaiah *et al*., (2009) [28] and Yisa and Jimoh, (2010) [34] in a related study and reported a WQI value

(> 100) and contrasts that of Etim *et al*., (2013) [14] in a similar study that reported WQI values that were within permissible limit (< 100).

A total of thirty-eight (38) species of phytoplankton belonging to five (5) taxa were identified. Thephytoplankton species composition was dominated by Bacillariophyceae with 15 species. Others were Cyanophyceae (12), Chlorophyceae (5), Dinophyceae (4) and Xanthophyceae (2). The dominance of Bacillariophyceae by species in this study synchronizes with the findings of (Akpan, (1997); Davies *et al*. (2009); Ogamba *et al*. (2004) and Ekeh and Sikoki (2004) [1, 12, 22, 13] and contrasts that of Onyema, (2013) [25] in Onijedi lagoon who reported cyanobacteria as the dominant taxa by species. Similar trend of Cyanobacteria dominating chlorophyta was reported by Ekeh and Sikoki (2004) [13] during their study in New Calabar River. The high abundance of Bacillariophyceae in the present study is an attribute of the concentration of silicates in the study area. This is consistent with the earlier assertion by Akpan (1997) [1] who reported a strong correlation between silicates and Diatom abundance. Seasonality in phytoplankton abundance was observed to be higher in the dry season than in the wet season. More stable conditions including flow characteristics, increased light penetration and other environmental conditions experienced in the dry season could have encouraged the development of a richer plankton community. Similar observations have been made by Onyema *et al*. (2003) for the Lagos lagoon.

Multivariate statistic using principal component analysis yielded a pattern which confirmed hierarchical values and effects of some water quality parameters on phytoplankton distribution and abundance regrouped into five factor components. The inter-relationships among the vari-factors as judge from their loadings confirmed direct and indirect relationship between physicochemical parameters and phytoplankton abundance. Generally, ordination of environmental variables revealed much similarity in growing environmental conditions which influence the distribution pattern and abundance of phytoplankton in Qua Iboe River Estuary. This finding however, deviates remarkably from those of Cui-ci *et al*. (2011) [11] and Lehman (2000) [18] who reported 4 factor components in a similar research. The first component explained the parameters governing the distribution and abundance of phytoplankton which indicate anthropogenic activities in the study area. This confirms the views of several authors who reported effects of environmental factors on plankton dynamics (Kagalou *et al*. (2001); Susanne *et al*. (2005); Ogbuagu *et al*. (2011) [16, 30, 23].

5. Conclusion

Phytoplankton species identified were seasonally dominated by the the class Bacillariophycea (diatoms) while the least encountered class was the xanthophycea. Phytoplankton abundance was relatively higher in the dry season than in the wet season, an observation that could be linked to water column perturbations. The dominance of Bacillariophyceae and Cyanophyceae during the study period indicate that Qua Iboe River Estuary is polluted which confirms the computed WQI value that categorize the water as unfit for drinking and other usages. The deterioration in the water quality was attributed to impacts of human activities within the study area. Application of water quality index (WQI) in this study has been found useful in assessing the overall quality of water and to get rid of judgment on the status of the water.

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