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Victor O. Eyo
Institute Of Oceanography, University Of Calabar, P.M.B.1115 Calabar, Nigeria.

Paul B. Ekpo
Department of Genetics and Biotechnology, University of Calabar, P.M.B. 1115 Calabar, Nigeria.

Andem B. Andem
Department of Zoology and Environmental Biology, University of Calabar, P.M.B.1115 Calabar, Nigeria.

Kalu A. Okorafor
Department of Zoology and Environmental Biology, University of Calabar, P.M.B.1115 Calabar, Nigeria.

Correspondence:
Victor O. Eyo
Institute Of Oceanography, University Of Calabar, P.M.B.1115 Calabar, Nigeria.
Tel: +2348065162221

Ecology and Diversity of Phytoplankton in the Great Kwa River, Cross River State, Nigeria

Victor O. Eyo, Paul B. Ekpo, Andem B. Andem, Kalu A. Okorafor

ABSTRACT
This Ecology and diversity of phytoplankton in the Great Kwa River, Nigeria was studied based on bi-monthly samples collected for six months (May to October, 2012). The objective of the study was to determine the abundance and species composition of phytoplankton from four sampling stations in the study area. A total of eighty-nine (89) species of phytoplankton belonging to six (6) taxonomic groups were recorded: 1 Dinophyceae (1.12%), 3 Chrysophyceae (3.37%), 4 *Euglenophyceae* (4.50%), 9 Cyanophyceae (10.11%), 23 Chlorophyceae (25.84%) and 49 Bacillariophyceae (55.06%). Total number of phytoplankton species in the study area in relation to sampling station was highest in Esuk Atu with 77 species (27.70%), followed by 71 species in Anantigha station (25.54%), followed by 69 species in Bofa Esuk station (24.82%) and lowest in Abitu station with 61 species (21.94%). Ten (10) absolutely constant species (AS) were found in Bacillariophyceae and none in Chrysophyceae, Cyanophyceae, Dinophyceae and *Euglenophyceae*. Species diversity indices were quite impressive in the four sampling stations leading to the conclusion that the Great Kwa River is in a healthy and unpolluted state.

Keywords: Diversity, Species Composition, Phytoplankton, Great Kwa River, Sampling Stations.

1. Introduction
In the aquatic ecosystem, phytoplanktons are foundation of the food web, in providing a nutritional base for zooplankton and subsequently to other invertebrates, shell and finfish[1]. According to Ekwu, Sikoki[2], the phytoplankton of an aquatic ecosystem is central to its normal functioning. Presently, phytoplanktons are being used increasingly by scientists to monitor the ecological quality and health of the aquatic environment. As reported by Brierley *et al*.[3], phytoplanktons are also used to measure the effectiveness of management or restoration programmes or regulatory actions in aquatic environment. Numerous studies on coastal water bodies in Nigerian investigated the abundance and diversity of Phytoplanktons[4, 5, 2, 1, 6], as high phytoplankton diversity represents an important ecological value often associated with high nutrient removal efficiency and buffer capacity against nutrient pollution[7].
The Great Kwa River is one of the major tributaries of the Cross River Estuary. As reported by Akpan[8], this important river takes its rise from the Oban Hills in Nigeria, flows southwards and discharges into the Cross River Estuary around latitude 4°45'N and longitudes 8°20'E. Its location makes the river prone to serious pollution threat especially as heavy rains wash human and industrial waste into the river[9]. Also, lack of sewage treatment facilities and increase in human population in Calabar municipality exposes the river ecology to pollution[9]. Hence, the present work was under taken to make a comprehensive assessment of the abundance and diversity of phytoplankton communities in the Great Kwa River with aim of evaluating the health status of the Great Kwa River.

2. Materials and Methods
2.1 Study Area
The Great Kwa River is one of the major tributaries of the Cross River Estuary. It takes its course from the Oban Hills in Aningeje, Cross River State, Nigeria which flows southwards and discharges into the Cross River Estuary around latitude 4°45′N and longitude 8°20′E (Akpan 2000)[8]. The lower reaches of the river drain the eastern coast of the Calabar municipality, the capital of Cross River State of Nigeria. Esuk Abitu (station 4).

The study was conducted in four sampling stations (Fig.1) including: Esuk Atu (station 1), Obufa Esuk (station 2), Esuk Anantigha (station 3) and Esuk Abitu (station 4).

2.2 Sampling and phytoplankton analysis

The four sampling stations were sampled twice monthly between May and October, 2012 for zooplankton. Sampling was carried out between 0700 and 1100hrs starting from Esuk Atu (station 1), Obufa Esuk (station 2), Esuk Anantigha (station 3) and Esuk Abitu (station 4) in that order. Quantitative phytoplankton samples were collected by filtering 100 liters of water fetched with a rubber bucket through 55 µm mesh standard plankton hydrobios net [10]. Phytoplanktons were preserved in 4% buffered formalin solution and stored in 500 ml plastic sample bottle [6] before transporting them to Fisheries and Aquaculture Laboratory, University of Calabar for phytoplankton analysis. In the laboratory, quantitative sample from the four stations were concentrated to 10 ml. From the 10 ml, 1 ml from each sample was taken and all individual taxa present were counted. Specimens were sorted, counted using Zeiss binocular microscope at different magnifications (X40, X100 and X400). Lugol's iodine solution was used for staining the samples to enhance proper discernment of the phytoplankton species based on morphological features, as individual species normally takes up the stain, thereby exposing the organelles for proper identification [11]. Phytoplanktons were identified using relevant literatures [12, 13, 14, 15, 16, 17, 18].

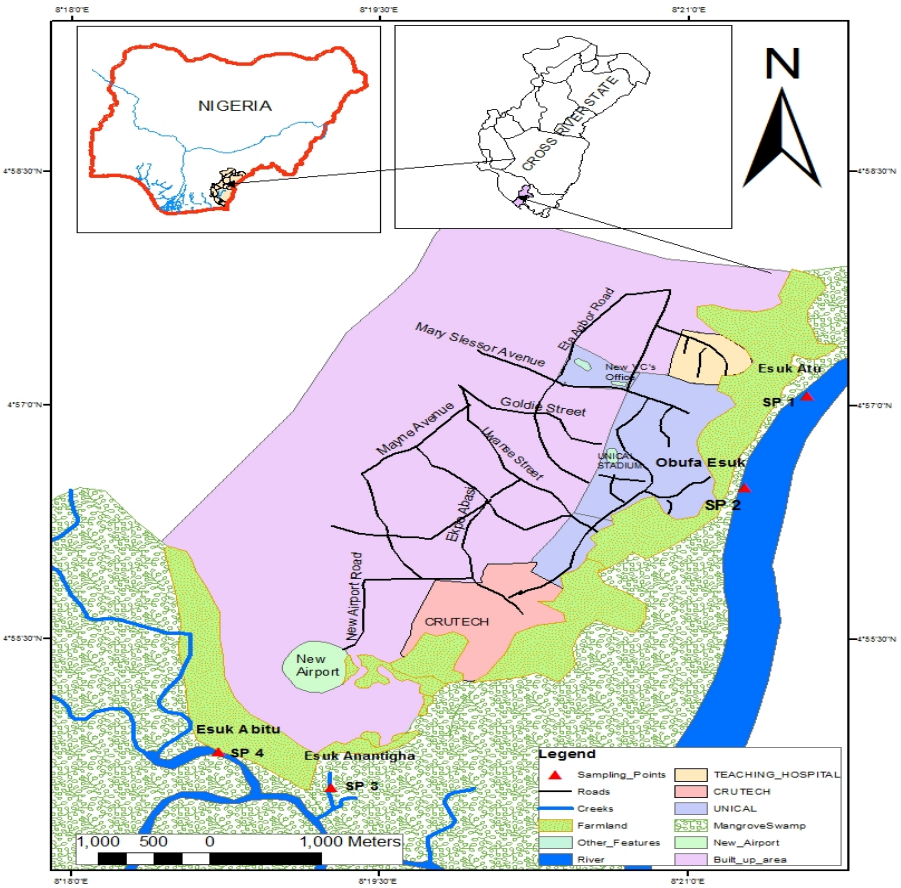

Fig 1: Map of the study area (Great Kwa river) showing the four sampling stations including: Esuk Atu (station 1), Obufa Esuk (station 2), Esuk Anantigha (station 3) and Esuk Abitu (station 4)

2.3 Species composition (%)

Species composition (%) was calculated as according to Eyo *et al.*[19] 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.

2.4 Relative abundance (%)

Relative abundance (%) was calculated according to Eyo *et al.*[19] as follows:

$$\% RA = n (100)/N,$$

Where;

n = the total number of individuals in each phytoplankton taxonomic group.

N = the total number of individuals in the entire phytoplankton taxonomic group.

2.5 Frequency of occurrence (FO)

Frequency of occurrence (FO) of phytoplankton species was evaluated using occurrence constancy index which is based on a four-degree scale[19]: absolute constant species (AS) - > 75%, constant species (S) – 51 -75%, absolute species (A) – 26 – 50% and accidental species (P) - < 25%.

2.6 Phytoplankton ecological indices in the Great Kwa River

Ecological indices of phytoplankton's in the Great Kwa river was determined using species composition, relative abundance, frequency of occurrence, Margalef's index (D), Shannon-wiener index (H), Evenness (E) and Simpson indices according to Ogbeibu[20] as follows:

2.6.1 Margalef's Index (d)
Margalef's Index (d) is given as:

$$d = \frac{S-1}{\ln(N)}$$

Where;
S is the total number of species
ln is the Natural log
N is the total number of individuals.

2.6.2 Shannon-wiener index (H)
Shannon-wiener index (H) is given as:

$$H = \frac{N \log N \sum_{i=1}^{S} fi \log fi}{N}$$

Where;
N is the total number of individual,
fi is the number of individuals in species and
S is the total number of species.

2.6.3 Evenness (E)
Evenness (E) is given as:

$$E = \frac{H}{\log S}$$

Where;
H is the Shannon-wiener index
S is the total number of species.

2.6.4 Simpson index (D)
Simpson index (D) is given as:

$$D = \sum_{i=1}^{s} \frac{ni(ni-1)}{N(N-1)}$$

3. Results
3.1 Phytoplankton Species Composition in the Great Kwa River
A total of eighty-nine (89) species of phytoplankton belonging to six (6) taxonomic groups were recorded during the six - month sampling period of the study (Table 1). The group Dinophyceae was represented by only one species consisting of 1.12% composition by species (Table 2), followed by Chrysophyceae represented by three species consisting of 3.37% species by composition. This was closely followed by Euglenophyceae, represented by four species (4.50%), followed by Cyanophyceae represented by nine species (10.11%), followed by Chlorophyceae twenty-three species (25.84%) while Bacillariophyceae had the highest species composition with forty-nine species (55.06%). Total number of phytoplankton species in the study area in relation to sampling station (Table 3) was highest in Esuk Atu with 77 species (27.70%), followed by 71 species in Anantigha station (25.54%), followed by 69 species in Obufa Esuk station (24.82%) and lowest in Abitu station with 61 species (21.94%).

3.2 Phytoplankton species diversity indices in the Great Kwa River
Phytoplankton species diversity indices in the Great Kwa River were high in the four sampling stations. Margalef's index (D) ranged from 7.39 (Abitu station) to 8.96 (Esuk Atu station), Shannon-wiener index (H) ranged from 3.73 (Abitu station) to 3.89 (Esuk Atu station), Evenness (E) ranged from 0.60 (Esuk Anantigha station) to 0.69 (Esuk Abitu station). Simpson index was 0.97 for the four sampling stations.

Table 1: Species composition and occurrence constancy of phytoplankton in the Great Kwa River in relation to sampling stations. Frequency of occurrence of a particular species on a four-degree scale: absolute constant species (AS) > 75%, constant species (S) – 51 -75%, absolute species (A) – 26 – 50% and accidental species (P) - < 25%. Number of sample = 12.

Taxa	Phytoplankton species	Esuk Atu	Obufa Esuk	Anan. Beach	Abitu Beach
Bacillariophyceae	*Achnanthes. gracillina*	AS	AS	AS	AS
	A. delicatula	A	P	P	P
	A. linearis	AS	AS	AS	S
	A. exigma	AS	AS	AS	AS
	Amphiprora oxalis	A	A	P	A
	Amphora coastata	A	P	A	A
	Bacillaria aurita	P	P	P	P
	B. paradoxa	AS	AS	AS	AS
	B. rhombus	P	-	P	-
	B. mobiliens	P	-	-	-
	Coscinodiscus radiatus	AS	AS	AS	AS
	C. rothii	AS	AS	AS	AS
	C. excentricus	P	P	P	-
	C. lacustris	P	A	-	-
	Cocconeis hustedti	P	-	-	-
	C. placentula	A	P	P	P
	C. diminula	A	-	P	P
	Cyclotella kurtzingii	AS	AS	AS	AS
	C. stelligra	S	S	A	A
	C. quadricinctra	AS	AS	AS	AS
	Cymbella affinis	P	A	A	A
	C. prostata	P	-	-	P
	Diploneis ovalis	S	A	AS	AS
	Inotia lunaris	A	A	P	A
	Eucampia zoodiacus	A	P	P	A
	Fragilaria capucina	P	P	P	P
	Gomphonema accuminatum	A	P	A	A
	Gyrosigma attenuatum	A	A	P	P

	Halosphaera viridis	A	A	A	A
	Melosira granulata	S	P	P	A
	M. damsel	A	A	A	P
	Navicula affinis	AS	S	S	AS
	N. linearis	A	A	S	A
	N. rabiosa	A	P	P	A
	N. gracilis	P	P	P	
	N. cuspidata	-	P	-	-
	Nitzschia closterium	P	-	-	-
	N. kurtzingiana	-	P	P	-
	Pinnularia viridis	-	-	-	P
	P. divergens	P	P	P	P
	Pleurosigma elongates	S	S	A	A
	Rhizosolenia alata	P	P	P	-
	R. longiseta	P	-	-	-
	Synedra affinis	P	A	P	-
	S. ulna	P	-	P	P
	Surirella elegans	S	A	A	A
	Tabellaria fenestra	P	-	-	P
	T. flocculosa	P	-	-	-
	Thalassiosira decipiens	P	P	P	P
Chlorophyceae	*Chlamydomonas reticulate*	A	A	P	P
	Closterium gracile	S	A	A	P
	C. Cynthia	AS	S	P	A
	C. intermedium	P	P	P	-
	C. circulare	AS	AS	AS	AS
	C. granatum	AS	S	A	S
	C. longissima	A	P	P	A
	C. lunula	S	S	S	S
	E. *ansatum*	A	A	A	A
	E. elegans	S	P	A	S
	Gonatozygon kinakani	P	-	P	-
	G. sculpta	P	-	P	-
	Pediastrum duplex	-	P	-	-
	Staurastrum apiculatum	-	-	P	-
	Scenedesmus acutus	A	P	P	A
	S. acuminatus	A	S	P	A
	S. abundans	S	A	S	A
	S. deticulatus	A	A	A	P
	S. quadricauda	S	A	S	A
	Spirogyra grassa	P	-	-	-
	S. spiralis	-	P	-	-
	Ulothrix sp	-	P	-	-
	Volvox aureus	-	-	-	P
Chrysophyceae	*Phaethamnion sp.*	P	P	P	P
	Dinobryon sp.	-	P	-	-
	Chrysalis spa	-	-	P	-
Cyanophyceae	*Anabaena affinis*	S	A	S	A
	A. spiroides	SS	A	A	A
	Anacystis cyanea	S	S	S	A
	Gomphosphaeria aponia	A	A	A	P
	Lyngbya birgei	A	A	P	P
	Oscillatoria sancta	A	A	A	P
	O. tenis	A	P	P	A
	Phormidium ambiguum	P	P	-	-
	P. cincinnati	-	P	-	-
Dinophyceae	*Ceratium hirundinella*	P	-	P	-
Euglenophyceae	*Euglena acus*	S	AS	S	S
	E. gracilis	S	A	A	A

	Phacus caudate	A	-	P	-
	P. longicaudata	-	-	P	-

Table 2: Number of species, species composition (%) and relative abundance (%) of phytoplankton taxonomic group in Great Kwa River

Taxonomic group	Total No. of species	Species composition (%)	% Rel. abundance
Bacillariophyceae	49	55.06	67.87
Chlorophyceae	23	25.84	20.88
Chrysophyceae	3	3.37	0.22
Cyanophyceae	9	10.11	7.56
Dinophyceae	1	1.12	0.07
Euglenophyceae	4	4.50	3.40
Total	**89**	**100.00**	**100**

Table 3: Number of species, species composition (%) and relative abundance (%) of phytoplankton in the Great Kwa River in relation to sampling stations

Station	Taxonomic group	Total No. of species	Species composition (%)	% Rel. abundance
Esuk Atu Station	Bacillariophyceae	46	59.74	67.05
	Chlorophyceae	18	23.37	20.82
	Chrysophyceae	1	1.30	0.16
	Cyanophyceae	8	10.39	8.16
	Dinophyceae	1	1.30	0.16
	Euglenophyceae	3	3.90	3.65
	Total	**77**	**100.00**	**100.00**
Obufa Esuk station	Bacillariophyceae	38	55.07	68.20
	Chlorophyceae	18	26.09	20.50
	Chrysophyceae	2	2.90	0.40
	Cyanophyceae	9	13.04	7.81
	Dinophyceae	0	0.00	0.00
	Euglenophyceae	2	2.90	3.09
	Total	**69**	**100.00**	**100.00**
Anantigha Station	Bacillariophyceae	39	54.93	69.18
	Chlorophyceae	18	25.35	19.38
	Chrysophyceae	2	2.82	0.21
	Cyanophyceae	7	9.86	7.82
	Dinophyceae	1	1.41	0.11
	Euglenophyceae	4	5.63	3.30
	Total	**71**	**100.00**	**100.00**
Abitu Station	Bacillariophyceae	36	59.02	67.22
	Chlorophyceae	15	24.59	23.16
	Chrysophyceae	1	1.64	0.10
	Cyanophyceae	7	11.48	6.09
	Dinophyceae	0	0.00	0.00
	Euglenophyceae	2	3.27	3.43
	Total	**61**	**100.00**	**100.00**

Table 4: Species diversity indices of phytoplankton taxonomic group in the Great Kwa River in relation to sampling stations

	Sampling stations			
	Obufa Esuk	**Anantigha**	**Esuk Atu**	**Abitu**
Taxa (s)	77	69	71	61
Individuals	4852	4210	3783	3350
Margalef's index (d)	8.96	8.15	8.50	7.39
Shannon-wiener index (H)	3.89	3.77	3.75	3.73
Evenness (E)	0.63	0.63	0.60	0.69
Simpson index (D)	0.97	0.97	0.97	0.97

4. Discussion

Results obtained in the present study indicates clearly that phytoplankton species diversity varied with sampling points with 77 phytoplankton species in Esuk Atu (27.70%), followed by 71 species in Anantigha station (25.54%), followed by 69 species in Obufa Esuk station (24.82%) and 61 species in Esuk Abitu station (21.94%). This observation is similar to findings of Sekadende *et al*.[21] who reported that phytoplankton diversity varied with sampling stations and season in the satellite lakes of lake Victoria basin (Tanzania side). Frequency of occurrence of phytoplankton evaluated using occurrence constancy index showed that the group Bacillariophyceae (diatom), had ten (10) absolute constant species including: *A. gracillina, A. linearis, A. exigma, A. paradoxa, C. radiata, C. rothii, C. kurtzingii, C. quadricinctra, D. ovalis* and *N. affinis*; followed by Chlorophyceae with three (3) absolute constant species including: *C. cynthia, C. circulare* and *C. granatum* whereas the groups Chrysophyceae, Cyanophyceae, Dinophyceae and Euglenophyceae lacked absolute constant species. This could be attributed to the fact that most diatoms are capable of surviving in the estuarine environment irrespective of the variable salinity[22, 23]. A total of eighty-nine phytoplankton species recorded for six families in this study is different from findings of Ekwu and Sikkoki[2] who identified recorded a total of 105 species of phytoplankton, belonging to 5 families were identified during the study in the Cross River estuary. However, dominance of Bacillariophyceae in the present study is similar to findings of Ekwu and Sikkoki [2] who recorded the family Bacillariophyceae (diatom) as the most abundant with 63 species in the Cross River estuary. Several authors including Akpan [4], Ekeh and Sikoki[5], Ekwu and Sikkoki[2] have reported similar findings of Bacillariophyceae abundance in Nigerian coastal waters and other water bodies[24, 25, 26, 27]. According to Egge and Aksnes [28], growth of diatoms depends on the presence of silicate which is evident in the siliceous cell

wall found in diatom. These findings indicate the presence of silicate in the four sampling stations in the Great Kwa River. This agrees with the findings of Ekwu and Sikkoki [2] who attributed the abundance of diatoms in the Cross River estuary to higher concentration of silicates in this zone and also corroborates with findings of Akpan[4], who reported a strong correlation between silicates and diatom abundance. In this study, the family Chlorophyceae was the second most dominant family with twenty three species, followed by Cyanophyceae (nine species), followed by Euglenophyceae (four species), followed by Chrysophyceae (three species) and Dinophyceae (one species). This observation disagrees with Kadiri[23], Kadiri and Omozusi[29], Kebede and Belay [30], who observed of more Chlorophyta than diatoms and very few Cyanophytes in some tropical water bodies. Species diversity indices obtained in this study was quite impressive with Margalef's index (D) ranging from 7.39 (Abitu station) to 8.96 (Esuk Atu station), Shannon-wiener index ranging from 3.73 (Abitu station) to 3.89 (Esuk Atu station), Evenness (E) ranging from 0.60 (Esuk Anantigha station) to 0.69 (Esuk Abitu station) and Simpson index of 0.97 for all the sampling stations. This finding is similar to findings of other authors such as Ekeh and Sikoki [5], Ekwu and Sikkoki[2], Eni *et al*.[6]. Values obtained for these species diversity indices in the four sampling stations were similar and Eni *et al.* [6] attributed such findings to good ecological condition arising from important factor governing the abundance and distribution of the phytoplankton communities such as food availability.

5. Conclusion

In conclusion, the results obtained in the present study indicated that a diverse phytoplankton population is present within the Great Kwa River in the following order of dominance: Bacillariophyceae > Chlorophyceae > Cyanophyceae > *Euglenophyceae* > Chrysophyceae > Dinophyceae. Species composition in the four stations was similar, however with some variations. Results obtained from the present study indicate the healthy and unpolluted nature of the Great Kwa River. Based on these findings, it is therefore concluded phytoplankton diversity in the Great Kwa River will contribute significantly to the sustenance of the Great Kwa River fishery.

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