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Influence of Some Physico-Chemical Parameters on the Spatio-Temporal Abundance and Diversity of Phytoplankton in the Great Kwa River, Southeast, Nigeria

ALBERT PHILIP EKANEM
Department of Fisheries and Mariculture, Faculty of Oceanography
University of Calabar, Calabar, Nigeria
BASSEY ETIM JOB[1]
Department of Biological Oceanography, Faculty of Oceanography
University of Calabar, Calabar, Nigeria
ABASIAMA EFFIONG ESSIEN
[3]Department of Zoology and Environmental Biology
Faculty of Biological Sciences, University of Calabar
Calabar, Nigeria

Abstract:

Studies were conducted on the influence of some physico-chemical parameters on the abundance and diversity of phytoplankton in the Great Kwa River, Nigeria, between May and July, 2017. Total of 277 phytoplankton cells were recorded in May, with a pH value of 6.52, dissolved oxygen of 6.6mgL^{-1} and temperature of 28.4 ^{0}C. In June, total of 283 phytoplankton cells were recorded at a temperature of 26.6^{0}C, pH of 7.24 and dissolved oxygen of 7.8mgL^{-1}, while in July, total of 277 phytoplankton cells were recorded at a temperature of 28.2^{0}C, pH of 6.55 and dissolved oxygen of 6.4mgL^{-1}. It was observed that at lower temperatures, higher phytoplankton biomass was recorded. High dissolved oxygen content and low pH values were generally observed to give rise to phytoplankton abundance and high diversity. pH was observed to range between 6.52 – 7.24, with an average value of 6.77,

[1] Corresponding author: bejob_u@yahoo.com

while dissolved oxygen ranged between 6.4 – 7.8mgL^{-1} with an average of 6.93mgL^{-1}. Temperature was observed to range between 26.6 – 28.4^{0}C with a mean of 27.73 ^{0}C. Altogether, 29 species of the phytoplankton belonging to five families namely Bacilariophyceae, Chlorophyceae, Euglenophyceae, Cyanophyceae, Charophyceae were identified. Total of 105 Bacilloriophyceae, which constituted 38.27% of the phytoplankton population were collected in May, with 90 individuals which formed 31.80% of the phytoplankton population in June and 97(35.01%) in July. Total of 52(18.77%) Chlorophyceae were recorded, with 50(17.67%) in June and 59(21.30%) in July. Total of 31(11.19%) Euglenophyceae were recorded in May, with 52(18.37%) in June and 45(16.25%) in July. In May, total of 38(13.72%) Cyanophyceae were recorded, with 40(14.13%) in June and 28(10.11%) in July, while a total of 50(18.05%) Charophyceae were recorded in May with 51(18.02%) in June and 48(17.33%) in July. Variations existed in the monthly ecological index values. In May, Margalef's index (d) calculated for the phytoplankton was 7.29, with a value of 7.97 in June and 8.18 in July. Shannon-Wiener index (H) was 2.195 in May, with a value of 2.180 in June and 2.158 in July. Pielou's Evenness index (E) had a value of 0.052 in May, with 0.047 in June, and 0.045 in July, while Simpson's Dominance of 0.022 was recorded in May, with a value of 0.025 in June and 0.028 in July. Significant relationship (P<0.05) was found between physico-chemical parameters and phytoplankton abundance and diversity. The ranges of the ecological indices recorded in this study are an indication of ecologically stable and unpolluted system.

Key words: Spatio-temporal abundance, Diversity, Phytoplankton, Physico-chemical parameters, Great Kwa River, Nigeria.

INTRODUCTION

Phytoplankton are microscopic unicellular organisms that float freely on the pelagic zone of the water column (Mann, 2000). They are abundance in the upper layer of the water column and are primary producers which manufacture their food using the energy from sunlight, water and carbon dioxide. The oxygen, a by-product of the photosynthesis, helps in balancing the aquatic ecosystem (Mann, 2000). Besides, their importance as primary producers in food webs and ensuring ecological balance, phytoplankton are useful indicators of water quality (Rey *et al.,* 2004; Job *et al.,* 2011; Egbai & Job, 2017).

Phytoplankton serve as a source of food to many aquatic organisms such as zooplankton, larva, small fishes and other aquatic organisms (Job *et al.,* 2017). All these organisms depend directly or indirectly on phytoplankton for their nutritional requirement. Phytoplankton is thus, the pioneer of an aquatic food chain: as the productivity of an aquatic ecosystem directly depends on the density and quality of phytoplankton. (Ewa *et al.,* 2013).

Physico-chemical parameters are the major factors that control the dynamics and structure of the phytoplankton of aquatic ecosystem (Ramesh *et al.,* 2015). Change in physico-chemical parameters of ecosystem have a substantial impact on the species that live within them (Hulyal and Kaliwal 2009; Ramesh *et al.,* 2015).Phytoplankton abundance and composition in an aquatic ecosystem are regulated by various physico-chemical factors such as light penetration, temperature, salinity, turbidity, nutrients and water mixing, (Lewis 2000, Ewa *et al.,* 2013).

Phytoplanktons are of great economic importance. It is documented that phytoplankton are used as feed for invertebrates in aquaria. Presently, phytoplankton are being used increasingly by scientists to monitor the ecological quality and health of the aquatic environment (Eyo *et al.,* 2013). In natural setting, organic compounds are also fixed by phytoplankton, photosynthetic microscopic aquatic flora that are found drifting on the euphotic zone of the water. Degradation of this organic matter contributes to the purification of the ecosystem and is therefore a major process controlling water quality (Mokbel and Yamakanamerdi, 2008; Egbai & Job, 2017).

Phytoplankton is also very useful in studying the biodiversity of the aquatic system, (Anupama, 2016). The study of phytoplankton is important in assessing the biotic component and add significantly to the total estimation of the nature and overall economic potential of the aquatic environment.

The Great Kwa River serves as a source of municipal drinking water and revenue generation for its inhabitants. The Great Kwa River is explored and exploited locally in aquaculture, artisanal fishery especially for shrimps and in small scale farming.

Physico-chemical characteristics of rivers can be significantly altered by human activities such as various agricultural practices and irrigation as well as natural dynamic which consequently affect the water quality and quantity (Egbai & Job, 2017; Job *et al.,* 2017), including species distribution and diversity, production capacity and even disruption in the balance of ecological system operating in the river (Dhanam *et al.,* 2016) and human activities such as industrial waste and sewage are known to be discharged into river system (Hulyal & Kaliwal, 2009).

From available literature, studies have been conducted the on diversity, ecology, abundance and spatial distribution of phytoplankton in the Great Kwa River, Nigeria. These include those of Antai and Joseph (2015), Victor *et al. (*2013), Ewa *et al.* (2013), Ebigwai *et al.* (2014), Joseph *et al.,* (2008), Victor *et al.* (2013), Antai *et al.* (2013) and Eni *et al.* (2014). None of these however, investigated the influence of physico-chemical parameters on the spatio-temporal abundance and diversity of phytoplankton in the River System which the present study is designed.

MATERIALS AND METHODS

Study area

The Great Kwa River (Fig.1) 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, and flows southwards discharging into the Cross River Estuary around latitude $4^0 45'$N and longitude $8^0 20'$E (Akpan, 2000).(Fig 1). Substratum here is covered with sand and clay with an average depth of 0.1m. It is slow flowing and has low to medium transparency. It is located in the thick swamp forested area in Calabar, Cross River State, Nigeria. The fringes of the river are dominated by the *Nypa fruticans* mangrove plants, elephant grasses (*Pennisetum purpurevn*), palm trees (*Elias guineesis*) and fan palm (*Hyphaene petersiana*) supporting an incredible array of animal life. The swampy region is greatly influenced by physical conditions as the tides continually exhibits fluctuations. The climate is governed by two seasons, the wet (April to October) and the dry (November to March). (Antai and Joseph, 2015). The lower reaches of the river drains the Eastern Coast of the Calabar Municipality, the capital of Cross River State, Nigeria (Victor *et al.,* 2013). The prevailing atmospheric weather condition is dry and wet season (Akpan, 2000).

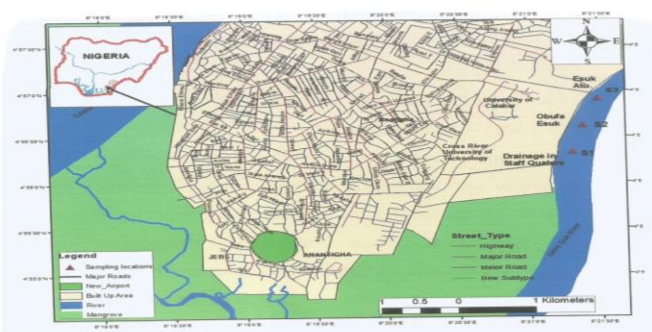

Fig.1: Map showing the Great Kwa River and sampling stations

Field Studies

Sampling for water parameters (pH, DO and Temperature) was done *insitu* during each month of sampling following APHA (1998) Temperature (^{O}C) was taken by use of mercury-in-glass thermometer, pH was measured using pH meter, while DO was measured using dissolved oxygen meter (HACH instrument) in mgL^{-1}.

Collection of phytoplankton samples

Phytoplankton samples were collected twice a month for three months (May-July, 2017) at three designated stations by filtration method as recommended by Dhanam *et al.* (2016). Samples collected at each of the stations were pooled into monthly sample for analysis. This involved filtering 20 liters of the habitats water through a 64µm bolting silk plankton net. The filtered samples were stored in 50mls plastic sample bottles and preserved with 4% buffered formaldehyde solution. Samples were collected between 07.00-09.00hrs during which time, solar radiation was not too intense to cause the phytoplankton to be photo-inhibited (Hulyal & Kaliwal, 2009;.Job *et al.,* 2017).

The collected samples were transported in plastic box to the Biological Oceanography Laboratory, Faculty of Oceanography, University of Calabar, Calabar- Nigeria, for analysis.

Laboratory analysis

In the Laboratory, the samples were concentrated to 10mls capacity and observed under an inverted microscope using x10 and x40 objectives. 1ml of Lugol's iodine solution was added as recommended (Job *et al.,* 2011) to enhance the identification of the phytoplankton species. On addition of the Lugol's iodine solution to phytoplankton samples, the stain become absorbed by the organelles of the phytoplankton cells, making them easily identifiable.

Identification of phytoplankton species

Identification of the phytoplankton species was done using standard schemes and guides of Whitford & Schumacher (1973) and Newell & Newell (1977). Identification of the phytoplankton was carried out to the nearest taxon possible.

Determination of numerical and relative abundance of the phytoplankton

The numerical abundance of each of the phytoplankton families was determined by counting the number of each species (n) in each of the families to know the total number (N) of the species in the family. This was used for the calculation of the relative abundance, based on the formula:

$$\% \text{ Ra} = \frac{n\,(100)}{N} \quad \text{...} \quad (1)$$

(Job *et al*., 2011; Udo *et al*., 2015; Job *et al*., 2017 and Job and Ekpo, 2017)

Where: % Ra = relative abundance
n = number of individual species
N = total number of all individuals

Determination of ecological indices of the phytoplankton

In this study, the following ecological indices were used to determine the diversity of the phytoplankton: Margalef's species diversity (S), Shannon-Wiener's index (H), Pielou's Evenness index (E), Simpson's Dominance index (D)

Margalef's index (d)

This index is dependent on sample size (Margalef, 1965; Ogbeigbu, 2005). It is based on the relationship "S" and the total number of individuals observed (N) (Job & Asuquo; 2009 and Job *et al.,* 2017), and in generally known to increase with increase in sample size (Ogbeigbu, 2005). The index is given by the formula:

$$d = \frac{S-1}{\ln N} \quad \text{..} \quad (2)$$

(Margalef, 1965, Ogbeigbu, 2005; Eyo *et al*., 2015 and Job *et al*., 2017).

where S= total number of species; N = total number of individuals samples and ln = the natural logarithm (Log_e).

The values of Margalef's diversity index (d) obtained from any ecological survey, usually windows the pollution status of the area (Ali *et al.,* 2003 and Job *et al.*, 2017).

Shannon-Wiener index (H)

This is sensitive to the number of species present and how evenly the individuals are distributed in the sample (Ogbeigbu, 2005 and Shannon-Wiener, 1949), and is given by the formula:

$$H = \frac{Nlog\ N - filogfi}{N} \qquad (3)$$

where N = total number of all individuals in the sample; fi = total number of individual species or group of species.

Pielou's Evenness index (E)

Evenness of the phytoplankton was determined by dividing the observed diversity (H) by the maximum diversity (H_{max}) of the phytoplankton during each month of sampling. This is represented by the formula:

$$E = \frac{H}{H_{max}} \qquad (4)$$

(Pielou, 1966, 1984 and Ogbeigbu, 2005).

Simpson's Dominance index (D)

Simpson's dominance index was determined using the formula:

$$D = \frac{ni\ (ni-1)}{Ni\ (Ni-1)} \qquad (5) \quad \text{(Ogbeibgu, 2005)}$$

This index usually varies between 0 and 1, and measures the extent one group of organisms dominates the other.

where:

ni = the number of individual species

Ni = the total number of all species from each group or family.

Statistical analysis

To compare the abundance of the phytoplankton during each month of sampling, the total number of the phytoplankton in each family was subjected to the single factor analysis of variance ANOVA by Rank (i.e. the KRUSKAL- WALLIS test) at 0.05 level of significance (Ogbeigbu, 2005).

RESULTS

Physico-chemical parameters and phytoplankton abundance

The abundance of the phytoplankton in relation to variations in the physico-chemical parameters is presented in Table 1. In May, total of 277 phytoplankton cells were recorded with a pH value of 6.52, dissolved oxygen of 6.6mgL^{-1} and temperature of 28.4^{0}C. In June, total of 283 phytoplankton cells were recorded at a temperature of 26.6^{0}C, pH of 7.24 and dissolved oxygen of 7.8mgL^{-1}, while in July, total of 277 phytoplankton cells were recorded at a temperature of 28.2^{0}C, pH of 6.55 and dissolved oxygen of 6.4mgL^{-1}.

It was observed that at lower temperatures, higher phytoplankton biomass was recorded. High dissolved oxygen content and low pH value was generally observed to also give rise to phytoplankton abundance and high diversity.

Table 1: Summary of the abundance of the phytoplankton in relation to the physico-chemical parameters of the Great Kwa River, Nigeria (May – July, 2017)

Month of sampling	Number of phytoplankton cells recorded	Physico-chemical parameters		
		pH	DOmgL-1	Temp. 0C
May	277	6.52	6.6	28.4
June	283	7.24	7.8	24.6
July	277	6.55	6.4	28.2
Mean values	279	6.77	6.93	27.72

Generally, pH was observed to range between 6.52 – 7.24, with an average value of 6.77, while dissolved oxygen ranged between 6.4 – 7.8mgL^{-1}, with an average of 6.93mgL^{-1} and temperature range of between 26.6 – 28.4^{0}C with an average of 27.73^{O}C (Table 1 and Figure 2).

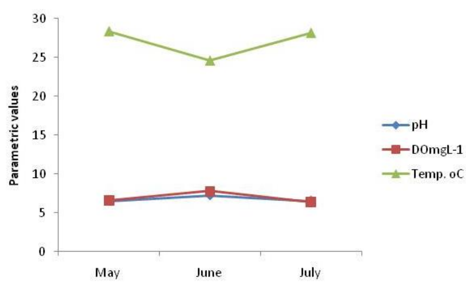

Fig. 2: Monthly variations in the physico-chemical parameters in the Great Kwa River, Nigeria (May – July, 2017).

Phytoplankton species composition

The phytoplankton species composition during the period of study is presented in Table 2. Altogether, 29 species of the phytoplankton belonging to five families were identified. These were **Baccilariophyceae** (*Hydrosera trignetra*, *Melosira ambugua*, *Stephanodiscus dubrius*, *Synedra rumpeus*, *Synedra ulna*, *Eunotia curvata*, *Eunotia elegans*, *Eunotia cunaris*, *Diatoma hiemala*, *Biddulphia laevia* and *Tebllaria binalis*), **Chlorophyceae** (*Tetrademus wisconsinensis*, *Gematozygon* *aculeatum*, *Crucigenia apiculata*, *Roya obtuse*, *Closterium ehrenbergii*, *Evastrum binale* and *Closterium*), **Euglenophyceae** (*Euglena vorax*, *Euglena tripteris*, *Euglena sengulena*, *Trachelomonas inspida* and *Trachedomonas sp*), **Cyanophyceae** (*Polycystis acroginosa*, *Polycystis acraginosa*, *Aphanotheca sp*, *Aphanotheca castagerei* and *Alphanotheca elelicatissima*) and **Charophyceae** (*Nitella acuminanta* and *Nitella flexilis*).

Table 2: Species composition of the phytoplankton identified from the Great Kwa River, Nigeria during the period of study (May- July, 2017)

	Taxonomic list of the phytoplankton	**May**			**June**			**July**		
		1st sampling	2nd sampling	Total	1st sampling	2nd sampling	Total	1st sampling	2nd sampling	**Total**
A	**Bacillariophyceae**									
1	*Hydrosera triguetra*	7	-	7	-	6	6	3	2	
2	*Melosira ambugua*	-	4	4	5	4	9	-	3	
3	*Stephanodiscus dubrius*	-	-	9	7	-	7	5	**4**	
4	*Synedra rumpeus*	9	4	15	-	7	7	8	**6**	
5	*S. ulna*	11	8	13	6	3	9	-	**3**	
6	*Eunotia curvata*	5	-	-	5	-	5	3	**-**	
7	*E. elegans*	-	9	17	5	4	9	5	**7**	
8	*E. Lunaris*	8	7	13	-	5	5	8	**-**	
9	*Diatoma hiemala*	6	-	-	3	-	3	11	**5**	
10	*Biddulphia Laevia*	-	5	14	7	9	16	4	5	
11	*Tebellaria binalis*	9	5	14	7	9	16	4	4	
	Abundance (N)	**63**	**43**	**106**	**47**	**43**	**90**	**54**	**43**	**97**
	Number of taxa (S)	**8**	**7**	**15**	**8**	**8**	**16**	**9**	**9**	**18**
B.	**Chlorophyceae**									
1	*Tetrademus wisconsinensis*	3	-	3	9	5	14	6	-	
2	*Gematozygon aculeatum*	6	5	11	3	-	3	7	5	
3	*Crucigenia apiculata*	4	6	10	-	6	6	4	3	
4	*Roya obtuse*	5	-	5	5	7	12	6	8	
5	*Closterium ehrenbergii*	-	2	2	-	4	4	10	-	
6	*Evastrum binale*	3	6	9	3	-	3	3	4	
7	*Closterium acceresum*	7	5	12	5	3	8	-	3	
	Abundance	**28**	**24**	**52**	**25**	**25**	**50**	**36**	**23**	**59**
	Number of taxa (s)	**6**	**5**	**11**	**5**	**5**	**10**	**6**	**5**	**11**
C.	**Euglenophyceae**									
1	*Euglena vorax*	3	5	8	6	11	17	5	3	
2	*E. Tripteris*	5	6	11	9	3	12	8	10	
3	*E. sangulena*	-	4	4	-	8	8	-	4	
4	*Trachelomonas inspida*	3	-	3	5	3	8	7	-	
5	*Trachelomonas sp*	5	-	5	-	7	7	6	2	
	Abundance	**16**	**15**	**31**	**20**	**32**	**52**	**26**	**19**	**45**
	Number of taxa (s)	**4**	**3**	**7**	**3**	**5**	**8**	**4**	**4**	**8**
D.	**Cyanophyceae**									
1	*Polycystis aeraginosa*	3	7	10	4	7	11	3	-	
2	*P. firma*	6	-	6	-	-	-	4	-	
3	*Aphanotheca sp*	4	5	9	3	4	7	6	-	
4	*Aphanotheca castagerei*	5	-	5	6	5	11	-	3	
5	*Aphanocapsa elelicatissima*	-	8	8	7	4	11	7	5	
	Abundance (N)	18	20	38	20	20	40	20	8	**28**
	Number of taxa (S)	4	3	7	4	4	8	4	2	**6**
E.	**Charophyceae**									
	Nitella acuminate	13	9	11	16	8	9	11	9	
	N. flexilis	11	17	8	14	13	6	16	12	
	Abundance (N)	**24**	**26**	**50**	**30**	**21**	**51**	**27**	**21**	**48**
	Number of taxa (S)	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**4**

Monthly spatial abundance; the major phytoplankton families

The monthly spatial abundance of the major phytoplankton is presented in Table 3.

Table 3: Summary of the numerical and relative abundance of the respective phytoplankton families during the period of study May-July, 2017) (Pooled Results)

Major phytoplankton families	Month of sampling May		June		July		Marginal total (Mt)
	Total (N)	%n	Total (N)	%n	Total (d)	%n	
Bacillariophyceae	106	38.27	90	31.80	97	35.01	293(35.0)
Chlorophyceae	52	18.77	50	17.67	59	21.30	161(19.24)
Euglenophyceae	31	11.19	52	18.37	45	16.25	128(15.29)
Cyanophyceae	38	13.72	40	14.13	28	10.11	106(12.66)
Charophyceae	50	18.05	51	18.02	48	17.33	149(17.80)
Overall total	**277**	**100.0**	**283**	**99.99≈100**	**277**	**100.0**	**837(100)**

Total of 105 Bacillariophyceae, which constituted 38.27% of the phytoplankton population were collected in May, with 90 individuals (31.80%) in June and 97(35.01%) in July.

In May, total of 52(18.77%) Chlorophyceae were recorded, with 50(17.67%) in June and 59(21.30%) in July. Total of 31(11.19%) Euglenophyceae were recorded in May, with 52(18.37%) in June and 45(16.25%) in July.

In May, total of 38(13.72%) Cyanophyceae were recorded, with 40(14.13%) in June and 28(10.11%) in July, while total recorded in May, with 51(18.02%) in June and 48(17.33%) in July.

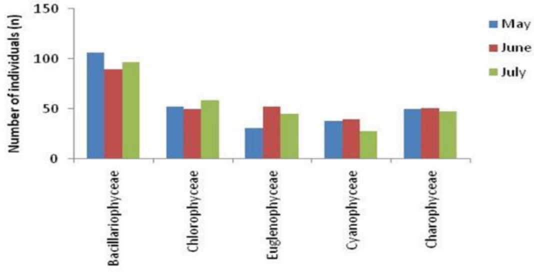

Fig. 3: Monthly abundance of the major phytoplankton families in the Great Kwa River, Nigeria (May – July, 2017)

Bacillariophyceae (Diatoms) were the most abundant phytoplankton in the Great Kwa River during the period of study with 293 cells (35.0%) of the overall phytoplankton. This was followed by Chlorophyceae with 161 cells (19.24%), Euglenophyceae with 128 cells (15.29%), Cyanophyceae with 128 cells (12.66%) and Charophyceae with 145 cells (17.80%), giving a distribution pattern of Bacillariophyceae > Chlorophyceae> Euglenophyceae> Cyanophyceae> Charophyceae.

Total Abundance (N)

Total abundance (N) of the phytoplankton individuals (N) and taxa number (S) of the phytoplankton is presented in Table 4.

Table 4: Summary of the number of individuals (N) and taxa number (S) of the phytoplankton in the Great Kwa River, Nigeria (May – June, 2017).

Month of sampling	Total abundance (N)	Number of taxa (S) (Pooled results)
May, 2017	277	42
June, 2017	283	46
July, 2017	277	47

In May, 277 individuals of the phytoplankton were recorded with a combined species (taxa) of 42, with 283 individuals and combined taxa of 46 in June, while in July, 277 individuals of the phytoplankton were recorded with a combined taxa of 47(Figure 4).

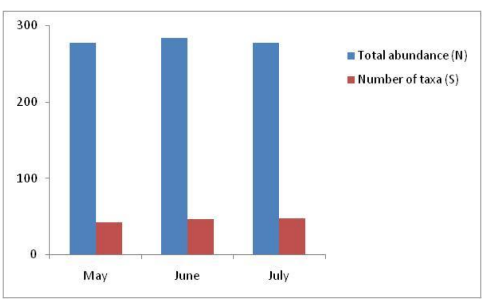

Fig. 4: Abundance of phytoplankton individuals and taxa from the great Kwa River, Nigeria (May – June, 2017).

Monthly ecological index values of the phytoplankton

The monthly variations in the ecological index values are presented in Table 5. In May, Margalef's index (d) calculated for the phytoplankton was 7.29, with a value of 7.97 in June and 8.18 in July. Shannon-Wiener index (H) was 2.195 in May, with a value of 2.180 in June and 2.158 in July. Pielon's Evenness index (E) had a value of 0.052 in May, 0.047 in June, 0.022 in May, 0.025 in June and 0.028 in July.

Table 5: Summary of the monthly ecological index values of the phytoplankton in the Great Kwa River, Nigeria during the period of study (May – July, 2017)

Ecological index values	Month of study		
	May	June	July
Margalef's index (d)	7.29	7.97	8.18
Shannon-Wienner index (H)	2.195	2.180	2.158
Pielou's index value (E)	0.052	0.047	0.045
Dominance index (D)	0.022	0.025	0.028

DISCUSSION

The ranges of the physico-chemical parameters are typical to those of tropical unpolluted riverine systems. Similar temperature ranges of 6.4 – 7.9mg/L were reported by Davies *et al.* (2009) in the Niger Delta area of Nigeria when studying seasonal abundance and distribution of plankton in the area. The ranges of pH and temperature recorded in this study are also in agreement with those of Davies *et al.* (2009), Obe *et al.* (2013), Francis *et al.* (2007) Unanam & Akpan (2013) and Egbai & Job (2017) The quality of water is known to play a vital role in the productivity of aquatic habitats (APHA, 1998; Francis *et al.,* 2007; Andem *et al.,* 2012 and Egbai & Job 2017), who respectively maintain that dissolved oxygen concentration of 6.0 – 8.0mg/L, pH of 6.5 – 8.0 and temperature of 25.0 – 30.3^{0}C is suitable for primary productivity and fish growth in a particular aquatic ecosystem. The range of the values of the physico-chemical parameters also agree with the report of Abubakar (2013), who studied the physico-chemical parameters of Dadin Kowa Dam, in Gombe State, Nigeria and Kolo & Tukura (2007), who studied some aspects of limnology of Tagweal Dam, Nigeria. The distribution and abundance of the phytoplankton seem to be dependent on the concentration of dissolved oxygen, pH and temperature. At dissolved oxygen of 7.8mg/L, higher number of phytoplankton cells was recorded, interplayed with reduced temperature. pH which was slightly acidic was quite optimum for primary productivity, and the Great Kwa River being a tidal river system, pH may be controlled by tidal incursions thereby influencing its values. Each species groups including phytoplankton in the aquatic environment may respond differently to changes in the environmental parameters, giving rise to their abundance or otherwise in a given period of the year (Slack, 1996; Abubakar, 2013; Uzukwu *et al.,* 2013 and Ndome *et al.,* 2012).

The phytoplankton species composition recorded in the Great Kwa River, Nigeria displays a typical tropical phytoplankton species composition. However, the monthly abundance of the phytoplankton was lower than those reported by Davis *et al.* (2009) in Minichinda stream, Niger Delta, Nigeria; Offem *et al.* (2011) in Okori Lake, Nigeria, Dimowo (2013) in River Ogun, Abeokuta, Ogun State, Nigeria; Chinda (2003) in a swamp forest stream in the lower Niger Delta, Nigeria and Eyo *et al.* (2013) in the Great Kwa River, Nigeria. The low abundance of phytoplankton in this study may be connected to the period (months) of sampling which coincided with the rainy period of the year which is known to reduce solar radiation, due to runoffs (Eni *et al.,* 2012; Eyo *et al.,* 2013) thereby deterring phytoplankton cell reproduction to its optimum level cell build-up (Nwankwo, 1998; Kadiri, 1999; Eni *et al.* 2012; Eyo *et al.* 2013).

The high abundance of *Bacillariophyceae* (the diatoms) in this study however agrees with the findings of Davies *et al.* (2009), Emmanuel & Onyema (2007), Akpan (1997), Ekeh & Sikoki (2004), Eni *et al.* (2012) and Eyo *et al.* (2013), who respectively maintained that the diatoms formed the buck of the phytoplankton in unpolluted tropical aquatic systems.

The phytoplankton diversity indices indicate Margalef index values of between 7.29 – 18.8, which portray an unpolluted environment. Ali *et al.* (2003) report that Margalef's index less than 1, windows highly polluted environment, while values from 1 – 3 show moderately polluted environment and values greater than 3 indicate clean environment. Aquatic systems are known for their capability for self-purification (Hynes, 1990; Ludwigs & Hallen, 1993; Macan, 1998). The Great Kwa River receives inputs from natural (runoffs) and anthropogenic activities including refuse discharge and sand mining which were physically observed during the period of this study. These would have been enough to impact on the quality of the water, but for the reason of self-purification, a platform was provided for the high Margalef's index values during the period of study. Again, the high Shannon-Wiener index values (2.158 – 2.195) indicate close range in the phytoplankton abundance (277 – 283) in the river system during the period of study, while the low Pielou's and Dominance indices are indicative of the evenness in the distribution of the phytoplankton species with dominance of the phytoplankton during the period of study falling within the same unit range (>200 cells) per month. Higher ranges of Margalef's, Shannon-Wiener, Pielou's and Simpson's Dominance indices were reported for phytoplankton in the Great Kwa River, Nigeria, by Eyo *et al.* (2013) and attributed it to longer period of sampling (May – October) 6 months, rather than the shorter period of this study (May – July) 3 months. Ogbeibu (2005) reported that close range in abundance of fauna and flora components in an ecosystem signals an unpolluted system.

SUMMARY AND CONCLUSIONS

In this study, 29 phytoplankton species belonging to five phytoplankton families were recorded. The major phytoplankton families were Bacillariophyceae, Chlorophyceae, Euglenophyceae, Cyanophyceae and Charophyceae. The Bacillariophyceae (Diatoms) were the most abundant phytoplankton family and contained 11 species. This was followed by Chlorophyceae with 7 species, Euglenophyceae and Cyanophyceae with 5 species each, and Charophyceae with 2 species. Physico-chemical parameters were generally within acceptable range for primary production and fish growth. May and July had the same phytoplankton abundance with 277 cells per month. Highest phytoplankton abundance was recorded in June with 283 cells.

Margalef's index ranged between 7.29 – 8.18, with Shannon-Wiener ranging between 2.158 – 2.195, while Pielou's index ranged between 0.045 – 0.052 and Simpson's index indicates an unpolluted system, while the range of values of Shannon-Wiener, Pielou's and Simpson's Dominace indices are respectively an indication of close abundance, even distribution and same range of dominance of the phytoplankton, which are indicative of an unpolluted and stable ecological system.

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