SEASONAL VARIATION IN COMPOSITION AND ABUNDANCE OF PHYTOPLANKTON COMMUNITIES IN CROSS RIVER ESTUARY, NIGERIA

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ABSTRACT

The seasonal variation of phytoplankton communities in the Cross River Estuary was investigated over a period of 24 months (March 2010 to February 2012), spanning two annual cycles. Taxa occurrence and abundance showed two peaks in March (dry season) and October (wet season), with the dry season peak higher than the latter. Bacillariophyceae recorded the highest taxa number (63) and cell density of 7.329 x 10^3 cells L^{-1} during the dry season, while recording 16 taxa and cell density of 3.499 x 10^3 cells L^{-1} during the wet season. Although species of Chlorophyceae and Euglenophyceae families conformed to the trend of higher dry season occurrence, both families rather showed higher wet season densities, deviating from the general trend of higher dry season densities. The only two species of Dinophyceae observed during this study were recorded during the dry season. Analysis of variance showed significant seasonal variation ($P < 0.05$; $n = 48$) in phytoplankton occurrence and abundance. Pearson's Correlation Coefficient revealed significant positive relationship ($P < 0.01$; $n = 48$; $df = 5$) between phytoplankton abundance and environmental factors during both wet and dry seasons. Blooms of blue green algae (Cyanobacteria) were observed to coincide with spontaneous mortality of *Heterotis niloticus* in the upper reaches of the estuary, during the dry season. The environmental implications of these results are discussed.

INTRODUCTION

The seasonality of phytoplankton taxa has been proven to have profound effects on aquatic productivity (Rochelle-Newall *et al*, 2011; Rahaman *et al*, 2013; Ewa *et al* 2013). Ezenwa *et al*, (1994) reported mean primary productivity values in Ikoyi fish pond ranging from 3.20gC/m^3/12hrs to 4.40gC/m^3/12hrs during the dry season, while wet season values were much lower, ranging from 0.22gC/m^3/12hrs to 0.34gC/m^3/12hrs. Dokulil (1994) reported a significant positive relationship ($P < 0.05$) between photo period and productivity in River Danube, Austria, while similar observations were reported by Hecky and Kling (1981), for Lake Tanganyika and Nyanayo *et. al,* (2006) for Brass River.

In areas of distinct wet and dry seasons, species composition, distribution and abundance are characterized by dry season maxima and wet season minima. Such observations have been reported in Cote D'Ivore (Adon *et al*, 2012), Shiroro Reservoir, Nigeria (Sikoki and Veen, 2004), and the Blue Nile (Talling and Rzoska, 1967). Furthermore, owing to the variable nature of estuaries, estuarine plankton exhibit a wide range of temporal variability in pattern, attributable to the combined effects of intrusion of seawater and inflow of freshwater from river discharge (Boxshall, 2006; Shivaprasad *et al*, 2013; Sarno *et. al*, 1993).

While seasonal variation of phytoplankton has been reported for other waters (Talling and Rzoska, 1967, Lind *et. al*, 1992, Rahaman *et al*, 2013) information on such temporal patterns and dynamics of this all important component of the aquatic ecosystem of Cross River Estuary

is rather scanty. Akpan and Ofem (1993) had earlier carried out studies on the Cross River waters, but with emphasis on water chemistry and hydrological regimes. Also, Ekwu and Sikoki (2006) had reported phytoplankton studies in this area but the study was limited to species composition and community structure. The dearth of scientific data on the seasonality of phytoplankton in this area has led to this research.

MATERIALS AND METHOD

Study Area

The Cross River Estuary ($8^0$00'E - $8^0$40'N; 4^0 30'N - $5^0$15'N) is situated in the Niger Delta region of Nigeria (Fig. 1). The estuary is located within the tropical rainforest belt, an area of distinct wet (April – October) and dry (November – March) seasons, characterized by torrential precipitation during the wet season, with extensive river discharge and surface runoff. This thus plays a tremendous role in the allochthonous input of organic and inorganic nutrients in the estuary, bringing about overall influence on the temporal dynamics of phytoplankton in the estuary.

Field Sampling Procedure

Water samples were collected monthly from six sampling stations (Fig. 1) at 1.5Km intervals, over a period of 24months, covering two annual cycles. The samples were collected vertically (surface and bottom), using a Hydrobios Nansen water sampler of 2 litre capacity. The surface samples were collected at 0.25m below the surface while the bottom samples were collected 0.25m above the bottom. Samples for physico-chemical parameters were kept separately in 1.5 litre polyethylene bottles and placed in ice boxes at 4^0C while in the field and during transportation to the laboratory. Samples for Biochemical Oxygen Demand (BOD_5) were collected in BOD bottles, sealed with black tape and later kept in the incubator for 5 days at 20^oC. Samples for Total Hydrocarbon Concentration (THC) were collected in 500ml glass bottles and sealed with aluminium foil until extraction, within 5 days of collection.

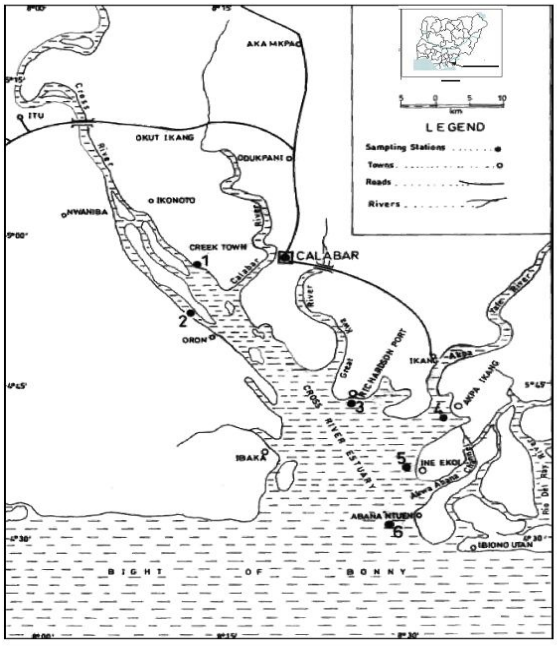

Fig. 1: Map of Lower Cross River Estuary Showing Sampling Stations

Vertical distribution of temperature (^{0}C), pH, turbidity (NTU), dissolved oxygen (mgl^{-1}) and conductivity ($mScm^{-1}$) were measured in-situ in the field using a Horiba digital water checker, model U – 10. Secchi disc transparency was measured using a Secchi disc, while salinity was measured using a refractometer.

For plankton analysis, two litres of water was collected from each station and filtered through a no. 20 net made of silk bolting cloth, of mesh size 76µm. For qualitative plankton studies trawl samples were collected from each station using a standard plankton net (which is a simple conical tow net) attached to a slow moving boat. Plankton filtered from each catch were washed into 1.5 litre polyethylene bottles and fixed immediately with 4% formalin, followed by 3 drops of Lugol's solution

Laboratory Analysis

Alkalinity, the acid neutralizing capacity of the water was determined titrimetrically with M0.02 H_2SO_4 using Phenolphthalein and Methyl Orange as indicators (APHA, 1985). Silicate was determined by using the silico-molybdate blue method (Parsons *et. al*, 1984). Total Hydrocarbon (THC) was determined spectrophotometrically after extraction of oil and grease with trichlorotrifloroethane and treatment with silica gel (APHA, 1985). For plankton analysis, one litre of sub-sample from each location was taken into a measuring cylinder (1 L capacity) and sedimented by adding 1 drop of household detergent. The supernatant was then decanted to 50ml of sedimented algal material. The settled sample was agitated and then transferred to a Sedgwick-rafter counting chamber fitted on a microscope. Microscopic examination was done at x 200 and x 400 magnification, using a Zeis inverted microscope. Identification was done using guides by Newell and Newell (1977), Maosen (1978), and APHA (1985).

A two-way analysis of variance (ANOVA) was used to compare the temporal dynamics of phytoplankton in the estuary vis-à-vis location. Also Pearson Correlation Co-efficient was used to evaluate the relationship between season and composition, distribution and abundance of phytoplankton in relation to physiochemical parameters across the six sampling stations.

RESULTS

The monthly variation of phytoplankton families and corresponding cell densities observed in Cross River Estuary during the two annual cycles are shown in Figure 2. Highest densities were recorded in March (dry season) and October (wet season) each year, with the dry season peak higher than the wet season peak.

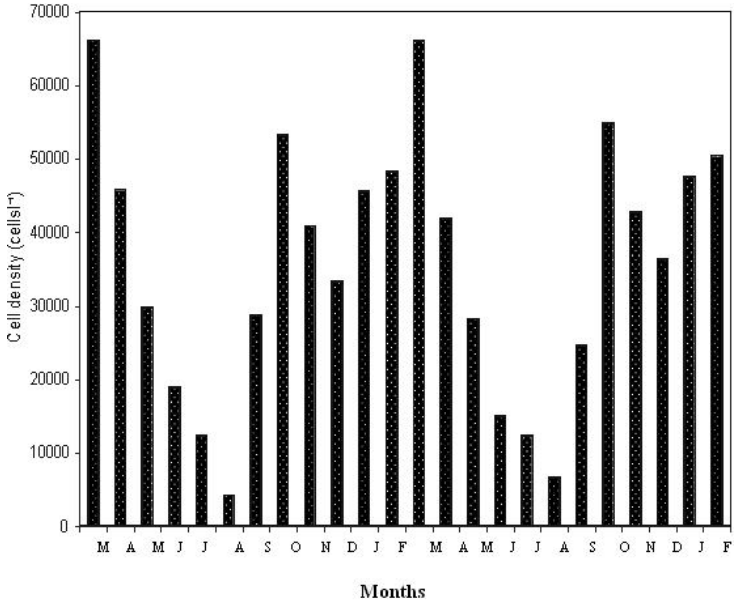

Figure 2: Monthly variation in total phytoplankton cell densities in Cross River Estuary March 2010 to February 2012

The family Bacillariophyceae recorded the highest taxa number of 63 species in March (dry season), each annual cycle. Similarly, cell densities for this family were highest in March during each cycle, with 7.329 x 10^3cells/L in the first cycle and 7.421 x 10^3cells/L in the second

cycle. The lowest taxa number (16 species) for this family was recorded in August (wet season) each cycle with corresponding cell densities of 3.499 x 10^3cell/L in the first cycle and 3.251 x 10^3cell/L in the second cycle. This pattern was also observed in Cyanobacteria with 17 species in March and 4 species in August (wet season) each cycle. Cell densities recorded for this group were in the first and second annual cycles, respectively, while wet season densities recorded in August of each cycle were 0.714 x 10^3cells/L and 0.659 x 10^3cells/L in the first and second cycles respectively.

Chlorophyceae, which was the next most abundant family, also showed higher dry season taxa number with 28 species during the dry season and 6 species in the wet season. This family, however, showed relatively higher cell densities compared to other groups (1.524 x 10^3cells/L and 1.531 x 10^3cells/L) during the wet season (August) in the first and second cycles respectively, contributing 14.5% of total wet season algal density. Dry season cell density for chlorophyceae was 0.975 x 10^3cells/L and 0.879 x 10^3cells/L for first and second annual cycles respectively.

Euglenophyceae showed a maximum taxa occurrence of 5 species in March of each cycle, while 4 species were recorded in the month of August (wet season) during each cycle. Cell densities for this family however showed higher values in the wet season, with 0.22 x 10^3cells/L and 0.324 x 10^3cells/L in the first and second cycles respectively.

The family Dinophyceae recorded zero taxa occurrence throughout the wet season, while the only two species observed during this study were recorded during the dry season. Analysis of variance showed significant seasonal variation ($P < 0.05$) in algal occurrence and abundance between wet and dry seasons. Also, during the dry season (Table 1), there was highly significant positive correlation ($P < 0.001$; $n = 48$; $df = 5$) between phytoplankton cell densities and water temperature ($r = 0.852$); salinity ($r = 0.730$); pH ($r = 0.793$); BOD_5 ($r = 0.770$); conductivity ($r = 0.852$); alkalinity ($r = 0.695$); silicates ($r = 0.720$); total hydrocarbon ($r = 0.764$); dissolved oxygen ($r = 0.820$) and inorganic phosphorus ($r = 0.804$). A significant negative correlation ($P < 0.05$) was however, observed during the same season between cell density and turbidity ($r=0.834$); nitrate – nitrogen ($r = -0.550$); ammonium – nitrogen ($r = -0.596$); lead ($r = -0.856$); orthophosphate ($r = -0.815$) and iron ($r = -0.504$), whereas a non-significant negative correlation ($P < 0.05$) existed between cell densities and nitrite – nitrogen, zinc, orthophosphate and cadmium (Table 1).

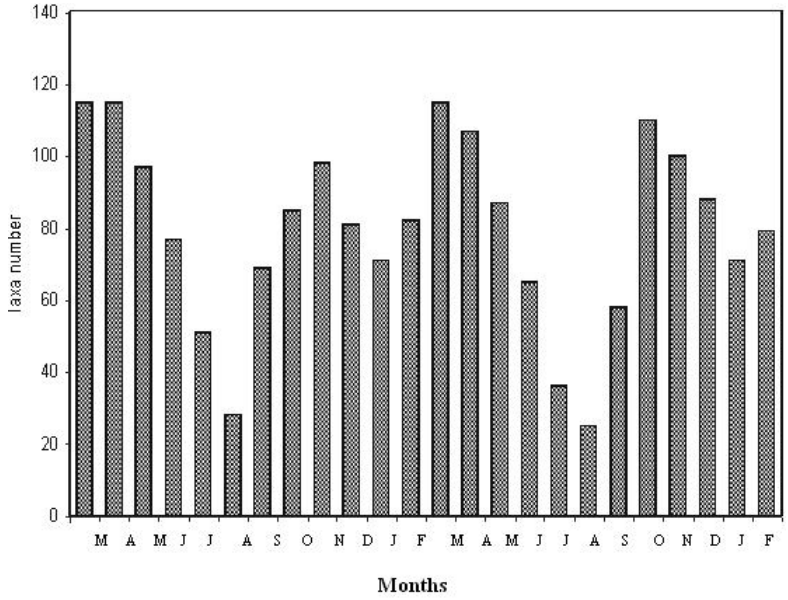

Fig.ure 3: Monthly variation in total phytoplankton taxa occurrence from March 2010 to February 2012

Table 1: Relationship between phytoplankton cell densities, nutrients and physico-chemical parameters of Cross River Estuary during the dry season

	Temp	pH	DO	Sal	Alk	Secchi	THC	Silicates	Cell Density	Inorg P	No_3	Turb.	No_2	Ortho P
Temp		0.864***	-0.748	-0.438*	0.031	0.114	0.499**	-0.542	0.852***	-0.376*	0.183	0.041	0.129	-0.623***
pH			0.070	0.763***	0.548***	0.043	0.311*	0.746***	0.793***	-0.601***	-0.318*	0.018	-0.056	-0.003
DO				0.882***	-0.135	-0.146	0.074	0.129	0.820***	0.354*	-0.098	-0.492**	0.151	0.235*
Sal					0.786***	0.121	0.381*	0.949***	0.730***	0.163	0.281*	0.010	0.032	0.003
Alk						-0.044	0.356*	0.897***	0.695***	0.041	0.015	0.203*	0.249*	0.018
Secchi							0.055	0.218*	0.467**	0.032	0.395*	0.420**	0.140	-0.052
THC								0.652***	0.764***	-0.016	-0.215*	-0.063	-0.043	-0.056
Silicates									0.720***	-0.257*	-0.458**	-0.264*	-0.236*	-0.203*
Cell Density										0.804***	-0.550**	-0.834***	-0.184	-0.815***
Inorg P											0.482**	0.126	-0.342*	0.504**
No_3												0.410**	0.523**	-0.087
Turb													0.392*	-0.208*
No_2														-0.037
Ortho P														

Table 2: Relationship between phytoplankton cell densities, nutrients and physico-chemical parameters Cross River Estuary during the wet season

	Temp	pH	DO	Sal	Alk	Secchi	THC	Silicates	Cell Density	Inorg P	No_3	Turb.	No_2	Ortho P
Temp		-0.580	-0.678	-0.115	0.204		-0.169	0.157	0.728***	-0.404*	0.232	0.111	0.185	-0.654***
pH			0.017	0.782***	0.785***		-0.085	0.761***	0.793***	-0.108	0.095	-0.059	0.119	0.123
DO				0.065	-0.140		-0.207	0.145	0.828***	-0.028	-0.080	-0.294	-0.334*	0.383*
Sal					0.879***		0.135	0.928***	0.511**	-0.349	-0.510**	-0.393*	-0.524**	-0.046
Alk							0.422*	0.674**	0.864***	0.216	-0.216	-0.353*	0.441	0.113
Secchi														
THC									-0.613**	-0.198	-0.198	-0.045	-0.034	-0.042
Silicates									0.649***	0.280	0.380	-0.250	-0.251	-0.143
Cell Density										-0.539**	0.482**	-0.866***	-0.115	-0.643***
Inorg P											-0.456*	0.014	0.025	0.321*
No_3												0.395*	0.611***	-0.064
Turb													0.0424	-0.301
No_2														-0.590**
Ortho P														

During the wet season (Table 2) a highly significant positive relationship ($P < .01$; $n = 48$; $df = 5$) was recorded for phytoplankton cell densities and temperature ($r = 0.513$), pH ($r = 0.793$); dissolved oxygen ($r = 0.828$); BOD_5 ($r = 570$) and conductivity ($r = 0.458$); alkalinity ($r = 0.864$) and silicates ($r = 0.649$) while a significant negative correlation ($P < 0.05$; $n = 48$) was observed between cell density and Turbidity ($r = -0.866$), orthophosphate ($r = -0.643$), alkalinity ($r = -0.864$), nitrates ($r = -0.482$), total hardness ($r = -.613$), total organic phosphates ($r = -0.539$) and total hydrocarbon ($r = 0.613$).

Furthermore, during the dry season, blooms of certain blue green algae such as *Oscilatoria tenius, O. nigroviridis, Nodularia spp, Lyngbya major* and *L. Majusculata* were observed. These blooms were observed to coincide with spontaneous mortality of certain ichthyofaunal species such as *Hetorotis niloticus* in large numbers in the upper reaches of the estuary and some tributaries in the basin area, each dry season. Dead fishes were found floating or stuck among weeds at the edges of the river course, during the months of February and March each annual cycle.

DISCUSSION

The temporal variability of phytoplankton observed during this study is consistent with other reports for tropical waters (Rahaman *et al*, 2013; Adon *et al*, 2012; Ezra and Nwankwo, 2001; Chindah and Amadi, 1993). The higher dry season values recorded for both taxa occurrence and cell densities could be attributed to increased insolation and higher transparency during this period, which promotes photosynthesis and increase in biomass (Sarno *et. al*, 1993; Perumal *et al*, 2009). The higher dry season temperatures, occasioned by higher insolation at this time, could also enhance increased phytoplankton densities, as indicated in the observed highly significant correlation between cell densities and water temperature in this study. Wetzel (2001) stated that the ecological effects of light and temperature on the photosynthesis and growth of algae are inseparable because of the interrelationship between metabolism and light saturation. The intensity of light required to saturate algal photosynthesis increases with increase in water temperature (Wetzel, 2001). Furthermore, algal respiration rate increases with increasing temperature. Thus, the complex of light intensity, temperature and respiration all work in concert to bring about growth and increase in phytoplankton biomass. Also, the dry season is characterized by cessation of rainfall and low river discharge, with attendant increased residence time of water in the estuary (Lowenberg and Kunzel, 1992 ; Perumal *et al*, 2009), which result in increased phytoplankton growth.

The higher diatom densities observed during the dry season in this study coincided with high levels of silicates at this time, also indicated by the observed highly significant correlation between cell densities and silicates (Table 1). Since diatoms were the most abundant group observed, their abundance significantly influenced the abundance of the entire phytoplankton.

The low wet season taxa occurrence and cell densities could be due to high river discharge with increased current speed and low residence time. Lowenberg and Kunzel (1992) reported an increase in river discharge in Cross River (study area) from $879m^3s^{-1}$ in January (dry season) to $2{,}533m^3s^{-1}$ in July (wet season). Talling and Rzoska (1967) and Biney (1990) reported similar observations of low wet season abundance in the Blue Nile and in coastal ecosystems in Ghana, respectively, attributing it to high river discharge. The low wet season densities could also be attributed to high turbidity during this period as is evident in the highly significant negative correlation ($r = -0.850$; $P < 0.001$) between cell density and turbidity.

Although Chlorophyceae and Euglenophyceae conformed to the general pattern of higher dry season taxa occurrence, cell densities in these two families showed relatively higher values during the wet season. This could be due to the declining salinities during this period, arising

from increased precipitation and river discharge. Chlorophyceae and Euglenophyceae have been known to prefer freshwater (Reynold, 1984; Wetzel, 2001; Rochelle-Newall *et al*, 2011). The observed lower wet season densities of Blue Green algae could be due to the prevalent lower temperatures of the wet season. Blue Green algae have a preference for higher temperatures (Wetzel, 2001)

CONCLUSION AND RECOMMENDATION

The temporal dynamics of phytoplankton play a key role in the aquatic productivity of the coastal region. The Cross River Estuary has been rated as one of the richest coastal resource bases in Nigeria, producing the bulk of smoke-dried shrimps (crayfish) and fin-fish marketed all over Nigeria and environs (Moses, 2000) and indeed the best quality shrimps in world (FAO, 1996). The seasonality of primary producers in the estuary is of serious ecological importance as it determines the seasonality of the overall productivity of the area. The spontaneous mortality of ichthyofaunal species especially *Heterotis niloticus* during the dry season, was observed to coincide with blooms of some blue green algae. This could be due to ingestion of some poisonous species of the algae by the fish. *Hetorotis niloticus* are known to be exclusively phytoplankton grazers (Reed *et al*, 1967). Further research on this strange phenomenon is recommended.

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