# Spatial and temporal variations of Phytoplankton pigments, Nutrients and Primary productivity in water column of Badagry Creek, Nigeria

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## ABSTRACT

The spatio-temporal variations of phytoplankton pigments, dissolved inorganic nutrients ($NO_2$, $NO_3$, $NH_4$, $PO_4$ and $SiO_4$) and primary productivity in Badagry creek, located in the most western part of barrier lagoon complex, Nigeria, were measured in nine stations on bimonthly basis for 2 years beginning in November, 2011. The dry season recorded higher mean values than wet season period for all parameters except transparency. Phosphate, Ammonium, Gross primary production and Community respiration showed significant differences ($P < 0.05$) between seasons. Nutrients concentration was higher in Ojo station than other stations studied except silicate (highest in Igbaji station). However, Lowest Chlorophyll-a mean value in Ojo station could be attributed to limit of Chlorophyll-*a* to certain levels by high phosphorus present in this station.

The rate of primary production was moderately uniform in all stations probably because of stable rate of photosynthesis caused by moderately stable water temperature experienced. The positive correlation between GPP and NPP revealed that high GPP was responsible for high NPP.

**Keywords:** Creek, Nutrients, Phytoplankton pigment, primary productivity

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## INTRODUCTION

Coastal waters are a very dynamic environment since they are influenced by both terrestrial inputs, natural and anthropogenic, as well as from inshore – offshore water exchanges, weather conditions and wind – driven water movements. In addition, coastal bathymetry complicates the system response to various inputs. All these physical mechanisms and the fact that nutrient transformations, nutrient uptake and phytoplankton growth proceed at a high rate, suggest that the trophic status of a coastal area should not be considered as an almost static entity (Giovanardi and Vollenweider, 2004).

Investigations of anthropogenic wastes and environmental modifications in the Lagos lagoon and adjoining creeks have revealed increased levels of pollution stress (Ajao, 1996). According to Nwankwo (2004), an important ecological ramification of increasing population pressure, poor sewage system, industrialization and poor waste management in Nigerian's coastal area is that pollutants freely find their way unabated into our coastal waters through drains, canals, rivers, creeks and lagoons that act as conduits.

Creeks are valuable part of the aquatic resources serving as Feeder Rivers, providing flood control, storm water drainage, and habitat to wildlife, creating neighborhood beauty and improving quality of life, yet they have become targets of destructive exploitation in recent times. Discharge of domestic and industrial effluents and sand mining activities according to Ajao, (1996) are some of man's actions which undermine the ecological integrity of lagoon ecosystem.

Nutrient concentrations are a common measure in evaluating trophic levels (Ignatiades *et al.* 1992). Nitrogen and phosphorus constitute a key factor in organic pollution in terms of their various organic and inorganic forms. Chlorophyll concentrations represent a very simple and integrative measure of the phytoplankton community response to nutrient enrichment. Increase in the phytoplankton biomass can be measured as an increase in the chlorophyll-a concentration. Chlorophyll is a useful expression of phytoplankton biomass and is arguably the single most responsive indicator of N and P enrichment in the marine system (Harding, 1994). Primary productivity of aquatic ecosystems is essential for a proper assessment of the biological potential of that habitat.The net primary productivity is of interest to ecologists, since this is the amount of energy that is available for use by consumers in an ecosystem and determines the energy budget of the ecosystem. In ecological studies, high primary productivity in an aquatic ecosystem indicates that the ecosystem is "healthy".

Badagry creek is one of the ecological important coastal waters in Nigeria for artisanal and commercial fisheries as well as recreation and domestic purposes. However, there is dearth of information with regards to functioning of the creek system. In the present study, as an essential first step, an attempt has been made to investigate Phytoplankton pigments, primary production and Dissolved inorganic nutrients of the creek. The information gathered will help to assess the current ecological status of the creek.

## MATERIALS AND METHODS

### *Study area*

Badagry Creek whose average depth is little more than 3m, is located (latitude 6°23¹ to 6°28¹N and longitude 2°42¹ to 3°23¹E) in the most western part of the Barrier Lagoon complex (200km) which lies between Badagry and Ajumo east of Lekki town in Nigeria. The Creek is approximately equidistant from the entrances of Lagos and Cotonou harbours. As a result, it is influenced by tides and floods from the Lagos Lagoon and Cotonou harbour through Lake Nokue and Lake Porto-Novo (Anyanwu and Ezenwa, 1988).

Nine stations were randomly selected and fixed with the aid of the Global Positioning System GPS (Magellan, SporTrak PRO MARINE [IEC – 529 IPX7 Model]) kit along transect of the creek for present study, viz., Apa (N6$^0$26'21.0" E2$^0$49'44.7"), Igbaji (N6$^0$25'14.6" E2$^0$51'37.9"), Badagry (N6$^0$24'22.0" E2$^0$53'04.0"), Akarakumo (N6$^0$24'37.0" E2$^0$57'40.9"), Ajido (N6$^0$24'48.6" E3$^0$00'30.0"), Irewe (N6$^0$25'16.9" E3$^0$08'38.4"), Igbolobi (N6$^0$24'35.7" E3$^0$11'07.4"), Iyagbe (N6$^0$25'09.5" E3$^0$11'56.1"E) and Ojo (N6$^0$27'02.9" E3$^0$12'30.6") (Figure 1).

### *Sample collection*

Water samples were collected bimonthly from nine stations between November, 2011 and September, 2013. The samples were collected just below the surface at each station due to the shallow nature of the water body using a plastic 2-L van Dorn sampler, and then poured in 1 litre screw- capped plastic containers for nutrients determination and in non-toxic 1-L opaque sampling bottle, protected from warming and light, transported to the laboratory and filtered without delay for measurement of chlorophyll-a (Alain and Francisco, 2000). Water samples were stored in a refrigerator at 4$^0$C ± 1$^0$C prior to analyses.

For primary productivity, water samples were collected at each station using a van Dorn bottle, poured in light and dark glass bottles (one of these was black glass or glass bottle painted black to make it opaque while the other bottles were transparent/clear). The initial clear bottles filled with water were fixed immediately according to Winkler’s method for initial Dissolved oxygen determination, and the duplicate clear and dark bottles suspended (incubated) in a vertical position at each sampling depth for 24 hours for total primary productivity determination (NOAA, 2000).

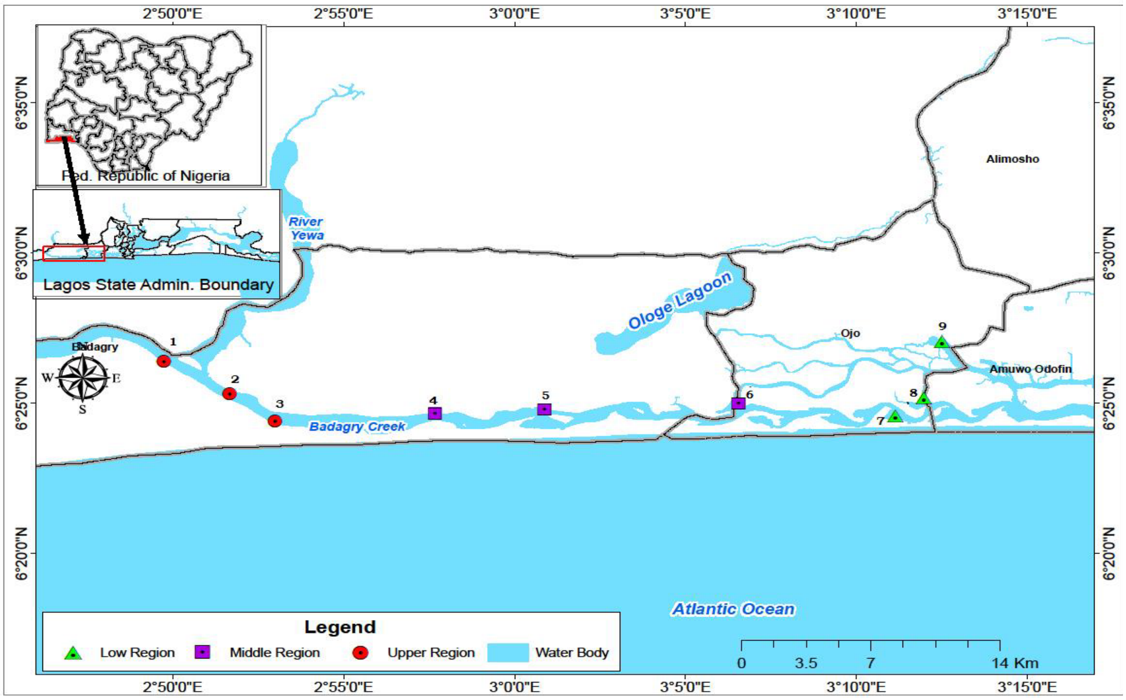


**Figure 1: Map of Badagry Creek showing sampling stations.**

1– Apa; 2 – Igbaji; 3 – Badagry; 4 – Akarakumo; 5 – Ajido; 6 – Irewe; 7 – Igbolobi; 8 – Iyagbe; 9 – Ojo

***Sample measurement***

The measured parameters were Chlorophyll-a (Chl-*a*), Nutrients (Nitrite $NO_2$, Nitrate $NO_3$, Ammonium $NH_4$, Phosphate $PO_4$ and Silicate $SiO_4$), Primary productivity, Water temperature, Secchi disc transparency and Dissolved oxygen.

Water temperature was measured *in situ* with mercury-in-glass thermometer, Dissolved oxygen concentration was measured using Winkler's method and water transparency with a 20 cm Secchi disc. Monthly rainfall data measured in mm of the study area for the study periods were obtained from the Nigerian Meteorological (NIMET) marine office at the Nigerian Institute for Oceanography and Marine Research, Victoria- Island Lagos**.**

The Phytoplankton pigments (Chlorophyll-*a*) samples were obtained by filtering the water sampled for each set of samples collected from the creek within 24hrs through Whatman GF/C glass fibre filters (approximately1.2µm pore size). Filters and water samples were stored frozen (−20 °C) until analysis. Filters were transferred to tubes containing 90% aqueous acetone solution, ground with a Teflon pestle, and the Chl-*a* extracted in the dark during 24 h. Extracts were then centrifuged at 3000 g for 15 minutes and analysed spectrophotometrically (Parsons *et.al.*, 1984 ).

For nutrients analyses, water samples were filtered due to turbid nature of the water through Whatman GF/C glass fibre filters for measuring manually nutrients concentration except for Ammonium. Nitrite-nitrate ($NO_2$, $NO_3$) and ammonium were analysed using the standard pink azo-dye and indophenol methods respectively. Phosphate and silicate were determined using the molybdenum-blue methods. In all cases the dissolved inorganic nutrient analyses followed the methods of Parsons *et al.*, (1984).

Productivity was calculated on the assumption that one atom is assimilated for each molecule of oxygen (32g) released for each molecule of carbon (12g) fixed (APHA, 1989). The change in oxygen level in the dark bottle (a negative number) is equal to the oxygen consumed by respiration. The change in oxygen level in the light bottle (most likely a positive number) is equal to the net oxygen production (net primary production). From these two values, the gross primary productivity was determined by adding the absolute value of the change in oxygen in dark bottle to the change in oxygen in the light bottle (NOAA, 2000). In converting the DO (mg/l) values to gC/m3/h, the factor 0.375 (12/32) was used and per hour values were multiplied by 24 to derive the productivity values per day (Michael, 1984).

***Data / Statistical analyses***

Based on the rainfall pattern of the study area, November to April was designated as dry season period while May to October as wet season period of each year. Data generated from this study were subjected to both descriptive (mean and standard deviation) and inferential statistics (one-way ANOVA and correlation) using Microsoft excel (2010) and Spss2 (2001).

Data were pooled and presented as seasonal and spatial mean variances. The data were compared by means of one-way ANOVA in order to evaluate if their difference was significant ($p$-value $< 0.05$). Correlation matrix analysis was employed to identify possible significant relationships among Phytoplankton pigments (Chl-*a*), Dissolved inorganic nutrients and Primary productivity at both 0.01 and 0.05 significant level.

## RESULTS

### *Rainfall*

Rainfall values recorded throughout this study was between 1.1mm in January, 2012 and 476.7mm in June, 2012. The total rainfall received was 3342.8mm throughout the study period, with 1827.8mm of rainfall during the first year and 1515mm during the second year (Fig. 2). The average rainfall in the Badagry creek during the period of study was 152.32mm and 126.25mm in the first and second year of study respectively. In this study, the month of June in each year produced the (maximum) peak values of rainfall. Although, the month of August falls into wet season, usually August break caused by a sharp drop in rainfall (downpour) was observed in both years.

### *Water Temperature*

Water temperature values throughout the sampling duration were between $24.8^0$C in the month of September, 2012 and $32^0$C in May, 2013. Mean water temperature values (Table 1) of stations were fairly stable in all the studied stations and varied from $29.04 \pm 2.54^0$C (Igbaji station) to $29.75 \pm 1.50^0$C (Ajido station) with a grand mean of $29.45 \pm 0.24^0$C (Table 2). Season-wise (Table 3), mean water temperature was slightly higher in the dry season ($29.71 \pm 0.48^0$C) than in the wet season ($29.19 \pm 2.43^0$C). However, all stations showed a sudden decline in water temperature in the month of September, 2012. A one way ANOVA on the results showed that there was no significant difference ($p > 0.05$) in water temperature values between stations and seasons.

### *Water Transparency*

Secchi disc transparency range of 45 to 261cm was recorded in the study area with the maximum value noted at Badagry station in May, 2012 and the minimum in November, 2012 (Ojo station), with a grand mean of 103.27 ± 13.91cm (Table 2). Spatially, mean transparency value (Table 1) was between 82.42 ± 49.70cm (Ojo station) and 121.33 ± 39.34cm (Apa station). Transparency average value (Table 3) was higher in the wet season (110.28 ± 27.99cm) than the dry season (96.26 ± 11.24 cm). However, ANOVA on the results showed no significant differences ($p > 0.05$) in transparency values between stations and seasons.

### *Phytoplankton pigments*

Chlorophyll-a (Chl-*a*) varied between 0.21 µg/l (Ajido station) in November, 2011 and 123.20 µg/l (Igbolobi station) in January, 2013 throughout the study period. The highest (22.21 ± 37.80µg/l) and lowest (8.68 ± 11.23µg/l) chlorophyll-*a* mean values were obtained at Igbolobi and Ojo stations respectively (Table 1), with a grand mean of 16.18 ± 17.61µg/l

(Table 2). Season-wise, the mean Chl-*a* concentration obtained for dry season (16.77 ± 9.86µg/l) was higher than value (15.59 ± 20.62µg/l) observed in wet season (Table 3). Statistical analyses on the results showed that there was no significant difference ($p > 0.05$) in Chl-*a* mean between stations and seasons.

***Primary productivity***

A range of 0 (compensation depth) and 0.90gC/m$^2$/d was obtained for Net primary productivity (NPP) in this study. No particular pattern was observed in spatial variation of NPP. The highest NPP value was in January, 2013 at Irewe station. NPP mean value was higher in the dry season (0.22 ± 0.12gC/m$^2$/d) than in the wet season (0.20 ± 0.03gC/m$^2$/d) (Table 3). However, no significant differences ($p > 0.05$) were observed in NPP between seasons and stations. Gross primary productivity (GPP) and Community respiration (CR) showed similar trend and ranged from 0.15 to 1.80gC/m$^2$/d and 0 to 1.65gC/m$^2$/d respectively, with the maximum values in January, 2012 at Igbolobi station. The highest and lowest average GPP (0.56 ± 0.35gC/m$^2$/d) and (0.38 ± 0.19gC/m$^2$/d) and community respiration (0.37 ± 0.33gC/m$^2$/d) and (0.15 ± 0.12gC/m$^2$/d) values were recorded at Akarakumo and Apa station respectively (Table 1). Seasonally, GPP and CR mean values were higher for dry season than wet season (Table 3). A one-way analysis of variance (ANOVA) on the GPP and CR mean values showed significant differences between seasons ($p < 0.05$).

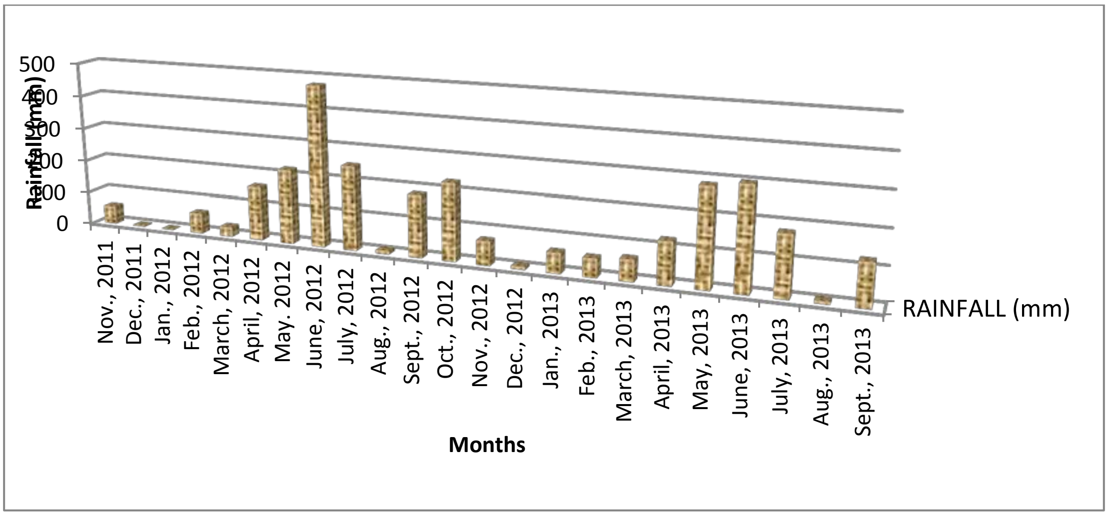


**Figure 2: Monthly Rainfall (mm) pattern in Badagry Creek (November, 2011 – September, 2013).**

**Table 1: Spatial distribution (Means ± standard deviation) of Temperature, Secchi disc transparency, Chlorophyll-a, Primary productivity and Nutrients in Badagry Creek (November, 2011 – September, 2013)**

| Parameters | St. 1 | St. 2 | St. 3 | St. 4 | St. 5 | St. 6 | St. 7 | St. 8 | St. 9 | P value |
|---|---|---|---|---|---|---|---|---|---|---|
| Water Temperature ($^0$C) | 29.63 ± 1.69 | 29.04 ± 2.54 | 29.38 ± 2.47 | 29.42 ± 2.20 | 29.75 ± 1.50 | 29.54 ± 1.88 | 29.58 ± 1.33 | 29.13 ± 1.58 | 29.58 ± 1.58 | > 0.05 |
| Transparency (cm) | 121.33 ± 39.34 | 117.00 ± 20.26 | 116.50 ± 47.99 | 97.08 ± 34.54 | 112.17 ± 45.77 | 100.83 ± 36.76 | 91.08 ± 69.15 | 91.00 ± 37.30 | 82.42 ± 49.70 | > 0.05 |
| Chlorophyll-a (µg/l) | 21.92 ± 19.90 | 15.55 ± 13.33 | 12.14 ± 15.73 | 20.72 ± 18.05 | 15.17 ± 15.17 | 14.99 ± 14.94 | 22.21 ± 37.80 | 14.22 ± 10.19 | 08.68 ± 11.23 | > 0.05 |
| NPP ($gC/m^2/d$) | 0.24 ± 0.15 | 0.19 ± 0.14 | 0.25 ± 0.18 | 0.19± 0.14 | 0.25 ± 0.20 | 0.22 ± 0.22 | 0.15 ± 0.08 | 0.18 ± 0.13 | 0.19 ± 0.15 | > 0.05 |
| GPP ($gC/m^2/d$) | 0.38 ± 0.19 | 0.43 ± 0.20 | 0.50 ± 0.20 | 0.56 ± 0.35 | 0.47 ± 0.25 | 0.50 ± 0.38 | 0.43 ± 0.45 | 0.49 ± 0.24 | 0.43 ± 0.26 | > 0.05 |
| CR ($gC/m^2/d$) | 0.15 ± 0.12 | 0.24 ± 0.25 | 0.25 ± 0.15 | 0.37 ± 0.33 | 0.23 ± 0.11 | 0.28 ± 0.31 | 0.28 ± 0.45 | 0.32 ± 0.21 | 0.25 ± 0.22 | > 0.05 |
| $NO_2$ (µM) | 1.72 ± 1.57 | 2.01 ± 1.72 | 1.57 ± 1.79 | 1.38 ± 1.31 | 2.15 ± 1.63 | 2.82 ± 2.15 | 2.59 ± 1.80 | 2.69 ± 2.71 | 3.36 ± 1.95 | > 0.05 |
| $NO_3$ (µM ) | 3.75 ± 3.26 | 4.74 ± 4.00 | 3.94 ± 3.87 | 6.85 ± 6.25 | 6.95 ± 5.50 | 9.87 ± 7.04 | 7.91 ± 6.67 | 8.06 ± 6.82 | 12.53 ± 6.69 | > 0.05 |
| $PO_4$ (µM) | 5.04 ± 3.24 | 4.90 ± 3.29 | 5.83 ± 3.51 | 4.94 ± 3.07 | 4.83 ± 2.98 | 5.28 ± 3.65 | 5.46 ± 3.24 | 6.79 ± 5.23 | 7.99 ± 4.64 | > 0.05 |
| $NH_4$ (µM) | 50.15 ± 15.49 | 55.10 ± 11.73 | 50.29 ± 15.70 | 43.33 ± 17.01 | 47.45 ± 17.37 | 50.34 ± 21.79 | 52.11 ± 16.11 | 49.22 ± 21.00 | 60.49 ± 18.36 | > 0.05 |
| $SiO_3$ (µM) | 154.43 ± 63.44 | 166.48 ± 103.69 | 161.48 ± 106.75 | 152.35 ± 108.86 | 165.38 ± 78.75 | 148.95 ± 83.56 | 132.53 ± 80.91 | 117.26 ± 89.65 | 135.81 ± 60.96 | > 0.05 |

**St. 1 - Apa; St.2 – Igbaji; St. 3 – Badagry; St. 4 – Akarakumo; St. 5 – Ajido; St. 6 – Irewe; St. 7 – Igbolobi; St. 8 – Iyagbe; St. 9 – Ojo**

**Table 2: Grand mean ± standard deviation of Temperature, Secchi disc transparency, Chlorophyll-a, Primary production and Nutrients in Badagry Creek (November, 2011 – September, 2013)**

| Parameters | Mean ± SD |
|---|---|
| Water temperature ($^0$C) | 29.45 ± 0.24 |
| Transparency (cm) | 103.27 ± 13.91 |
| Chlorophyll-a (µg/l) | 16.18 ± 17.61 |
| NPP ($gC/m^2/d$) | 0.21 ± 0.09 |
| GPP ($gC/m^2/d$) | 0.47 ± 0.21 |
| CR ($gC/m^2/d$) | 0.26 ± 0.21 |
| $NO_2$ (µM) | 2.25 ± 0.66 |
| $NO_3$(µM) | 7.18 ± 2.86 |
| $PO_4$ (µM) | 5.67 ± 1.07 |
| $NH_4$ (µM) | 50.94 ± 4.80 |
| $SiO_4$ (µM) | 148.30 ± 16.65 |

**Table 3: Seasonal variation (Mean ± Standard Deviation) of Temperature, Secchi disc transparency, Chlorophyll-a, Primary productivity and Nutrients in Badagry Creek (November, 2011 – September, 2013)**

| Parameters | Dry season | Wet season | P value |
|---|---|---|---|
| Water temperature ($^oC$) | 29.71 ± 0.48 | 29.19 ± 2.43 | > 0.05 |
| Transparency (cm) | 96.26 ± 11.24 | 110.28 ± 27.99 | > 0.05 |
| Chlorophyll-a (µg/l) | 16.77 ± 9.86 | 15.59 ± 20.62 | > 0.05 |
| NPP ($gC/m^2/d$) | 0.22 ± 0.12 | 0.20 ± 0.03 | > 0.05 |
| GPP ($gC/m^2/d$) | 0.54 ± 0.29 | 0.39 ± 0.06 | < 0.05 |
| CR ($gC/m^2/d$) | 0.33 ± 0.28 | 0.19 ± 0.06 | < 0.05 |
| $NO_2$ (µM) | 2.43 ± 1.60 | 2.08 ± 1.11 | > 0.05 |
| $NO_3$ (µM ) | 7.20 ± 4.44 | 7.15 ± 4.67 | > 0.05 |
| $PO_4$ (µM) | 6.54 ± 3.48 | 4.80 ± 3.10 | < 0.05 |
| $NH_4$ (µM) | 54.36 ± 9.39 | 47.53 ± 5.41 | < 0.05 |
| $SiO_4$ (µM) | 165.16 ± 93.94 | 131.43 ± 49.46 | > 0.05 |

**Table 4: Correlation coefficients between Water temperature, Secchi disc transparency, Rainfall, Chlorophyll-a, Primary productivity and Nutrients in Badagry Creek. (November, 2011 – September, 2013) *P < 0.05, **P < 0.01**

| | Trans-parency | Chl-a | NPP | GPP | CR | $NO_2$ | $NO_3$ | $NH_4$ | $PO_4$ | $SiO_4$ | Rainfall |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Water temp. | 0.59* | 0.63* | -0.24 | -0.46 | -0.35 | 0.33 | 0.16 | 0.11 | 0.04 | -0.30 | 0.24 |
| Transpa-rency | 1.00 | 0.18 | -0.03 | -0.12 | 0.00 | 0.14 | 0.36 | 0.32 | 0.15 | 0.07 | 0.12 |
| Chl-a | | 1.00 | 0.12 | 0.12 | -0.17 | 0.70* | 0.27 | 0.36 | 0.51 | 0.16 | -0.15 |
| NPP | | | 1.00 | 0.47 | -0.45 | 0.39 | 0.53 | 0.05 | 0.35 | 0.81** | 0.11 |
| GPP | | | | 1.00 | 0.50 | 0.13 | 0.05 | 0.55 | 0.45 | 0.56 | -0.40 |
| CR | | | | | 1.00 | -0.41 | -0.52 | 0.35 | -0.05 | -0.19 | -0.49 |
| $NO_2$ | | | | | | 1.00 | 0.65* | 0.54 | 0.83** | 0.38 | -0.11 |
| $NO_3$ | | | | | | | 1.00 | 0.39 | 0.70* | 0.71** | -0.16 |
| $NH_4$ | | | | | | | | 1.00 | .755** | 0.28 | -0.49 |
| $PO_4$ | | | | | | | | | 1.00 | 0.58* | -0.44 |
| $SiO_4$ | | | | | | | | | | 1.00 | -0.23 |

***Dissolved inorganic nutrients***

Nitrite ($NO_2$) values in this investigation varied from 0.022µM at Badagry station in November, 2011 to 9.565µM at Iyagbe station in May, 2013. Nitrite average values (Table 1) spatially ranged between 1.38 ± 1.31µM (Akarakumo station) and 3.36 ± 1.95µM (Ojo station). Seasonally, Nitrite mean value (Table 3) was higher in dry season (2.43 ± 1.60µM) than wet season (2.08 ± 0.11µM). Nitrate concentration ranged from 0.161µM at Irewe (November, 2011), Ajido (September, 2012), Badagry and Igbaji stations (May, 2013) to 18.387µM at Irewe station in July, 2013. Season-wise, nitrate mean concentration (Table 3) was higher in dry season (7.20 ± 4.44µM) than wet season (7.15 ± 4.67µM). The maximum and minimum mean nitrate content (12.53 ± 6.69µM) and (3.94 ± 3.87µM) were obtained at Ojo and Badagry stations respectively (Table 1). However, a one-way ANOVA on the nitrite and nitrate results showed that there were no significant differences ($p > 0.05$) between seasons and stations.

Ammonium concentration varied from 4.12µM at Iyagbe station (May, 2013) to 81.18µM at Irewe station (November, 2011). Comparatively, Ojo station had the highest Ammonium mean concentration (60.49 ± 18.36µM) whereas Akarakumo station recorded the least mean value of 43.33 ± 17.01 µM (Table 1). Average Ammonium value of 54.36 ± 9.39 µM obtained in dry season period was higher than 47.53 ± 5.41µM obtained in wet season (Table 3). Statistical analysis revealed significant differences ($p < 0.05$) in Ammonium mean values between seasons.

The concentration of phosphate in this study was from 0.11µM (May, 2012) at Iyagbe station to 15.27µM at Ojo station (January, 2012). Seasonally, inorganic phosphate was higher in dry season than wet season with mean concentration of 6.54 ± 3.48 and 4.80 ± 3.10µM in dry and wet season respectively (Table 3). Spatially, the highest average inorganic phosphate concentration was obtained at Ojo station (7.99 ± 4.64µM) and the least concentration (4.90 ± 3.29µM) at Igbaji station (Table 1). A one way analysis of variance on the results showed there was no significant difference ($p > 0.05$) in phosphate mean between stations, but the differences between seasons was significant ($p < 0.05$). The values of silicate were higher than the other nutrients ($NO_2$, $NO_3$, $PO_4$ and $NH_4$) in this study. The minimum silicate concentration (0.79 µM) was recorded at Iyagbe station (November, 2011) while the maximum silicate value (368.01µM) was obtained in January, 2013 at Ajido station. The highest (166.48 ± 103.69 µM) and least (117.26 ± 89.65 µM) silicate mean concentration were obtained at Igbaji and Iyagbe stations respectively (Table 1). Generally, higher concentrations of silicate were recorded in all the studied stations in January, 2013. Seasonally, silicate mean value (165.16 ± 93.94 µM) obtained in dry season was higher than (131.43 ± 49.46µM) recorded for wet season (Table 3). However, no significant spatial and seasonal differences ($P > 0.05$) were detected with regards to silicate.

Correlation analyses (as shown in Table 4) were carried out between all the parameters measured. Transparency significantly correlated positively with water temperature. Rainfall correlated inversely with $NO_2$, $NO_3$, Ammonium, Phosphate, Silicate, Chlorophyll-a, GPP and CR but showed a weak positive correlation with NPP. Chlorophyll-a (Chl.a) showed significant positive correlation with water temperature and nitrite. There was a significant positive correlation of nitrate with nitrite. Phosphate showed highly significant positive correlation with nitrite and ammonium and significant positive correlation with nitrate. Silicate also revealed highly significant positive correlation with nitrate and significant positive correlation with phosphate.

## DISCUSSION

The rainfall data of study duration were typical of tropical and subtropical regions that are characterized by heavy rainfall. The water temperatures obtained in this study compare favorably with temperatures reported by previous workers in Nigeria southwestern coastal waters. All stations showed similar temperature trend with similar changes. This phenomenon is typical for the tropics.

The minimal variation in temperature between stations and zones could be attributed to their exposure to the same climatic elements. Transparency measures the light penetrating through the water body. Low transparency values recorded in some stations was an indication of low light penetration which may possibly be caused by the turbid nature of the water and relatively high density of algae while the relatively high transparency values obtained in others stations may be attributed to less turbulence created in the water body. Wet months in this study exhibited higher transparency mean values than dry months. This is shown by the positive correlation between transparency and rainfall ($r = 0.12$), although the magnitude of the correlation is weak. The declined mean transparency value in dry months may be ascribed to higher evaporation caused by high air temperature and reduced relative humidity, which subsequently decreased transparency of water. This observation was in line with finding of Chisty (2002).

The nutrients average concentration in Ojo station was higher than other stations studied except silicate (highest in Igbaji station). Higher Dissolved inorganic nutrients observed at Ojo sampling station could probably due to anthropogenic effects. Ojo community, which is geographically closer to the harbour, has over the past few years, experienced rapid population growth, and the establishment of more human settlements. The resulting domestic sewage discharges and surface run-off from the other land-based sources might have increased the nutrient levels of the estuarine waters at Ojo station. Relatively higher Dissolved inorganic nitrogen recorded during the dry months may be attributed to the effect of direct discharges of sewage and other biodegradable wastes into the creek coupled with the enrichment of adjoining water bodies. It may also be as a result of the release of trap nutrients in the sediment bed caused by the sand mining activities, a common phenomenon during the dry month's period. The slightly decreased nitrates concentration as the rainfall increased in this study could be due to dilution effect of rainfall. Similar finding had been reported by Ajibola *et al.* (2005). Phosphate is one of the most important nutrient and a limiting factor in the maintenance of aquatic ecosystem fertility. The higher mean value during the dry months may be related to the weathering of rocks and sand mining activities liberating soluble alkali phosphate coupled with inputs of domestic sewage and industrial effluents. This finding was in agreement with that in Udaipur lakes (Chisty, 2002). Although ammonium is only a small component of the nitrogen cycle, it contributes to the trophic status of a body of water. The criteria set for ammonium to protect aquatic life are dependent on the temperature and pH of the water. The slightly high ammonium reported (4.12 – 81.18µM) with the peak value (81.18 µM) observed in Irewe station could probably be due to the decomposition of organic matter from sewage entering the station. Generally, high ammonium concentration is an indication of organic pollution in aquatic ecosystem. Silicate levels showed a negative correlation with rainfall. This suggests that the recorded higher dry month's silicate content may be due to the release of silicate to the water by disturbances in substrates or silicate leaching out of silicates from bottom sediments exchanging with overlying water possibly due to the turbulent nature of the water body. The lower concentration during wet months may be attributed to uptake of silicate by phytoplankton for their biological activity (Mishra *et al.*, 1993).

The rate of primary production in Badagry creek was found to be moderately uniform in stations studies and throughout the study probably because of stable rate of photosynthesis caused by moderately stable water temperature experienced. Planktonic photosynthetic productivity is one of the major contributors to the overall productivity of open aquatic ecosystems. Temperature, solar radiation and available nutrients may be important limiting factors for primary production and contributing to seasonal variation in any aquatic ecosystem (Sultan *et al.*, 2003).

The higher mean of the pooled values of Gross primary productivity (GPP) and Net primary productivity (NPP) during the dry season period may be due to penetration of more light, intensity which facilitates higher rate of photosynthesis and ultimately the productivity of the ecological system. The positive correlation between GPP and NPP ($r = 0.47$, $P = 0.126$) in this study, revealed that high GPP was responsible for high NPP.

The observed decreased value of NPP and GPP during the rainy season period in this study agrees with the observation of (Wondie *et al.*, 2007) from Lake Tana in Ethiopia. They reported a drop in primary productivity in the wet months and a rise of the same in the dry periods. This finding may be due to the fact that high suspended solids in the flood water restrict light penetration into the water and thereby results in less photosynthetic activities and productivity. NPP is a measure of available photosynthetically fixed carbon after eliminating the catabolic loss of organic matter due to respiration (CR). The lower NPP values in the creek as compared to community respiration showed that carbon utilization was comparatively high in comparison to carbon assimilation. This finding could possibly be that a rise in nutrient rich freshwater influx in the habitat waters under warm conditions led to an increase in the heterotrophic population which accounted for the enhanced carbon utilizations. A similar result was also obtained from the Mandovi River estuary (Verlencar and Qasim, 1985).

The range of primary productivity indices obtained in this study were lower than the range reported in Krishnasayer lake (Banerjee and Chattopadhyay, 2008) but higher than range reported in ponds of Otamiri River, Nigeria (Ogbuagu, 2013). The moderately low productivity observed in this present investigation could probably be linked to intense sand mining operations in this creek. Sand mining could exert negative influences on the productivity of aquatic ecosystems (Tamuno, 2005). The community respiration (CR) exhibited a similar seasonal pattern with a higher mean of pooled value during dry season. A higher community respiration value during dry season may probably be due to increased water temperature which stimulates the growth of microbial population which in turn utilized more oxygen for their metabolic activities.

Chlorophyll is both a useful and an easy estimator of phytoplankton standing crop and is now more generally used than cell number or cell volume. The fluctuation of Chlorophyll-*a* (Chl.a) was irregular in this study and did not show obvious seasonal variation. Similar observation had been reported (Kamatani *et al.*, 1981). Lowest Chlorophyll-a mean value in Ojo station could be attributed to limit of Chlorophyll-*a* to certain levels by high phosphorus present in this station. High Chlorophyll-*a* concentration would result in high values of productivity and reflect on high phytoplankton biomass. Chlorophyll-*a* values greater than 15 µg/L are generally considered to indicate high productivity (eutrophic waters). Chlorophyll-*a* concentration in this study were relatively low during the wet season and high during dry season, coinciding with higher dry season nutrients and primary productivity.

## CONCLUSION

Although, before the functioning of the creek system can be fully understood, the in-depth study of hydrochemistry, sedimentology, planktonic, benthic and fish population are required. But based on the parameters investigated in the present study, Badagry creek has revealed a fairly stable ecological system. The creek showed eutrophic condition based on Chlorophyll-a classification. Furthermore, the creek is prone to severe environmental problems as a result of nutrient loading from land-based, agriculture and rapid urbanization in the surrounding areas.

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## REFERENCES

Ajao, E. A. Review of the state of pollution of Lagos Lagoon. Nigerian Institute of Oceanography and Marine Research (NIOMR) Technical Paper No. 106. (1996).

Ajibola VO, Funtua II, Unuaworho AE. Pollution studies of some water bodies in Lagos, Nigeria Caspian J. Env. Sci., Vol. 3 No.1 pp. 49-54 (2005)

Alain Aminot and Francisco Rey,. Standard procedure for the Determination of Chlorophyll a by spectroscopic methods ISSN 0903 – 2606 (2000)

Anyanwu, A. J. & Ezenwa, B. I. O. Incidence of parasitic infection of pond raised *Tilapia* spp. and some cultivable fish species from three ecological areas of Lagos state. Nigeria Institute of Oceanography and Marine Research, Technical Paper No. 32 (1988)

APHA, AWWA, WPCF. Standard Method for the Examination of Water and Waste water. American Public Health Association, 17th ed. New York. (1989)

Arctic Ocean Expedition NOAA,; http://oceanexplorer.noaa.gov (2000)

Banerjee T. C and Chattopadhyay, C Water Temperature and Primary Production in the Euphotic Zone of a Tropical Shallow Freshwater Lake Asian J. Exp. Sci., Vol. 22, No. 1; 103-108 , (2008).

Chisty, N.: Studies on biodiversity of fresh water zooplankton in relation to toxicity of selected heavy metals. Ph.D. Thesis submitted to Mohanlal Sukhadia University, Udaipur, India. (2002)

Giovanardi F. and Vollenweider R.A. Trophic conditions of marine coastal waters: experience in applying the Trophic Index TRIX to two areas of the Adriatic and Tyrrhenian seas, *Journal of Limnology*, 63, 199-218. (2004)

Harding, L.W. Long-term trends in the distribution of phytoplankton in Chesapeake Bay: roles of light, nutrients and stream flow. Marine Ecology-Progress Series 104, 267-267 (1994)

Ignatiades, L Karydis,, M and P. Vounatsou. A Possible method for evaluating oligotrophy and eutrophication based on nutrient concentration scales. *Marine Pollution Bulletin* 24 (5): 238–243. (1992)

Kamatani, A., N. Ogura, N. Nakamoto, M. Funakoshi, and S. Iwata.. Distribution of nutrients in Sagami Bay during 1971–1973. Bull. Jour. Soc. Sci. Fish. 47: 1493–1498. (1981)

Michael, P. Ecological methods for field and laboratory investigations. Tata McGraw Hill Publishers (1984)

Mishra S., Panda D & Panigraphy R. C, Physicochemical characteristics of the Bahuta estuary (Orrisa) east coast of India, *Ibidi*., 20 75 – 77. (1993)

Nwankwo, D.I The Microalgae: Our indispensable allies in aquatic monitoring and biodiversity sustainability. University of Lagos Press. Inaugural lecture seris. 44pp. (2004)

Ogbuagu D. H In situ yields in primary productivity of sand mine ponds of the Otamiri River in a southeastern city of Nigeria. Scientific journal of Environmental sciences 2(4) 84 – 92 (2013).

Parsons, T. R., Y. Maita, and C. M. Lalli.. A manual of chemical and biological methods for seawater analysis. Pergamon. Press 173. (1984)

Spss2 SPSS for Window, Release 11 Standard Version. Copyright SPSS Incorporation, Cary, NC, USA, 1989–(2001).

Sultan, S., Chauhan, M. and Sharma, V.I Physico-chemical status and Primary Productivity of Pahunj reservoir, Uttar Pradesh. *J. Inland Fish. Soc. India*, 35: 73-80 (2003).

Tamuno, P. B. L.,Eco-livelihood assessment of inland river dredging: the kolo and Otuoke creeks, Nigeria, a case study. Ph.D, Thesis, Loughbourogh University 351pp. (2005)

Verlencar, X.N. and S.Z. Qasim Particulate organic matter in the coastal and estuarine waters of Goa and its relationship with phytoplankton production. *Estuar. Coast Shelf Sci.* 21:235–242 (1985)

Wondie, A, Mengistu, S, Vijverberg, J and Dejen, E Seasonal variation in primary production of a large high altitude tropical lake (Lake Tana, Ethiopia): effects of nutrient availability and water transparency. *Aquat. Ecol.* 41:195–207 (2007).