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# Environmental characteristics, plankton diversity and seasonal variation at the Makoko creek

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**Abstract**
Environmental characteristics, plankton diversity and seasonal variation at the Makoko Creek were investigated for eight months (February – September, 2015). Air and water temperatures were high in the dry season (≤ 28.5 °C, ≤ 27.0 °C, and ≥ 29.0 °C, ≥ 29.5 °C, respectively). Transparency was higher in the dry season (18 cm) and the highest value of TDS (24990 mg/L) and TSS (16 mg/L) were recorded in the dry season. The highest water depth (1.39 m) was recorded in the dry season. pH values revealed alkaline conditions (>7.0) while conductivity values were lower in the rainy season. Dissolved oxygen was low (1.34 mg/L) in the dry season while the highest value (4.95 mg/L) was recorded in the rainy season. Biochemical oxygen demand (≥9.0 mg/L) and chemical oxygen demand were higher in the dry season. Salinity level in the creek varied between (14 ‰ and 17 ‰). The micro-nutrients were higher in dry season than the wet season. Heavy metals occurred as trace. Higher values of chlorophyll-*a* were recorded in the dry season while phytoplankton abundance and diversity were higher in the dry season than in the rainy season. The copepods dominated the zooplankton spectrum of which the calanoids were more abundant. Three divisions of phytoplankton Bacillariophyta, Cyanophyta and Chlorophyta were recorded. The more frequent was Cyanophyta constituting 80% of the total number of 2440 species. Trophic state index depicted eutrophic to hyper-eutrophic conditions.

**Keywords:** Environmental characterisitics, creek, diversity, plankton

## Introduction

Creeks are common hydrological features in Southwest Nigeria draining floodwaters from the hinterland into the marine environment. They are of two types: the tidal creeks which are partly surrounded by mangrove swamps dominated by aquatic flora such as *Rhizophora racemosa, Phoenix reclinata, Acrosticum aureum,* and benthic fauna such as *Tympanotonus fuscatus, Pachymelania aurita* as well as mangrove crabs and also partly surrounded by freshwater swamps, dominated by aquatic macrophytes like *Pistia stratiotes* and *Eichhornia crassipes*. The non-tidal freshwater creeks are completely surrounded by freshwater biota all through the year (Nwankwo and Amuda, 1993) [14] stated this in their findings Periphytic diatoms on free floating Aquatic Macrophytes in a polluted South-Western Nigerian Creek. *International Journal of Ecology and Environmental Sciences.* 19:1 – 10.
Tidal creeks experience horizontal environmental gradient profile and therefore are transitory zones in coastal ecosystems.
Hill, M. B. and Webb, J. E. (1958) [8]. The Ecology of Lagos Lagoon II: The topography and physical features of the Lagos Harbour and Lagos Lagoon. *Philosophical Transaction Royal Society, London.* 241:307 – 417. And Nwankwo (1996) [18] Phytoplankton diversity and succession in Lagos Lagoon, Nigeria. *Archiv fur Hydrobiologie*. 135(4):529-542. Reported that rainfall and salinity are the forcing functions that determine the annual brackish regime in a tidal lagoon while tidal incursions govern the salinity regime and determine the brackish conditions in the Lagos Lagoon. In the tropics, rainfall is ecologically more important than temperature in determining environment (Webb, 1960) [28]. Biology in the tropics. *Nature*. 188: 617 – 619.
Plankton are drifters, and therefore are at the mercy of currents and waves. Earlier studies of plankton in creeks of the Niger Delta include those of: Okpuruka, D. U., (1986) [21]. Tidal and semilunar variations in the surface phytoplankton of a Port Harcourt mangrove creek. Proceedings of the Workshop on Nigerian Wetlands, August 27 – 29, 1986, Lagos, Nigeria, 183 – 183pp indicated the effect of lunar variation on the plankton of a brackish creek in the

Niger Delta, Nwadairo (1990) [12] on the hydrobiological survey of the Chanomi Creek in the lower Niger Delta, and also Adesalu and Nwankwo (2005) [2] who reported on the phytoplankton of Olero Creek and parts of the Benin River.
Nwankwo *et al.* (2013) [19] reported the temporal variations in water chemistry and chlorophyll *a* at the Tomaro Creek, Lagos, Nigeria.
In Southwest Nigeria, Nwankwo and Amuda (1993) [14] reported on the Periphytic Diatoms on three floating aquatic macrophytes at the Ogbe creek.
Nwankwo and Gaya (1996) [18] reported the phytoplankton of the Abule Agege creek in Lagos
Egborge (1988) [8] documented the epiphytic biota on the roots of water hyacinth at the Porto Novo creek Onyema and Ojo (2008) [22] studied the zooplankton and phytoplankton biomass of Agboyi creek, in relation to water quality indices while Adesalu and Nwankwo (2008) [3] studied the effect of water quality indices on phytoplankton of Abule Eledu creek in Lagos, Nigeria.
Adesalu *et al.* (2008) [3] studied the Epiphytic Algae associated with Two Floating Aquatic Macrophytes in the Ajegunle Creek, Lagos.
Nwankwo *et al.* (2012) in a comparative study, reported on the nutrient status and chlorophyll *a* variations in two Lagos Harbor creeks while Nwankwo *et al.* (2015) reported on the water quality and biota of the FESTAC Creek, Lagos.

Adesalu *et al.* (2016) documented the Diatom communities in the riparian systems associated with Lagos Lagoon, Nigeria.
Adedipe and Nwankwo (2016) [1] reported on the effect of rainfall cessation on the plankton abundance and diversity in Ogudu Creek, while Adesalu *et al.* (2016) assessed the Water quality, plankton and Macrobenthos at Porto- Novo and parts of Gulf of Guinea.
At the moment there is no published work on the plankton of Makoko Creek. The aim of this study was to assess the environmental characteristics, plankton diversity and seasonal variation at the Makoko Creek Lagos.

## Materials and Methods

### Study Site

The Makoko Creek (Fig. 1) is located between co-ordinates (Latitude N06°29′41.1″ and Longitude E03°23′43.3″). The creek is micro tidal and drains into the Lagos Lagoon from the western part. It is deep and provides transport facilities for the four ethnic groups that inhabit the wetlands. The main occupation is artisanal fishing and petty trading. There is poor sewerage system. Common halophytes include *Paspalum virginatum*, the White mangrove *Rhizophora langucularia*, Red mangrove *Rhizophora racemosa*, and Black mangrove *Avicennia nitida*, *Phoenix reclinata*, Salt water ferns *Acrosticum aureum* as well as *Pachymelania, Typmpanotonus* and Mangrove crabs.

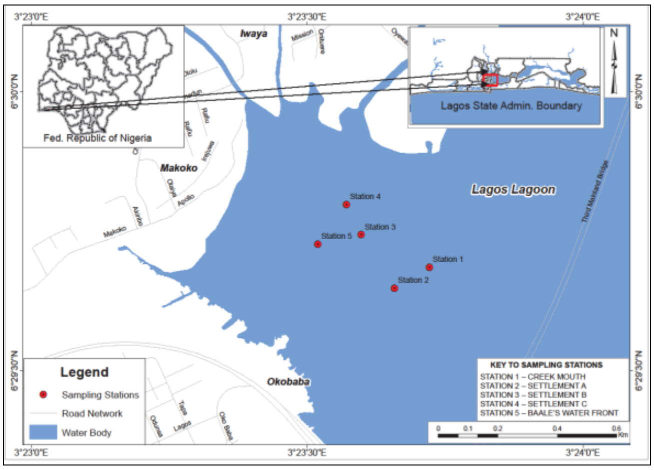


**Fig 1:** Map of Lagos Lagoon showing Makoko Creek

### Collection of water samples

Surface water samples for physicochemical analyses were collected monthly for eight months (February – September 2015) from the creek using 500 ml screw-capped and well labeled plastic bottles. All samples were collected between 09:00hr and 13:00hr, sampling equipment were calibrated while the containers were washed before sampling. Water samples were then collected 20 centimeters below the water surface. The collected samples were transported in an ice chest to the Laboratory.

### Collection of biological samples

Plankton samples were collected for eight months using a standard 55µm mesh sized plankton net towed horizontally at low speed(<4 knots) for five minutes. Samples for chlorophyll *a* analysis were collected quantitatively using 500ml well labeled plastic containers by dipping the container a (20cm) below the water surface.

### Plankton Investigation

Plankton species were examined, identified and counted using an Olympus binocular microscope with a calibrated eye piece at different magnifications (10X and 40X). Direct counts of planktonic forms were made using the drop count method described in Lackey (1938). Identification was done using relevant texts (Zooplankton: Newell and Newell, 1966; Wiafe and Frid, 2001. Phytoplankton: Whitford and Schumacher, 1973; Compère, 1975, 1976 and 1977; Valangdiham, 1982).

### Physicochemical Analysis of Water Samples

On each sampling occasion, air and water temperatures were measured *in situ* using mercury-in-glass thermometer which was held about 1m from the water surface for three minutes. Transparency was measured using a 20 cm diameter black and white painted Secchi disc. Water depth was determined by lowering a weighted rope down into the creek until it reached the bottom. This is estimated by using the Gravimetric method 22540D (APHA, 1998) [4]. The total dissolved solids were determined using gravimetric method

2540C (APHA, 1998) [4]. The pH values were determined by the electrometric method using the Cole Parmer Test.

The salinity at the site was determined *in situ* using a refractometer (model RHS-10ATC). Conductivity was determined using the Philips PW9505 conductivity meter (Range 3 – 100,000 µS/cm).The dissolved oxygen was measured by titrimetric (iodometric) method involving the Azide modification procedure 4500 ºC. Biochemical oxygen demand value was measured after 5-days incubation period using the method described in APHA (1998) [4]. Chemical oxygen demand was determined using the closed reflux method 5220C with higher concentration of potassium dichromate solution. The heavy metals: iron, zinc and lead were determined using the atomic absorption spectrophotometer (AAS).

**Determination of micro nutrients**

Nitrate concentration of each sample was determined using the colorimetric method (4500D APHA, 1998) [4] using an APHA/HACH DR 2010 Colorimeter with internal standard. Phosphate-Phosphorus concentration was determined using the colorimetric method (stannous chloride method 4500-PD). Sulphate ($SO_4^{2-}$) concentration was determined using the Turbidimetric method 4500 E (APHA, 1998) [4].

**Determination of chlorophyll *a* (µg/L)**

The chlorophyll *a* content was determined using the fluorometric method. The fluorometer was equipped with filters for light emission and excitation. 200 ml of each sample was filtered through 0.45 µm glass fibre membrane filter. The residue on the filter was transferred to a tissue blender and covered with 3 ml 90% aqueous acetone and then macerated for 1 minute.

**Determination of Biomass using the drop count method (per ml)**

Plankton sample was allowed to settle in the lab for 24 hrs and concentrated to 20 ml. The plankton species were examined, identified and counted using an Olympus® binocular microscope with a calibrated eyepiece at different magnifications (5x, 10x and 40x). For each settled sample, five drops of well mixed sample were thoroughly investigated. On each occasion, one drop of sample was thoroughly investigated using the drop count method described by Lackey (1938). For each drop five transacts were investigated by moving the stage at different positions.

**Community Structure**

Community structure was determined using four indices:

**Margalef Index (d) (Margalef, 1957; Ogbeibu, 2005)** [2]

This is a diversity of species richness, which does not take into account dominant diversity, but is largely dependent on the species richness, that is, the more species present in a sample, the greater the diversity.

$$d = \frac{S-1}{\log_e N}$$

Where:
d = Diversity Index
S = Number of Species
N = Number of Individuals
$\log_e$ = Natural logarithm

**Shannon-Weaver Information Index (H) (Shannon and Weaver, 1963, Ogbeibu, 2005)** [26, 2]

This index is sensitive to the number of species present. It is sensitive to both species and dominance diversity.

$$H = \frac{N\log N - \sum fi\log fi}{N}$$

Where:
H = Shannon-Weaver Information Index
Σ = Summation
fi = Observed proportion of individuals that belong to the ith species
$\log_e$ = Natural logarithm.

**Species Equitability or Evenness (j) (Ogbeibu, 2005)** [2]

This is a measure of how evenly the individuals are distributed among the species present in a sample. It ranges between 0 and 1, the maximum value. One represents a situation where individuals are spread evenly among the species present.

It is calculated as follows:

$$j = \frac{H}{H_{max}} \quad \text{or} \quad j = \frac{H}{\log_e S}$$

Where:
j = Equitability measure
H = Shannon-Wiener Information Index
S = Number of species in the sample

**Similarity Index (Nwankwo, 1998) [13].**

The Similarity Index (S) between two samples is given by the equation:

$$S = \frac{2C}{A + B}$$

Where:
S = Similarity index
C = Number of species common to both samples
A = Number of species in sample A
B = Number of species in sample B

The data obtained for the physical, chemical and biological parameters at the Makoko Creek from February to September, 2015 are presented graphically in Figs. 2 – 12 and tables 1 and 2.

Air and water temperatures were higher in the dry season than in the rainy season (≤ 28.5 ºC, ≤ 27.0 ºC, and ≥ 29.O ºC, ≥ 29.5 ºC respectively) (Fig. 2). Transparency was higher in the rainy season than in the dry season (Fig. 3). The highest value of total suspended solids (16 mg/L) was recorded in the rainy season (Fig. 4). Conductivity and pH were higher in dry season than the wet season (Fig. 5). Dissolved oxygen, chemical oxygen demand and biochemical oxygen demand values were higher in the dry season than in the rainy season (Fig. 6). Rainfall, Nitrate and phosphate were high in the rainy season (Fig. 7). Plankton were in abundance during the dry season (Fig. 8). Chlorophyll *a* (Fig. 9) and salinity (Fig. 10) were high in the dry season, respectively.

The heavy metal concentration of the Makoko Creek from February to September 2015 are represented in Table 1 while the diversity and abundance of plankton species at Makoko

Creek from February to September, 2015 are represented in Table 2. The Phytoplankton population was represented by three divisions namely; Bacillariophyta (17%), Cyanophyta (80%) and Chlorophyta (3%). Cyanophyta was more abundant at the time of study and was represented by the Order Chroococales and Hormogonales respectively. The zooplankton spectrum was represented by two phyla namely: Arthropoda (85%) and Rotifera (2%). The Phylum Arthropoda was more abundant as Copepods dominated the zooplankton spectrum constituting (90.91%) of the number of individuals recorded.

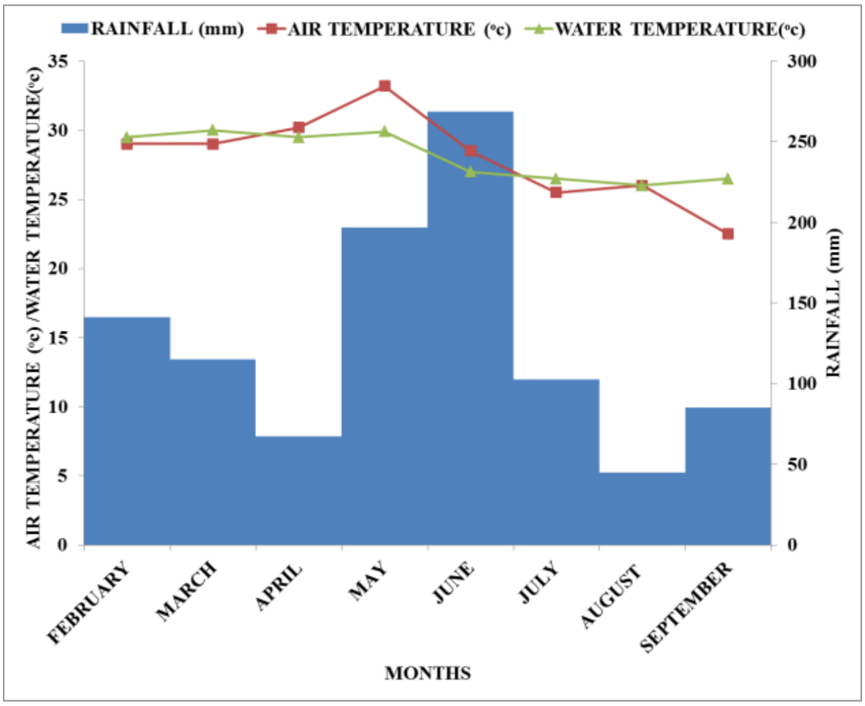


**Fig 2:** Monthly variation in levels of rainfall, air and water temperature at Makoko Creek (February – September 2015)

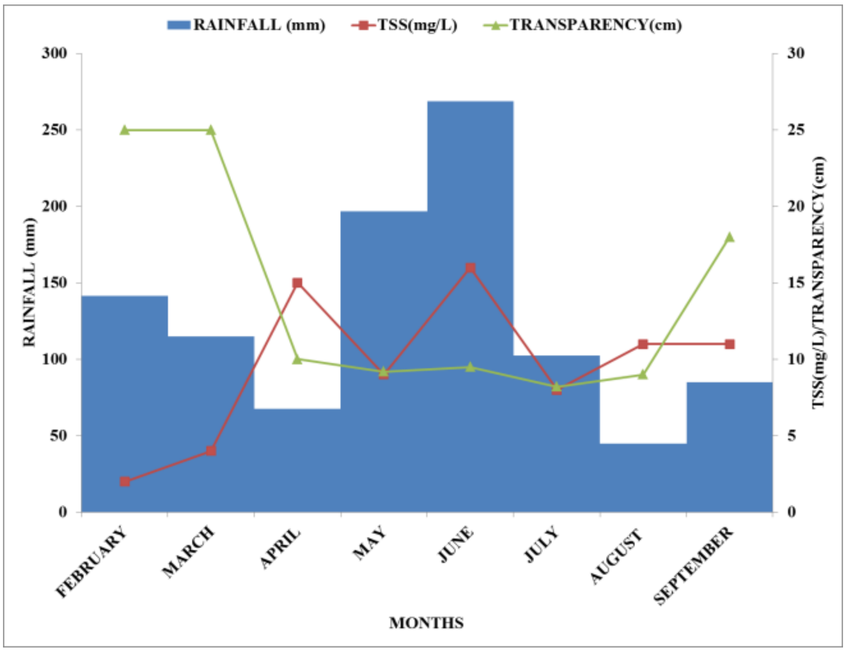


**Fig 3:** Monthly variation in levels of rainfall transparency, total suspended solids at Makoko Creek (February – September 2015)

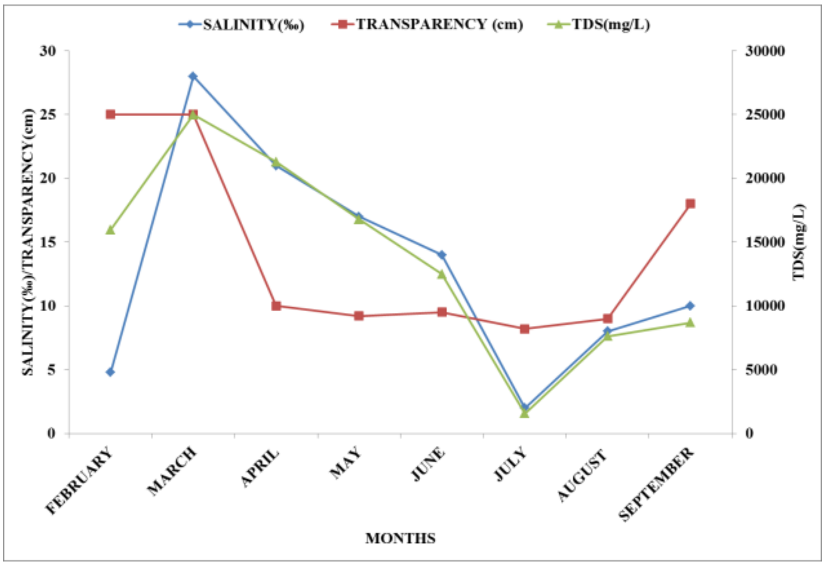


**Fig 4:** Monthly variation in levels of salinity, transparency and total dissolved solids at Makoko Creek (February – September, 2015)

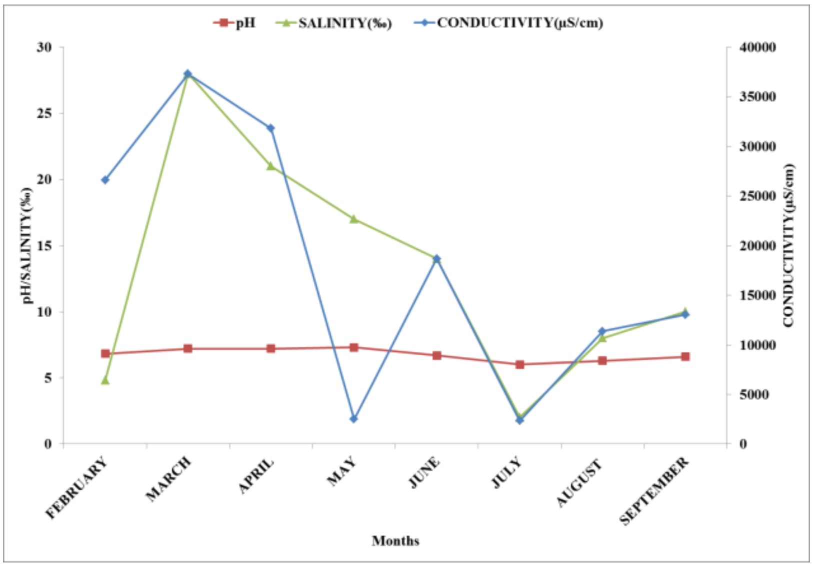


**Fig 5:** Monthly variation in levels of salinity, pH and conductivity at Makoko Creek (February – September 2015)

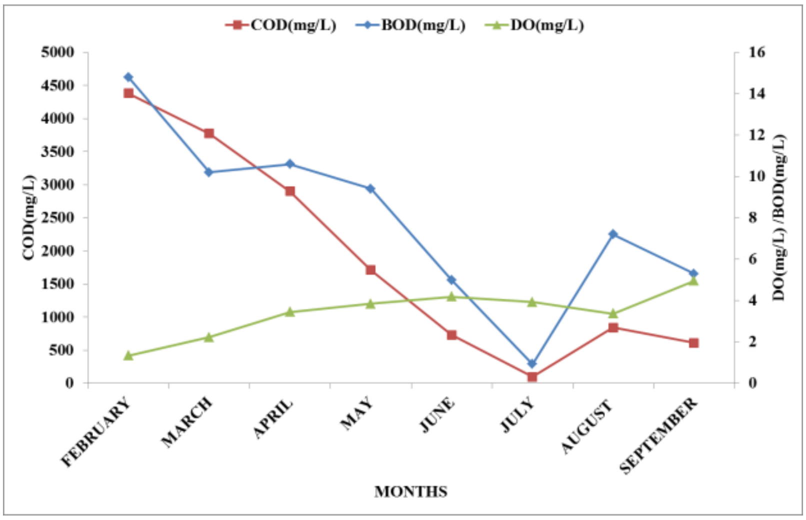


**Fig 6:** Monthly variation in levels of dissolved oxygen, biochemical oxygen demand and chemical oxygen demand at Makoko Creek (February - September 2015)

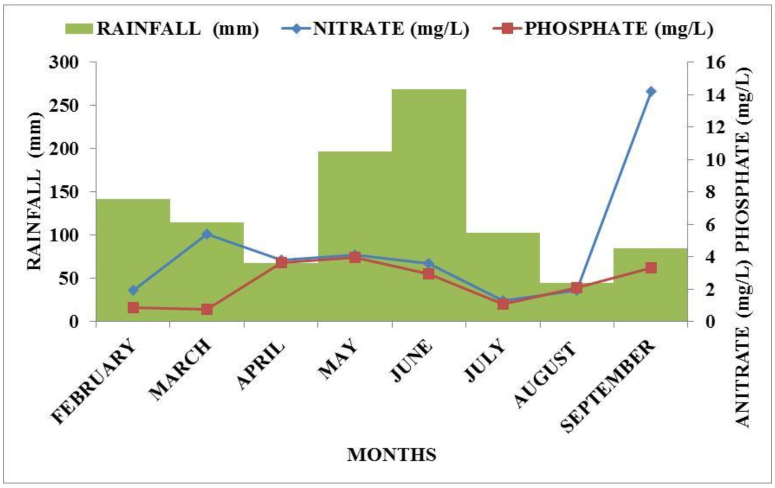


**Fig 7:** Monthly variation in levels of Rainfall, Nitrate and phosphate at Makoko Creek (February – September 2015)

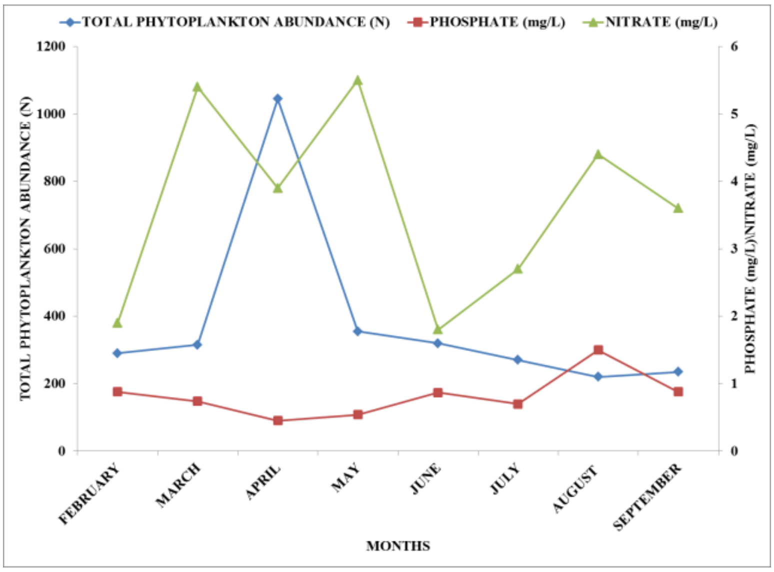


**Fig 8:** Monthly variation in levels of plankton abundance, phosphate and nitrate at Makoko Creek (February – September, 2015)

**Table 1:** Heavy Metal Concentration (February - September, 2015).

| February | March | April | May | June | July | August | September |
|---|---|---|---|---|---|---|---|
| 0.19 | 0.11 | 0.07 | 0.19 | 0.38 | 0.09 | 0.46 | 0.33 |
| 0.11 | 0.1 | 0.03 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| 10.61 | 3.45 | 0.045 | 0.132 | 0.01 | 0.5 | 0.141 | 0.001 |
| 1.39 | 1.34 | 1.0414 | 0.8433 | 0.94 | 1.06 | 1.0287 | 1.0795 |

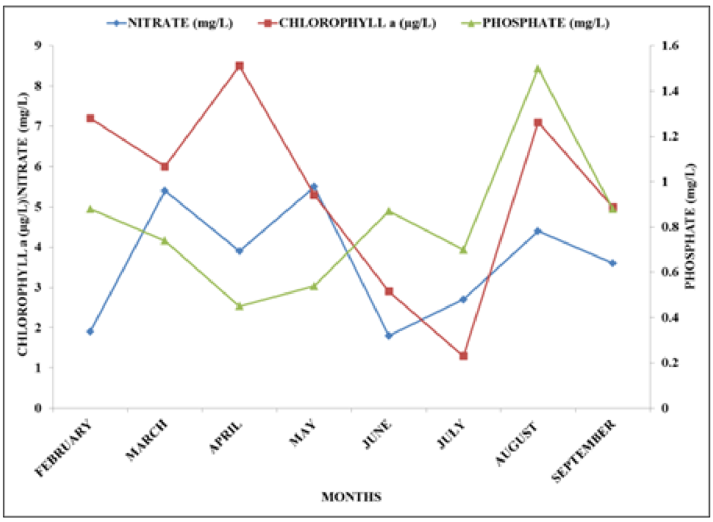


**Fig 9:** Monthly variation in levels of chlorophyll *a* and nitrate and phosphate abundance at Makoko Creek (February 2015 – September 2015)

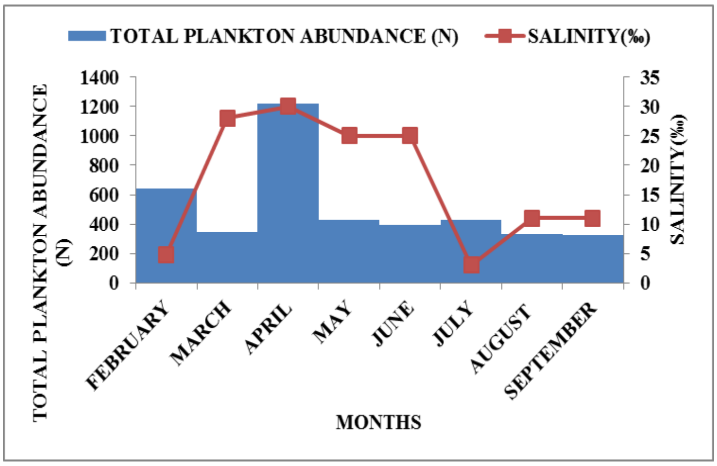


**Fig 10:** Monthly variation in levels of plankton abundance and salinity at Makoko Creek (February 2015 – September 2015)

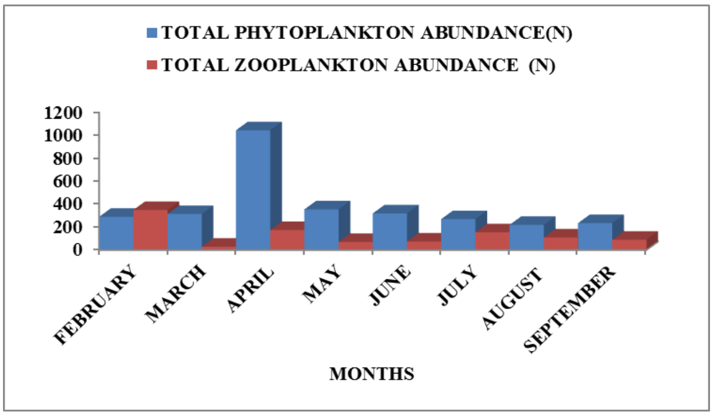


**Fig 11:** Monthly variation in total plankton abundance at Makoko Creek (February 2015 – September 2015)

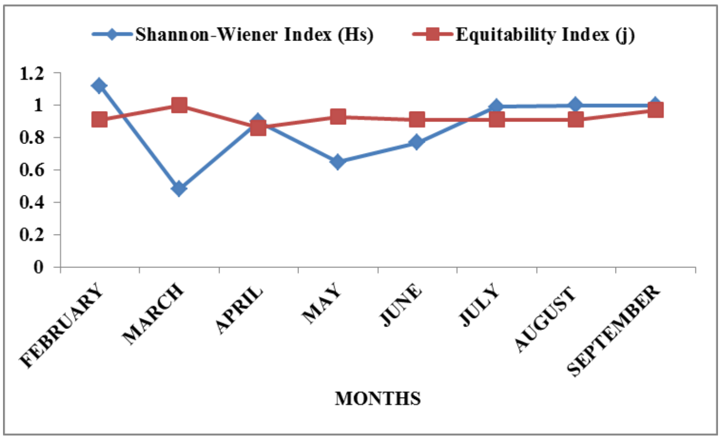


**Fig 12:** Diversity indices at the Makoko Creek (February – September 2015)

**Table 2:** Plankton composition and abundance of makoko creek (February, 2015 - September, 2015).
Phytoplankton

| Taxa | FEB. | MAR. | APR. | MAY | JUN. | JUL. | AUG. | SEPT. |
|---|---|---|---|---|---|---|---|---|
| Divison: Bacillariophyta | | | | | | | | |
| Class: Bacillariophyceae | | | | | | | | |
| Order: Centrales | | | | | | | | |
| *Aulacoseira granulata* | 10 | – | 5 | – | – | 10 | – | 10 |
| *Cocconeis placentula* | – | 5 | 10 | – | – | 5 | – | – |
| *Coscinodiscus centralis* | – | – | 5 | – | – | 5 | – | 5 |
| *Coscinodiscus oculus-iridis* | – | 5 | 5 | – | 5 | – | – | – |
| *Cyclotella meneghiniana* (Kütz) Grunow | 5 | – | – | 5 | – | – | – | – |
| *Lepocinlis acuminata* | – | – | – | – | – | 5 | – | - |
| *Stephanodiscus astraea* Grunow | – | 5 | – | – | 5 | – | 5 | – |
| Order: Pennate | | | | | | | | |
| *Amphora coffaeiformis* Agardh | – | 10 | 15 | – | 5 | 5 | - | 5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Amphora ovalis* var. *affinis* | 10 | 5 | -- | -- | 10 | -- | 10 | -- |
| *Cymbella prostata* | – | 5 | 5 | – | – | 10 | – | 10 |
| *Gyrosigma fasciola* | 5 | – | 10 | – | 5 | – | 5 | – |
| *Navicula amphibola* | 5 | – | 5 | 5 | – | 10 | – | 5 |
| *Navicula placenta* | – | 5 | – | 10 | 15 | – | 10 | – |
| *Nitzschia closterium* | 10 | – | – | 5 | – | 10 | – | 10 |
| *Nitzschia obtusa* var. *scalpelliformis* Grun. | – | 5 | 10 | – | – | 5 | – | 5 |
| *Striatella unipunctata* | 10 | – | – | – | – | 5 | – | 5 |
| *Pleurosigma capense* | – | 10 | – | – | 5 | 20 | 5 | 10 |
| *Pleurosigma obscurum* | – | -- | 5 | -- | 5 | -- | 5 | -- |
| *Thalassionema bacillare* | 20 | 10 | – | 5 | – | 10 | – | 10 |
| Division: Chlorophyta | | | | | | | | |
| Class: Chlorophyceae | | | | | | | | |
| Order: Chloroococales | | | | | | | | |
| *Actinastrum hantzschii* | – | 5 | – | 5 | – | – | – | – |
| *Ankistrodemus falcatus* | 5 | – | 10 | – | 15 | – | 10 | – |
| *Coelastrum microporum* Nägeli | – | 5 | – | 5 | – | – | – | 5 |
| *Desmodesmus quadricauda* | 5 | – | 10 | – | – | 10 | 5 | - |
| Division: Cyanophyta | | | | | | | | |
| Class: Cyanophyceae | | | | | | | | |
| Order:Chroococcales | | | | | | | | |
| *Microcystis aeruginosa* | 105 | 130 | 550 | 125 | 170 | 110 | 120 | 90 |
| *Nostoc commune* Vaucher | – | 5 | – | – | – | – | 5 | – |
| Order: Hormogonales | | | | | | | | |
| *Anabaena spiroides* | – | 35 | 15 | – | 5 | – | 5 | – |
| *Anabaena circinalis* Rabenhorst | – | – | – | – | – | – | – | – |
| *Lyngbya martensiana* Meneghini | 15 | – | 10 | 20 | – | 5 | – | 5 |
| *Oscillatoria agardhii* Gomont | 10 | 35 | – | – | 20 | – | 10 | 15 |
| *Oscillatoria borneti* Zukal | 30 | – | 45 | 15 | – | 30 | – | 15 |
| *Oscillatoria formosa* Bory | 5 | – | 5 | – | – | – | – | – |
| *Oscillatoria nigra* Vaucher | 20 | – | – | – | 5 | – | 5 | – |
| *Oscillatoria limnetica* | 10 | 10 | 150 | 60 | – | 5 | – | 5 |
| *Oscillatoria minima* Gicklhorn | 5 | 15 | 160 | 45 | – | 5 | – | 5 |
| *Phormidium* sp. | – | 5 | – | 5 | – | – | – | – |
| *Spirulina platensis* | 5 | – | 15 | 45 | 50 | – | 20 | 15 |
| *Spirulina major* | – | 5 | – | – | – | 5 | – | 5 |
| Total species diversity (S) | 19 | 20 | 20 | 14 | 14 | 19 | 14 | 19 |
| Total abundance (N) | 290 | 315 | 1045 | 355 | 320 | 270 | 220 | 235 |

Zooplankton

| **Taxa** | **Feb.** | **Mar** | **Apr.** | **May** | **Jun.** | **Jul.** | **Aug.** | **Sept** |
|---|---|---|---|---|---|---|---|---|
| Phylum: Arthropoda | | | | | | | | |
| Sub-Phylum: Crustacea | | | | | | | | |
| Class: Maxillopoda | | | | | | | | |
| Sub-Class: Copepoda | | | | | | | | |
| Order: Calanoida | | | | | | | | |
| Superfamily: Calanoidea | | | | | | | | |
| Family I: Acartiidae | | | | | | | | |
| *Acartia clausii* | 20 | - | - | 10 | - | - | 5 | - |
| *Acartia discaudata* | 5 | - | - | - | 5 | - | 5 | - |
| *Acartia danae* | 25 | - | - | - | - | - | - | - |
| *Acartia tonsa* | - | - | 35 | - | - | 15 | - | - |
| Family Ii: Centropagidae | | | | | | | | |
| *Centropages violaceus* | 10 | - | - | 5 | - | 5 | - | - |
| Family Ii: Calanidae | - | - | - | - | - | - | - | - |
| *Calanoides carinatus* | 15 | - | - | - | 5 | - | 5 | 10 |
| Family Iii: Eucalaniidae | | | | | | | | |
| *Eucalanus elongatus* Dana | - | 10 | - | - | 15 | - | - | 5 |
| Family Iv: Paracalanidae | | | | | | | | |
| *Paracalanus aculeatus* | 25 | - | - | - | 10 | 5 | - | 10 |
| *Paracalanus parvus* | 25 | - | 45 | - | - | 10 | 5 | - |
| Family V: Temoridae | | | | | | | | |
| *Temora stylifera Dana* | 10 | - | - | 15 | - | - | 5 | - |
| Order Ii: Cyclopoida | | | | | | | | |
| Family: Cyclopoidae | | | | | | | | |
| *Cyclopina longicornis* | 30 | - | 10 | - | - | 20 | 15 | 10 |
| Family: Oithonidae | | | | | | | | |
| *Oithona brevicornis* | 65 | - | 5 | - | 10 | 5 | - | 15 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Oithona nana* | 20 | - | - | 25 | - | - | | |
| *Oithona similis* | 50 | - | 5 | - | - | 25 | 20 | 5 |
| Order Iii: Harpacticoida | | | | | | | | |
| Family: Miracidae | | | | | | | | |
| *Microsetella norvegica* | 15 | - | 25 | - | - | 35 | 25 | 5 |
| Order Iv: Poecilostomatoida | | | | | | | | |
| Family: Sapphirinidae | | | | | | | | |
| *Sapphirina gemma* | 15 | - | 10 | - | - | 10 | 5 | 5 |
| *Sapphirina ovatolanceolata* | - | 10 | 5 | - | 5 | - | 5 | 10 |
| Phylum: Rotifera | | | | | | | | |
| Order: Ploima | | | | | | | | |
| *Albertia naidis* | 5 | - | 5 | - | - | 10 | 5 | - |
| Juvenile Stages | | | | | | | | |
| Barnacle nauplius larva | 10 | - | 25 | - | - | 10 | 5 | - |
| Copepod egg | - | 10 | 5 | - | 25 | - | 5 | 10 |
| Copepod nauplius larva | 5 | - | - | 15 | - | 5 | - | 5 |
| Total species diversity (S) | 17 | 3 | 11 | 5 | 7 | 12 | 13 | 11 |
| Total abundance (N) | 350 | 30 | 175 | 70 | 75 | 155 | 110 | 90 |

**Discussion**

The observed higher air and water temperatures in the dry season may be due to higher temperatures arising from increased insolation. Lower cloud cover enhances greater insolation in the dry season. Similar observations in tidal creeks have been reported in Nwankwo and Gaya (1993) [14], Onyema and Ojo (2008) [22], Nwankwo *et al.* (2012).

Increased rainfall in the rainy season corresponded with a decrease in salinity level in the creek. This is in consonance with (Nwankwo 1996) [15] which stated that salinity created horizontal environmental barriers to the biota of the creek and this salinity is directly linked with the rainfall distributive pattern. The introduction of floodwaters associated with the rains on entry into the Makoko Creek may have resulted in dilution and possibly scoured and stirred up detritus and organic matter and consequently accounted for the high TDS and TSS values observed in the wet months at the Makoko Creek.

The increase in transparency and salinity at the Makoko Creek in the dry season may be due to the absence of flood water incursion and the influx of tidal sea water. Similar observations were made by Adesalu and Nwankwo (2008) [3] at the Abule Eledu Creek, Emmanuel and Onyema (2007) [7] at the Abule Agege Creek and Nwankwo *et al.* (2010) at the creeks of the Lagos Harbour.

The creek water was acidic in the wet months possibly due to the flood water that drained through the mangroves while the pH values (>7.0) observed in the dry months may be due to the buffering effect of tidal sea water.

Low dissolved oxygen, high biochemical oxygen demand and high chemical oxygen demand recorded in the creek may be an indication of the pollution status in the creek. Hynes (1960) [9] suggested that in lotic fresh water environment, biochemical oxygen demand value greater than 8.0 mg/L may reflect high organic pollution. In the Makoko Creek the observed BOD value of between 5 mg/L and 14 mg/L may indicate eutrophic to hyper-eutrophic condition. However, because of the interplay of tidal incursion and floodwater influx, eutrophic conditions are experienced in the wet months while hyper-eutrophic conditions are experienced in the dry months. According to Nwankwo and Akinsoji (1989) [17], the Lagos Lagoon is under intense pressure from pollution as a result of untreated sewage, sawdust, petrochemical materials, detergent and industrial effluents. A reduction in the pollution status of the creek during the rains could be linked to flood water dilution and reduced resident time of the polluted water, which probably ameliorated the aquatic environment.

Conductivity was high during the dry months and this must have given rise to marine conditions as sea water inflow affected the lagoon environment (Nwankwo, 1998) [13].

The Micronutrient values were higher in the dry season than the wet season possibly because of the enrichment of the creek waters through the floodwaters and the increased oxidation of materials owing to higher temperatures. This increase in micronutrients level may have accounted for the increased micro algal biomass in the dry season.

Furthermore, the higher chlorophyll *a* values in the dry season may be a response of the high micro algal biomass at this period; this confirms earlier reports by Ogamba *et al.* (2004) [20].

The community structure indicated a higher diversity in the dry season than wet season possibly because of the elimination of flood waters and apparent calmness of the creek waters. Similar observations have been made by Kusemiju *et al.* (1993) [10], Onyema *et al.* (2003, 2007) [7, 23] and Onyema and Nwankwo (2009) [25] in a similar environment.

The heavy metals observed in this creek remain within acceptable limits possibly because of the seasonal flushing of the Makoko Creek.

The observed variety of larval stages may be an indicator that the Makoko Creek serves as a nursery and breeding ground for some aquatic fauna. The use of coastal waters of Southwest Nigeria as breeding and nursery grounds has been reported by Nwankwo and Gaya (1996) [18], Solarin and Kusemiju (2003) [27] and Onyema *et al.* (2007) [23].

**Conclusion**

The creek water chemistry varied between Eutrophic and Hyper eutrophic conditions which reflect that the environment is polluted. The presence of *Microcystis aeruginosa*, *Spirulina platensis* and *Spirulina major* indicates heavy organic pollution. High BOD values (≥9.0) in the dry month indicate high organic pollution. Productivity of the creek as measured by chlorophyll-*a* increased in the dry months while Zooplankton abundance and diversity were higher in the dry months than in the wet months.

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