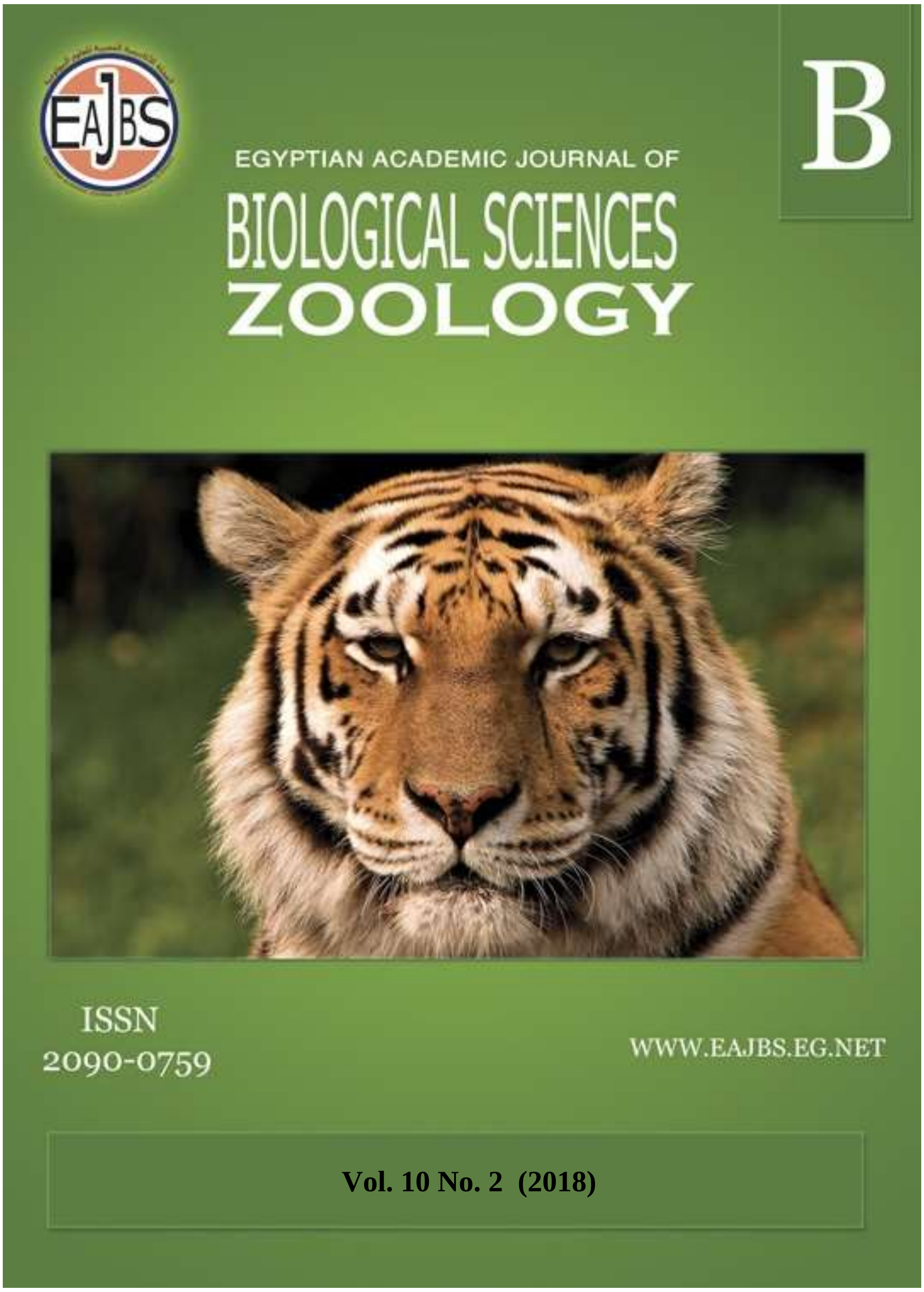

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Phytoplankton Composition and Dynamics at A Tropical Tidal Creek, Lagos.

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ABSTRACT

The diversity and dynamics of phytoplankton at a tropical tidal creek in Lagos, in relation to water chemistry changes, were investigated for twenty-four months. Water samples were collected with a 75cl plastic bottle whereas phytoplankton samples were collected by a 55 µm mesh size standard plankton net towed horizontally for 5 mins at <4 Km/h. Water samples were processed to the laboratory for analysis and the phytoplankton samples were preserved by the addition of 4% unbuffered formalin. Water chemistry characteristics were measured using standard methods. The drop count microscopic analysis method was used to study the phytoplankton. Notable parameters that showed marked variations with season include salinity (0.17 – 30.4‰), rainfall (6 – 330mm), transparency (26 – 191cm), total suspended solids (30 - 360 mg/L), total hardness (18 - 3760 mg/L), chloride (60 - 11165 mg/L), conductivity (263 - 32900 µS/cm), total dissolved solids (197 - 21230 mg/L), sulphate (18.9 - 1140 mg/L), nitrate (4.1 - 42 mg/L), calcium (4.9 – 400.2 mg/L), Magnesium (1.4 - 648 mg/L) and iron (0.08 – 0.99 mg/L). A total of sixty-four phytoplankton species (dominated by diatoms) from five (5) algal classes namely Bacillariophyceae (43 species), Cyanophyceae (11 species), Chlorophyceae (7 species), Euglenophyceae (2 species) and Chrysophyceae (1 species) were observed. The green algae, euglenoids and golden brown algae were more frequently occurring during the wet season. The species with the highest biomass (in terms of numbers) was *Aulacoseira granulata* var. *augustissima.* The preponderance of very few species primarily *Aulocoseira* and *Microcystis* species in the wet season and *Coscinodiscus, Actinoptycus, Odontella* and *Parabelius* species in the dry season is a reflection of the changing water conditions within the tidal creek system from season to season and from fresh to high brackish water conditions. Freshwater taxa in the lagoon were primarily recruited from the freshwater areas especially upstream and including the Ologe lagoon from where they existed in higher concentration and usually brought in with floodwater inflow during the rains. Species of *Surirella* where likely scoured from the creek substratum whereas *Parabelius* (tube diatoms) were detached from attached submerged hard substrates.

INTRODUCTION

The Nigerian coastal area is dominated by extensive stretches of sandy beaches, lagoons, estuaries, mud beaches, a deltaic complex of swamps, salt-tolerant mangrove forests and creeks (Ibe, 1988; Dublin-Green and Tobor, 1992; Onyema, 2009). In this region, creeks are common hydrological features and gravitate towards coastal lagoons and estuaries in their immediate area enroute to the Atlantic ocean. Flood waters associated with rainfall are known to enrich creek ecosystems, dilutes its ionic concentration and break down existing environmental gradients (Olaniyan, 1969; Nwankwo, 1996; Onyema and Nwankwo, 2006; Geetha and Kondalarao, 2004). Conversely, in the dry season, freshwater inflow is greatly reduced and seawater/saltier water enters thereby giving rise to more marine conditions within creek ecosystems (Onyema *et al.*, 2016). Creeks and mangrove swamps are part of the array of productive ecosystems in coastal environments due to their high level of aquatic primary productivity largely from the phytoplankton and other algae (Onyema and Nwankwo, 2006).

The phytoplankton is free floating and mostly microscopic plants that contain chlorophyll and grow by photosynthesis and lack roots, stems (non-vascular) and leaves (Lee, 2008; Nwankwo, 2004; Onyema and Akanmu, 2017). They constitute the basis of food chain composition in the aquatic
environment as they play the role of primary producer and serve as food for aquatic animals such as zooplankton, shellfish and finfish and also play an important role in maintaining the biological balance and quality of water. (Varadharajan and Soundarapandian, 2014). Phytoplankton is additionally known to satisfy conditions to qualify as suitable environmental indicators in that they are simple, capable of quantifying changes in water quality, applicable over large geographic areas and can also furnish data on background conditions and natural variability (Onyema, 2007; Wu *et al*., 2014). Phytoplankton in a marine environment is an important biological indicator of water quality (Varadharajan and Soundarapandian, 2014). The phytoplankton forms the first step in the aquatic food chain with the zooplankton forming the second step (Onyema and Okedoyin, 2017). Diatoms, dinoflagellates, blue-green algae, chlorophytes and so on are some important groups of phytoplankton in brackish and marine ecosystems (Subrahmanyan , 1959; Nwankwo, 1006; Geetha and Kondalarao, 2004; Onyema, 2008).

There is a dearth of information on the phytoplankton community (with identified species by microscopic investigation) of creeks in Nigeria and indeed Lagos. Some available literature on phytoplankton include Chindah *et al.*, (1993) for the Elechi creek in the Niger Delta and Nwankwo and Akinsoji (1988), Nwankwo and Amuda (1993); Adesalu and Nwankwo (2005); Onyema and Nwankwo, (2006); Emmanuel and Onyema, (2007); Onyema and Ojo, (2008); Nwankwo *et al* (2012); Onyema and Lawal-Are, (2017); Onyema and Ajao, (2017) and Onyema and Akanmu, (2018) for different creeks in the Lagos coastal area.
The aim of this study was to microscopically investigate the diversity and dynamics of phytoplankton at a tidal creek in Lagos, in relation to water chemistry changes.

MATERIALS AND METHODS

Description of Study Site:

The sampling station for this study is at Latitude 6°26′28″ N, Longitude 3°11′25″ E located at around the Idiagbon / Igbolobi area of Lagos (Fig. 1). This area is one of the tributaries of the Elite creek and significantly devoid of human presence and structures including houses. The Elite creek eventually drains to the Atlantic Ocean. It transverses the Proto-Novo creek in the Iyagbe lagoon and the Lagos habour. The riparian mangrove forest in the study area is also well developed. The creek is sheltered tidal, narrow and meandering. The area is fed by water from the Lagos harbour and the Porto-Novo creek at high tide, and as the tide ebbs water from the Ologe lagoon via the Elite creek fills the study ecosystem. The Porto-Novo creek is a large depository of the invasive aquatic macrophyte weed water hyacinth (*Eicchornia crassipes*) and is one of the two conduits by which the weed entered the country in September 1984 (Onyema, 2009).

As in south-western Nigeria, the region is exposed to two distinct seasons, the wet (May – October) and dry season (November – April). Fresh water discharges into the creek are associated with the seasonal bi-modal rainfall distribution in the region. Whereas the wet season is dominated by fresh water discharges and fresh water/low brackish conditions, the dry season is influenced significantly by tidal inflow from the ocean (Nwankwo, 2004; Onyema 2008). An extensive expanse of mudflats which is submerged at high tide is evident at low tide. Some dominant vegetation in the area of the creek includes *Paspalum orbiquilare*, *Typha* sp, *Mariscus alteriforlus*, *Rhynchospora* sp. and sparsely populated white (*Avecennia nitida)* and red mangroves (*Rhizophora racemosa).* Notable macrofauna includes *Periopthalmus*, *Balanus pallidus*, *Chthamalus* sp., *Gryphea gasar*, *Tympanotonus fuscatus* var. *radula*, herons and other birds that feed on exposed intertidal biota especially at low tide.

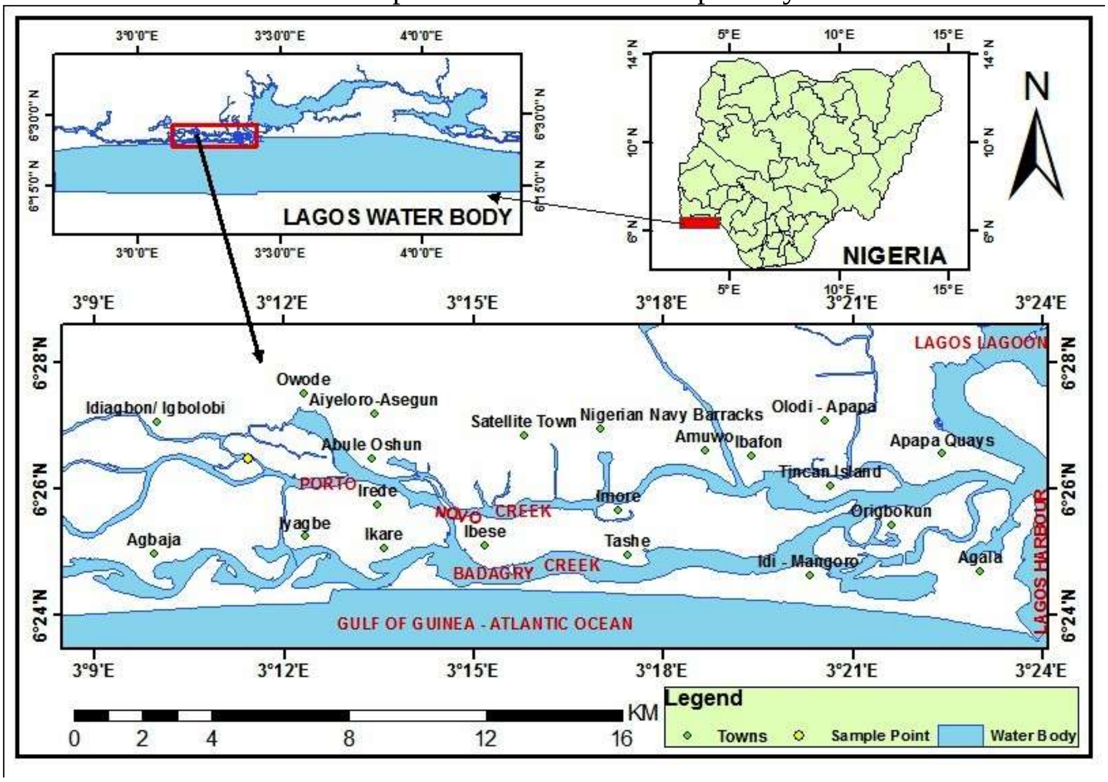

Fig. 1: Badagry and Porto-Novo creek systems in Lagos state, showing the study sample point.

Collection of Water and Plankton Samples:

Water sample for water chemistry analysis and plankton analysis were collected monthly between 10h and 13h for twenty-four consecutive months (Oct. 2004 – Sept. 2006). Surface water samples were collected using a 2.0L non – metallic water sampler just below the water surface. Water samples were then transferred into well-labeled 200ml glass bottles with screw caps and analyzed on getting to the laboratory on the same day. Plankton samples were collected using a 55µm mesh size standard plankton net by horizontally towing for 5 mins at <4 Km/h. plankton samples were preserved by the addition of 4% unbuffered formalin.

Analysis of Physicochemical Parameters:

Air and surface water temperatures were measured using a mercury thermometer. Rainfall values were obtained from the Nigerian Meteorological Agency, Lagos (NIMET). Transparency was estimated by the Secchi disc method, Total Dissolved Solids by Cole Palmer TDS meter, pH by Electrometric / Cole Parmer Testr3. Total Suspended Solids, Chloride, Total hardness, Conductivity, Salinity, Alkalinity, Acidity, Dissolved oxygen, Biological oxygen demand, Chemical oxygen demand, Nitrate – nitrogen, Phosphate – phosphorus, Sulphate, Silica, Calcium and Magnesium were measured using methods according to American Public Health Association (2012) for water analysis. Copper, Iron and Zinc were estimated with an Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS and using Perkin Elmer Application methods (2002).

Plankton Analysis:

The drop count microscopic analysis method as adapted by Onyema (2007) was used for the investigation of the phytoplankton. Five drops of concentrated plankton sample were used (using a long nose disposable pipette / dropper) of the concentrated sample (10 ml) were investigated differently at different magnifications (50X, 100X and 400X) using an OLYMPUS CH binocular microscope with a calibrated eyepiece (X10) and the average recorded. The final data were presented as the number of organisms (cells, filaments, colonies, and organism) per ml.

Phytoplankton Community Structure Analysis:

Total species diversity (S) referred to the number of species in a population per month during the study. Additionally, Species Richness Index (d) also referred to as Margalef index (Ogbeibu, 2005) was used to assess community structure for the phytoplankton spectrum. The equation below was applied.

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

d = Species richness index
S = Number of species in a population
N = Total number of individuals in S species.

RESULTS

The results for physicochemical parameters showed variations from month to month and season to season for the period of study. A summary of physicochemical results are presented in Table 1. Whereas Air temperature, surface water temperature, total dissolved solids, transparency, sulphate, silica, dissolved oxygen, conductivity, salinity, chloride, pH, acidity, alkalinity, total hardness, calcium and magnesium recorded increased values in the dry than wet season. On the other hand chemical oxygen demand, biological oxygen demand, total suspended solids, nitrate, phosphate, copper, zinc and iron recorded higher values in the wet season during the two year study.

Phytoplankton:

A total of five (5) algal groups (Classes) were recorded by microscopic examination. They were the Bacillariophyceae, Cyanophyceae, Chlorophyceae, Euglenophyceae and Chrysophyceae. A total of sixty-four phytoplankton species were recorded in all. Fig. 2 shows the ranking of the top 30 of the 64 phytoplanktonic algal species recorded. This is in the order of more abundant and frequently occurring species. *Aulacoseira granulata* var. *augustissima* is the most notable in this regard recording a total of 24,810 individuals for the period of study. Additionally, a succession of dominant phytoplankton species and its associated forms in terms of biomass (number of cells, filament or colonies) are presented in Table 2. The notable variation in Total phytoplankton species diversity (S), Margalef index (d) in relation to variation in salinity for the 24 consecutive months of study is shown in Fig. 3. Species diversity (S) was strongly and positively correlated with Margalef index (d) (r = 0.91).

Table 1: Physicochemical characteristic at a tropical tidal creek ecosystem (Dec. 2004 – Nov. 2006).

	Physicochemical parameter	Min.	Max.	Mean	±SD
1	**Air Temperature (^oC)**	26	33	30.06	2.12
2	**Water Temperature (^oC)**	26	32	29.56	1.95
3	**Transparency (cm)**	26	191	87.75	44.78
4	**Rainfall (mm)**	6	330	141.83	119.38
5	**Total Suspended Solids (mg/L)**	30	360	131.17	91.70
6	**pH @ 25°C**	6.95	7.75	7.37	0.22
7	**Acidity (mg/L)**	4.6	36	11.76	7.42
8	**Alkalinity (mg/L)**	16.8	266.2	68.74	68.22
9	**Total Hardness (mg/L)**	18	3760	1672.34	1344.43
10	**Salinity (‰)**	0.17	30.4	11.34	10.22
11	**Chloride (mg/L)**	60	11165	3788.95	3747.38
12	**Conductivity (μS/cm)**	263	32900	9984.13	10136.09
13	**Dissolved Oxygen (mg/L)**	4.2	5.3	4.64	0.23
14	**Biological Oxygen Demand**	3	14	7.08	3.20
15	**Chemical Oxygen Demand**	10	55	26.54	11.87
16	**Total Dissolved Solids (mg/L)**	197	21230	6482.50	6631.52
17	**Nitrate (mg/L)**	4.1	42	10.73	7.35
18	**Phosphate (mg/L)**	0.01	1.3	0.30	0.34
19	**Sulphate (mg/L)**	18.9	1140	280.68	301.12
20	**Silica (mg/L)**	1.2	5	2.74	0.92
21	**Calcium (mg/L)**	4.9	400.2	159.36	123.50
22	**Magnesium (mg/L)**	1.4	648	262.26	241.16
23	**Iron (mg/L)**	0.08	0.99	0.29	0.25
24	**Copper (mg/L)**	0.001	0.016	0.00	0.00
25	**Zinc (mg/L)**	0.001	0.005	0.00	0.00

Bacillariophyceae (Diatoms):

The Bacillariophyceae were the predominant group. Forty-three diatom species were recorded with the centric forms being more diverse than the pennate forms. *Actinoptychus splendens* (0.87 – 65.32%), *Aulacoseira granulata* (0.02 – 23.53%), *Aulacoseira granulata* var. *augustissima* f. *spiralis* (1.57 – 68.75%). *Coscinodiscus centralis* (1.59 – 88.24%), *C. eccentricus* (1.59 -28.21%) , *C. radiatus* (3.4 – 64.22%), *C. maginatus* (2.37 – 9.30%), *Cyclotella menighiniana* (0.23 – 15.79%) were the frequently occurring centric diatom species that occurred throughout the year. Frequently occurring pennate diatoms included *Synedra crystallina* (0.02 – 13.04%), *S. ulna* (3.03 - 50%), *Surirrela straitula* (1.52 – 50.0%), *Nitzschia sigmoidea* (0.87 – 24.10%) and *Fragillaria construens* (3.49 – 13.04%). Rarely occurring diatoms at included, *Rhizosolenta styliformis* (7.23%), *Paralia sulcata* (0.79

– 5.56%), *Aulacoseira islandica* (4.59%), *Amphipora alata* (5.26%), *Amphora ovalis* (5.26%), *Parabelius delognei* (13.25%) and *Pleurosigma angulatum* (11.11%).

Cyanophyceae (Blue-green algae):

The blue-green algae recorded a total of eleven species. *Microcystis aureginosa* (6.06 – 95.45%) was the single more important cyanobacteria at this station. Others included *Oscillatoria limnosa* (1.81 – 4.35%), *Scytonema crustaceum* (3.03%), *Lyngbya limnetica* (5.26%), *L. martensiana* (5.26%), *Anabaena constricta* (11.11%) and *A. spiroides* (0.76%).

Chlorophyceae (Green algae):

The green algae recorded seven species namely *Pediastrum simplex* (0.23%), *Spirogyra africana* (0.91 – 33.33%), *Cladophora glomerata* (8.7%), *Akistrodesmus* sp. (79.37%), *Scenedesmus quadriqauda* (0.91 – 1.52%) and *Gonatozygon monotaenium* (24.24%). These species occurred more frequently during the wet than dry season.

Euglenophyceae (Euglenoid):

The euglenoids were represented at this station by two species recorded in the wet season – *Phacus acuminatus* (3.03%) and *Trachelomonas hispida* (3.02%). These species occurred more frequently during the wet than dry season.

Chrysophyceae (Gloden brown algae):

The chrysophytes recorded only a sole species – *Synura uvella* (3.03%) throughout the survey.

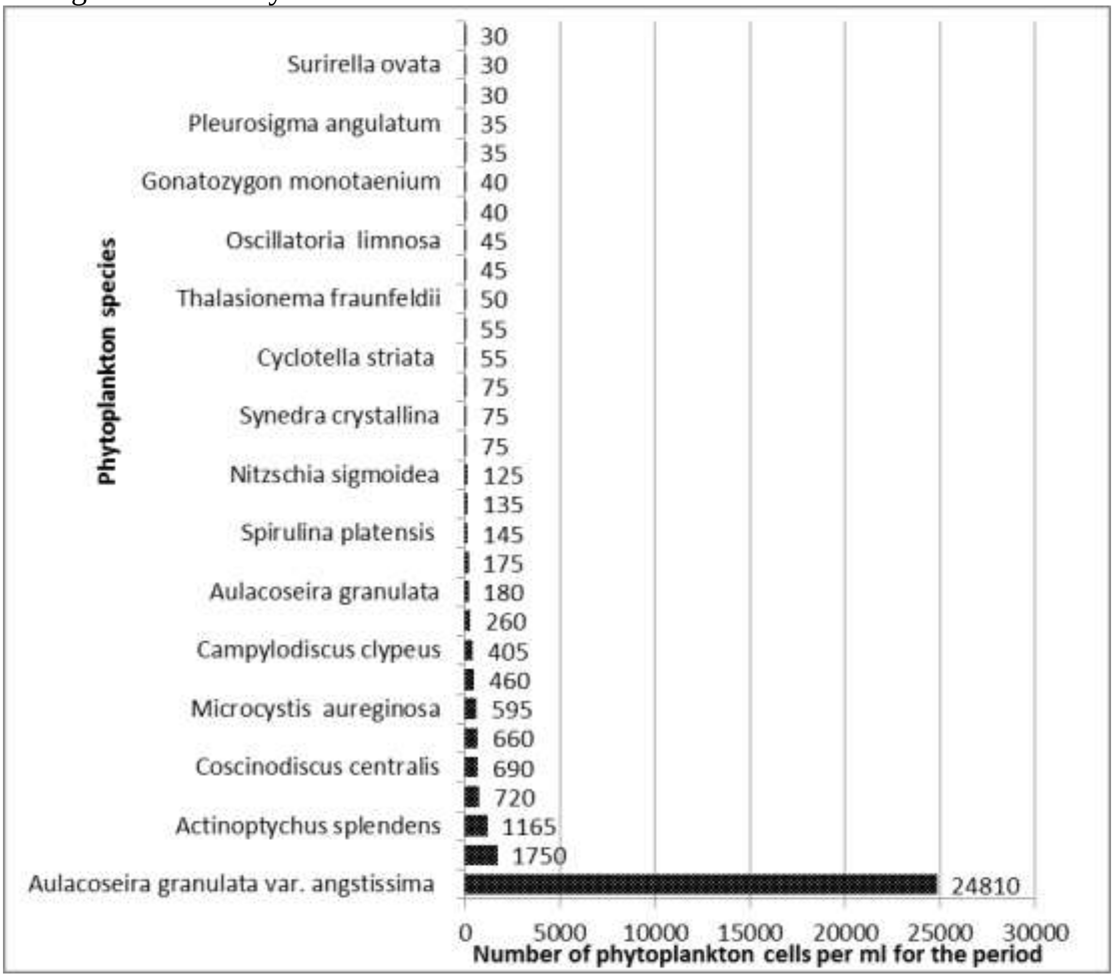

Fig. 2: Ranking of the top 30 species in terms of numbers of cell, filament or colonies recorded at the tidal creek ecosystem.

Table 2: Summary of dominant species and their most frequent associates in the tropical tidal creek.

Month	Dominant Species	Associated Species
October, 2004	*Spirogyra africanum*	*Gonatozygon monotaenium, Actinoptychus splendens Aulocoseira granulata* var. *augustissima*
November, 2004	*Aulocoseira granulata* var. *augustissima*	*Fragillaria construens, Actinoptychus splendens, Synedra crystallina*
December, 2004	*Aulocoseira granulata* var. *augustissima*	*Coscinodiscus marginatus, Actinoptychus splendens, Bacillaria paxillifer*
January, 2005	*Cyclotella striata*	*Podosira tenobro, Bacillaria paxillifer, Coscinodiscus eccentricus.*
February, 2005	*Nitzschia sigmoidea*	*Parabelius delognei, Coscinodiscus radiatus, Fragillaria construens*
March, 2005	*Coscinodiscus centralis*	*Coscinodiscus radiatus, Anabaena constricta, Aulocoseira granulata* var. *augustissima*
April, 2005	*Coscinodiscus centralis*	*Coscinodiscus eccentricus, Coscinodiscus radiatus, Coscinodiscus eccentricus*
May, 2005	*Actinoptychus splendens*	*Coscinodiscus centralis, Biddulphia leavis, Coscinodiscus eccentricus.*
June, 2005	*Surirella striatula*	*Synedra ulna*
July, 2005	*Actinoptychus splendens*	*Aulocoseira granulata* var. *augustissima* f. *spiralis, Aulocoseira granulata* var. *augustissima, Coscinodiscus centralis*
August, 2005	*Aulocoseira granulata* var. *augustissima* f. *spiralis*	*Aulocoseira granulata* var. *augustissima Actinoptychus splendens, Coscinodiscus eccentricus*
September, 2005	*Aulocoseira granulata* var. *augustissima*	*Aulocoseira granulata, Aulocoseira granulata* var. *augustissima* f. *spiralis, Aulocoseira varians.*
October, 2005	*Actinoptychus splendens*	*Aulocoseira granulata, Aulocoseira granulata* var. *augustissima, Aulocoseira granulata* var. *augustissima* f. *spiralis.*
November, 2005	*Actinoptychus splendens*	*Aulocoseira granulata* var. *augustissima, Coscinodiscus centralis, Aulocoseira granulata* var. *augustissima* f. *spiralis*
December, 2005	*Coscinodiscus radiatus*	*Coscinodiscus centralis Coscinodiscus eccentricus Actinoptychus splendens*
January, 2006	*Coscinodiscus centralis*	*Coscinodiscus radiatus Actinoptychus splendens Aulocoseira granulata* var. *augustissima*
February, 2006	*Coscinodiscus centralis*	*Actinoptychus splendens Aulocoseira granulata*
March, 2006	*Synedra crystallina*	*Cyclotella menighiniana, Aulocoseira granulata, Amphiprora alata*
April, 2006	*Skeletonema coastatum*	*Thalassionema fraunfeldii, Oscillatoria sancta, Aulocoseira nummulaides, Asterionella jopanica.*
May, 2006	*Akistrodesmus* sp.	*Microcystis aureginosa, Coscinodiscus radiatus Coscinodiscus centralis*
June, 2006	*Microcystis aureginosa*	*Synedra ulna*
July, 2006	*Actinoptychus splendens*	*Aulocoseira granulata* var. *augustissima, Coscinodiscus centralis, Nitzschia sigmoidea*
August, 2006	*Actinoptychus splendens*	*Skeletonema coastatum, Pleurosima augulatum Coscinodiscus centralis*
September, 2006	*Aulocoseira granulata* var. *augustissima*	*Microcystis aureginosa, Bacillaria paxillifer, Aulocoseira granulata* var. *curvata.*

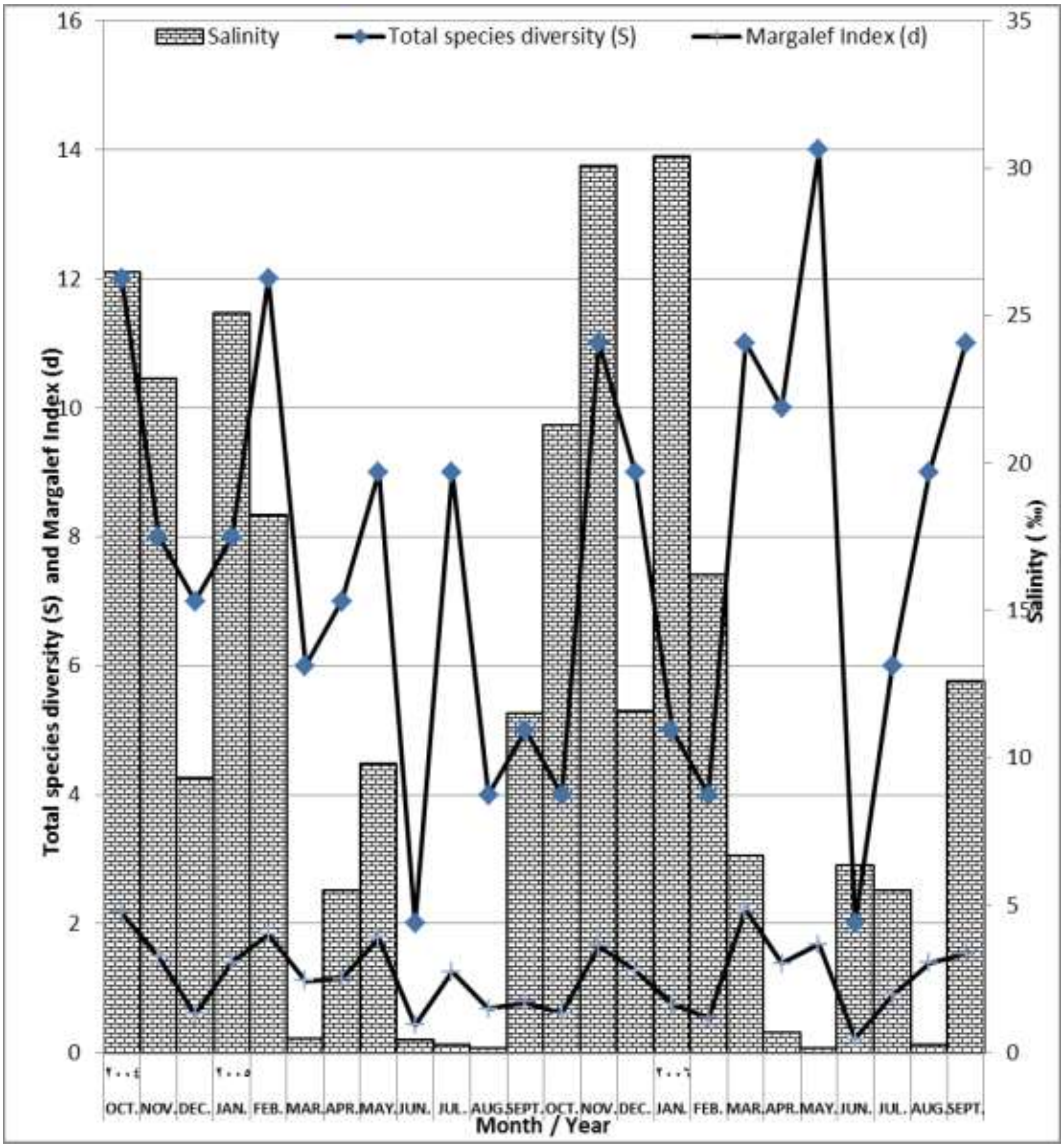

Fig. 3: Monthly variation in Total species diversity (S), Margalef Index (d) in relation to Salinity.

DISCUSSION

The data on water chemistry and phytoplankton diversity fall within natural condition known for tropical fluctuating estuarine creek ecosystem as described by previous works in especially the coastal waters of Nigeria (Adesalu and Nwankwo, 2005; Nwankwo, 1988, 1990; Onyema, 2008, 2013). The water physicochemistry stretched from fresh water (0.17‰) to marine conditions (30.4‰) during the study. The effects of rainfall on flood waters largely regulated the water chemistry changes especially in the wet season. On the other hand, the salinity, chloride, conductivity and total dissolved solids trends reflected the effect of saltier/seawater inflow into the study area. Life in this water is thus subjected to seasonal fluctuation of fresh, brackish or marine conditions and various species adapted to the varying environmental conditions appear at different times. According to Nwankwo (1990), two factors, fresh water discharge from rivers and tidal seawater incursion influence the biological, physical and chemical characteristics of the Lagos lagoon. The marked variation in nitrate and sulphate is notable during the course of study.

Generally, there was comparatively higher phytoplankton diversity and abundance of phytoplankton species in the dry than the wet season and this was positively related with salinity, chloride, conductivity, cation content, total hardness, total dissolved solids, pH, transparency and alkalinity levels. The phytoplankton community and the environmental factors exhibited seasonal changes closely related to the pattern of rainfall. Furthermore, there were greater changes in species composition in the dry than wet seasons with the dry season recording more spread of species. Notable freshwater taxa include *Aulacoseira granulata, Aulacoseira granulata* var. *angustissima, Aulacoseira granulata* var. *angustissima* f. *curvata, Aulacoseira granulata* var. *angustissima* f. *spiralis* and *Microcystis* spp. while brackish water / marine forms included *Coscinodiscus centralis Coscinodiscus eccentircus, Coscinodiscus radiatus, Coscinodiscus marginatus, Aulacoseira nummuloides* and *Parabelius delognei*. Whereas *Coscinodiscus, Odontella* and *Parabelius* spp. and the dinoflagallates were more biodiganostic of marine condition and the dry season, *Aulacoseira granulata, Aulacoseira granulata* var. *angustissima, Aulacoseira granulata* var. *angustissima* form *curvata*, *Aulacoseira granulata* var. *angustissima* f. *spiralis*, *Microcystis aureginosa* and euglenoids better represented fresher water conditions and periods.

High numbers of *Aulacoseira granulata* var. *angustissima* and *Microcystis aeruginosa* in the wet season may be the indication of a number of situations. It is possible that these species multiplied and developed in high numbers from the Ologe lagoon and upstream where nutrients levels were high and in the dry season. This plankton spectrum was then subsequently flushed downstream as the flood water pushed them downstream during the rains and floodwater flows enroute to the ocean. Hence phytoplankton spectrum is recorded much more in the study area in high numbers during the raining season.

Freshwater taxa in the lagoon were primarily recruited from the freshwater areas from where they existed in higher concentration and usually brought in with freshwater inflow during the rains and also from the scoured phytobenthic community. Notable genera include *Aulacoseira*, *Microcystis*, *Synedra* and *Surirella* species. Life in this water is thus subjected to seasonal fluctuation of fresh, brackish or marine conditions and various species adapted to the varying environmental conditions appear at different times (Onyema and Akanmu, 2017).

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