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EFFECTS OF MACRONUTRIENTS AND RAINFALL PATTERN ON MICROALGAL SPECTRUM OF TIDAL CREEKS ADJOINING LAGOS LAGOON, SOUTHWEST, NIGERIA

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ABSTRACT

Variations in macronutrient contaminants and microalgal spectrum of three tidal creeks adjoining Lagos Lagoon, southwest Nigeria were investigated for six months (September, 2013 – February, 2014). Microalgae samples were collected using a 55 μmplankton net hauled at low speed for 5mins. Physico-chemical parameters of surface waters analysed showed monthly variations linked to seawater intrusion and rainfall distribution pattern. Air and water temperatures were high (≥ 25°C) all through the sampling period. Transparency and total dissolved solids increased in the dry months (≤ 75.5 cm, ≤ 14100 mg/L) while the total suspended solids were low throughout the study period (≤ 1.5 mg/L). The waterbodies were slightly alkaline (≤ 8.2) all through the sampled months. Salinity and conductivity values increased steadily during the dry months Dissolved oxygen ranged between 1.1 and 8.0 mg/L while Chemical Oxygen Demand and Biochemical Oxygen Demand values at the creeks were low (≤ 50.0 mg/L; ≤ 4.2 mg/L). Macronutrients concentration were higher in the dry months than in the wet months, whereas, heavy metals occurred as traces (≤ 4 mg/L) throughout the period. Microalgal biomass in terms of numbers was relatively higher in the wet months than in the dry months. A total of 25 species from 20 genera were recorded. The observed classes in terms of abundance were Bacillariophyceae (83 %), Cyanophyceae (13 %) and Chlorophyceae (4 %). There was no significant difference (p > 0.05) in species diversity between the three creeks investigated.

Keywords: microalgae, tidal creek, macronutrients, diversity, pollution

INTRODUCTION

Tidal creeks and lagoons are distinct features in coastal environments of southwest Nigeria (Chukwu and Nwankwo, 2004). These waterbodies are connected and lie parallel to the Gulf of Guinea coastline over a distance of 237 km (Hill and Webb, 1958; Nwankwo and Akinsoji, 1989). They are brackish in nature due to tidal seawater movement upstream and the inflow of freshwater from rivers downstream and according to Nwankwo (1996), the characteristics of these environments are determined by interactions between the tidal seawater incursion and the freshwater inflow. The creeks and lagoons of southwest Nigeria have numerous economic and ecological importance, nevertheless, they are frequently being used as sink for disposal of wastes (Onyema, 2007). The pollution of these waterbodies due to indiscriminate waste disposal has consistently affected the quantity and quality of organisms inhabiting the environments (Emmanuel and Kusemiju, 2005).

Algae generally range in size from microscopic unicellular forms to highly differentiated multicellular organisms (Akinsoji and Nwankwo, 1992). Many algal taxa have specific environmental requirements and are usually ecologically restricted (Smith, 1950). Their ecology is crucial in understanding aquatic ecosystem productivity and water quality challenges (Hoffman, 1998). Microalgae respond rapidly to changes in the environment as a result they are suitable bio indicators of water conditions. In many instances, the species composition of planktonic microalgae (phytoplankton) in aquatic environments are being monitored as an indicator of water quality (Nwankwo and Akinsoji, 1992).

Nutrients are important requirements for algal growth in aquatic environments, some are desirable in trace amounts (micronutrients such as cobalt, iodine and zinc). Others are required in large quantities (macronutrients such as nitrogen, phosphorus and silicon), consequently, altering hydo-environmental parameters are at the detriments of these marine algae (Onyema, 2013).

Previous studies on creeks in southwest Nigeria include Emmanuel and Onyema (2007) on the plankton and fishes of Abule-Agege creek, they observed species diversity varies with seasonality. Adesalu and Nwankwo (2008) reported the implications of water quality indices on microalgae of Abule Eledu creek. Adesalu and Kurunmi (2012) documented the impacts of physico-chemical parameters on microalgae of Majidun creek. Nwankwo *et al*. (2012) investigated variations in nutrient status and chlorophyll *a* of Light house creek and five cowrie creek, it was reported that phytoplankton biomass are most abundant in dry months. Adesalu *et al*. (2017) studied microalgal communities of Ito-Iwolo creek and observed the dominance of diatoms population. Onyena and Okoro (2019) investigated the spatio-temporal changes in water and sediments of three tidal creeks in southwest Nigeria and reported that creeks in the region are highly impacted with anthropogenic stressors. Despite numerous studies on creeks in this area, the need to continuously monitor the changes in macronutrient contaminants and their implication on microalgal spectrum cannot be over emphasized. Hence, the aim of this study was to investigate variations in macronutrient contaminants and microalgal spectrum at Abule-Agege, Abule- Eledu and Makoko creeks in relation to water chemistry.

MATERIALS AND METHOD

Description of Study Area

The tidal creeks under investigation are Abule-Agege creek (Longitude 3°24.024' E and Latitude 6°30.864' N), Abule- Eledu creek (Longitude 3°23.914' E and Latitude 6°31.413' N) and Makoko creek (Longitude 3°23.433' E and Latitude 6°29′411' N). Abule-Agege and Abule-Eledu creeks are located within the University of Lagos, Akoka campus, Nigeria and are connected to the Lagos Lagoon (Figure 1). These waterbodies are shallow, tidal and sheltered. At high tide, they receive waters from Lagos lagoon, and at low tide the water recedes into the lagoon. Makoko creek is micro-tidal, drains into Lagos lagoon and it is deeper than Abule- Agege and Abule-Eledu creeks. Two distinct seasons occur in the region where these creeks are located, the wet (May- October) and the dry season (November-April) (Emmanuel and Onyema, 2007). Active fishing activities via cast nets is noticeable at the shoreline of these areas. Some of the distinguished riparian flora of creeks in the area includes, *Acrotiscum aureum, Phoenix reclinata, Paspalum orbiquilare Rhizophora racemosa, Avicenia nitida, Drepoanocarpus lunatus* and *Cyperus articulatus.* Prominent fauna in the creeks include *Tympanotomus fuscatus Pachymelenia aurita Periopthalmus* sp, *Chthamalus* sp, *Uca tangeria, Seserma huzardi, Gryphea gasar* and seabirds such as herons.

Collection of Microalgae and Water Samples

Planktonic microalgae and water samples were collected monthly for six months (September 2013 - February 2014) between 09:00 and 12:00 h. Biological samples were obtained using standard plankton net of 55 μm mesh size towed steadily for five min at low speed. Planktonic microalgal samples were stored in properly labelled screw capped plastic containers and preserved in 4 % unbuffered formalin. For physico-chemical analysis, duplicate water samples were stored in 1 L (litre) properly labelled plastic containers with screw caps. Samples were transported in ice-chest except samples for dissolved oxygen and biochemical oxygen demand which were stored in a black polythene bag to prevent photo-oxidation of the samples. Water samples were stored in refrigerator (≤ 4 %) for further analysis within 24 h in the laboratory.

Figure 1: Map of Lagos lagoon showing the tidal creeks investigated.

Physico-chemical Analysis

Surface water and air temperatures were measured *in-situ* using a mercury-in-glass thermometer while, pH values were determined using Cole-parmer pH meter. Salinity was measured with a hand-held Refractometer (model RHS-10 ATC). The dissolved oxygen was estimated by titrimetric (Iodometric) method using the Azide Modification procedure 4500-OC (APHA, 1998). The chemical oxygen demand was determined by using the closed Reflux method 5220C (APHA, 1998). Total dissolved solids and total suspended solids were determined using gravimetric methods. Colorimetric method was used for nitrate-nitrogen and phosphate-phosphorus and silicate contents; whereas, sulphate content was estimated using the Turbidimetric method (APHA, 1998). Chlorophyll *a* was determined by Fluorometric method while, Iron and Lead were determined using Atomic Absorption Spectrophotometer (AAS). Information on rainfall distributive pattern for the period was obtained from the Federal Meteorological Department Oshodi, Lagos, Nigeria.

Biological Analysis

In the laboratory five drops of each concentrated samples (10 ml) were investigated at different magnifications (40x, 100x and 400x) after mounting on a glass slide and covering with a cover slip using a wild MII binocular microscope with calibrated eye piece. An average of 5 outcomes of this procedure was carried out per sample, thereafter, proper identifications of species was done using relevant texts (Wimpemy, 1966; Patrick and Reimer, 1966; 1975; Whitford and Schumacher, 1973; Bettrons and Castrejon, 1999; Nwankwo, 1990; 2004).

Community Structure Analysis

Community structure was determined using three indices: Species richness index (d) (Margalef, 1970), Shannon-Weiner index (H^1) (Shannon and Weiner, 1963) and Species evenness (j) (Pielou, 1975).

Statistical Analysis

Analysis of variance (ANOVA) of physicochemical parameters and microalgal densities to determine significant differences across stations were done using SPSS version 22. Effects were considered significant if ($p < 0.05$). Further test of significance (post-hoc analysis) was done using Duncan Multiple Range test (DMRT). Paleontological statistics (PAST 4.03) was used to conduct Principal components analysis (PCA) and Canonical correspondence analysis (CCA).

RESULTS

Physico-chemical Parameters

The results of the physico-chemical parameters of the sample sites are presented in Table 1. The air and surface water temperature values ranged from 25 to 30 °C and 26 to 31 °C respectively, the highest values (30 °C and 31 °C) were recorded in February 2014 at Abule Eledu creek. Transparency ranged between 15 and 75.5 cm with lowest and highest values (15 cm and 75.5 cm) recorded in September 2013 and February 2014 at Makoko and Abule-Agege creeks respectively. Rainfall data ranged from 18.4 mm in December to 306.7 mm in September. The water sample in the study areas was slightly alkaline with values between 7.4 and 8.4 in September and November at Abule-Agege and Makoko creeks respectively. Dissolved oxygen, biochemical oxygen demand and chemical oxygen demand were all high in wet season than in dry season (Table 1). The highest nitrate-nitrogen and phosphate-phosphorous contents (14.51 mg/L and 11.51 mg/L) were recorded at Makoko creek in January and December (Figure 5), while the lowest value (1.62 mg/L and 0.02 mg/L) were recorded in November at Abule-Agege creek. The reported silicate contents were relatively low (≤ 0.04 mg/L) throughout the sampling period. The total suspended solids showed no clear monthly variation (1 - 1.5 mg/L) while the total dissolved solids ranged from 23 mg/L to 14100 mg/L. Salinity ranged between 5 ‰ and 26 ‰ (Figure 4), the highest and lowest values (5 ‰ and 26 ‰) were recorded in November and February at Abele-Agege, Abule- Eledu creeks and Makoko creeks respectively. Lead (Pb) content values were comparatively low (≤ 0.03 mg/L) throughout the sampling period. The highest value (0.03 mg/L) was recorded in January at all stations and in February at Makoko creek. Iron (Fe) content recorded ranged from 1.55 mg/L to 4mg/L. Chlorophyll *a* values were relatively low (≥ 0.003 μg/L), the lowest value (0.001 μg/L) was recorded in October, December and February. Whereas, the highest values were recorded in November and December at Makoko creek. Principal component analysis of the physico-chemical parameters at the study sites (Figure 2) showed that the controlling factors in the wet months are rainfall, biochemical oxygen demand and silicate, whereas, salinity, transparency and phosphate are controlling factors for the dry months. Rainfall have a strong positive correlation (≥ 0.5) with total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), Iron (Fe), total species diversity and abundance. Results of the Analysis of variance (ANOVA) of data obtained in the study revealed there were no statistical differences (P = 0.832) in the physico-chemical parameters reported across the stations investigated.

Phytoplankton Composition and Community Structure

Three major divisions of microalgae were recorded in this study (Table 2 and Figure 6), Bacillariophyta (Diatoms, 83 83 %), Cyanophyta (blue-green algae, 13 %) and Chlorophyta (green algae, 4 %). The microalgae community was dominated by diatoms with 20 species out of the total 25 microalgae taxa identified in this study (Table 2). The blue-green algae made up three (3) species while the green algae comprised two (2) species. The highest microalgal cell count (317) was recorded in September 2013 at Makoko creek while, the lowest cell count (27) was recorded in January 2014 at Abule-Eledu creek. Canonical correspondence analysis of data obtained in the creeks (Figure 3) showed microalgae species concentration was influenced by rainfall, silicate, phosphate, salinity and transparency. Highest species diversity (3.69) was observed in September 2013 at Abule-Agege creek (Table 2 and Figure 7) while the lowest species diversity was recorded in January 2014 at Makoko creek. The highest and lowest Shannon-weiner index values (2.79 and 1.36) were recorded in September 2013 (Makok creek) and January 2014 (Abule-Agege creek) respectively. The species evenness was highest (0.93) in September 2013 (Abule-Agege and Abule Eledu creeks) while the lowest value (0.74) was recorded in January 2014 at Abule-Eledu creek. Results of the Analysis of variance (ANOVA) showed there is no significant differences (P = 0.252) in microalgal densities amongst the creeks investigated.

Table 1: Results of physico-chemical parameters investigated at the creeks (September 2013 – February 2014). A = Abule-Agege creek; B= Abule-Eledu creek; C= Makoko creek.

Parameters	**Sept. 2013**			**Oct. 2013**			**Nov. 2013**			**Dec. 2013**		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Air Temperature (°C)	25	25	25	25	26	26	28	28.5	28.5	28	28	28
Water Temperature (°C)	26	26	26	29	29	30	30	30.5	30.5	28	29	28.5
Transparency (cm)	21	18	15	44	32	26	43	38	30	47	40	38
Rainfall (mm)	306.7	306.7	306.7	258.1	258.1	258.1	47.8	47.8	47.8	18.4	18.4	18.4
Conductivity (µS/cm)	1850	1242	1870	470	397	445	1520	1131	1442	9160	5107	8500
pH	7.4	7.5	7.8	7.97	7.8	8	8.1	8	8.2	8.07	8	8.1
TSS (mg/L)	1.1	1.3	1.5	1.4	1.2	1.3	1	1.1	1.2	1.1	1	1.2
TDS (mg/L)	916	973	1521	23	25	26	756	782	810	4470	4550	5425
Salinity (‰)	8	8	8	6	5.5	6	5	5	6	12	11.5	12.5
Nitrate (mg/L)	5.01	6.21	8.23	4.7	4.8	5.2	1.62	1.84	2.44	11.55	12.05	12.75
Sulphate (mg/L)	0.77	1.12	1.46	0.89	0.91	1.2	1.26	1.44	1.86	2.8	2.89	3.11
Phosphate (mg/L)	0.07	0.09	0.08	0.09	0.11	0.14	0.02	0.08	0.12	9.9	10.2	11.51
Silicate (mg/L)	0.03	0.02	0.04	0.01	0.02	0.02	0.02	0.03	0.04	0.01	0.02	0.02
DO (mg/L)	8	6	5.8	4.8	4.4	4.6	1.4	1.2	1.1	6.1	6	5.8
BOD (mg/L)	4.2	3.4	2.8	0.9	0.8	1	1	0.9	0.7	1.1	0.9	1.1
COD (mg/L)	50	40	38	21	18	19	18	18	17	17	18	17
IRON (mg/L)	3.9	3.7	4	2.75	2.55	3.05	3.4	3.2	3.4	1.69	1.55	1.89
LEAD (mg/L)	0.002	0.002	0.002	0.002	0.001	0.002	0	0	0	0	0	0
Chlorophyll *a* (µg/L)	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.003	0.003	0.001	0.002	0.002

Parameters	**Jan. 2014**			**Feb. 2014**					
	A	**B**	**C**	**A**	**B**	**C**	**Mean**	**Standard Deviation**	**Standard Error**
Air Temperature (°C)	28	28.5	28	30	30	29	27.47	1.65	0.39
Water Temperature (°C)	29	29.5	29	30	31	30	28.94	1.51	0.36
Transparency (cm)	69	54	42	75.5	65	58	41.97	16.82	3.96
Rainfall (mm)	80.1	80.1	80.1	132.7	132.7	132.7	140.63	106.98	25.21
Conductivity (µS/cm)	19440	10850	15040	2830	1820	2540	4758.56	5420.98	1277.74
pH	7.92	7.8	8	8.05	8	8.1	7.93	0.20	0.05
TSS (mg/L)	1	1.1	1.2	1.3	1.2	1.4	1.20	0.14	0.03
TDS (mg/L)	9720	9811	1020	14100	1570	1740	3235.44	3970.06	935.75
Salinity (‰)	20	19	21	26	25	26	12.81	7.60	1.79
Nitrate (mg/L)	12.7	13.2	14.51	9.16	9.21	10.15	8.07	4.09	0.96
Sulphate (mg/L)	210	241	285	540	554	625	137.48	215.04	50.69
Phosphate (mg/L)	6.1	6.5	7.8	3.3	4.1	4.85	3.61	4.02	0.95
Silicate (mg/L)	0.01	0.01	0.02	0.01	0.02	0.03	0.02	0.01	0.00
DO (mg/L)	4.4	4.2	4.2	5	4.8	4.6	4.58	1.75	0.41
BOD (mg/L)	0.5	0.7	0.9	1.5	1.2	0.9	1.36	0.99	0.23
COD (mg/L)	18	19	18	17	15	16	21.89	9.61	2.27
IRON (mg/L)	2.2	2.1	2.5	3.3	3.1	3.4	2.87	0.73	0.17
LEAD (mg/L)	0.03	0.03	0.03	0.02	0.02	0.03	0.010	0.013	0.003
Chlorophyll *a* (µg/L)	0.002	0.003	0.003	0.001	0.002	0.002	0.002	0.001	0.000

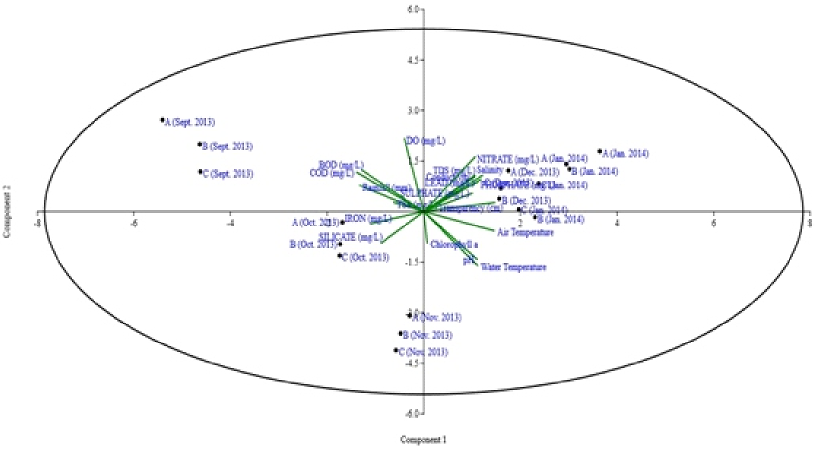

Figure 2: Principal Component Analysis of the physico-chemical parameters at Abule-Agege creek (A), Abule-Eledu creek (B) and Makoko creek (C). Rainfall, biochemical oxygen demand and silicate were the controlling factors in wet months whereas, in dry months salinity, transparency and phosphate were the controlling factors.

Table 2: Microalgae composition and diversity at the study sites (September, 2013 – February, 2014). A= Abule-Agege creek; B= Abule-Eledu creek; C= Makoko creek.

Taxa	Sept. 2013			Oct. 2013			Nov. 2013		
	A	B	C	A	B	C	A	B	C
Division: Bacillariophyta									
Class: Bacillariophyceae									
Aulacoseira granulata	15	10	20	25	15	15	10	5	15
Biddulphia laevis	2	1	5	-	-	-	-	-	-
Bacillaria paradoxa	-	-	-	-	-	-	-	-	-
Coscinodiscus centralis	20	15	25	5	-	10	15	20	25
Coscinodiscus lineatus	25	10	35	5	5	10	50	25	35
Chaetoceros dicipiens	15	5	10	5	-	2	-	-	-
Cyclotella meneghiniana	-	-	-	-	-	-	-	-	-
Pleurosigma angulatum	10	5	15	-	-	-	-	-	-
Gyrosigma balticum	15	10	15	2	1	1	-	-	-
Terpsinoe musica	10	5	5	-	-	-	-	-	-
Cocconeis pediculum	10	5	10	5	2	5	-	-	-
Cocconeis placentula	5	2	5	-	-	-	-	-	-
Melosira granulata	20	31	42	25	33	35	10	5	5
Melosira granulata var. angustissima	25	15	25	35	20	45	5	2	5
Nitzschia sigma	15	5	10	5	1	5	1	-	-
Nitzschia longissima	10	2	5	1	-	-	-	-	-
Skeletonema costatum	15	15	25	2	5	5	-	-	-
Surirella ovata	10	5	10	-	-	-	-	-	-
Synedra ulna	-	-	-	5	5	5	15	10	15
Synedra crystalline	-	-	-	1	1	1	5	5	5
Division: Cyanophyta									
Class: Cyanophyceae									
Microcystis sp	10	10	15	5	2	5	2	1	1
Oscillatoria limosa	55	15	25	25	10	10	-	-	-
Lyngbya martensiana	10	5	10	5	1	1	2	1	1
Division: Chlorophyta									
Gonatozygon sp	5	2	5	5	2	2	-	-	-
Merismopedia glauca	-	-	-	-	-	-	10	5	15
Total species diversity (S)	20	20	20	17	14	16	11	10	10
Total abundance (N)	302	173	317	161	103	157	125	79	122
Shannon-Wiener Index (H')	2.787	2.717	2.792	2.342	2.04	2.2	1.91	1.876	1.928
Margalef Index (d)	3.327	3.687	3.299	3.149	2.805	2.967	2.071	2.06	1.873
Equitability Index (j)	0.9302	0.9069	0.9321	0.8266	0.773	0.7935	0.7965	0.8147	0.8372

Taxa	**Dec. 2013**			**Jan. 2014**			**Feb. 2014**		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Division: Bacillariophyta Class: Bacillariophyceae									
Aulacoseira granulata	55	20	25	5	1	2	2	-	1
Biddulphia laevis	-	-	-	-	-	-	-	-	-
Bacillaria paradoxa	-	-	-	-	-	-	5	3	10
Coscinodiscus centralis	15	15	10	5	5	10	25	15	20
Coscinodiscus lineatus	25	5	10	35	15	20	50	25	25
Chaetoceros dicipiens	5	1	1	2	-	-	-	-	-
Cyclotella meneghiniana	-	-	-	-	-	-	5	2	5
Pleurosigma angulatum	-	-	-	-	-	-	5	-	5
Gyrosigma balticum	-	-	-	-	-	-	-	-	-
Terpsinoe musica	-	-	-	-	-	-	-	-	-
Cocconeis pediculum	-	-	-	-	-	-	-	-	-
Cocconeis placentula	-	-	-	-	-	-	-	-	-
Melosira granulata	2	5	-	-	-	-	-	-	-
Melosira granulata var. angustissima	2	1	1	-	-	-	-	-	-
Nitzschia sigma	-	-	-	-	-	-	2	1	5
Nitzschia longissima	-	-	-	-	-	-	1	-	1
Skeletonema costatum	-	-	-	-	-	-	50	25	45
Surirella ovata	-	-	-	-	-	-	-	-	5
Synedra ulna	20	10	15	-	-	-	-	-	-
Synedra crystalline	10	5	10	5	1	1	-	-	-
Division: Cyanophyta									
Class: Cyanophyceae									
Microcystis sp	-	-	-	-	-	-	5	2	5
Oscillatoria limosa	-	-	-	15	5	10	25	10	15
Lyngbya martensiana	-	-	-	-	-	-	1	2	1
Division: Chlorophyta									
Gonatozygon sp	-	-	-	-	-	-	10	5	10
Merismopedia glauca	5	2	5	-	-	-	-	-	-
Total species diversity (S)	9	9	8	6	5	5	13	10	14
Total abundance (N)	139	64	77	67	27	43	186	90	153
Shannon-Wiener Index (H')	1.745	1.829	1.77	1.36	1.195	1.265	1.945	1.832	2.164
Margalef Index (d)	1.621	1.924	1.611	1.189	1.214	1.063	2.296	2	2.584
Equitability Index (j)	0.7943	0.8326	0.851	0.7591	0.7427	0.7858	0.7585	0.7957	0.8199

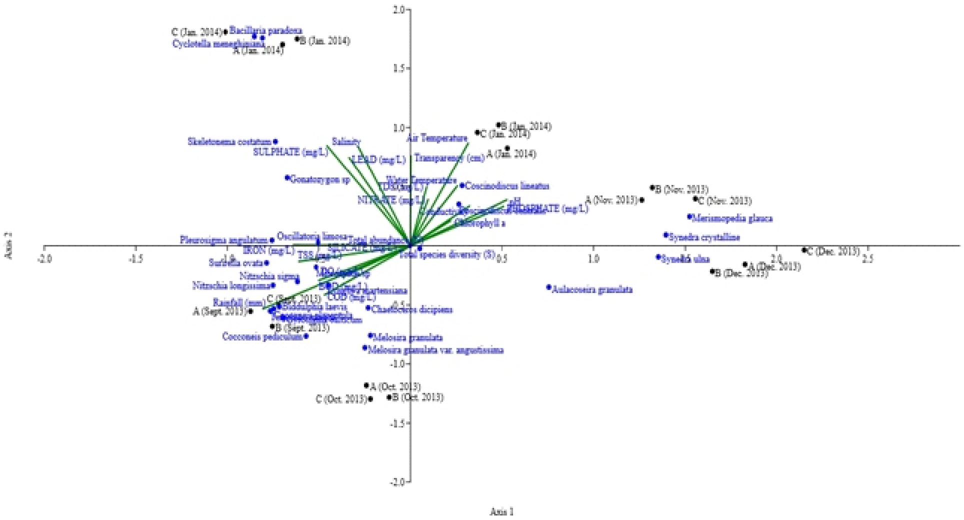

Figure 3: Canonical correspondence analysis of environmental variables and biota abundance at the study stations. A= Abule-Agege creek; B= Abule-Eledu creek; C= Makoko creek.

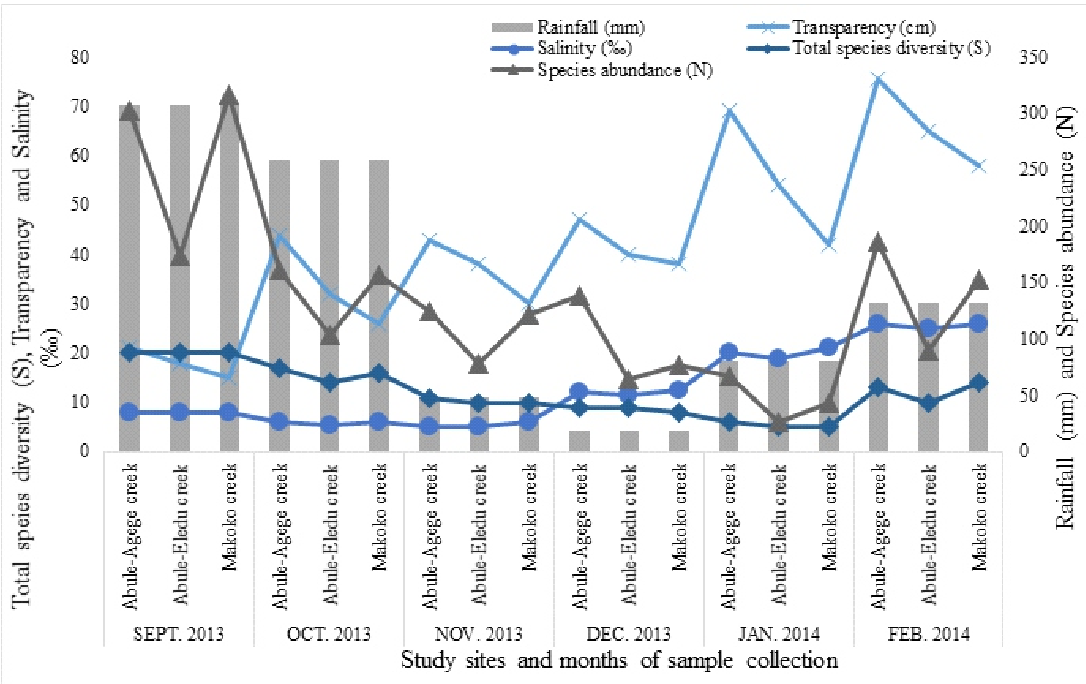

Figure 4: Relationship between rainfall pattern, transparency, salinity, total species diversity and species abundance at the study sites.

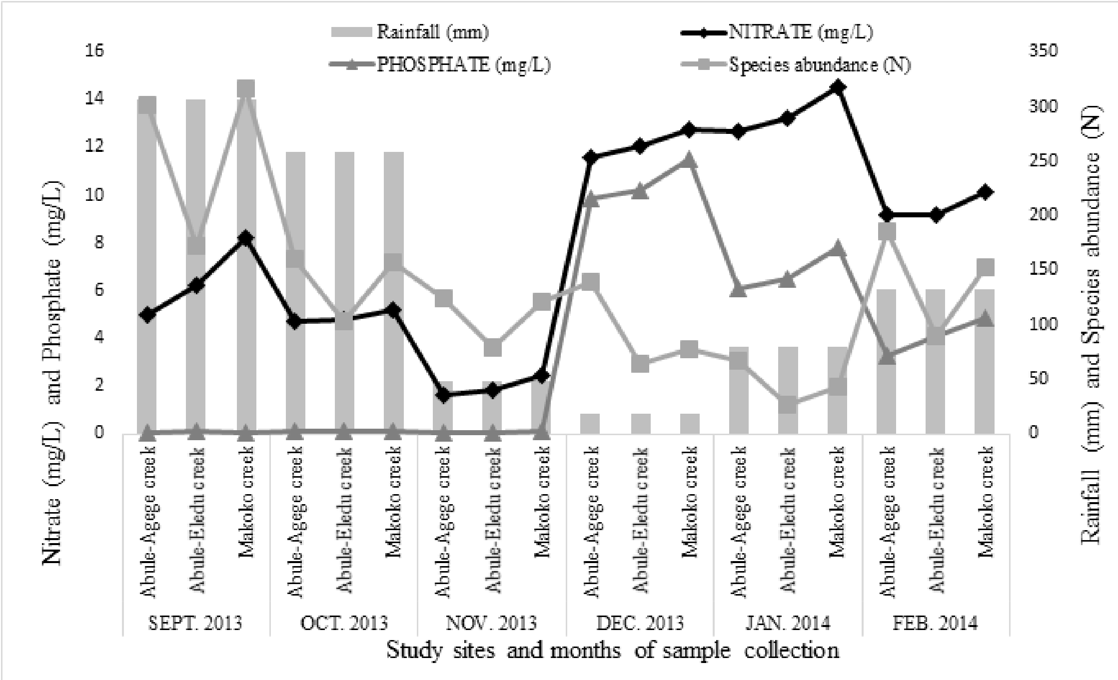

Figure 5: Relationship between rainfall patterns, Nitrate-nitrogen, Phosphate-phosphorous and species abundance at the study locations.

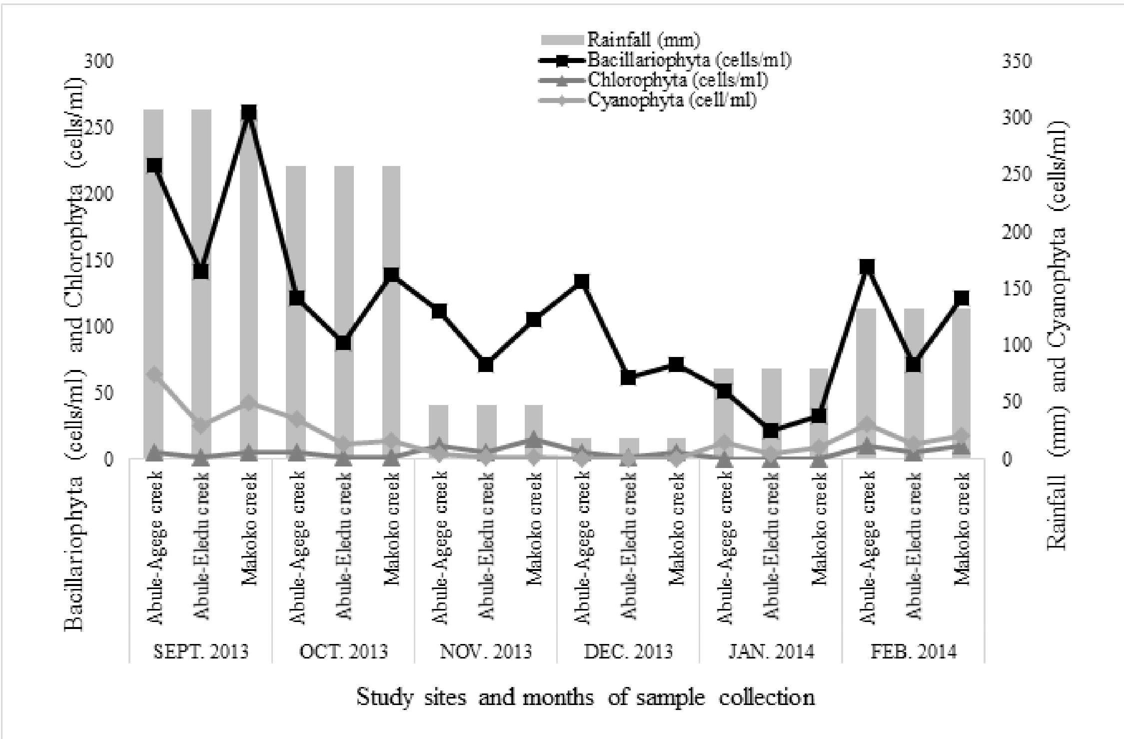

Figure 6: Relationship between rainfall pattern and the different microalgae group at the study sites.

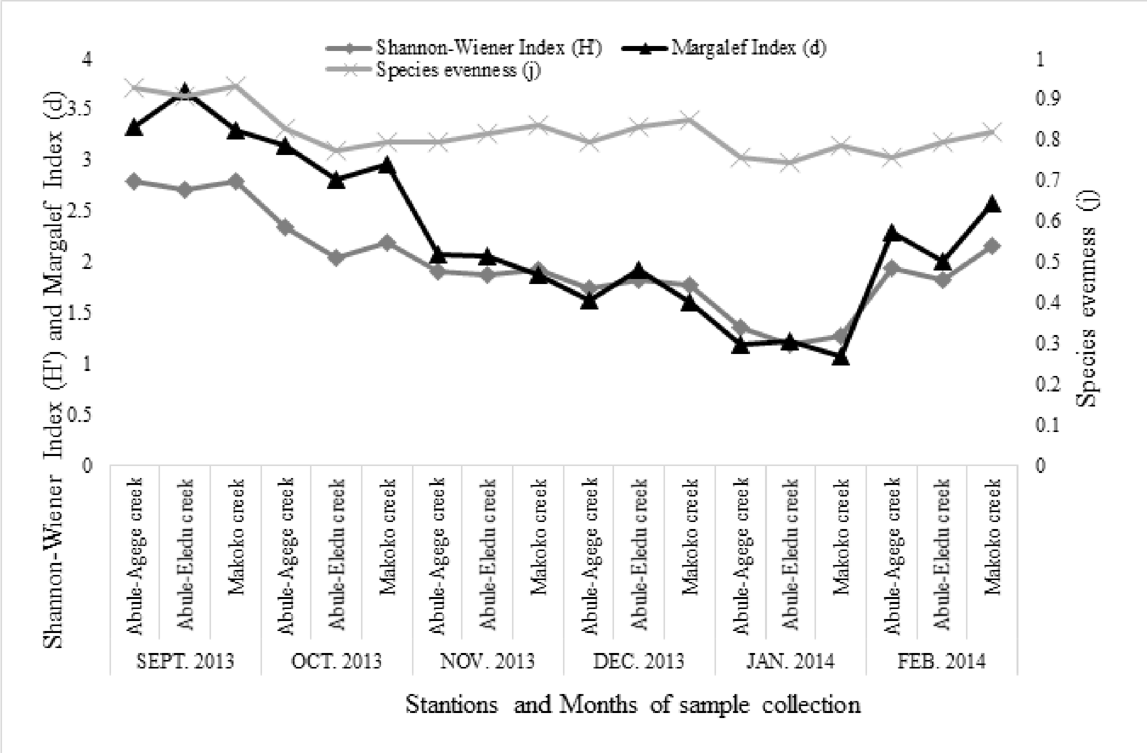

Figure 7: Comparison of community structure at the tidal creeks investigated.

DISCUSSION

Environmental characteristics recorded in this study showed monthly variation in all the parameters investigated. The fluctuation in water quality conditions could be attributed to flood water inflow and sea water intrusion from the Lagos Lagoon. Two major factors rainfall and salinity determine the hydro-climatic conditions and the biotal spectrum in the study sites (Figures 2 and 6). According to Webb (1960) rainfall distribution pattern in the tropics is more important than temperature in determining the environments. Rainfall influence floods which usually results to increase in suspended and dissolved solids, reduce salinity via dilution effects and cessation of stratification. Flooding also impacts the environment by influencing changes in water volume and nutrients dilution. The observed temperature regime in this study is in consonant with the reports of Alabaster and Lloyd (1980) which stated that temperature of natural inland waters in the tropics usually ranged from 25- 35 °C. Lower temperature values recorded in the wet months is in agreement with Nwankwo (1984) for Lagos lagoon and Adesalu and Nwankwo (2008) for Abule Eledu creek.

Dissolved oxygen values in the creeks ranged between (1.4 – 8 mg/L) at Abule-Agege creek, (1.2 – 6 mg/L) at Abule-Eledu creek and (1.1 – 5.8 mg/L) at Makoko creek. The Dissolved oxygen values have direct relationship with biochemical oxygen demand and chemical oxygen demand, similar trend was reported in Ito-Iwolo creek by Adesalu *et al.* (2017). The pH values recorded were slightly alkaline (⩾ 7.4) all through the sampling months probably due to the buffering effects of tidal sea water, related observation was made by Nwankwo (1991) in Lagos lagoon and Nwankwo *et al.* (2012) in five cowrie and light house creeks. Phosphate- phosphorus, Nitrate- nitrogen and sulphate values were high in dry months in the three creeks investigated (Figure 5), this observation is supported by earlier report by Adesalu and Kunrunmi (2016) who investigated Majidun creek and associated the decrease in nutrients to high rainfall in wet season and the increase in nutrients in the dry months were linked to difference in rate of evaporation and precipitation.

Conductivity values recorded in this study increases with increase in salinity, this observation have been reported by some workers (Ogbeibu and Egborge, 1995; Adesalu *et al*., 2010; Adesalu and Kunrunmi, 2012). Transparency values were lower in the wet season and higher in the dry season. A similar trend in values was documented by Onyema (2013) where the reduction in transparency values in the wet months were attributed to increase in total suspended solids (TSS) and total dissolved solids (TDS). This result also confirms earlier report by Nwankwo (1998) that seasonal variation in transparency of coastal waters of South-western Nigeria is linked to rainfall pattern and associated floods. In addition, the transparency values confirm the supposition that transparency and rainfall are inversely related in the region.

The abundance and diversity of microalgal species varied with rainfall pattern and the most abundant species were diatoms (Bacillariophyta). Similar dominance of diatoms among microalgal assemblages have also been reported by other ecologists in the region (Emmanuel and Onyema, 2007; Adesalu *et al*., 2017; Adejumobi *et al*., 2019). In this study, microalgal biomass in terms of numbers was relatively higher in the wet months than in the dry months (Table 2 and Figure 4). This agreed with the reports of Ezra and Nwankwo (2001) and Onyema (2007) where higher microalgal cell densities were recorded in wet season. Biological indices values were also generally higher in the wet months than dry months (Figure 7). Microalgae species reported in this study with noteworthy record as bioindicators include: *Pleurosigma angulatum*, *Synedra ulna, Microcystis* sp.*, Cocconeis pediculum, Melosira granulate, Nitzschia* sp. and *Cyclotella menighiniana.* The Occurrence of Pleurosigma species are biological indications of marine waterbody, alkaline pH, high cation and nutrient level (Onyema, 2013). The presence of *Synedra ulna* and *Microcystis* sp. indicate organic pollution or eutrophication (Ahmad 1996). *Cocconeis* sp. are mainly benthic marine phytoplankton species, their presence usually indicates eutrophication or near shore waterbody (Newton and Horner, 2003). *Melosira granulate* usually indicate mid to high salinity water situation, Alkaline pH, high cation and nutrient levels (Onyema, 2013). The presence of *Nitzschia* sp. and *Synedra* sp. is an indication of a polysaprobic waterbody while occurrence of *Cyclotella menighiniana* is a strong indication of high nutrient level (Jindal and Sharma, 2011).

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