

Successional pattern of phytoplankton (>55 μ m) in Lekki lagoon, Nigeria

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Abstract: Lagoons are dominant features along large stretches of the West Africa coast. These freshwater environments are very valuable areas where phytoplankton constitute the basis of aquatic food webs. In order to know the effects of environmental variables on phytoplankton, a study of the successional pattern of phytoplankton in Lekki lagoon was carried out monthly for two years (June 2003-May 2005). Phytoplankton samples were collected from 12 stations using a plankton net of 55 μ m mesh, and samples preserved in 4% unbuffered formalin. Besides, surface water samples were taken for physico-chemical analysis. For each year, the seasonal distribution and succession of dominant phytoplankton followed different patterns. Phytoplankton abundance was higher during the dry season (November-April) for the two annual cycles. The diatoms (*Aulacoseira granulata* and *A. granulata* var *angustissima*) and blue green algae, *Microcystis aeruginosa*, *Merismopedia tenuissima* and *Trichodesmium lacustre* showed this trend by being the abundant species in some of these months. For the rainy season, the green alga *Mougeotia* sp. dominated. The replacement of one form by another throughout seasonal cycles was probably controlled by the changes in environmental variables such as rainfall, nitrate-nitrogen and phosphate-phosphorus. Rev. Biol. Trop. 60 (1): 143-155. Epub 2012 March 01.

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According to Solarin (1998), Lagoons represent 15% of the world coastal zone and their productivity results from the interaction between oceanic and continental inputs, which enable them to play a considerable biological and economical role, far beyond their seemingly limited geographical extent. Lagoons are dominant features along large stretches of the West Africa coast. They are of utmost importance as natural harbours, nursery grounds for marine fishes and shrimps and often sustain significant fisheries.

Early studies on freshwater phytoplankton in Nigeria included those of Holden & Green (1960), Eaton (1966) investigated the plankton of parts of River Niger, while Imevbore (1967, 1968) studied plankton of Eleiyele reservoir, Ibadan. Imevbore *et al.* (1969) investigated plankton of Ikogosi warm spring; and Egborge

(1973, 1974, 1979) described the phytoplankton of Osun river and subsequently its seasonal variation. Additionally, Dahlin *et al.* (1985) investigated the composition of the phytoplankton and zooplankton communities in the Niger Delta area, Kadiri (1999) on phytoplankton of some coastal waters in Nigeria, while Powell & Chindah (1986) reported variations in phytoplankton communities and densities along the Bonny/New Calabar estuary. Adeniji (1971) made preliminary investigations into the composition and seasonal variation of phytoplankton in Kainji lake Nigeria. On the South Western coast of Nigeria, algological data on the lagoons are limited to the 9 lagoons (Yewa, Badagry, Ologe, Kuramo, Iyagbe, Lagos, Epe, Lekki and Mahin). Out of these lagoons only Lagos has been subjected to extensive investigations (Hill & Webb 1958, Webb & Hill

1958, Nwankwo 1984, 1993, 1996, 2000). Some published works on Lekki lagoon include Kusemiju (1973, 1976) who studied catfishes of the Lekki lagoon with particular reference to distribution, reproduction and growth of catfish *Chrysichthys walkeri* (Gunther). Marc *et al.* (2006) studied species assemblage succession in the shallow tropical lake Guiers, Senegal. Hence this paper aims on the study of the successional pattern of phytoplankton of Lekki for environmental biological monitoring.

MATERIALS AND METHODS

Study area: Lekki lagoon, a large expanse of shallow freshwater, is located in Lagos and Ogun States of Nigeria, where the alternation of the dry and wet seasons are phenomenal (Adesalu & Nwankwo 2009). It covers an area of nearly 247km². A greater part of the lagoon is shallow (<3.0m), while some areas are up to 6.0m deep (Adesalu 2007). It lies between 06°25'-06°35' N and 004°00'-004°13' E. Two peaks of rainfall are associated with the Lekki lagoon, a major peak in July and a lesser peak in September. There are two peaks of sunshine hours which approximately correspond to the equinoxes. The environment is characterized by fringing macrophyte vegetations which are dominated by mangrove and freshwater types. The mangrove species are dominated by few genera: *Rhizophora racemosa* (Red mangrove), *Avicennia nitida* (White mangrove), *Acrosticum aureum*, *Paspalum orbiculare* and *Dryopteris*. The riparian vegetation is also dominated by *Cocos nucifera* and *Terminalia cattapa* trees. A number of floating macrophytes find their way through the numerous adjoining rivers, creeks and creeklets into this lagoon. Notably important is *Eichhornia crassipes* Solm (Mart.) that may disturb navigation by impeding traffic and fishing within the lagoon. Other observed macrophytes were *Pistia stratiotes*, *Lemna pausicaudata* and *Vosia cuspidata*. Associated with these plants are periphytic organisms such as algae and mollusks. The mainstay of human communities that live around this environment is artisanal fishing.

Collection of samples: A motorized boat and Global Positioning System (GPS) were used during the 24 months sampling period (June 2003-May 2005). Phytoplankton samples were collected monthly from 12 stations (Adesalu & Nwankwo 2009) chosen to reflect distance and confluence of rivers and creeks into the lagoon. All samples were taken using a standard plankton net of 55µm mesh size towed steadily for ten minutes at low speed, and samples preserved in 4% unbuffered formalin. For physico-chemical analysis, surface water samples were stored in 1L properly labeled plastic containers with screw caps and transported to the laboratory in ice-chests. In the laboratory, all water samples were stored in refrigerator (4°C) for further analysis within 24h. All samples were collected during daylight hours to minimize variations due to diurnal migration (Bainbridge 1972).

Physical and chemical analysis of water samples: The methods described by America Public Health Association (APHA 1998) were used for physical and chemical analysis. Air and surface water temperature were measured *in situ* with a simple mercury thermometer. The transparency was measured using a 20cm diameter Secchi disc. The depth was measured with a calibrated pole and the water pH determined using a Phillips pH meter (Model PW950). The chemical factors determined include salinity, conductivity, dissolved oxygen (DO) and biological oxygen demand (BOD₅). Salinity was determined using the Silver Nitrate Chromate titration method as described by Barnes (1980), while Dissolved oxygen content was determined using a Griffin oxygen meter. Biological Oxygen Demand was done after the dissolved oxygen had been measured using the standard method of biochemical consumption of oxygen in five days at 20°C, while conductivity was determined using the HANNA instrument (H18733) and values recorded as mS/cm at 25°C. Chemical oxygen demand and Chloride ion were determined using titrimetric and titration methods, respectively. Oil and grease values were

determined using Soxhlet extraction method (APHA 1998). Copper and Iron analysis were done by Atomic absorption spectrophotometer (APHA 1998). The Federal Meteorological Department, Oshodi, Lagos kindly provided rainfall and sunshine hours data for the investigation period.

Nutrient determination: For nitrate determination the colorimetric method was applied (APHA 1998). Phosphate-phosphorus was determined by the ascorbic acid method, and the values obtained were recorded in milligrams per liter (mg/L).

Phytoplankton studies: Dilution factor was used for quantitative analysis of biological samples. From a known volume, a 0.1mL aliquot of the sample was placed in a Palmer-Maloney counting chamber using Eppendorf pipette and enumerated using Olympus BX51 photomicroscope. A total of 30 fields were observed for each sample throughout the analysis. In this study, the filamentous blue green were counted using 10µm of filament length, that represented one unit (unicells), and solitary cells were tallied as separate individuals. Since many algae are colonial and consist of a few to many cells, all colonial forms were counted by the individual cell that comprised that colony, except for *Microcystis* sp. in which the method used for filamentous algae was applied. For further analysis, one unit was equated as one cell. Calculations for individual and total numbers of organisms per millimeter were made using the following formula:

$$\text{Cells/mL in sample} = \frac{n(V/v)(\text{Dilution factor})}{V}$$

Calculation of number of cells per mL:

Where,

n=cells counted

V=original sample volume

v=volume counted, which is given by the following calculation (Number of fields x volume of fields)

Volume of fields=One Palmer cell count field=00008954

Number of fields=30

(Number of fields x volume of fields)=(30 x 0.0008954)=0.0026862

Since specific identification of most species of diatoms could not be determined using high dry objective, samples were acid cleaned using concentrated Nitric acid (HNO₃). Taxonomic keys employed in the identification included Hustedt (1930, 1937, 1942 and 1971), Patrick & Reimer (1966, 1975), Prescott (1961, 1973 and 1982), Komarek & Fott (1983), Round (1981), John & Robert (2003), Krammer & Lange-Bertalot (1986, 1988, 1991a, 1991b, 2000), Komarek & Anagnostids (1998, 2005) and Wolowski & Hindak (2005).

Community structure: To obtain the estimate of species diversity, three community structure indices were used. The species richness given by the equation (Margalef 1970):

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

Shannon-Wiener diversity index using the following equation (Shannon & Wiener 1973):

$$H^1 = -\sum_{i=1}^s p_i \log_2 p_i$$

Species equitability with the following equation (Pielou 1975):

$$J = H^1 / \ln S$$

Correlation coefficient values (r): The coefficient of correlation values for the relationship between some physico-chemical parameters and different classes of phytoplankton in the study site were calculated using

$$r = \frac{\sum XY - (\sum X)(\sum Y)/N}{\sqrt{(\sum X^2 - (\sum X)^2/N)(\sum Y^2 - (\sum Y)^2/N)}}$$

Where r=coefficient of correlation
 X and Y=variables under consideration
 N=Total number of individuals

Multidimensional Scaling (MDS): Multidimensional scaling (MDS) is specifically designed to graphically represent relationships between objects in multidimensional space. Analysis of similarities (ANOSIM) using Bray-Curtis dissimilarities was applied. The following equation was used:

$$R = \frac{(-r_B) - (-r_W)}{n(n-1)/4}$$

Principal Component Analysis (PCA): Principal Component Analysis (PCA) objects

were plotted in multidimensional space with the distance between objects representing the biological dissimilarities. All multivariate plots were obtained using the PRIMER 5 computer program of Clarke & Gorley (2001).

RESULTS

Physico-chemical parameters: The mean physico-chemical characteristics of Lekki lagoon water is shown in Table 1. Mean surface water temperature values ranged between 30.23°C and 30.73°C with the highest value recorded at station B. The surface water is essentially neutral as pH mean values ranged between 7.38-7.46 throughout the sampling period. Surface water salinity values were low throughout the study period (≤ 0.55 mg/L) while phosphate-phosphorus content (mg/L)

TABLE 1
 Mean physico-chemical values for Lekki lagoon (concentrations in mg/L)

STATIONS	A	B	C	D	E	F	G	H	I	J	K	L
Surface Water temperature (°C)	30.54	30.73	30.55	30.61	30.40	30.31	30.35	30.23	30.38	30.63	30.70	30.55
Air temperature (°C)	29.68	29.60	29.60	29.71	29.51	29.44	29.55	29.08	29.29	28.90	29.27	29.21
Transparency (cm)	5.74	7.38	11.33	9.25	11.67	10.29	11.08	10.42	14.42	7.30	10.04	12.33
Total suspended solids	9.07	8.56	9.16	8.45	9.28	9.78	11.76	12.71	8.39	11.50	8.87	8.87
pH	7.42	7.43	7.41	7.43	7.44	7.46	7.44	7.46	7.44	7.42	7.37	7.38
Salinity (‰)	0.47	0.47	0.45	0.45	0.40	0.55	0.47	0.44	0.45	0.44	0.50	0.47
Phosphate-phosphorus	2.53	2.70	2.42	2.50	2.56	2.61	2.47	2.49	2.96	2.53	2.54	2.44
Nitrate-nitrogen	2.73	2.93	3.42	2.98	2.54	3.85	3.44	3.25	2.75	3.31	2.70	3.97
Chloride	9.23	9.67	9.59	10.00	9.88	9.52	9.40	9.17	9.31	9.31	9.54	9.99
Conductivity (mS/cm)	0.56	0.52	0.56	0.47	0.47	0.48	0.49	0.52	0.46	0.53	0.62	0.56
Dissolved Oxygen (%)	4.15	3.46	4.21	4.10	4.16	4.25	4.25	4.19	4.17	4.16	4.18	4.17
Biological Oxygen demand	0.23	0.22	0.26	0.23	0.22	0.25	0.29	0.30	0.31	0.28	0.26	0.24
Chemical oxygen demand	0.36	0.30	0.26	0.25	0.24	0.29	0.34	0.32	0.30	0.31	0.31	0.25
Oil and grease	0.03	0.02	0.02	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Turbidity (FTU)	8.59	9.25	10.00	7.46	9.57	8.87	8.37	7.99	8.42	10.29	9.15	8.69
Total dissolved solids	9.48	10.29	10.65	8.51	11.29	11.50	9.87	9.95	10.31	10.58	10.81	10.29
Sulphate	0.03	0.02	0.03	0.04	0.03	0.03	0.02	0.02	0.05	0.04	0.06	0.03
Calcium	10.46	11.11	11.92	12.07	11.57	10.71	11.04	10.96	10.70	10.21	11.40	11.52
Fe	0.30	0.23	0.24	0.26	0.22	0.25	0.21	0.23	0.25	0.28	0.30	0.55
Pb	0.01	0.08	0.25	0.08	0.08	0.01	0.02	0.01	0.00	0.00	0.04	0.02
Hg	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
Cu	0.05	0.02	0.02	0.02	0.03	0.06	0.01	0.01	0.01	0.00	0.02	0.04
Ni	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zn	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01

recorded mean values ranged from 2.44 to 2.96 in stations L and H respectively. High nitrate-nitrogen content (3.97mg/L) was recorded at station L while the low value (2.73mg/L) was recorded in station A. Chloride ion values recorded throughout the study period was generally low with the mean highest value (10.00mg/L) recorded at Station D, and mean values for conductivity in the various stations ranged from 0.46 to 0.62mS/cm.

In general, higher dissolve oxygen content with mean value (4.25mg/L) was recorded at station F. The Biological oxygen demand value ranged from 0.22-0.31mg/L while chemical oxygen demand values ranged from 0.40-0.36mg/L for all the stations. Oil and grease values were generally low; it ranged from 0.001 to 0.090mg/L throughout the sampling period.

Community structure: Throughout the sampling period, higher species richness (d) value (5.12) was recorded in March 2004 during the first annual cycle while the lowest value (0.18) was recorded in August 2004 of the second annual cycle. Shannon-Weiner (H^1) index was generally low throughout the sampling period. The highest diversity ($H=4.05$) and lowest ($H=0.04$) values were recorded in August and October 2003 respectively throughout the 12 stations (Table 2). The H^1 during the wet season apparently was related to the introduction of numerous benthic forms in the phytoplankton. Highest (0.92) and lowest (0.01) equitability values were recorded during the wet season (August and October 2003) at stations I. Station L recorded highest (0.92) equitability value as station L. The Shannon-Weiner information value (H^1) and species richness (d) followed almost same pattern with lowest value for species richness (2.09) corresponded with lowest value (2.52) for Shannon-Weiner index (Fig. 1).

Seasonal succession: The seasonal succession of phytoplankton which followed different pattern as shown in Table 3. The phytoplankton abundance was higher during the dry season (November-April) for the two annual cycles.

TABLE 2
Comparison of diversity indices at different studied stations of Lekki lagoon (June 2003-May 2005)

Stations	Margalef species richness(d) $d = \frac{S-1}{\log e N}$																							
	Jun. 03	Jul. 03	Aug. 03	Sep. 03	Oct. 03	Nov. 03	Dec. 03	Jan. 04	Feb. 04	Mar. 04	Apr. 04	May. 04	Jun. 04	Jul. 04	Aug. 04	Sep. 04	Oct. 04	Nov. 04	Dec. 04	Jan. 05	Feb. 05	Mar. 05	Apr. 05	May. 05
A	2.45	1.37	0.92	2.24	1.28	1.24	0.37	0.61	0.62	0.87	0.81	0.88	0.78	1.10	2.13	0.79	0.95	0.52	1.13	0.57	0.61	1.46	1.32	1.49
B	4.09	0.81	0.89	1.07	3.11	1.20	0.59	1.23	1.60	0.78	1.88	1.88	1.31	1.56	1.36	0.58	3.07	3.00	0.62	1.49	2.04	0.66	0.76	2.26
C	1.01	1.07	0.76	0.91	0.52	1.76	0.88	0.73	1.19	1.21	2.13	2.57	1.15	0.49	1.83	1.65	0.65	2.89	2.56	1.50	1.95	1.02	0.64	2.92
D	0.98	1.32	1.69	1.71	1.03	0.67	0.68	1.14	2.01	2.54	3.17	1.56	0.28	2.16	0.34	1.26	1.47	1.27	2.58	1.04	2.66	1.46	2.41	4.10
E	1.40	0.52	0.51	1.14	1.52	0.89	1.98	0.96	2.61	1.13	1.09	3.15	1.43	0.89	0.57	1.05	2.75	0.79	1.60	2.65	1.76	2.30	1.96	4.06
F	1.75	1.57	0.75	1.29	3.14	1.12	1.28	1.43	2.23	1.97	3.27	2.42	1.15	2.71	1.06	2.80	1.84	0.89	1.50	2.06	3.14	2.96	2.23	2.50
G	0.77	1.73	0.80	1.41	1.00	3.13	0.60	1.05	1.47	5.12	3.59	1.43	1.62	1.33	0.68	1.55	2.62	1.51	1.58	0.85	0.80	0.64	0.87	1.81
H	4.40	1.50	0.60	1.73	0.70	0.83	1.85	1.35	0.84	0.96	2.68	0.60	0.40	1.06	2.24	0.71	1.90	3.01	0.57	1.21	1.86	1.02	0.82	1.63
I	1.70	1.08	0.24	1.62	1.21	0.80	0.55	0.73	1.56	1.74	1.44	2.09	1.98	0.52	0.97	1.16	0.60	1.65	0.57	0.63	1.04	1.13	1.53	1.73
J	1.20	0.70	0.60	0.45	1.55	0.96	0.81	3.41	1.39	1.09	1.27	1.40	1.13	0.83	0.89	0.73	1.83	0.95	0.58	2.13	0.62	1.13	1.89	1.83

TABLE 2 (Continued)
Comparison of diversity indices at different studied stations of Lekki lagoon (June 2003–May 2005)

Stations	Jun. 03	Jul. 03	Aug. 03	Sep. 03	Oct. 03	Nov. 03	Dec. 03	Jan. 04	Feb. 04	Mar. 04	Apr. 04	May. 04	Jun. 04	July. 04	Aug. 04	Sep. 04	Oct. 04	Nov. 04	Dec. 04	Jan. 05	Feb. 05	Mar. 05	Apr. 05	May. 05
K	2.63	0.49	0.39	0.88	0.59	0.78	0.49	1.02	0.71	1.58	1.26	1.43	2.12	0.27	0.18	0.87	0.86	0.25	1.96	0.77	0.52	1.31	0.78	2.20
L	1.39	1.05	1.19	1.36	0.58	1.40	0.70	0.66	1.60	0.93	1.70	1.26	2.14	1.09	0.38	0.83	0.30	0.90	1.78	0.92	0.72	2.92	1.23	1.53
Shannon-Weaver $H^1 = -\sum_{i=1}^I pi \log_2 pi$																								
A	2.67	2.06	1.54	2.78	1.93	1.87	1.02	1.32	1.10	1.51	1.53	1.61	1.94	2.18	2.25	1.79	1.00	1.48	1.61	0.90	0.79	1.35	1.33	1.90
B	3.09	1.88	4.05	1.71	2.99	1.78	1.45	1.55	1.55	1.30	1.93	1.59	2.14	1.84	1.70	1.06	2.71	2.04	1.18	1.64	1.99	1.30	1.19	2.75
C	1.11	1.38	1.68	1.76	1.42	2.44	2.04	1.39	1.43	1.65	1.93	2.86	0.16	1.36	2.00	1.83	1.76	1.97	2.00	2.11	1.82	1.18	1.21	2.99
D	1.94	1.85	1.65	2.69	2.11	1.89	1.92	1.59	1.60	1.58	2.12	1.95	1.23	2.10	0.88	1.65	2.38	1.91	2.45	1.54	2.02	1.55	1.57	3.04
E	0.80	1.63	1.53	2.33	2.39	1.84	2.75	1.94	1.82	2.39	1.34	2.71	1.12	1.89	1.42	2.01	2.82	1.62	2.41	2.80	2.42	1.54	2.05	3.33
F	1.80	2.39	1.96	2.36	2.87	2.21	2.17	1.57	1.83	2.09	1.83	2.94	2.01	2.81	2.05	2.97	2.29	1.73	2.56	2.31	2.32	2.57	2.19	2.74
G	1.71	2.57	1.92	2.09	1.28	2.78	1.56	1.30	1.59	2.89	2.54	2.43	2.30	1.90	1.99	2.43	2.72	2.23	2.24	1.78	1.59	1.38	1.50	2.63
H	3.62	2.47	1.24	2.56	1.80	1.75	2.66	2.18	1.31	2.01	2.65	1.70	1.32	2.10	2.38	1.56	1.43	2.98	1.19	1.21	1.66	1.32	1.81	2.37
I	2.34	2.34	1.01	2.52	0.04	1.93	1.85	1.23	1.57	1.70	2.08	2.51	2.01	1.40	0.88	2.21	1.74	2.25	1.37	1.28	1.76	1.31	1.97	1.77
J	1.71	1.30	1.51	0.82	1.36	1.89	1.24	2.21	1.11	1.38	1.25	2.17	1.92	1.67	1.48	1.74	2.37	1.05	1.27	2.69	1.66	1.44	1.44	2.29
K	2.10	0.90	1.15	2.14	1.82	1.59	1.12	1.43	1.34	2.56	2.46	1.84	2.37	0.54	0.94	1.83	2.02	0.95	2.70	1.99	1.68	1.51	1.27	2.56
L	0.58	1.92	2.36	2.17	1.27	1.97	1.41	1.33	1.47	1.30	2.43	1.59	2.29	1.64	0.54	1.31	0.24	1.56	2.15	1.96	1.30	2.69	1.36	2.30
Species Evenness (J) $J = H^1 / \ln S$																								
A	0.78	0.80	0.67	0.87	0.70	0.66	0.63	0.55	0.48	0.63	0.58	0.67	0.88	0.83	0.70	0.78	0.39	0.76	0.61	0.41	0.34	0.41	0.46	0.65
B	0.74	0.78	1.76	0.67	0.81	0.63	0.74	0.50	0.46	0.54	0.56	0.49	0.74	0.61	0.61	0.54	0.73	0.54	0.51	0.54	0.60	0.52	0.54	0.83
C	0.43	0.54	0.73	0.73	0.62	0.80	0.89	0.58	0.46	0.61	0.54	0.78	0.06	0.76	0.62	0.61	0.84	0.51	0.57	0.73	0.51	0.45	0.51	0.83
D	0.78	0.65	0.52	0.87	0.82	0.86	0.83	0.53	0.44	0.41	0.55	0.65	0.77	0.64	0.55	0.57	0.84	0.66	0.68	0.52	0.56	0.52	0.43	0.76
E	0.25	0.84	0.85	0.91	0.83	0.74	0.87	0.78	0.48	0.86	0.47	0.74	0.77	0.82	0.73	0.78	0.78	0.70	0.77	0.79	0.72	0.41	0.59	0.85
F	0.55	0.80	0.89	0.85	0.78	0.84	0.78	0.48	0.49	0.63	0.46	0.84	0.72	0.79	0.82	0.82	0.71	0.72	0.84	0.70	0.59	0.71	0.60	0.81
G	0.74	0.87	0.87	0.74	0.50	0.76	0.80	0.46	0.48	0.65	0.65	0.84	0.77	0.67	0.83	0.83	0.78	0.74	0.75	0.74	0.69	0.57	0.57	0.85
H	0.87	0.89	0.57	0.85	0.87	0.66	0.87	0.77	0.47	0.74	0.76	0.87	0.74	0.85	0.72	0.75	0.44	0.82	0.57	0.43	0.48	0.47	0.75	0.79
I	0.76	0.91	0.92	0.85	0.01	0.84	0.95	0.46	0.46	0.53	0.71	0.76	0.60	0.78	0.33	0.86	0.89	0.71	0.59	0.58	0.63	0.44	0.63	0.57
J	0.60	0.59	0.73	0.46	0.46	0.76	0.47	0.57	0.37	0.49	0.41	0.75	0.73	0.72	0.58	0.79	0.77	0.40	0.55	0.82	0.76	0.47	0.43	0.71
K	0.56	0.46	0.72	0.86	0.88	0.69	0.51	0.52	0.51	0.81	0.81	0.61	0.72	0.39	0.85	0.72	0.81	0.69	0.87	0.83	0.73	0.48	0.47	0.78
L	0.19	0.77	0.92	0.77	0.61	0.68	0.55	0.52	0.44	0.46	0.77	0.55	0.72	0.62	0.34	0.51	0.15	0.63	0.67	0.79	0.49	0.73	0.43	0.80

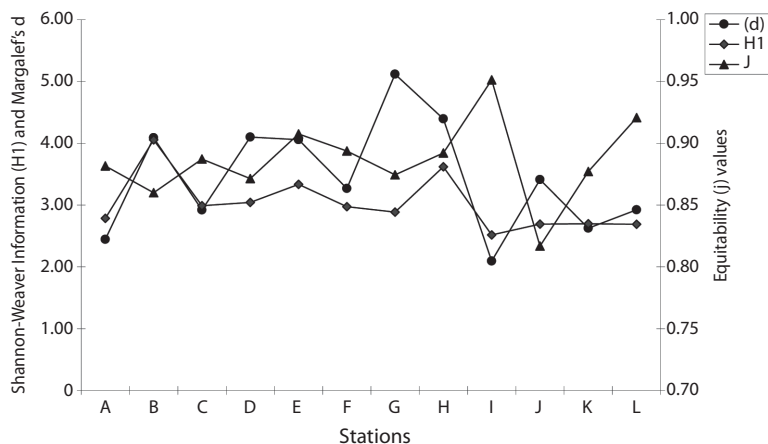


Fig. 1. Relationships between Margalef's d value, Equitability (j) and Shannon-Weiner Information (H^1).

TABLE 3
Successional pattern of phytoplankton abundance (cells/mL) of Lekki Lagoon (Average of the totality of the stations)

Months	Dominant Species	Associated Species
June 2003	<i>Mougeotia</i> sp. 1 (4927)*	<i>Chroococcus turgidus</i> (161), <i>Tetraspora gelatinosa</i> (134), <i>Microcystis aeruginosa</i> (101).
July 2003	<i>Mougeotia</i> sp. 1 (1440)*	<i>A. granulata</i> (610), <i>Oscillatoria germinata</i> (595), <i>A. islandica</i> (431).
August 2003	<i>Aulacoseira granulata</i> (3439)*	<i>A. islandica</i> (206), <i>A. granulata</i> var <i>angustissima</i> (150), <i>A. granulata</i> var <i>angustissima</i> f. <i>spiralis</i> (446).
September 2003	<i>Microcystis aeruginosa</i> (2234)*	<i>A. granulata</i> var <i>angustissima</i> (350), <i>A. granulata</i> (335), <i>Microcystis flos-aquae</i> (246).
October 2003	<i>A. granulata</i> (9703)*	<i>A. islandica</i> (8452), <i>A. granulata</i> var <i>angustissima</i> (7350), <i>A. granulata</i> var <i>angustissima</i> f. <i>spiralis</i> (1084).
November 2003	<i>A. granulata</i> (2297)*	<i>A. granulata</i> var <i>angustissima</i> (1154), <i>A. islandica</i> (1431), <i>Lyngbya hypolimnetica</i> (323).
December 2003	** <i>Cyanosarcina huebeliorum</i> (1072)*	<i>A. granulata</i> (9576), <i>A. granulata</i> var <i>angustissima</i> (5042), <i>A. islandica</i> (4880).
January 2004	<i>Microcystis aeruginosa</i> (3469)*	<i>A. granulata</i> (2687), <i>A. islandica</i> (2346), <i>A. granulata</i> var <i>angustissima</i> (2305).
February 2004	<i>A. granulata</i> (4304)*	<i>A. granulata</i> var <i>angustissima</i> (3218), <i>A. islandica</i> (3046), <i>A. granulata</i> var <i>angustissima</i> f. <i>spiralis</i> (1067).
March 2004	<i>A. granulata</i> var <i>angustissima</i> (1490)*	<i>A. granulata</i> (1450), <i>A. islandica</i> (1417), <i>A. granulata</i> var <i>angustissima</i> f. <i>curvata</i> (917).
April 2004	<i>A. granulata</i> (5488) *	<i>A. islandica</i> (3307), <i>A. granulata</i> var. <i>angustissima</i> f. <i>spiralis</i> (2860), <i>A. granulata</i> var. <i>angus</i> (2598).

TABLE 3 (Continued)
Successional pattern of phytoplankton abundance (cells/mL) of Lekki Lagoon (Average of the totality of the stations)

Months	Dominant Species	Associated Species
May 2004	<i>Mougeotia</i> sp.11 (3942)*	<i>A. granulata</i> (3320), <i>A. granulata</i> var. <i>angustissima</i> (3320), <i>Mougeotia</i> sp. I (2829).
June 2004	<i>A. granulata</i> (1109)*	<i>A. granulata</i> var. <i>angustissima</i> (687), <i>A. islandica</i> (453), <i>M. flos-aquae</i> (347).
July 2004	<i>A. granulata</i> (8413)*	<i>Mougetia monotaenium</i> (722), <i>A. islandica</i> (603), <i>Mougetia</i> sp. II (588).
August 2004	<i>A. granulata</i> (5733)*	<i>A. granulata</i> var. <i>angustissima</i> (4586), <i>Aphanocapsa delicatissima</i> (2788), <i>Mougetia</i> sp. II (409).
September 2004	<i>Microcystis aeruginosa</i> (1209)*	<i>A. granulata</i> (2747), <i>A. islandica</i> (2427), <i>Chroococcus minutus</i> (1503).
October 2004	<i>M. aeruginosa</i> (6053)*	<i>A. granulata</i> (1254), <i>O. formosa</i> (1079), <i>Microcystis aeruginosa</i> var. <i>major</i> (1034).
November 2004	<i>Trichodesmium lacustre</i> (6403)*	<i>A. granulata</i> (5945), <i>A. granulata</i> var. <i>angustissima</i> (3787), <i>A. islandica</i> (3132).
December 2004	<i>M. aeruginosa</i> (3797)*	<i>Pseudoanabaena curta</i> (2267), <i>M. flos-aquae</i> (1454), <i>M. wesenbergii</i> (151).
January 2005	<i>A. granulata</i> (9920)*	<i>A. islandica</i> (8526), <i>A. granulata</i> var. <i>angustissima</i> (7903), <i>A. granulata</i> var. <i>angustissima</i> f. <i>spiralis</i> (1805).
February 2005	<i>A. granulata</i> (2370)*	<i>A. granulata</i> var. <i>angustissima</i> (2174), <i>A. islandica</i> (1844), <i>Mougeotia</i> sp. II (309).
March 2005	<i>A. granulata</i> (2848)*	<i>A. islandica</i> (2348), <i>A. granulata</i> var. <i>angustissima</i> (2299), <i>A. granulata</i> var. <i>angustissima</i> f. <i>curvata</i> (245).
April 2005	<i>A. granulata</i> var. <i>angustissima</i> (2058)*	<i>Aulacoseira granulata</i> (2104), <i>A. islandica</i> (1899), <i>Mougetia</i> sp. II (278)
May 2005	<i>Merismopedia tenuissima</i> (1295)*	<i>Microcystis aeruginosa</i> (180), <i>Mougetia monotaenium</i> (89), <i>Mougetia</i> sp. II (81).

Note: * = Phytoplankton abundance (cells/mL)

** = New species for Lagos lagoon complex.

For example, diatoms (*Aulacoseira granulata* and *A. granulata* var. *angustissima*); blue green algae, *Microcystis aeruginosa*, *Merismopedia tenuissima* and *Trichodesmium lacustre* showed this trend by being the abundant species in some of these months. In the rainy season, green alga, *Mougeotia* sp1 dominated this season in June-July 2003 with *Chroococcus turgidus*, *Tetraspora gelatinosa* and *M.*

aeruginosa as the sub-dominant species in June while *A. granulata*, *Oscillatoria germinata* and *A. islandica* were sub-dominant species in July.

In corresponding year (June-July 2004) the diatom, *A. granulata* was recorded as the dominant species with *Mougeotia* sp. 11, *A. islandica* and *Microcystis flos-aquae* as some of the sub-dominant species. In August 2003 and 2004 *A. granulata* dominated and have

Mougeotia sp. 11, *Aphanocapsa delicatissima* and *Aulacoseira* spp. as important members of the phytoplankton spectrum. *M. aeruginosa* remained dominant in September 2003 and 2004 while two members of the division Cyanophyta (*Microcystis flos-aquae* and *C. minutus*) were associated species in addition to *Aulacoseira* spp. October and November 2003 recorded *Aulacoseira granulata* as the dominant species while *Aulacoseira* spp. and *Lynghya hypolimnetica* were recorded as the sub-dominant species.

In October 2004, *M. aeruginosa* took over the succession while *T. lacustre* for the first time was recorded as the dominant species in November 2004. December 2003 and 2004 also recorded different cyanophytes (*Cyanosarcina huebeliorum* and *M. aeruginosa*) as the dominant species. *M. aeruginosa* and *A. granulata* were recorded as dominant species in January 2004 and 2005, respectively. For the first time *A. granulata* maintained the dominance throughout February to April 2004 and 2005. *Mougeotia* sp. 11 was dominant in May 2004 while May 2005 recorded *M. tenuisima*.

Generally, *A. granulata* had variable patterns of abundance as it recorded its dominance

both in dry and wet season. The correlation values between different classes of phytoplankton and some physico-chemical parameters showed inverse relationship between Bacillariophyceae, Chlorophyceae, Euglenophyceae and Xanthophyceae with phosphate-phosphorus (Table 4). Phytoplankton dynamics from different stations showed that is being controlled by the same factors and recorded almost same species (Figs. 2 and 3). These factors according to the result generated using Primer 5 software included Phosphate-phosphorus, Nitrate-nitrogen, rainfall, pH and depth.

DISCUSSION

Dilution of lagoon water during the wet season and the degree of dilution and flushing depended on the amount of rainfall in the catchment areas and the attendant effects of flood waters. Flooding caused seasonal changes in the volume of water and the dilution of cations in the lagoon complex. Thomas (1966) and Biswas (1972) reported similar effects of dilution in some water bodies in Ghana. The low phytoplankton biomass in the rainy season may be due to flood water which diluted the

TABLE 4
Correlation Coefficient (r) value of different divisions and some physico-chemical parameters in Lekki Lagoon

Divisions	Surface water temp.	NO ₃ -N	PO ₄ -P	SO ₄	Salinity	Dissolved Oxygen	Transparency	Oil and grease	Conductivity	Chloride ion	Total suspended solids	Total dissolved solids
Bacillariophyta	0.201	0.328	-0.091	0.360	0.280	0.167	0.509	-0.185	0.170	0.682	-0.493	0.006
Chlorophyta	0.364	-0.054	-0.125	0.638	0.516	0.083	0.046	-0.115	0.631	0.121	-0.219	0.332
Cyanophyta	-0.215	-0.152	0.767	0.429	-0.107	0.107	0.716	-0.428	-0.332	-0.008	-0.335	0.249
Euglenophyta	-0.004	0.062	-0.345	-0.135	-0.161	0.143	0.119	0.098	-0.262	0.460	-0.189	-0.238
Xanthophyta	-0.263	-0.253	-0.139	-0.135	-0.474	0.122	0.207	-0.198	-0.379	0.408	-0.148	0.311
Chrysophyta	-0.197	0.433	0.340	0.001	-0.001	0.209	0.644	-0.309	-0.154	-0.015	-0.120	0.100
Dinophyta	-0.612	-0.095	0.164	-0.071	-0.194	0.133	0.233	-0.248	-0.292	-0.408	0.496	-0.228

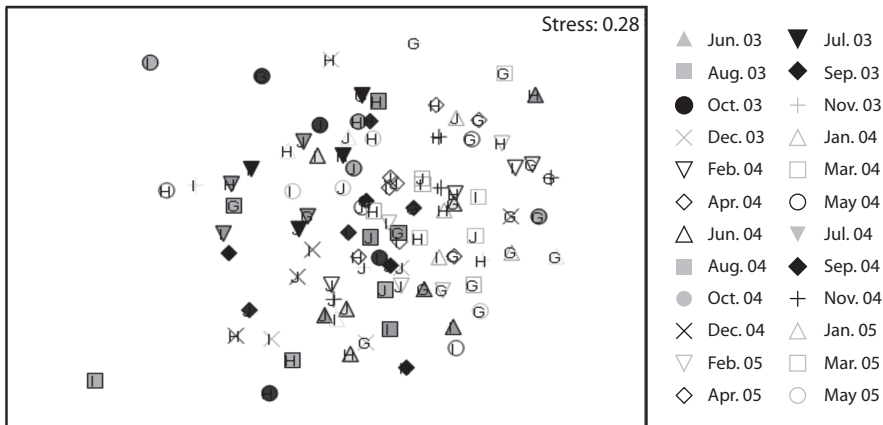


Fig. 3. Phytoplankton analysis of stations G-J of Lekki lagoon throughout the sampling period using Multivariate analysis for the duration July 2003-May 2005.

Note: Clustering of the symbols together indicates that there is probability of same species spreading out in different sampling sites which are then controlled by same factors.

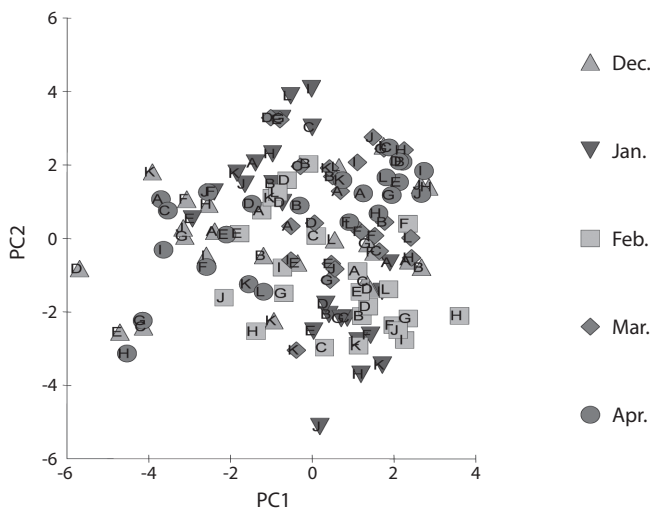


Fig. 2. Principal component analysis for physico-chemical parameters in all stations of Lekki lagoon (December 2003 - April 2004).

physico-chemical environment, reduced retention time, reduced transparency and flushed out phytoplankton taxa. The present observation that diatoms dominate the phytoplankton community confirms earlier reports by Imevbore (1965, 1968) and Egborge (1979) who reported

similar results for reservoirs of South Western Nigeria and Nwankwo (1984) for Lagos lagoon and adjacent sea. Centric diatoms were dominant almost all through each annual cycle with major floristic changes between the seasons. Centric diatoms dominance also conforms to

Nwankwo (1984) who reported that *Melosira* was the dominant species in Lagos lagoon and the adjacent sea. The dominance of centric diatoms most especially *Aulacoseira granulata* could be an indication that *Aulacoseira* species needed low salinity level to thrive, since an increased salinity value especially in September 2003, favored the blue green algae during which highest relative abundance (96.7%) was recorded with *Microcystis aeruginosa* recording 95.5% out of the total (96.7%), this indicated that salinity range of 0.85-1.05mg/L probably favored *M. aeruginosa* and not *Aulacoseira* sp. In general, pH value recorded in this study highly favored *A. granulata* which remained dominant at most of the time and this supported Talling (1986) report, who by using data collected from some central African lakes suggested that the effects of pH and alkalinity in lake waters may be reflected in the occurrence of some species such as *A. granulata*.

The phytoplankton community and the physio-chemical parameters exhibited seasonal changes closely related to the pattern of rainfall. According to Egborge (1974) and Tezuka (1984), seasonal fluctuation in abundance of phytoplankton is influenced by changes in the physical and chemical properties of the water, which themselves can be dependent on rainfall. Differences in abundance of most species during the two seasonal cycles could be attributed to significant variations in the physico-chemical variables and nutrients levels within these periods. This probably explained the successional pattern of the phytoplankton taxa, which showed that between September and December 2004, the blue green dominated the phytoplankton spectrum, living *Aulacoseira* spp. to be sub-dominant among the blue green that dominated the phytoplankton spectrum in one month; or the other during this study were, *Cyanosarcina huebeliorum* (December 2003) which is a new record for Lagos lagoon complex *Merismopedia tenuissima* (May 2005), *Trichodesmium lacustre* (November 2004) and *M. aeruginosa* that recorded its abundance in many occasions while *Mougeotia* sp. 1 dominated in June and July 2003 and May 2004.

All the green and blue green algae showed dominance in the wet season, when the nitrate level was high, except for *M. aeruginosa* that appeared in both seasons but most abundantly in wet. The increase and decrease of phytoplankton populations and the replacement of one form by another throughout the season is controlled by the varying environmental parameters such as Phosphate-phosphorus, Nitrate-nitrogen and rainfall. Influence of the sea on phytoplankton of Lekki lagoon is not significant, because is fresh all year through and is not close to the sea as Lagos lagoon.

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RESUMEN

La costa oeste de África se caracteriza por la dominancia de lagunas, como ambientes de agua dulce tienen un gran valor, en donde el fitoplancton constituye la base de las cadenas tróficas acuáticas. Con el objetivo de conocer el efecto de las variables ambientales en el fitoplancton, se llevó a cabo un estudio sucesional mensual del fitoplancton, en la laguna Lekki, durante dos años (junio 2003-mayo 2005). En 12 estaciones, se obtuvieron muestras de fitoplancton mediante una red de plancton que tiene una malla de 55µm, que posteriormente fueron preservadas en formalina al 4%. Además, se tomaron muestras de agua superficial, para análisis físico-químico. En cada año, la distribución estacional y la sucesión de fitoplancton dominante siguieron patrones diferentes. La abundancia de fitoplancton fue mayor durante la estación seca (noviembre-abril) durante los dos ciclos anuales. Esta misma tendencia la presentaron las diatomeas (*Aulacoseira granulata* y *A. granulata var angustissima*) y las algas verde azules, además de *Microcystis aeruginosa*, *Merismopedia tenuissima* y *Trichodesmium lacustre*, las mismas fueron especies abundantes en algunos de estos meses. En la temporada de lluvias, el alga verde *Mougeotia* sp. fue la que dominó. La sustitución de una forma por otra a lo largo de los ciclos estacionales fue controlada probablemente por los cambios en las variables ambientales como la lluvia, el nitrato y fósforo.

Palabras clave: fitoplancton, laguna tropical, aguas someras, Laguna Lekki, cambios estacionales.

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