Spatio-temporal Variations in Phytoplankton Biomass and diversity in a Tropical Eutrophic Lagoon, Nigeria

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Abstract: Taxonomic inventorisation and spatio-temporal variations in the phytoplankton species biomass and diversity, in relation to environmental parameters at the Ologe lagoon, Lagos were investigated from February, 2002 to January, 2004. The annual rainfall, concentrated in one season, initiated increased total solids and nutrient values whereas low dissolved oxygen, conductivity, transparency, and cation concentrations were recorded. The phytoplankton species biomass, composition and water quality indices exhibited seasonal changes closely related to the pattern of rainfall. Estimation of phytoplankton biomass by cell count showed a range of 849 to 1771707cells/ml with mean value of 44052cell/ml. The phytoplankton flora of the lagoon belonged to five main algal phyla, namely Bacillariophyta (84%), Cyanophyta (15.92%), Chlorophyta (0.06%), Euglenophyta (0.018%) and Prryophyta (0.002%). One hundred and nineteen species belonging to forty-nine genera were observed, with diatoms forming the most abundant and diverse. A total of forty-eight species belonging to eighteen genera was found in diatoms. This was followed by green algae, with thirty-two species from fourteen genera, Cyanobacteria, with twenty-three species from eleven genera, euglenoids with seventeen species from five genera, while the dinoflagelates had one species. Nine phytoplankton species were reported to be potentially harmful/toxic bloom species. 57 bio-indicator species were recorded during the period of study. With regard to existing checklist of phytoplankton species, 10 new species are the first reports for Lagos lagoon complex, south-western Nigeria.The centric diatom *Aulacoseira* and cyanobacterium *Microcystis* dominated the phytoplankton community spectrum and their dominance in the Lagoon in both seasons suggests a single floristic grouping. The observed range of bio-indicator species within Ologe lagoon showed that the lagoon is eutrophic. Co-efficient of similarity index indicated that stations close to each other are more similar, than stations further apart.
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Key words: Seasonal changes, phytoplankton composition, cell number, bio-indicator, diversity, eutrophic, rainfall.

1. Introduction

Lagoons are prominent features along the coastal regions of south-western Nigeria. Some of these lagoons are part of West African lagoon system in origin and location but are in form and features similar to freshwater lakes (Alanine 1981). The other types of lagoon are essentially brackish and tidal effects are experience particularly in the dry season. However, all the lagoons of south-western Nigeria enter the sea through the Lagos Harbour. Ologe lagoon is essentially a fishing resource of the people of Lagos and Ogun States. Its location, within these two states and openings into the Atlantic Ocean through Lagos Harbour and Republic of Benin, makes the lagoon national and inter-regional important, in the sense that ecological changes within it, directly affect the productivity and consequently, the fish and fisheries within it and West African coast.

Algological data on the Nigerian lagoons are limited. Of the six lagoons (Mahin, Lekki, Epe, Lagos, Ologe, and Yewa) on the south-western coast, only the Lagos Lagoon has been subjected to extensive published investigations. The available information includes Nwankwo (1986, 1990a, 1990b, 1991a, 1991b, 1994, 1996), Nwankwo and Akinsoji (1989), and Nwankwo *et al.* (1994). Two other papers (Nwankwo and Akinsoji 1992, and nwankwo 1993) extended investigations to other parts of the lagoon system, while currently only one published work on algae in the Epe Lagoon (Nwankwo and Onitiri 1992) dealing with the periphyton algae associated with species of *Ceratophyllum* and *Utricularia,* with special reference to water quality, exist. More recently, Onyema,(2008b) ,Adesalu, and Nwankwo (2009) investigated the phytoplankton dynamics of Iyagbe lagoon and Lekki lagoon respectively.

There are no previous in-depth biological characterization of the Ologe Lagoon, its physico-chemical regime and the extent and effects of varieties anthropogenic stressors to which the lagoon and endemic biological resources are exposed to. There is great need therefore for gross understanding of the nature and dynamics of the Ologe lagoon. This is due to the numerous scientific, ecological and economic implications now and for the future. Additionally it is also necessary to study the resident phytoplankton diversity, abundance and distribution in relation to seasonal changes in environmental characteristics operating within the Ologe lagoon.

2. Material and methods

Description of Study Site

Ologe lagoon is a freshwater and non-tidal Lagoon, at the distal end of Badagry creek(low brackish). It is fed throughout the year by the waters of adjoining rivers, creeks, and swamps (fig. 1). The lagoon is located in Lagos State, Nigeria and is one of the nine lagoons in South-western Nigeria (Webb, 1958; Nwankwo, 2004b). It is pressumbaly the smallest of the lagoons in South Western Nigeria with a surface area of 9.4km^2, and lies at the distal end of Badagry creek between longitudes 6° 26'N to 6° 30'N and latitudes 3° 01'E to 3° 07'E. The main body of the lagoon lies within Badagry Local Government Area and it opens up to the Atlantic ocean via the Lagos Harbour and Dahomey in the Republic of Benin. The major source of water are River Owo with a source in a town called Toto Owo where River Ore and Illo form a confluent with River Oponu in Ogun State (Akanni, 1992). Seventeen stations were chosen for sampling within the lagoon. The lagoon is shallow at most points and is open all year round via the Lagos habour to the sea (Hill and Webb, 1958; Sandison, 1966; Sandison and Hill, 1966). Like all parts of South-western Nigeria, the Ologe lagoon is exposed to two distinct seasons namely the wet (May – October) and the dry (November – April) (Nwankwo, 2004b). Like all parts of South-western Nigeria, the Ologe lagoon is exposed to two distinct seasons namely the wet (May – October) and the dry season (November – April) (Nwankwo, 2004b; Sandison and Hill, 1966). The harmmattan, a short season of dry, dusty North-East Trade winds experienced sometimes between November and January in the region reducing visibility and lowering assemblages is the common macrofloral assemblages especially in areas with reduced anthropogenic influence. The lagoon deposits are varied, and are reflected in the pattern and type of vegetation in the region. Most parts of the Ologe lagoon are colonized by recognizable riparian dense swamp rainforest community dominated by raphia palms especially *Raphia hookeri, Elaeis guineensis, Acrotiscum aureum* and *Cocos nucifera* (Akinsoji *et al.,* 2002).Very few mangrove communities are recognizable around the Badagry creek end. Notable fauna of the area includes amphipods, Oligochaetes, few polychaetes, isopods, barnacles, oysters, periwinkle, nematodes, fiddler crabs, crabs, among others (Sandison and Hill, 1966; Onyema, 2008b).

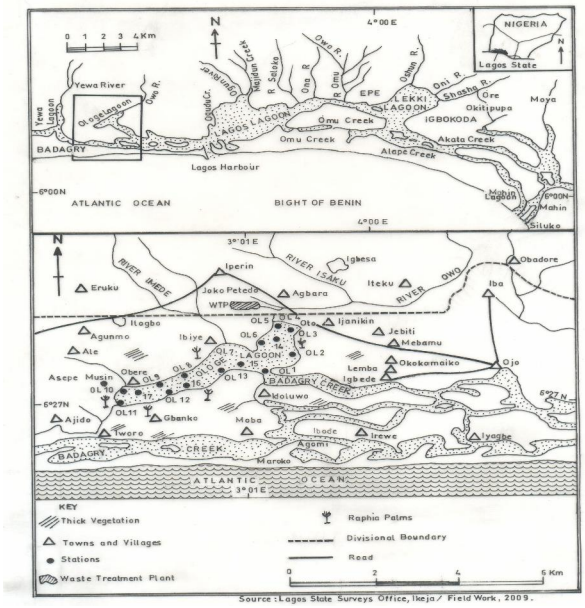

Fig. 1: Parts of Ologe lagoon Showing Sampling Stations

Collection of samples

Collection of water samples

Seventeen sampling stations were selected to cover the lagoon area and for the collection of sample. Table 1 shows the G.P.S location, names and number of sampling stations. Monthly surface water sample was collected for twenty-four consecutive months for physico-chemical characteristics analysis using 500ml plastic containers with screw caps. Collection of samples from the stations was always between 10 and 15hr each time. Water samples were collected just a few centimeters below the water surface at each of the twelve stations. The plastic containers was then labeled appropriately and transported to the laboratory immediately after collection for further analysis. Water samples for dissolved oxygen was collected also in 50cl bottles and fixed on site with white and black ampoules. Water samples for biochemical oxygen demand (BOD_5) were collected in 200 ml light and dark bottles.Table 2 shows the summary of environmental factors and method/device used for their estimation.

Table 1: G.P.S. locations and station names of sampled areas in the Ologe lagoon

Station No.	Station name	G.P.S. locations
Station OL1	Idolowu	Latitude 6º28'.3 N, Longitude 3º05'.3 E
Station OL2	Between Idolowu and Otto-jetty	Latitude 6º28'.6 N, Longitude 3º05'.5 E
Station OL3	Otto-jetty	Latitude 6º29'.0 N, Longitude 3º06'.0 E
Station OL4	Point of effluent discharge	Latitude 6 º29'.5 N, Longitude 3 º06'.0 E
Station 0L5	Confluence of Owo River and Ologe lagoon	Latitude 6º30'.0 N, Longitude 3 º06'.1 E
Station OL6	Between station 5 and Ibiye	Latitude 6 º29'.3 N, Longitude 3 º06'.0 E
Station OL7	Ibiye	Latitude 6 º29'.0 N, Longitude 3 º05'.6 E
Station OL8	Between Ibiye and Obele	Latitude 6 º29'.2 N, Longitude 3 º06'.9 E
Station OL9	Obele	Latitude 6 º28'.2 N, Longitude 3 º05'.7 E
Station OL10	Asepe Mushin	Latitude 6 º28'.6 N, Longitude 3 º06'.0 E
Station OL11	Gbanko	Latitude 6 º28'.0 N, Longitude 3 º05'.8 E
Station OL14	Centre of Ologe lagoon between otto-jetty and station 6	Latitude 6o ,30'.5 N Longitude 3o 06'.4 E
Station OL15	Centre of Ologe lagoon between Ibiye and Idolowu	Latitude 6o ,30'.2 N Longitude 3o 06'.6 E
Station OL16	Centre of Ologe lagoon between Obele and Ajido	Latitude 6o ,29'.5 N Longitude 3o 06'.0 E
Station OL17	Centre of Ologe lagoon between Asepe Mushin and Gbanko	Latitude 6o ,28'.7 N Longitude 3o 06'.7 E

Table 2: Summary of environmental factors and method/device used for their estimation.

	Parameter/Unit	Method/Device	Reference
1.	Air temperature (^{o} C)	Horiba U-10	
2.	Water temperature (^{o} C)	Horiba U-10	
3.	Transparency (cm)	Secchi disc method	Onyema 2008
4.	Depth (cm)	Graduated pole	Brown 1998
5.	Rainfall (mm)	Acquired from NIMET, Oshodi, Lagos	
6.	Total Dissolved Solids (mgL^{-1})	Cole Palmer TDS meter	
7.	Total Suspended Solids (mgL^{-1})	Gravimetric method	APHA(1998)
8.	Total hardness (mgL^{-1})	Titrimetric method	APHA(1998)
9.	pH	Electrometric / Cole Parmer Testr3	
10.	Conductivity (µS/cm)	Philip PW9505 Conductivity meter	
11.	Salinity (‰)	HANNA Instrument	APHA(1998)
12.	Alkalinity (mgL^{-1})	Titration method	APHA(1998)
13.	Dissolved oxygen (mgL^{-1})	Titration method	APHA(1998)
14.	Biological oxygen demand (mgL^{-1})	Incubation and Titration	APHA(1998)
15.	Chemical oxygen demand (mgL^{-1})	Titration method	APHA(1998)
16.	Nitrate – nitrogen (mgL^{-1})	Colorimetric method	APHA(1998)
17.	Phosphate – phosphorus (mgL^{-1})	Colorimetric method	APHA(1998)
18.	Silica (mgL^{-1})	Colorimetric (DR2010)	APHA(1998)
19.	Sodium (mgl-1)	Flame Photometer	APHA(1998)
20.	Potassium (mgl-1)	Flame Photometer	APHA(1998)
21.	Calcium (mgL^{-1})	Titrimetric method	APHA(1998)
22.	Magnesium (mgL^{-1})	Titrimetric method	APHA(1998)
23.	Copper (mgL^{-1})	Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application (2002)
24.	Iron (mgL^{-1})	Atomic absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application (2002)
25.	Zinc (mgL^{-1})	Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application (2002)
26	Chromium (mgl-1)	Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application (2002)

Collection of Phytoplankton Samples

Phytoplankton sample was collected on each occasion and station with a 55 µm mesh size standard plankton net towed from a motorized boat for 5 min at low speed (<4 knots). The net was hauled in and the sample transferred into 250 ml. well labeled plastic container with screw cap. Each sample was preserved with 4% unbuffered formalin and stored in the laboratory. The preserved samples were later taken to Protistology and Aquatic Ecology Research Laboratory, University of Ghent, Belgium for taxonomic studies and scanning electron microscopy. After 48hrs and prior to microscope analysis, samples were concentrated to 10 mL (Nwankwo, 1984).

Biological Analysis

In the laboratory, one drop of the concentrated sample, five different times for each sample was investigated at different magnifications (X100 and X400) using a Wild M11 binocular microscope with a calibrated eye piece. The microtransect drop count method described by Lackey (1938) and employed by Nwankwo (1984) was used to estimate abundance. Since each drop is 0.1 mL and two drops were used for each sample amount, results on abundance were multiplied by 5 to give the values as numbers of organisms per mL. Another sub-sample was acid-cleaned as described by Barber and Haworth (1981) to aid diatom identification. Appropriate texts were used to aid identification (Smith, 1950; Hendey, 1958, 1964; Desikachery, 1959; Wimpenny, 1966; Patrick and Reimer, 1966, 1975; Whitford and Schmacher, 1973; Valandingham, 1982; Nwankwo, 1984, 1990, 2004a; Bettrons and Castrejon, 1999; Siver, 2003; Rosowski, 2003).

Statistical Analysis

Total numbers of species were counted and the species richness estimated according to Margalef (1951, d=(S-1)/InN). The Shannon and Weaver (1949) diversity index ($H=-\sum P_i \ InP_i$) and Pielou (1966) evenness index (J=H/InS) were calculated. The similarities between stations were calculated using the Sorensen index (q=100*2c/(a+b)),while statistica 4.0 was used to calculate ANOVA.

4. Results

4.1 Physical and chemical features

The minimum and maximum values obtained for the estimates of environmental factors, their means and standard deviation are presents in Table 3. Also in Table 3 is whether each parameter recorded higher values in the wet or dry season for the two (2) years of study. Fig. 2 showed seasonal variations in some environmental factors at some stations in Ologe lagoon from Feb., 2002 to Jan., 2004. Stations represented were selected based on their importance as confluence points and areas exposed to possible anthropogenic stresses or not.

Table 3: A summary of the minimum, maximum and mean / standard deviation estimate values for environmental factors from the Ologe lagoon (February, 2002 – January, 2004).

	Parameter/ Unit	Minimum value	Maximum value	Mean value ± S.D.	Higher values reported
1	Air temperature (oC)	27	34	31.10 ± 0.22	Dry season
2	Water temperature (oC)	25.2	31.8	29.01 ± 0.47	Dry season
3	Transparency (cm)	24	76	51.54 ± 5.65	Dry season
4	Depth (m)	3.2	7	4.4	Wet season
5	Total Dissolved Solids (mgl-1)	48	294	139.23 ± 17.89	Dry season
6	Total Suspended Solids (mgl-1)	7	378	184.36 ± 14.90	Wet season
7	Rainfall (mm)	0.6	383	137.37	Wet season
8	Total hardness (mgl-1)	62	342	146.38 ± 26.52	Dry season
9	pH	5.8	8.1	6.92 ± 0.14	Dry season
10	Conductivity (µS/cm)	83	621	256.59 ± 36.65	Dry season
11	Salinity (‰)	0.0	0.5	0.10 ± 0.03	Dry season
12	Alkalinity (mgl-1)	42	162	100.20 ± 9.37	Dry season
13	Dissolved oxygen (mgl-1)	7	12.7	9.08 ± 0.42	Wet season
14	Biological oxygen demand (mgl-1)	0	28	13.11 ± 1.79	Dry season
15	Chemical oxygen demand (mgl-1)	6	39	21.34 ± 2.52	Dry season
16	Nitrate – nitrogen (mgl-1)	0.02	1.02	0.44 ± 0.08	Wet season
17	Phosphate – phosphorus (mgl-1)	0.03	1.79	0.80 ± 0.10	Wet season
18	Silica (mgl-1)	2.05	9.54	5.07 ± 0.45	Wet season
19	Sodium (mgl-1)	2.6	22.7	30.82 ± 6.13	Dry season
20	Potassium (mgl-1)	0.1	7.6	8.71 ± 1.78	Dry season
21	Calcium (mgl-1)	34	227	91.27 ± 17.89	Dry season
22	Magnesium (mgl-1)	0.01	7.6	2.64 ± 0.62	Dry season
23	Copper (mgl-1)	0.02	0.06	0.03 ± 0.001	Dry season
24	Iron (mgl-1)	0.12	0.99	0.35 ± 0.04	Dry season
25	Zinc (mgl-1)	0.002	0.03	0.01 ± 0.001	Dry season
26	Chromium (mgl-1)	0.001	0.04	0.02 ± 0.002	Dry season

The mean values of the physico-chemical factors of the investigated stations clearly indicated a seasonal trend resulting from the concentration of rainfall in the period from May to November (fig. 2).

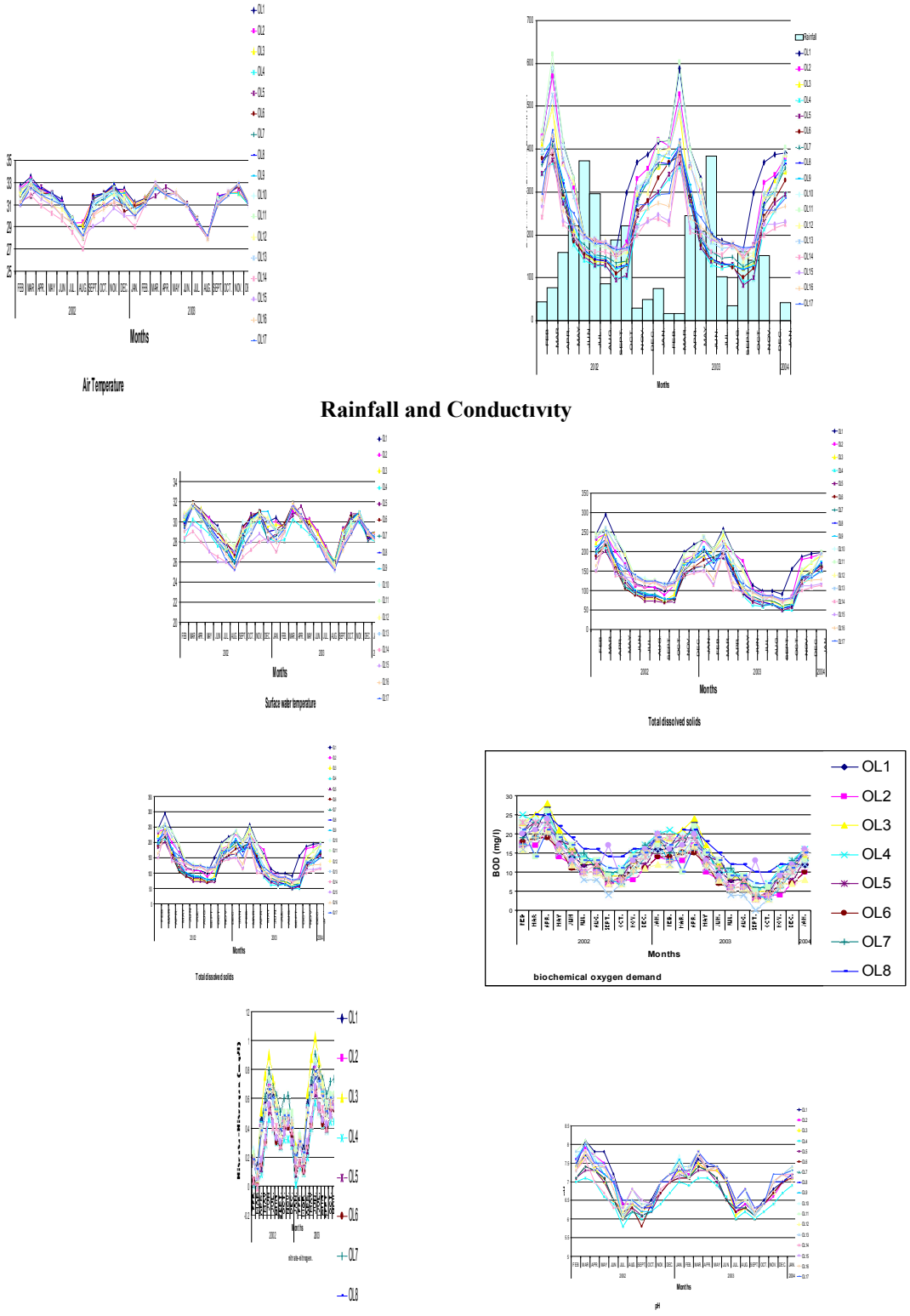

Fig 2: Seasonal changes in the physico-chemical parameters in the Ologe Lagoon, Lagos.

4.2 Phytoplankton

4.2.1 Compositional Abundance

The phytoplankton comprised four groups: Bacillariophyceae, Chlorophyta, Dinophyceae, and Cyanobacteria (Table 1). The Bacillariophyceae had the highest relative abundance and species diversity throughout the year (Fig 3).

Table 1. Mean density of phytoplankton (ind. mL $^{-1}$) in Ologe Lagoon from February 2002 to January 2004.

Taxa	Seasons		
	Jan-Apr.	May-Sep.	Oct.-Dec.
BACILLARIOPHYCEAE			
Centric			
Aulacoseira granulata (Ehr.) Sim.	10400-50200	2250-25200	32500-72500
A. granulata var.*angustissima* (O.F.Mullar) Sim.	3700-6180	5100-8850	9850-11220
**A. granulata* var.*angustissima f.spiralis* Hust.	1420-4650	880-2260	2660-6100
**A. granulata* var.*angustissima f.curvata* (Hust.)	1600-5040.	1020-2040	2250-5670
A. granulata var.*muzzaensis* (Meist.) Hust	2490-4880	640-2840	3600-6680
**A. islandica* (O. Muller)	1020-2140	150-400	1400-3660
Stephanocyclus sp	10-30		
Cyclotella meneghiniana (Kutzing)	40-50	6-10	50-120
C.striata (Kutz.) Grunow			6-20
C.stelligera Cleve ex Grunow		8	
Coscinodiscus centralis Ehrenberg			4-20
C. eccentricus Ehrenberg	6		10-20
**Melosira varians* Agargh		10	
Actinoptychus sp	4-15		
**Biddulphia laevis* Ehrenberg		2-10	2-6
ORDER 11: PENNALES			
Synedra ulna (Nitzschia) Her	10-30	40-120	20-60
S.acus Kutzing	8-20	30-70	40-60
Nitzschia palea (Kutz) W.M.Smith	8	20-30	10-20
N. closterium (Ehr.) W.M.Smith		10	6
N. acicularis (Kutz.) W.M.Smith		4-15	
N.vermicularis Hantzsch		4-10	2
Pinnularia major (Kutz.) Cleve	8	20-40	10
P. interrupta W.M.Smith		2-12	
P.laevis (Ehr.) Compere		10-30	
P.hemiptera (Kutz.) Rabenh.	2-6	4-16	
P.ambigua Cleve	6-8	20-30	6-10
Pinnularia sp		15-25	
Navicula oblonga Ehrenberg		20-40	10-20
N. radiosa Kutzing		6-14	8
N. gracilis Ehrenberg	4	6-10	
N. mutica Kutzing		8	4
N. cuspidata Meist		4-10	2-4
Cocconeis placentula (Ehr.) Cleve		8	
C. Disculum (Schum) Cleve			4
*Epithemia sp	2-8		2-10
Cymbella affinis Kutzing	6-20	10-30	10-20
C. minuta Hisle ex.Rabenh	8		
Eunotia gracilis Meister		8-20	2-10
E.lunaris (Ehr.) Grunow		6	2
E.monodon Ehrenberg	4		

Surirella elegans Ehrenberg	10-20	10-50	8
S. ovata Kutzing	6		
Fragilaria construens Ehrenberg	4-10	10-40	
**Gomphonema parvulum* Kutzing	8		4-30
DIVISION: CHLOROPHYTA			
CLASS: CHLOROPHYCEAE			
ORDER I: CHLOROCOCCALES			
Pediastrum simplex (Meyer) Lemm	4-40	15-40	10
P. simplex var.echinulatum (Wittr.)		6-14	
P. duplex Meyer	4-10	10-50	8-20
P. duplex var.gracillimum (W. West)		6	
P. tetras (Ehr.) Ralfs		4-15	
P. tetras var. tetraodon Rabenhorst		4	4
*P. boyanum (*Turpin) Meneghini		4	
Scenedesmus acuminatus (Lagerh.) Chordat	8-50	6-30	2-10
S. quadriacuada (Turp.) Breb	4	2-10	6
**S. dimorphus* (Turp.) Kutzing		4	
S. apiculatus (W.et G.S.West) Chordat		8	2-10
S. arcuatus Lemm.	4	2-10	
Ankistrodesmus acicularis (A.Braun) Korsh.	2	10-30	4-15
A. falcatus (Corda) Ralfs.			6
Tetraedron sp	2	10-20	
ORDER II:VOVOLVOCALES			
Volvox aureus Ehrenberg	20-50		10-20
V. africana Ehrenberg	8-20		
Eudorina elegans Ehrenberg	4-20		20-30
ORDER III: ZEGNEMATALES			
Staurastrum leptocladium Nordst	10-20	2-10	10-40
Staurastrum paradoxum Meyen	6		
Staurastrum sp	2-10		8
Desmidium swartzii Ag		2-8	2
Micrasterias sp		2-20	
Spirogyra africana (Fritsch) Czurda	4		
Zygnema sp		8	6
Closterium ehrenbergii Menegh		10-40	6-20
C. aciculare T.West		4-10	4
C. kuetzingii Breb.	4-10	6-40	6-20
C. intermidium Ralfs			4
C.moniliferum (Bory) Ehr.Ex Ralfs		6-20	2-10
Spondylosum sp		2-4	
Cosmarium sp		4	
DIVISION: EUGLENOPHYTA			
CLASS: EUGLENOPHYCEAE			
ORDER: EUGLENALES			
Euglena acus Ehrenberg	10-20	4	4-10
E. caudata Hubner	4-10		2-6
E. convoluta Korishikor	6-14	2	2-8
E. viridis	4-15		4-6
E. polymorpha Dangeard	2-8	4	2-10
Euglena spirogyra Ehrenberg	6	2	2-6

Lepocinolis sp	6		
Phacus accuminatus Stokes	8-20	2-4	4-15
P. longicauda Duj.	4-8		2
P. orbicularis Hubner	6		
P. curvicauda Swir	4		
P. tortus (Lemm) Skvort	2-8		4
Trachelomonas caudata stein	12-25		4-12
T. hispida Lemm	2-4		
T. armata (Ehr.) Stein	6		
T. acanthostoma (St) Deft			4
Eutreptia sp	2-6		
DIVISION: CYANOPHYTA			
CLASS: CYANOPHYCEAE			
ORDER I: CHROOCOCCALES			
Microcystis aeruginosa Kutzing	3300-8450	820-2800	4950-12420
M. flos-aquae Kirchn.	1660-4400	1060-2050	2660-6110
M.wesenbergii Komark	650-970	240-400	820-1020
Merismopedia glauca Ehr. Nag.	350-510		
Gloeocapsa decortisans	40-80		20-60
ORDER II: HORMOGONALES			
Spirulina major Kutzing	420-1500	100-250	400-2110
S. princeps W.et G.S.West	30-50		50-150
S. platenensis Geitler	160-450	40	200-550
Spirulina jenneri Geitler	320-850	60-120	450-1200
Aphanocapsa sp	30-50		20-60
Aphanothece sp	10-30	8	5-20
Anabaenopsis sp	12		10
Anabaea spiroides Klebahn	280-400	30-60	
A. flos-aquae Elenkin	1200-2000	40-120	1650-2500
Lyngbya contorta Lemm.	30-70	120-200	50
L. circumcreta	10-30		
L. limnetica Lemm	10-20		30-120
**Oscillatoria formosa* Bory	20-30	30-120	10-20
O. limnetica Lemm.	8-20		
O. nigro-viridis Thwaites		8-20	
Nostoc sphaerica Vaucher	30-60	40-120	20-50
**N. linckia* Bornet et Thuret		10-30	
**N. caeruleum* Lyngbye	8	4-20	10
DIVISION:DINOPHYTA			
CLASS:DINOPHYCEAE			
ORDER:PERIDANALES			
Peridinium cintum (O.F. Mull.) Her			2

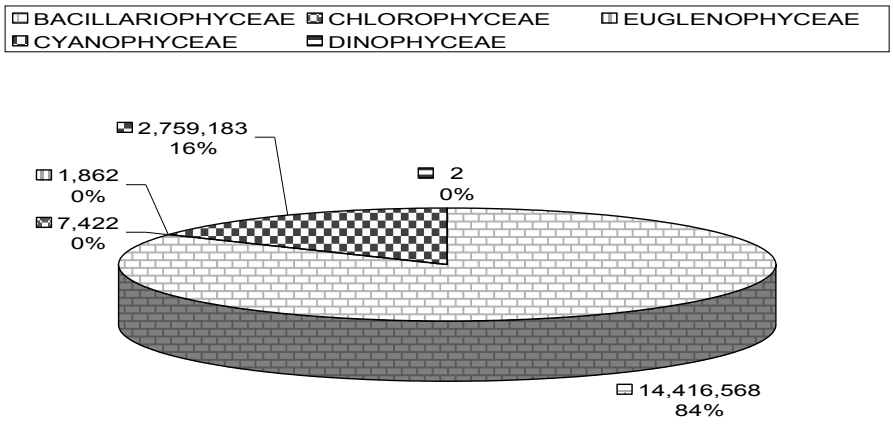

Fig 3: Total Percentage Compositions of the different Classes of Phytoplankton species at Ologe lagoon, Lagos.

Cemtric diatoms were quantitatively dominant in the Ologe Lagoon throughout the year but in terms of species richness, the Pennate were more abundant and prevalent during the raining season. The commonest species were *Aulacoseira granulata, A. granulata* var. *angustissima, A. granulata* var. *angustissima f. spiralis, A. granulata* var. *angustissima f. curvata* and *A. islandica* and they made up to 70% of the total diatom cell counts.

Pediastrum simplex, P. duplex, P. boryanum, Eudorina elegans, Scenedesmus acuminatus, Scenedesmus quadricauda and their varieties were the most prevalent rheophilic green algae. Filamentous desmids such as *Desmidium swartzii, Staurastrum leptocladiu, Closterium ehrenbergii, C. kuetzingii* and *C.moniliferum* were prominent species in the dry season.

The euglenoids were more abundant and prevalent during the dry season. Most common occurring species species were *Euglena acus,*

E. caudata, E. convoluta, E. polymorpha, Phacus accuminatus, and *Trachelomonas caudata*

The most dominant Cyanobacteria were *Microcystis aeruginosa, M. flos-aquae,* and *M. wesenbergii.* Their share in terms of number was high in the dry season, when these chroococal taxa reached their maximum, and immediately after the rainy season of each year. Filamentous forms (genera Synedra, *Anabaena, Lyngbya, Aphanotheca, Aphanocapsa, Anabaenopsis, Oscillatoria, Nostoc* and *Spirulina* were frequent but in smaller numbers.

The member of Dinophyceae, *Peridinium cinctum* was rarely and therefore its contribution to the total phytoplankton density was insignificant.

4.2.2. Seasonal variations

In the dry season (January-April) the diatom cell counts were high during the study period. Centric diatoms (especially *Aulacoseira* spp.), chroococcal Cyanobacteria (*Microcystis* spp.), constituted more than 91.1% of the total density. Between January and April each year *Microcystis* spp. increased from 650 to 8450 cells mL^{-1}.Filamentous desmids ranged from 10 to 30 cells mL^{-1}, while *Aulacoseira* spp. ranged from 1020 to 50200 cells mL^{-1} in April. During this period many of the Pennatae diatoms though frequent, maintained small numbers, but green algae (*Eudorina, Volvox, Pediastrum, Scenedesmus*) attained their maxima.The euglenoids were more prevalent and abundant during this period.

The period May-september is characterized by the prevalence of non-motile green algae *(Ankistrodesmus, Tetraedron, Closterium*). Generally, this was a period of low phytoplankton biomass. For instance, *Aulacoseira* species dropped from 2840 cells mL^{-1} in May to 150 cells mL^{-1} in July but increased again to 32500 cells mL^{-1} in October. Biomass of Cyanobacteria dropped during this period, *Microcystis* sp. From 2800 cells mL^{-1} in May to 240 cells mL^{-1} in September, while Hormogonale Cyanobacteria and the euglenoids followed similar trends with some of them being absent this period.

After the low counts observed in the wet months, between October and December significant increases were recorded. *Microcystis* spp. increased from 820 cells mL^{-1}in October to 12420 cells mL^{-1} in December. Among the diatoms *Aulacoseira* spp. increased from 1400cells mL^{-1} to 72500 cells mL^{-1} while in green algae had Pediastrum spp., Scenedesmus spp. and *Staurastrum leptocladium, Closterium spp.* and most euglenoids as some of the prominent taxa.

Fig 4 below showed the spatio-temporal variations in the total count of phytoplankton species among the stations during the period of study, while fig 5 showed the spatial distribution of different classes of phytoplankton species at Ologe lagoon. The values for this parameter ranged between 849 cells/ml and 177107 cells/ml among all the sampling stations with a mean value of 44052 cells/ml for the duration of study. The highest total count (177107 cells/ml) was recorded at station OL10 (Asepe Mushin) in the month of December 2002, while the lowest value (849 cells/ml) was observed at station OL4 (point of effluent discharge) in the month of May 2003. Mean values for this parameter were comparatively higher during the dry season than the wet season among all sampling stations during the study period.

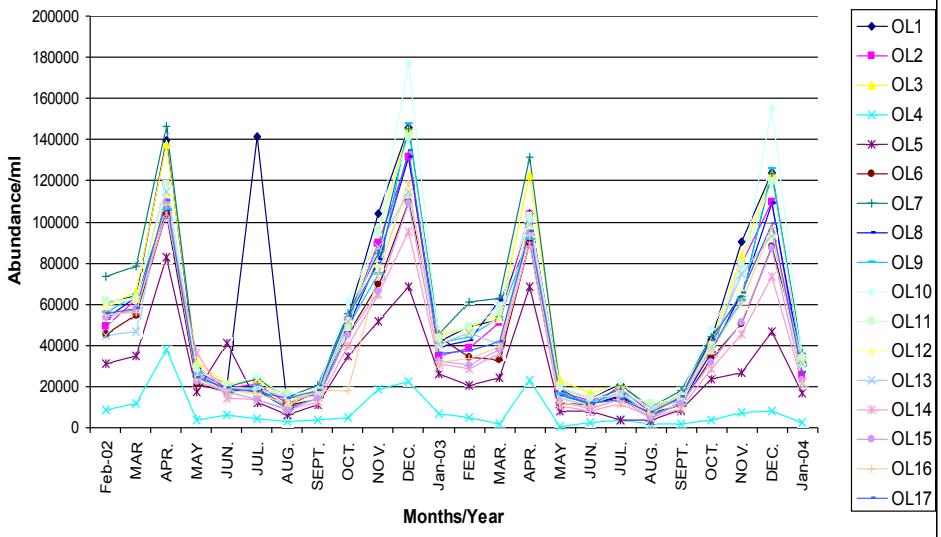

Fig : Spatial and Temporal Distribution of Phytoplankton species Biomass among stations at Ologe lagoon,Lagos.

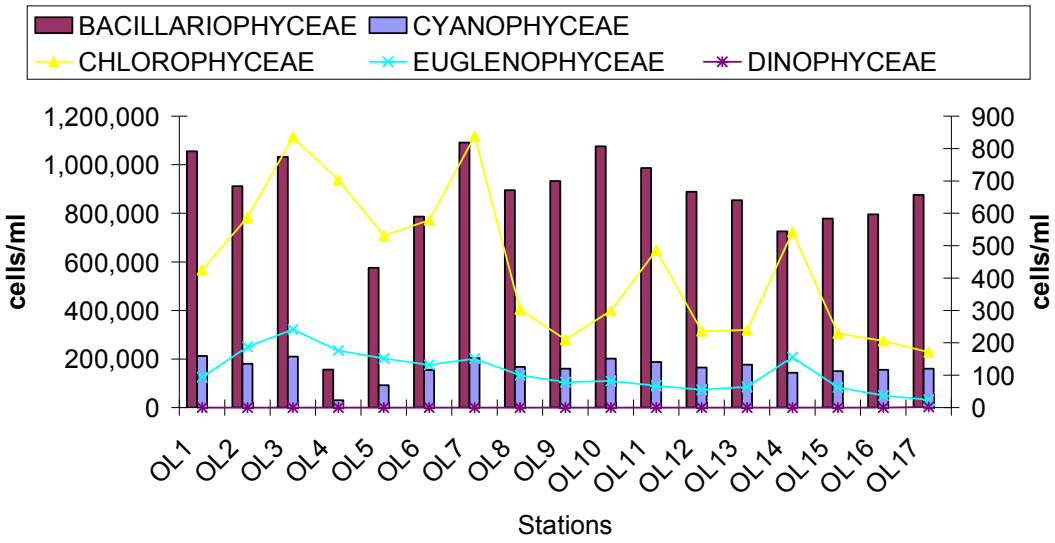

Fig 5: Spatial distribution of different classes of phytoplankton species at Ologe lagoon, Lagos

4.2.3 Species diversity

Diversity was comparatively lower in the dry season than during the rainy one with the exception of Margalef index which recorded highest index in February (fig. 5).The number of taxa (species and varieties) and abundance were higher in

the dry season than the rainy season. The compositions of phytoplankton were relatively similar at all the stations of the Ologe lagoon. Between Station 1 and 11 similarity values of more than 90% were recorded, suggesting the control of similar forcing functions.

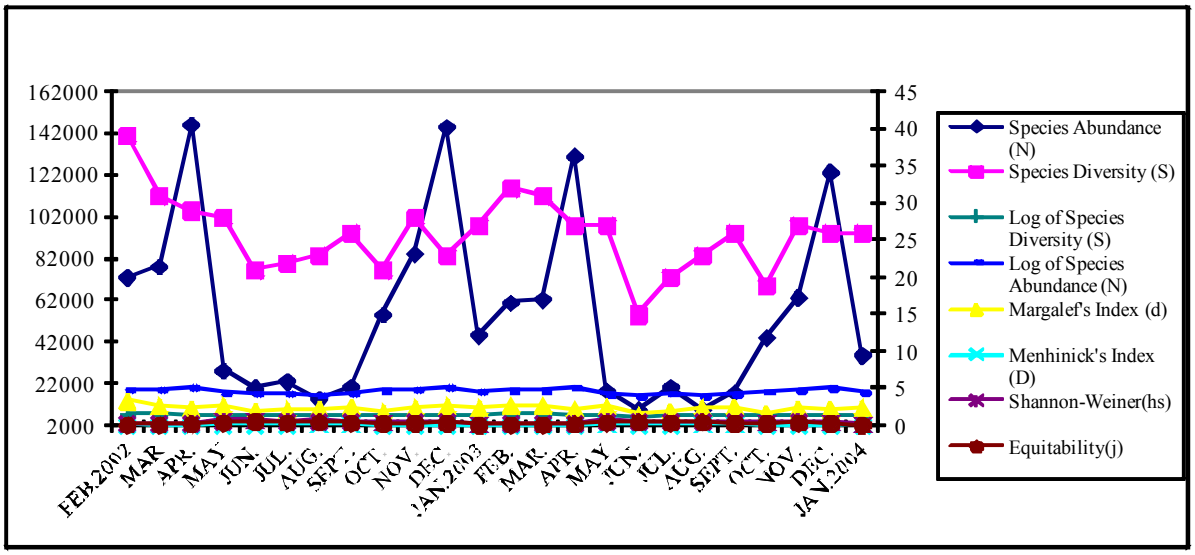

Fig 6: Some community composition parameters at Ibiye station in Ologe Lagoon, Lagos.

5.0 DISCUSSION The ecological factors operating in the lagoon of South-western Nigeria have been documented by several workers (Hill and Webb, 1958; Olaniyan, 1969; Ezenwa, 1878; Nwankwo, 1984; Solarin, 1985). The observed physico-chemical parameters showed that, although Ologe lagoon is part of Lagos lagoon complex, in origin and location, it remained freshwater throughout the year ,due to it's distance from the Lagos harbour and constant influx of water from the rivers, adjoining creeks and swamps. Sandison and Hill (1966), noted that there was obvious decrease in maritime influence as points from the lagoon were increasingly distant from the harbour. According to Sandison and Hill (1966), all the waters entering from the west of the Lagos harbour flow through the Badagry creek and the harbour forms the main outlet to the sea for the brackish and fresh water flowing through the marginal lagoon system of South-western Nigeria. Nwankwo and Onitiri (1992), observed that rainfall and flood waters were the most important factors operating in a distant lagoon from the Lagos harbour. According to them, these factors act as forcing function by introducing nutrient through flood waters which affects the chemical environment. The flood effect determined the rate at which resident phytoplankton species within the lagoon were pushed westwards towards the sea. A similar flood effect on periphyton assemblages in the Epe lagoon has been reported by (Nwankwo and Onitiri, 1992).

The physico-chemical parameters observed in the lagoon exhibited seasonal changes that are closely related to the distributive pattern of rainfall of the region. According to Brown and Kusemiju (2002), rainfall pattern in the tropics creates the dry and wet season experienced in West Africa.For instance the raining season concentrated between May and October was accompanied by low conductivity, pH, temperature, transparency, cations, total dissolved solids, salinity, total alkalinity, biochemical oxygen demand, chemical oxygen demand and total hardness.On the other hand,the total suspended solids,total solid, dissolved oxygen, and nutrients levels increased (Sandison,1966; Sandison and Hill,1966; Nwankwo1996).Past researchers had observed that hydrological conditions and the phytoplankton spectrum of the Lagos and Epe lagoons are governed by the rainfall events and tidal seawater inflow (Hill and Webb, 1958). Seasonal and spatial changes in the phytoplankton biomass and community were recorded during the two year seasonal cycle and were in response to changes in environmental factors. There were clear differences in phytoplankton species biomass between stations within Ologe lagoon further off the effluent discharge station and stations closer to, or on it during the different seasons. The phytoplankton species biomass ranged between 849 cells/ml and 177107 cells/ml among all the sampling stations with a mean value of 44052 cells/ml for the duration of study. The highest total count (177107 cells/ml) was recorded at station OL10 (Asepe Mushin) in the month of December 2002, while the lowest value (849 cells/ml) was observed at station OL4 (point of effluent discharge)

in the month of April. Investigating phytoplankton dynamics as influenced by effluent discharges from Agbara industrial and residential estates and other human activities will give an in-sight into the exploitation of various microhabitats offered by the underlying causal factors.

The seasonal variations in the composition of the observed phytoplankton species were similar to that of the rest of the lagoon system (Nwankwo,1996) and probably falls into a single floristic grouping dominated by the species of genera of centric diatom *Aulacoseira* sp and cyanobacteria (*Microcystis* sp). Similar dominance of diatoms among phytoplankton assemblages have been reported by other ecologists in the coastal waters of Nigeria (Nwankwo and Onyema, 2004; Onyema and Nwankwo, 2006).

Phytoplankton densities were higher in the dry season than the wet (rainy) season. Ezra and Nwankwo (2001) also recorded higher cell densities in phytoplankton in the dry season than was in the wet season in Gubi reservoir, Bauchi state.Similar observation was made by Nwankwo(1998) in Epe Lagoon. Some of the recorded taxa such as *Microcystis aeruginosa, M.flos-aquae, Anabaena spiroides, Aulacoseira granulata, A. granulata* var. *angustissima, Desmidium swartzii* and *Ankistrodesmus* sp and euglenoid species are indicators of organic pollution and have been associated with eutrophic waters elsewhere. They may have existed in the Lagoon owing to increased influx of nutrients through Agbara industrial effluents and other human activities.

Analysis using ANOVA showed significant differences in the sample means of physico-chemical parameters of effluent discharge station (OL4) and the other stations within the lagoon at 5% level of probability. Changes in species diversity and phytoplankton abundance are attributed to changes in rainfall pattern and its associated influx of floodwaters. Comparatively, lower species diversity recorded during the dry season than the wet season was in consonance with Nwankwo (1996) for the Lagos lagoon. Co-efficient of similarity index indicated that stations close to each other are more similar, than stations further apart. There was also, dissimilarity among stations in the different seasons of the year. Nine phytoplankton species were reported to be potentially harmful/toxic bloom species (Hallegraeff *et al*., 1995; Nwankwo et al., 2003).

The seasonal data which were based on cell counts may be an accurate reflection of biomass. The main growth period appeared to begin immediately after the rains, this being associated with increased nutrients, decreasing flood conditions, and increasing transparency. The prevalence of pennate diatoms in the rainy season may be due to their recruitment from the littoral, rivers, and adjoining swamps. The present observation that diversity varied with the season and changes in phytoplankton composition agrees with observations made in the Lagos Lagoon (Nwankwo 1996). Following the use of the above community structure indices, a biological appraisal of that lagoon was satisfactorily done. Between November and December, the period immediately after the rains, there was the *Aulacoseira-Microcystis* assemblage while between January and April, the *Aulacoseira-Microcystis*-euglenoids assemblage dominated. The dominance of these taxa may have accounted for the low diversity indices recorded during the study period.

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References

[1] Adesalu,T.A., Nwankwo, D. I. (2009). A checklist of Lekki lagoon diatoms. International Journal of Botany. (5) 2:126-34.
[2] Alanine C.I.O. 1981. A review of the potentialities for research and fish culture in the coastal lagoons of West Africa. UNESCO Tech. Pap. Marine Sci., 33 (Proc. UNESCO/IABO Seminar "Coastal lagoon research present and future"), 261-272.
[3] Barber H.G., and Haworth E.Y. 1981. A guide to the morphology of the diatom frustule. Freshwater Biol. Assoc. Publ., 44, 9-11.
[4] Barnes R.S.K. 1980. Coastal lagoons. London, Cambridge Univ. press, 106 pp.
[5] Desikachary T.V. 1959. Cyanophyta. New Delhi, Indian Council of Agricultural Research, 686 pp.
[6] Hendey N.I. 1964. An introductory account of the smaller algae of British coastal waters. 5. Bacillariophyceae (Fishery Investigations, Ser. 4). London, HM Stationery Office, 317 pp.

[7] Lund J.W., Kipling G.C. and Le Cren E.D. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimation by counting. Hydrobiologia, 11, 143-170.
[8] Kusemiju K. 1988. Strategies for effective management of water hyacinth in the creeks and lagoons of south-western Nigeria. Proc. Internat. Workshop on water hyacinth, Lagos, 7-17 August 1988 (eds: Oke O.L., Imevbore A.M.A. and Farri T.A.). 39-45.
[9] Macereth F.J.H. 1971. Water analysis for limnologists. Windermere, Freshwater Biol. Assoc.
[10] Margalef R. 1951. Diversidad de especies en las comunidades naturals. Publ. Inst. Biol. Apl. Barcelona). 9, 5-27.
[11] Nwankwo D.I. 1984. Seasonal changes of phytoplankton of Lagos Lagoon and the adjacent sea in relation to environmental factors. PhD thesis, University of Lagos, 447 pp.
[12] Nwankwo D.I. 1986. phytoplankton of a sewage disposal site in Lagos Lagoon, Nigeria. 1. The algae. Nig. J. Biol. Sci. 1, 89-96.
[13] Nwankwo D.I and Akinsoji A. 1989. the benthic algal community of a sawdust deposition site in Lagos Lagoon. Internt. J. Ecol. Env. Sci., 15, 197-204.
[14] Nwankwo D.I. 1990a. Contributions to the diatom flora of Nigeria. 1. Diatoms of Lagos Lagoon and the adjacent sea. Nig. J. Bot., 3, 53-70.
[15] Nwankwo D.I. 1990b. Distribution and seasonal variation of dinoflagellates in Lagos Lagoon, Nigeria. Nig. J. Bot., 3, 197-207.
[16] Nwankwo D.I 1991a. A survey of the dinoflagellates of Nigeria. 1. Armoured dinoflagellates of Lagos Lagoon and associated tidal creeks. Nig. J. Bot., 4, 49-60.
[17] Nwankwo D.I. 1991b. Periphyton algae on fish fences "Acadja" in a tropical open lagoon. Internat. J. Ecol. Env. Sci., 17, 1-10.
[18] Nwankwo D>I. and Akinsoji A. 1992. Epiphyte community on water hyacinth, *Eichhornia crassipes* (Mart.) Solms in coastal waters of south-western Nigeria. Arch. Hydrobiol., 124, 501-511.
[19] Nwankwo D.I. and Onitiri A.O. 1992. Periphyton (Aufwuchs) community on submerged aquatic macrophytes in Epe Lagoon. Nigeria. J. Agric. Sci. Tech., 3, 135-141.
[20] Nwankwo D.I. 1993. Cyanobacteria bloom species in coastal waters of south-western Nigeria. Arch. Hydrobiol., Suppl. 90, 533-542.
[21] Nwankwo D.I. 1994. Hydrochemical properties and bottom-dwelling diatoms of a Lagos lagoon sewage disposal site. Pol. Arch. Hydrobiol., 41, 37-47.
[22] Nwankwo D.I., Abosede A.O. and Yusuf A. 1994. Floating timber logs as a substrate for periphyton algae in the Lagos Lagoon, Nigeria. Pol. Arch. Hydrobiol., 41, 419-430.
[23] Nwankwo D.I. 1996. Phytoplankton diversity and succession in Lagos Lagoon, Nigeria. Arch. Hydrobiol., 135, 529-542.
[24] Onyema, I.C. (2008b): A checklist of phytoplankton species of the Iyagbe lagoon, Lagos. Journal of Fisheries and Aquatic Sciences. **3**(3): 167 – 175.
[25] Patrick R. and Reimer C.W. 1966. The diatoms of the United States exclusive of Alaska and Hawaii (vol. 1). Monogr. Acad. Nat. Sci. Philadelphia, 13, 686 pp.
[26] Patrick R. and Reimer C.W. 1975. The diatoms of the United States exclusive of Alaska and Hawaii (vol. 2, part 1). Monogr. Acad. Nat. Sci. Philadelphia, 213 pp.
[27] Pielou E.C. 1966. The measurement of diversity in different types of biological collections. J. Theoret. Biol., 13, 131-144.
[28] Prescott G.W. 1961. Algae of the Western Great Lakes Area. Dubugue (lowa), Brown, 977 pp.
[29] Shannon C.E. and Weaver W. 1949. The mathematical theory of communication. Urbana, Univ. Illinois Press, 125 pp.
[30] Welch P.S. 1984. Limnological methods. New York, McGraw-Hill, 370 pp.
[31] Wetzel G. and Likens G.E. 1979. Limnological analyses. Philadelphia, Saunders, 357 pp.

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