Chlorophyll *a* dynamics and environmental factors in a tropical estuarine lagoon

*Onyema, I.C. and Nwankwo, D.I.

Department of Marine Sciences, University of Lagos, Akoka.
*e-mail: iconyema@gmail.com

Abstract: The chlorophyll *a* dynamics and environmental factors of the Iyagbe lagoon, Lagos was investigated for 2 years (Oct., 2004 - Sept., 2006). The environmental indices reflected seasonal changes related to rainfall distributive pattern and tidal seawater incursion. Air temperature (26 - 34°C), surface water temperature (26 - 33°C), total dissolved solids (90 - 25,000mgl^{-1}), transparency (22 - 231cm), sulphate (20.8 - 1140mgl^{-1}), silica (0.9 - 6.0mgl^{-1}), dissolved oxygen (4 - 5.6mgl^{-1}), conductivity (110 - 40850 S/cm), salinity (0.06 - 35.1%), chloride (20.5 - 15,015mgl^{-1}), pH (6.7 - 8.42), acidity (3.8 - 44mgl^{-1}), alkalinity (15.3 - 30mgl^{-1}), total hardness (18 - 6875mgl^{-1}), calcium (10 - 720.1mgl^{-1}) and magnesium (1.4 - 900mgl^{-1}) recorded increased values in the dry than wet season. On the other hand chemical oxygen demand, biological oxygen demand, total suspended solids(18 - 2310mgl^{-1}), nitrate (3.3 - 59.8mgl^{-1}), phosphate (0.01 - 1.68mg), copper (0.001 - 0.079mgl^{-1}), zinc (0.001 - 0.015mgl^{-1}) and iron (0.06 - 1.08mgl^{-1}) recorded higher values in the wet season. Values for chlorophyll *a* were higher in the dry than wet season for the lagoon. Positive correlation coefficient was recorded between chlorophyll *a* and salinity, total dissolved solids, alkalinity, pH, conductivity total hardness, chloride, transparency, acidity, nitrate, sulphate, calcium and magnesium levels. Recorded chlorophyll *a* values places the Iyagbe lagoon between the mesotrophic and eutrophic status. It is suggested that increasing tidal influence associated with reduced rain events may have encouraged elevated salinities and created conditions for the development of more algal cells, hence higher chlorophyll *a* records. [Academia Arena, 2009;1(1):18-31]. ISSN 1553-992X.

Keywords: Physico-chemical factors, brackish, microalgae, hydroclimatic factors, Nigeria.

Introduction

Lagoons are ecologically and economically important aquatic ecosystems in South-western Nigeria. They provide natural food resources rich in protein which includes an array of fish and fisheries. They are also important in water transportation, energy generation, exploitation and exploration of some mineral resources including sand (FAO, 1969; Kirk and Lauder, 2000; Onyema *et al*., 2003, 2007; Chukwu and Nwankwo, 2004; Onyema, 2008a). Lagoons also inadvertently serve as sinks for the disposal of both domestic, municipal and industrial wastes in the region. There are nine lagoons in South-western Nigeria namely: Yewa, Ologe, Badagry, Iyagbe, Lagos, Kuramo, Epe, Lekki and Mahin lagoons from the west to the east (FAO, 1969, Webb, 1958a; Nwankwo, 2004b; Onyema, 2008).

Furthermore, chlorophyll *a* is an essential plant pigment and concentrations of it could be used to reflect algal biomass and hence, level of primary production. Chlorophyll *a* can be an effective measure of trophic status (Lee, 1999). However, elevated chlorophyll *a* concentrations often indicate poor water quality and low levels often suggest good conditions (Ogamba, *et. al*., 2004). According to Lee (1999), higher Phytoplankton biomass would directly reflect in a higher level of chlorophyll *a* in such regions. One method to determine the amount of plant materials present in a water sample is to filter out the phytoplankton, count the cells and multiply the number counted by the average mass per individual cell (Sverdrup *et al*., 2006). A less tedious method is to extract the chlorophyll from a sample of phytoplankton and determine the concentration of pigment present. Hence chlorophyll concentration can be used to estimate the total quantity of plant material or biomass (Sverdrup *et al*., 2006).

The immense ecological significance of phytoplankton diversity studies especially in relation to aquatic trophic relationships cannot be understated (Smith, 1950; Lee, 1999; Nwankwo, 1984, 2004a). Coastal areas are generally more productive than the open oceans because rivers and land run-offs supply nutrients along coasts and adjoining estuarine systems. With regard to the annual rates of global primary production and productivity, Lagos offshore falls under the high productivity category (= 300gC/m^2/yr) (Sverdrup *et al*., 2006).

Determination of primary production in the Lagos lagoon has primarily been by biomass estimation using cells number of phytoplankton (Nwankwo, 2004). With regard to chlorophyll *a* in Nigeria, there exist a report by Kadiri (1993) on the Ipkoba reservoir in Benin and another by Ogamba *et al*., (2004) on chlorophyll *a* levels and variations in the Niger Delta region. Hence studies in Nigeria using chlorophyll *a* method are limited.

At present, there is no report on any of the nine lagoons of South-western Nigeria with regard to the chlorophyll *a* method of estimation. The aim of this study was to investigate the seasonality in chlorophyll *a* concentration and relate findings to environmental factors in the Iyagbe lagoon.

Materials and Methods

Description of Study Site

The Iyagbe lagoon (Fig 1) is located in Lagos state, Nigeria and is one of the nine lagoons in South-western Nigeria (Webb, 1958a; Nwankwo, 2004b; Onyema, 2008a). It is located between Latitude 6^0 26'N Longitude 3^0 19' E and Latitude 6^0 23'N Longitude 3^0 06' E (Webb, 1958a; Onyema, 2008a,b). It is majorly made up of the Porto-Novo and Badagry creeks. The Iyagbe lagoon is centered about the town of Iyagbe (Webb, 1958a). The lagoon is shallow at some point especially in the Badagry creek arm and is open all year round via the Lagos harbour to the sea (Webb, 1958b; Webb and Hill, 1958; Sandison, 1966; Sandison and Hill, 1966). Like all parts of South-western Nigeria, the Iyagbe 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 are experienced sometimes between November and January in the region reducing visibility and lowering temperatures (Onyema *et al.*, 2003). Dense rain forest zone vegetation preceded by littoral mangrove 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 of the Iyagbe lagoon area away from the Tin can Island and Apapa Ports are colonized by a recognizable riparian mangrove swamp community especially where man made structure are absent. These mangrove environments are inhabited by amphipods, polychaetes, isopods, barnacles, oysters, periwinkles, nematodes, fiddler crabs, sea cucumbers, mangrove crabs, mudskippers and shrimps among others (Sandison and Hill, 1966; Onyema, 2008b). The notable macro-floral species in the area include *Rhizophora racemosa, R. harrisoni, Avicennia germinans, Phoenix reclinata, Raphia hookeri, Elaeis guineensis, Acrotiscum aureum* and *Cocos nucifera* (Akinsoji *et al*., 2002).

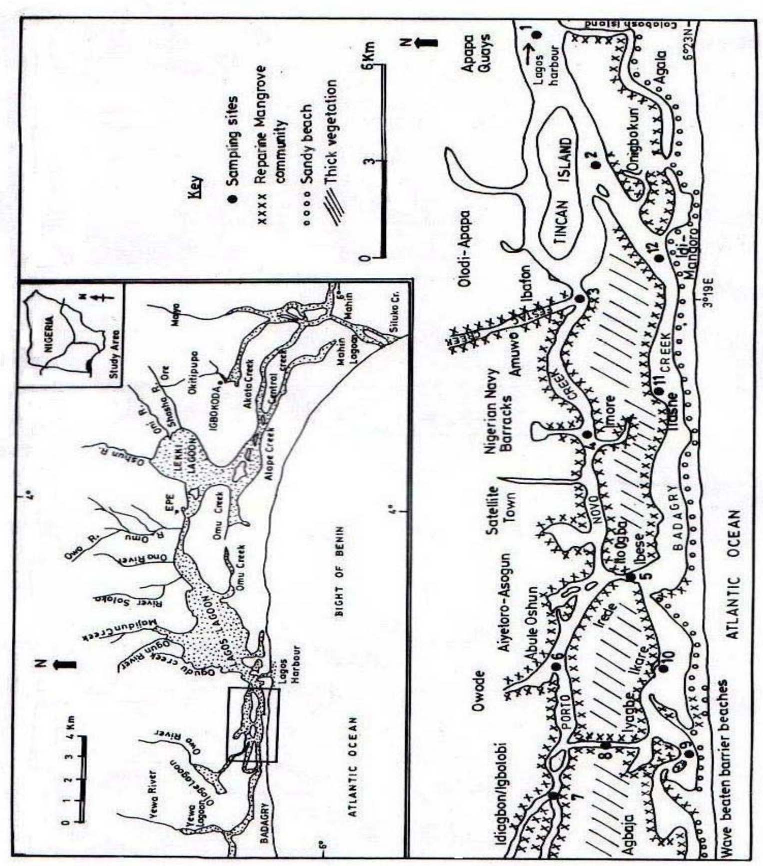

Fig. 1: Parts of Iyagbe Lagoon, Porto-Novo and Badagry Creeks Showing Sampling Sites.

Collection of samples.

Collection of water samples

Twelve sampling stations were selected to cover the lagoon area and for the collection of samples. Table 1 shows the G.P.S. location, names and number of sampling stations. Monthly surface water samples was collected for twenty-four consecutive months (October, 2004 – September, 2006) 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 to further analysis. Water samples for Dissolved Oxygen was collected also in 50cl bottles and fixed on site with white and black ampoules.

Table 1: G.P.S. location and station name of sampled areas in the Iyagbe lagoon.

Table 2 below presents the methods / device used in estimating the various environmental factors for this study with corresponding references.

Station No.	**Station name**	**G.P.S. locations**
Station 1	Calabash Island	Latitude 6^o 25^1.987 N, Longitude 3^o 23^1.400 E
Station 2	Tin-can Island	Latitude 6^o 25^1 .833 N, Longitude 3^o 21^1 .532 E
Station 3	Ibafon	Latitude 6^o 25^1 .964 N, Longitude 3^o 19^1 .244 E
Station 4	Imore	Latitude 6^o 25^1 .755 N, Longitude 3^o 19^1 .915 E
Station 5	Ito-ogba	Latitude 6^o 25^1 .409 N, Longitude 3^o 14^1 .624 E
Station 6	Abule-oshun	Latitude 6^o 26^1 .134 N, Longitude 3^o 13^1 .224 E
Station 7	Idiagbon / Igbolobi	Latitude 6^o 26^1.214 N, Longitude 3^o 11^1 .826 E
Station 8	Iyagbe	Latitude 6^o 25^1 .603 N, Longitude 3^o 11^1 .990 E
Station 9	Agbaja	Latitude 6^o 24^1 .473 N, Longitude 3^o 12^1 .744 E
Station 10	Ikare	Latitude 6^o 24^1 .632 N, Longitude 3^o 13^1 .705 E
Station 11	Ilashe	Latitude 6^o 24^1 .676 N, Longitude 3^o 16^1 .938 E
Station 12	Idimangoro	Latitude 6^o 24^1 .717 N, Longitude 3^o 19^1 .307 E

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

	Parameter/ Unit	Method / Device	Reference(s)
1	**Air temperature (^oC)**	Mercury – in – glass thermometer	Nwankwo (1984)
2	**Water temperature (^oC)**	Mercury – in – glass thermometer	Onyema (2008)
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	**Chloride (mgL^{-1})**	Argentometric method	APHA (1998)
9	**Total hardness (mgL^{-1})**	Titrimetric method	APHA (1998)
10	**pH**	Electrometric / Cole Parmer Testr3	
11	**Conductivity (µS/cm)**	Philip PW9505 Conductivity meter	
12	**Salinity (‰)**	HANNA Instrument	APHA (1998)
13	**Alkalinity (mgL^{-1})**	Titration method	APHA (1998)
14	**Acidity (mgL^{-1})**	Titration method	APHA (1998)
15	**Dissolved oxygen (mgL^{-1})**	Titration method	APHA (1998)
16	**Biological oxygen demand (mgL^{-1})**	Incubation and Titration	APHA (1998)
17	**Chemical oxygen demand (mgL^{-1})**	Titration method	APHA (1998)
18	**Nitrate – nitrogen (mgL^{-1})**	Colorimetric method	APHA (1998)
19	**Phosphate – phosphorus (mgL^{-1})**	Colorimetric method	APHA (1998)
20	**Sulphate (mgL^{-1})**	Turbidimetric method	APHA (1998)
21	**Silica (mgL^{-1})**	Colorimeter (DR2010)	APHA (1998)
22	**Calcium (mgL^{-1})**	Titrimetric method	APHA (1998)
23	**Magnesium (mgL^{-1})**	Titrimetric method	APHA (1998)
24	**Copper (mgL^{-1})**	Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application methods (2002)
25	**Iron (mgL^{-1})**	Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application methods (2002)
26	**Zinc (mgL^{-1})**	Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application methods (2002)
27	**Chlorophyll *a* (µg/L)**	Florometric method	APHA (1998)

Correlation Coefficient Values (r)

The Pearson correlation coefficient (r) (Ogeibu, 2005) for the relationship between the different environmental parameters and chlorophyll *a* were obtained using the formula:

$$r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{(n(\sum X^2 - (\sum X)^2] [n\sum Y^2 - (\sum Y)^2}}$$

Where
r = Coefficient of correlation
X and Y = Variables under consideration

Results

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.

Air temperature values ranged between 26 and 34^{0}C throughout the sampling period. Whereas the lowest value estimated was 26^{0}C (September, 2006), the highest value obtained was 34^{0}C recorded in March of the same year. The lowest surface water temperature estimated was 25^{0}C (September, 2005) and the highest value obtained was 33^{0}C (May, 2005). Transparency was between 11 (March, 2006) and 280 cm (December, 2004). Total dissolved solids ranged between 90 and 25000 mg/L with the lowest value recorded in September, 2005 and the highest value in April, 2006. Total suspended solids values ranged between 18 (February, 2005) and 2310 mg/ L (August, 2005). Rainfall volumes showed both monthly changes and varied from one year to the next. In the first year the highest rainfall volume was recorded in June 2005 (330 mm) and the least was in February 2005 (8.9 mm). In the second year the highest rainfall was in June 2006 (315.7 mm) and the least in January 2006 (6.0 mm). Recorded chloride values were between 20.5 (October, 2005) and 17710mg/L (April, 2006). Whereas the lowest value estimated for total hardness was 18 mg/L (July, 2006) whereas the highest value obtained was 6875 mg/L (December, 2005). Hydrogen ion concentration (pH) values ranged between 6.7 (June, 2006) and 8.42 (February, 2006) throughout the sampling period. Whereas the lowest conductivity estimated was 110µS/cm and recorded in October, 2004, the highest value obtained was 33092 µS/cm recorded in April, 2006.

Salinity value ranged between 0.06 (October, 2004), and 35.1$^o/_{oo}$ (April, 2006). Alkalinity values were between 18 (August, 2006) and 311.2 mg/L (February, 2005). Acidity estimates ranged between 3.8 and 60 mg/L (November, 2005 and January, 2006) respectively.

Dissolved Oxygen values ranged between 4 (September, 2005) and 5.6 mg/L (January, 2006) throughout the sampling period. Biological Oxygen Demand values ranged between 2 (March, 2005) and 22mg/L (September, 2006) throughout the sampling period. Chemical oxygen demand ranged between 8 (March, 2005) and 211mg/l (Feburary, 2006). Nitrate-nitrogen values werebetween 3.3 (November, 2005) and 59.8 mg/L (June, 2006) whereas Phosphate-phosphorus recorded between 0.01 mg/L (January, 2006) and 1.68 mg/L (August, 2005). Sulphate values ranged between 20.8 (October, 2005) and 1160 mg/L (January, 2006) throughout the sampling period. Silica values fell between 0.9 (August, 2005) and 6.0mg/L (September, 2006). Calcium levels were between 10mg/L in October, 2005 and 720.1 mg/L in November, 2004. Magnesium estimates were between 1.4 mg/L in July, 2006 and 981.1 mg/L in January, 2005 and Copper values was between 0.001 (May through July 2005) and 0.09 mg/L (August, 2005). Iron levels ranged between 0.06 and 1.08 mg/L (October 2004). Zinc values ranged between 0.001 and 0.015 mg/L (August, 2005).

Chlorophyll *a* values were between 4.2 and 55 µg/L. whereas the lowest value estimated was in June, 2005, the highest value obtained was recorded in November 2005. Chlorophyll *a* values showed a positive relationship with salinity (r = 0.21), transparency (r = 0.24), chloride (r = 0.21), total dissolved solids (r = 0.22), water temperature (r = 0.18), air temperature (r = 0.09), pH (r = 0.23), conductivity (r = 0.23), acidity (r = 0.10), alkalinity (r = 0.27), calcium (r = 0.17), magnesium (r = 0.27), nitrate (r = 0.11), chemical oxygen demand (r = 0.03), iron (r = 0.05) and sulphate (r = 0.20). A negative relationship existed between chlorophyll *a* and biological oxygen demand (r = -0.16), zinc (r = -0.02), copper (r = -0.04), total suspended solids (r = -0.07) and phosphates (r = -0.13) estimates. Table 4 shows the Seasonal variation in Chlorophyll *a* values at the different stations in the Iyagbe lagoon from Dec., 2004 to Nov., 2006, Table 5 tabulates the Pearson correlation co-efficient matrix of environmental characteristics. Fig. 2: Seasonal variation in some environmental factors at four selected station each and chlorophyll *a* at the Iyagbe lagoon from Dec., 2004 to Nov., 2006. Stations represented were selected based on their importance as confluence points and areas exposed to possible anthropogenic stresses or not. Furthermore, Fig. 3 shows the Pearson correlation coefficient between chlorophyll *a* and environmental factors.

Table 3: A summary of the minimum, maximum and mean / standard deviation estimate values for environmental factors from the Iyagbe lagoon (December, 2004 – November, 2006).

	Parameter/ Unit	Minimum value	Maximum value	Mean value ± S.D.	Higher values reported in the ….
1	**Air temperature (°C)**	26	34	30.07 ± 1.98	Dry season
2	**Water temperature (°C)**	26	33	29.42 ± 1.81	Dry season
3	**Transparency (cm)**	22	231	102.42 ± 51.47	Dry season
4	**Total Dissolved Solids (mgL^{-1})**	90	25000	8467.65 ± 6641.66	Dry season
5	**Total Suspended Solids (mgL^{-1})**	18	2310	172.48 ± 259.01	Wet season
6	**Rainfall (mm)**	6	315.7	141.83 ± 116.87	Wet season
7	**Chloride (mgL^{-1})**	20.5	15015	6316.55 ± 24167.13	Dry season
8	**Total hardness (mgL^{-1})**	18	6875	2035.82 ± 1485.42	Dry season
9	**pH**	6.7	8.42	7.40 ± 0.28	Dry season
10	**Conductivity (µS/cm)**	110	40850	13208.59 ± 10418.71	Dry season
11	**Salinity (‰)**	0.06	35.1	14.43 ± 18.10	Dry season
12	**Alkalinity (mgL^{-1})**	15.3	330	74.32 ± 74.25	Dry season
13	**Acidity (mgL^{-1})**	3.8	44	11.80 ± 7.48	Dry season
14	**Dissolved oxygen (mgL^{-1})**	4	5.6	4.67 ± 0.23	Dry season
15	**Biological oxygen demand (mgL^{-1})**	2	22	7.15 ± 3.52	Wet season
16	**Chemical oxygen demand (mgL^{-1})**	8	89	30.21 ± 21.08	Wet season
17	**Nitrate – nitrogen (mgL^{-1})**	3.3	59.8	10.54 ± 8.37	Wet season
18	**Phosphate – phosphorus (mgL^{-1})**	0.01	1.68	0.26 ± 0.29	Wet season
19	**Sulphate (mgL^{-1})**	20.8	1140	279.71 ± 232.16	Wet season
20	**Silica (mgL^{-1})**	0.9	6.0	2.63 ± 0.91	Dry season
21	**Calcium (mgL^{-1})**	10	720.1	188.49 ± 130.05	Dry season
22	**Magnesium (mgL^{-1})**	1.4	900	333.36 ± 264.92	Dry season
23	**Copper (mgL^{-1})**	0.001	0.079	0.003 ± 0.001	Wet season
24	**Iron (mgL^{-1})**	0.06	1.08	0.29 ± 0.25	Wet season
25	**Zinc (mgL^{-1})**	0.001	0.015	0.002 ± 0.002	Wet season
26	**Chlorophyll *a* (µg/L)**	4.2	55	19.63 ± 7.90	Dry season

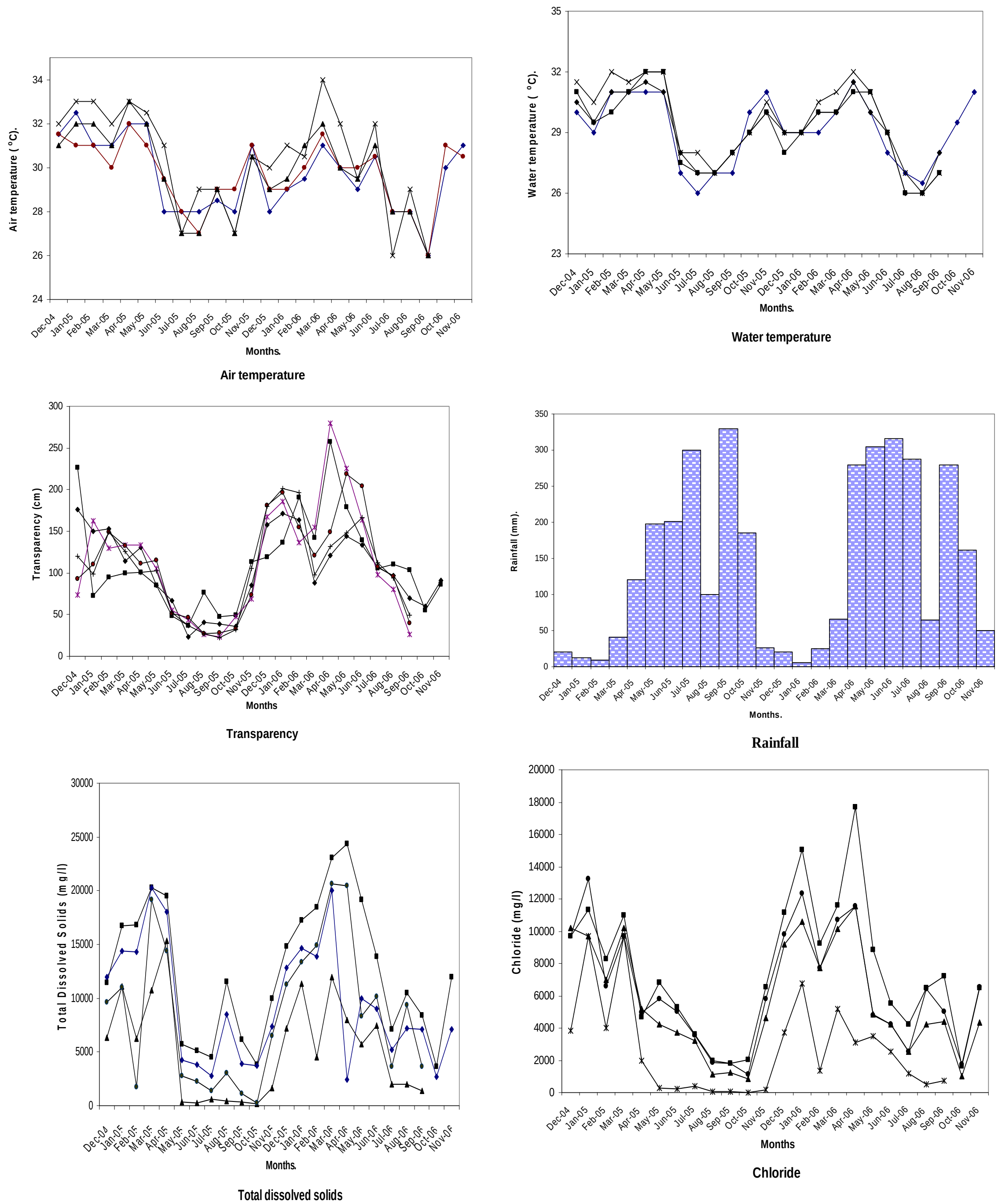

Fig. 2: Seasonal variation in some environmental factors and chlorophyll *a* at the Iyagbe lagoon from Oct., 2004 to Sept., 2006.

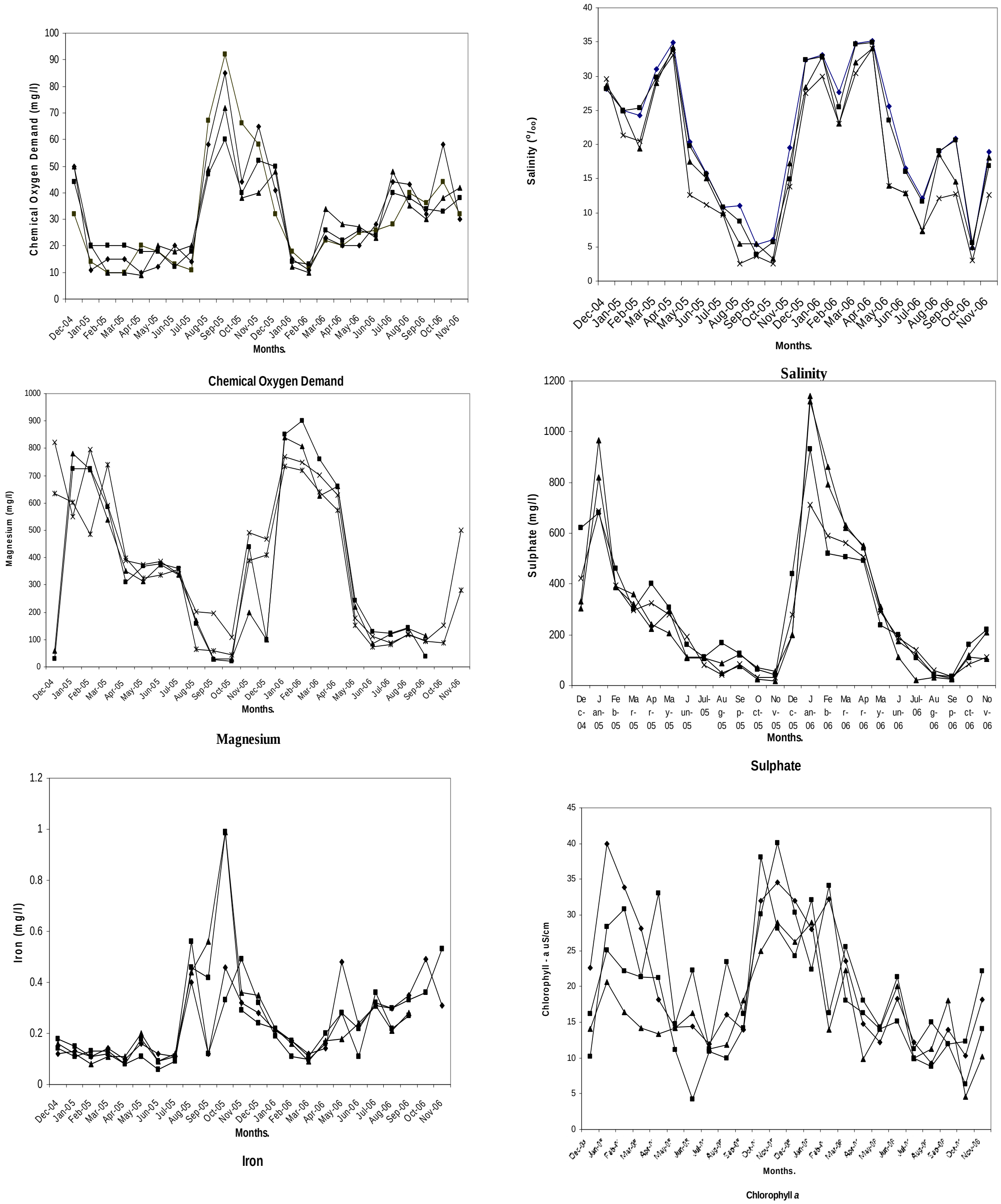

Fig. 2: Seasonal variation in some environmental factors and chlorophyll *a* at the Iyagbe lagoon from Oct., 2004 to Sept., 2006.

Fig 3: Pearson correlation coefficient between chlorophyll *a* and environmental factors.

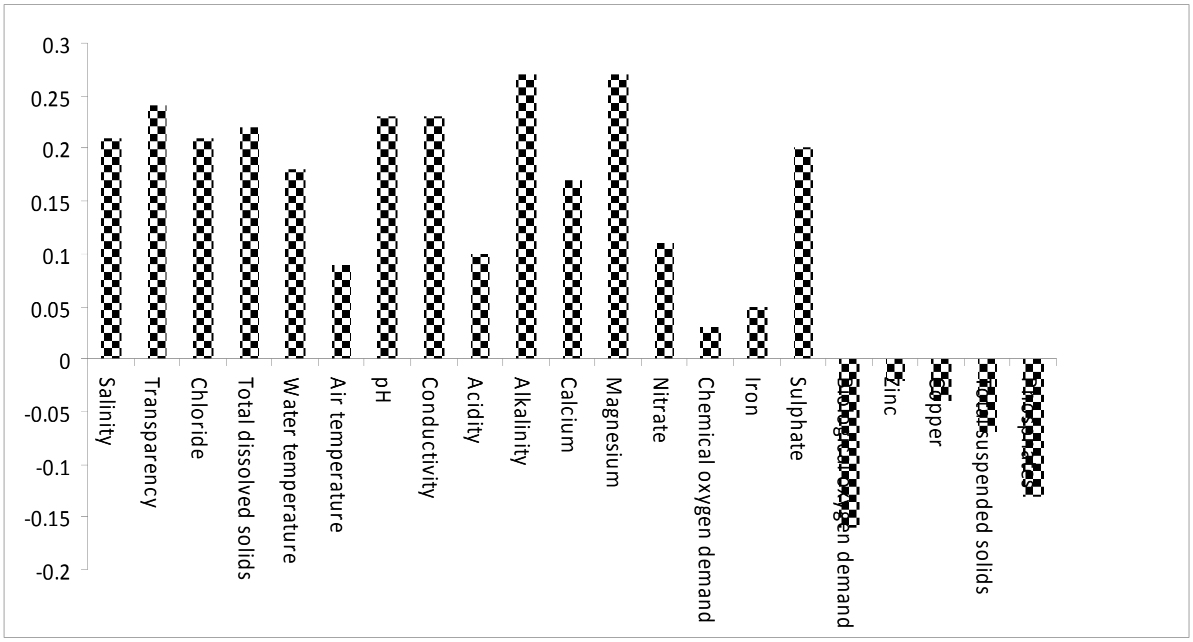

Table 4: Seasonal variation in Chlorophyll *a* values at the different stations in the Iyagbe lagoon, (Dec., 2004 – Nov., 2006).

	2004	2005														2006								
	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.
Calabash Island	22.6	40	33.9	28.1	18.2	14.3	14.4	12	16	14	32	34.6	32	28	32.2	23.6	14.8	12.2	18.3	12.2	9.3	14	10.3	18.2
Tincan Island	10.2	28.4	30.8	21.3	33.1	14.8	22.3	11.3	23.4	16.2	30.1	40.1	30.3	22.4	34.1	18	16.3	14.1	15.1	10	8.8	12	12.3	22.1
Ibafon	14.1	22.3	33.4	20.8	30	20.1	18.3	14.9	20.1	14.3	32.1	33.2	26	15.2	30.8	20.1	20.2	18.8	15.3	10.8	12.1	18	14.2	11
Imore	11.3	30.1	33.1	16.9	28.1	16.3	11.4	12.2	18.2	18.1	24	36	20.1	22	16	14.2	21.6	16.2	20	25	16.3	20	16.8	8.6
Ito-Ogba	19.2	22.4	28.6	14.8	20.1	14.1	16.3	16.4	12.6	11.3	33.2	30.8	22	18.9	14.2	22.3	25	20.1	32.3	22.6	28.1	13	14.2	11.3
Abule Oshun	18	21.3	15.1	18.3	20.6	15.2	19.2	14.4	10.7	18.3	34.1	26.1	20.3	30.2	21.3	26.1	28.1	21.6	30.6	18.4	15.2	16	11.1	10.3
Idiagbon	11.3	20.8	15.9	21.2	14.4	14.8	18.3	12.3	12.3	21.3	30.2	24.2	24.6	26.3	20.6	23.2	22.3	24.1	22.8	19.3	14.3	21	6.6	9.6
Iyagbe	12.1	21.2	20.3	15	21.3	16.3	16.2	14.2	14.1	10.2	39	50.1	22.9	24	13	28.4	33.2	23.8	22.4	10.2	12.1	16	4.9	8.3
Agbaja	14.8	22.3	16.2	18.1	16.8	14.1	14.8	18.6	10	16.3	33.3	22.6	33.6	33.4	14.2	20.1	29.3	20.6	28	16.8	16.3	11	18.2	9.4
Ikare	10.3	24.4	18.1	16.3	17.1	21.2	11.3	10.1	16	12.1	34	55	38.1	26	23	29.2	25.3	26.5	24.3	14.1	18.8	20	10	8.6
Ilashe	16.2	25.1	22.1	21.3	21.2	11.1	4.2	10.9	10	14.2	38.1	28.1	24.2	32.1	16.3	25.6	18.1	14.3	21.3	11.2	15	12	6.3	14.1
Idi-Mangoro	14.1	20.6	16.4	14.2	13.4	14.2	16.3	11.3	11.8	18.1	25	29	26.3	29	14	22.3	9.8	14.1	20	10	11.3	18	4.6	10.2

Table 5: Pearson correlation co-efficient matrix of environmental characteristics at the Iyagbe lagoon, Lagos (December, 2004 – November, 2006)

	Air temperature	Water temperature	Transparency	T.D.S.	T.S.S.	Chloride	Total hardness	pH	Conductivity	Salinity	Alkalinity	Acidity	D.O.	B.O.D.	C.O.D.	Nitrate	Phosphate	Sulphate	Silica	Calcium	Magnesium	Copper	Iron	Zinc	Chlorophyll *a*
Air temperature	1																								
Water temperature	0.77	1																							
Transparency	0.34	0.40	1																						
T.D.S.	0.35	0.39	0.54	1																					
T.S.S.	-0.18	-0.22	0.38	0.22	1																				
Chloride	0.06	0.10	0.20	0.17	-0.08	1																			
Total hardness	0.39	0.41	0.55	0.62	-0.19	0.20	1																		
pH	0.27	0.32	0.43	0.46	-0.19	0.16	0.60	1																	
Conductivity	0.40	0.44	0.57	0.96	-0.25	0.17	0.64	0.49	1																
Salinity	0.38	0.45	0.57	0.88	-0.29	0.17	0.73	0.48	0.89	1															
Alkalinity	0.34	0.26	0.41	0.28	-0.16	0.14	0.54	0.71	0.33	0.28	1														
Acidity	0.13	0.10	0.42	0.33	-0.24	0.13	0.38	0.48	0.33	0.32	0.64	1													
D. O.	-0.13	-0.07	0.19	0.18	-0.26	0.22	0.08	0.10	0.17	0.20	0.06	0.18	1												
B.O.D.	-0.39	-0.45	-0.38	-0.36	0.37	-0.14	-0.46	-0.25	-0.40	-0.45	-0.31	-0.36	-0.05	1											
C.O.D.	-0.25	-0.26	-0.18	-0.26	0.45	-0.07	-0.15	-0.09	-0.29	-0.27	-0.16	-0.26	-0.20	0.57	1										
Nitrate	-0.01	-0.04	0.25	0.18	0.20	0.22	0.27	0.33	0.15	0.18	0.34	0.45	0.14	-0.07	0.11	1									
Phosphate	-0.25	-0.24	-0.32	-0.28	0.50	-0.08	-0.31	-0.13	-0.32	-0.37	-0.26	-0.29	-0.07	0.54	0.36	0.00	1								
Sulphate	0.46	0.37	0.50	0.53	-0.18	0.15	0.60	0.56	0.55	0.57	0.67	0.58	0.16	-0.40	-0.23	0.49	-0.30	1							
Silica	-0.18	-0.14	0.12	-0.01	-0.36	-0.04	-0.19	-0.16	0.02	0.04	-0.17	0.03	0.12	0.02	-0.08	-0.24	-0.16	-0.17	1						
Calcium	0.41	0.43	0.33	0.49	-0.15	0.11	0.64	0.38	0.52	0.56	0.27	0.14	0.18	-0.35	-0.16	0.07	-0.24	0.35	-0.09	1					
Magnesium	0.45	0.43	0.46	0.64	-0.18	0.21	0.77	0.60	0.67	0.66	0.60	0.52	0.14	-0.51	-0.30	0.32	-0.34	0.70	-0.16	0.52	1				
Copper	-0.23	-0.29	-0.20	0.08	0.59	-0.04	-0.10	0.01	-0.11	-0.17	-0.04	-0.12	-0.04	0.38	0.34	0.20	0.53	-0.08	-0.31	-0.10	-0.12	1			
Iron	-0.21	-0.16	-0.35	0.44	0.11	-0.10	-0.38	-0.21	-0.47	-0.48	-0.28	-0.31	-0.08	0.43	0.22	-0.12	0.37	-0.44	-0.26	-0.33	-0.44	0.21	1		
Zinc	-0.11	-0.19	-0.27	-0.11	0.16	-0.07	-0.13	0.01	-0.14	-0.15	-0.03	-0.16	-0.02	0.46	0.24	-0.03	0.37	-0.06	-0.25	-0.09	-0.14	0.43	0.27	1	
Chlorophyll *a*	0.09	0.18	0.24	0.22	-0.07	0.12	0.33	0.23	0.23	0.21	0.27	0.10	0.09	-0.16	0.03	0.11	-0.13	0.20	-0.18	0.17	0.27	-0.04	0.05	-0.02	1

Discussion

The characteristics of environmental factors from this study shows clearly that the Iyagbe lagoon experiences environmental gradients likened to a tropical estuarine aquatic environments from year to year (Hill and Webb, 1958; Webb, 1960; Sandison and Hill, 1966; Kjerfve, 1994; Kirk and Lauder, 2000). Furthermore environmental factors of the lagoon exhibited seasonal changes that were closely related to the distributive pattern of rainfall of the region. For instance during the wet season, reduced levels for air and water temperatures, transparency, salinity, pH, total dissolved solids, conductivity, chloride, total hardness, sulphate, calcium, magnesium, acidity, total dissolved solids and alkalinity were recorded. Conversely, in the dry season the values for these parameters increased. Reduced rain events and its associated input of floodwaters from rivers, creeks, adjoining wetlands and the effect of tidal seawater incursion probably lead to this trend of environmental gradients. Reduced phytoplankton densities as reflected in chlorophyll *a* values in the wet season may be linked to the low water clarity which reduces the amount of light getting to planktonic algal component for photosynthesis. Higher chlorophyll *a* values recorded in the dry season is a pointer to improved water clarity at this time which probably allowed greater light penetration. According to Suzuki *et al*. (2002), low chlorophyll *a* values reflecting limited phytoplankton growth in an investigation of a Mexican lagoon were associated to dark water which reduced light penetration into the lagoon considerably.

Pearson correlation co-efficient showed positive correlation between chlorophyll *a* values, salinity, total dissolved solids, alkalinity, pH, conductivity, total hardness and chloride values among others. The flushing of planktonic algal forms towards the sea during the rains by flood waters and hence dilution, could also account for the low chlorophyll *a* values (phytoplankton densities) recorded at such times. The range of chlorophyll *a* values for the Iyagbe lagoon was between 12 and 55µg/l i.e between the mesotrophic and eutrophic productivity status (Suzuki *et al*., 2002, APHA, 1998). Furthermore, Ogamba *et al*., (2004) reported a chlorophyll *a* range of 0.15 – 37.4µg/l for the wet season and 0.10 and 40.28µg/l for the dry season in the Elechi creek in the Niger delta. Kadiri (1993) also reported a range of 4.20 – 35.20 mgm^{-3} for chlorophyll *a* for the Ikpoba reservoir in Benin.

Kadiri (1993) reported on the seasonal changes in the chlorophyll *a* situation of a shallow reservoir in Benin, Nigeria. Higher cloud cover situations attributed to the rainy season have been noted to impair chlorophyll *a* estimates (Kadiri, 1993) and phytoplankton biomass (Nwankwo, 1988) in some parts of the country. On the other hand, increases in insolation usually noted in the dry season likely encourage higher productivity, as recorded for this study. Furthermore, Onyema *et al*. (2003, 2007), are of the view that higher insolation, increased hydrological stability and marine situation are important encouraging factors for primary production in the Lagos lagoon. According to Kadiri (1993) 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. Similarly, sainfall and salinity are known to regulate the occurrence and distribution of biota in the Lagos lagoon and its associated creeks (Nwankwo and Onyema, 2003; Nwankwo, 2004).

Besides the ample availability of nutrients in this region, values for chlorophyll *a* were comparatively low especially in the wet season which likely indicated limited phytoplankton production. Similarly, Dissolved oxygen levels throughout the period of study were comparatively higher in the dry season than the wet season. It is possible that higher primary productivity necessarily resulted in higher chlorophyll *a* value and revealed a similar trend in dissolved oxygen values, since oxygen is a by-product of photosynthesis. It is possible to infere that chlorophyll *a* values from this study were largely determined by the trend and continuum of environmental characteristics of the lagoon which varies tidally and seasonally.

Author:
I.C. ONYEMA Ph.D.
Dept. of Marine Sciences
Faculty of Science
University of Lagos, Akoka.
Lagos, Nigeria.
iconyema@yahoo.com.au, iconyema@gmail.com
+2348023446934, +2348060442323

9/2/2008

References.

American Public Health Association. (1998): Standard Methods for the Examination of Water and Waste Water. 20th ed. APHA New York. 1270pp.

Akinsoji, A., John, A. and Adekanye, M. (2002): Aquatic macrophytes of three selected sites in Lagos, Southwest Nigeria. Journal of Science, Technology Research and Development. 2(1): 9 – 15.

Brown, C.A. (1998): Distribution and population dynamics of an estuarine population of *Aloidis trigona* Hinds (Bivalvia). Acta. Hydrobiol. 40(4): 227 – 237.

Brown, C.A. and Oyenekan, J.A. (1998). Temporal variability in the structure of benthic macrofauna communities of the Lagos lagoon and harbour, Nigeria. Pol. Arch. Hydrobiol. 45(1): 45 – 54.

Chukwu, L. O. and Nwankwo, D. I. (2004): The impact of land based pollution on the hydro-chemistry and macrobenthic community of a tropical West African Creek. The Ekologia. 2 (1-2): 1 – 9.

F.A.O. (1969): Fisheries Survey in the Western and Mid-Western Regions of Nigeria. FAO/Sf: 74/NIR 6. 142pp.

Kjerfve, B. (Ed.) 1994: Coastal lagoon processes. Elsevier Oceanography Series 60. Elsevier, Amsterdam. 577pp.

Kirk, R.M. and Lauder, G.A. (2000): Significant coastal lagoon systems in the South Island, New Zealand. Coastal processes and lagoon mouth closure. *Science for conservation*.146**:** 47 p.

Kadiri, M.O. (1999): Phytoplankton distribution in some coastal waters of Nigeria. *Nigeria Journal of Botany*.**12** (1): 51 – 62.

Lee, R.E. (1999): Phycology. Cambridge University Press, New York. 614pp.

Nwankwo, D.I. (1984): Seasonal changes of phytoplankton of Lagos lagoon and the adjacent sea in relation to environmental factors. Ph.D. Thesis, University of Lagos. 447pp.

Nwankwo, D.I. (2004b). The Microalgae: Our indispensable allies in aquatic monitoring and biodiversity sustainability. University of Lagos Press. Inaugural lecture seris. 44pp.

Ogamba, E.N. Chindah, A.C., Ekweozor, I.K.E. and Onwuteaka, J.N. (2004): Water quality of phytoplankton distribution in Elechi creek complex of the Niger delta. Journal of Nigerian Environmental Society. 2(2): 121 – 130.

Ogbeibu, A.E. (2005): *Biostatistics*: A practical approach to reseach and data handling. Mindex Publishing Company limited, Benin city, Nigeria.264pp.

Onyema, I.C. (2008a): Phytoplankton biomass and diversity at the Iyagbe lagoon Lagos, Nigeria. University of Lagos, Akoka. Department of Marine Sciences. 266pp

Onyema, I.C. (2008b): A checklist of phytoplankton species of the Iyagbe lagoon, Lagos. Journal of Fisheries and Aquatic Sciences. **3**(3): 167 – 175.

Onyema, I.C. and Nwankwo, D.I. (2006): The epipelic assemblage of a polluted estuarine creek in Lagos, Nigeria. Pollution Research. **25** (3): 459 – 468.

Onyema, I.C., Otudeko, O.G. and Nwankwo, D.I. (2003): The distribution and composition of plankton around a sewage disposal site at Iddo, Nigeria. Journal of Scientific Research Development.**7:** 11-26.

Onyema, 1.C., Okpara, C.U., Ogbebor, C.I. Otudeko, O. and Nwankwo, D.I. (2007): Comparative studies of the water chemistry characteristics and temporal plankton variations at two polluted sites along the Lagos lagoon, Nigeria. Ecology, Environment and Conservation. 13: 1 – 12.

Sandison, E.E. (1966). The effect of salinity fluctuation on the life of *Balanus pallidus strusburi* (Darwin) in Lagos Habour, Nigeria. Journal of Animal Ecology. 35: 365 – 378.

Sandison, E.E. and Hill, M.B. (1966): The distribution of *Balanus pallidus* Strusburi (Darwin), Gryphaea gasar (Adanson) Dautzenbergi, *Mercierella enigmatica* farvel and *Hydroides uncinata* (Philippi) in relation to salinity in Lagos Harbour and adjacent creek. Journal of Animal Ecology. **38**: 235-258.

Suzuki, M.S., Figueiredo, R.O., Castro, S.C., Silva, C.F., Pereira, E.A., Silva, J.A. and Aragon, G.T. (2002): Sand bar opening in a castal lagoon (Iquipari) in the Northern region of Rio De Janeiro state: Hydrological and hydrochemical changes. Braz. J. Biol., 62 (1): 51 – 62.

Sverdrup, K. a., Duxbury, A. B., and Duxbury, A. C. (2006): Fundamentals of Oceanography 5th ed. New York: McGraw Hill Companies, Inc. 342. pp.

Webb, J.E. (1958a): The Ecology of Lagos lagoon. 1: The lagoons of the Guinea Coast. Philosophical Transaction Royal Society London. Ser B: 241-283.

Webb, J.E. (1958b): The life history of *Branchiostoma nigeriense* Webb. Philosophical Transaction Royal Society London. Ser B:335-354

Webb, J.E. (1960): Biology in the tropics. Nature. London. 188(4151): 617 - 619.

Webb, J.E. and Hill, M.B. (1958): On the Reactions of *Branchiostoma nigerence* Webb to its environment. Philosophical Transactions of the Royal Society of London. Ser B. 241: 355-391.

11/25/2008