Zooplankton Dynamics and Chlorophyll *a* Concentrations at The Tomaro Creek In Relation To Water Quality Indices

*Onyema, I.C.

Department of Marine Sciences, University of Lagos, Akoka.

*e-mail: iconyema@gmail.com

ABSTRACT

Aspects of zooplankton dynamics at the Tomaro creek in relation to water quality characteristics were investigated for a period of six months (October, 2007 to March, 2008). Rainfall distribution and possibly tidal seawater inflow were the key factors that govern the variation in zooplankton distribution, species diversity, chlorophyll *a* concentration and water quality indices of the creek. Salinity and rainfall recorded a strongly negative correlation (r = -0.85). Chlorophyll *a* concentrations were higher in the dry season months than in the wet season. Values range between 6 and 22µg/L for the study. A total of 18 species from 15 genera were recorded for the zooplankton and the population was grouped under 2 phyla and 3 classes. The classes observed were Crustacea, Mysidacea and Scyphozoa. The class crustacea with the subclass Copepoda was the most dominant, accounting for 59.15% of the total species recorded. The juvenile stages accounted for 39.02% of the total species recorded. The Shannon-Wiener index (Hs) was highest (0.85) in February, 2008 and lowest (0.22) in November, 2007. The Species richness index (d) was generally high (>0.26), while species evenness was low (<0.97) throughout the period of study. [Report and Opinion 2009;1(6):51-64]. (ISSN: 1553-9873).

INTRODUCTION

An intricate network of creeks, rivers and lagoons exist in South-western Nigeria which eventually connects to the sea via the Lagos harbour. Flood waters associated with rainfall are known to enrich the coastal environment, dilute its ionic concentration and break down existing environmental gradients (Nwankwo, 1996; Onyema, 2008). The coastal waters of South-western Nigeria include a system of lagoons which receives a number of large rivers and creeks draining more than 64,000km^2 of the country (Chukwu, 2002).

Owning to the seasonal distribution of rainfall, the lagoon system and creeks experiences seasonal flooding which dilutes the ionic concentration of the coastal waters and introduces a lot of detritus, nutrients, as well as land based potential environmental pollutant from land based activities which includes domestic and industrial effluents, urban storm run-off agricultural land run-off and shipping activities (Akpata *et al*., 1993; Nwankwo, 1993; Onyema *et al*., 2003, 2007; Onyema and Nwankwo, 2006).

According to Nwankwo (2004), an important ecological ramification of increasing population pressure, poor sewerage system, industrialization and poor waste management in Nigeria coastal area is that pollutants freely find their way unabated into our coastal waters through drains, canals, rivers, creeks and lagoons that act as conduits. The increase in available nutrients coupled with reduced current speed causes an increase in phytoplankton population and hence an increase in zooplankton.

Studies on the planktonic components of Lagos coastal waters have concentrated more on the phytoplankton components (Hendey, 1958; Nwankwo, 1984, 1986, 1988). Existing information on creeks, chlorophyll *a* levels and zooplankton spectrum of South Western Nigeria are scanty. The aim of the project was to investigate the aspects of zooplankton dynamics and chlorophyll *a* at the Tomaro creek in relation to water quality situations.

MATERIALS AND METHODS

Description of Study Site

The Tomaro creek is linked to the Badagry creek which joins the Lagos lagoon at the harbour in South-western Nigeria. The creek is located in Amuwo Odofin L.G.A of Lagos State and is bordered by a predominantly rural and sparsely populated community showing very little signs of urbanisation. The study site located at the Tomaro creek lies around Longitude 03^0 22' 52E and Latitude 06^0 25' 43N. Creeks and lagoons are common hydrological features of South-western Nigeria and form part of the numerous ecological niches associated with the Nigerian coastal environment (Chukwu and Nwankwo, 2004; Onyema, 2007).

This site experiences tidal influences from the adjacent Badagry creek and lagoon to which it opens. As with the lagoon, rising tide ushers in high water levels, which increase salinity. At low tide, the water level and salinity fall exposing tidal flats in the furthest extremes.

The Tomaro creek area falls within the rainforest zone which experiences a well marked dry (December -

April) and wet (May - November) seasons. Tidal oscillation along the creeks length is of the semi-diurnal tidal regime and the same as the whole Gulf of Guinea (West African coast). The effect of the tide is more discernable in the dry season and decreases inland resulting in characteristics environmental and biota gradients (Nwankwo and Akinsoji, 1989). The entire length of the creek is covered by a luxuriant growth of mangroves species with Red Mangrove (*Rhizophora racemosa*) being the dominant member. Tidal mudflats are observable at low tide and especially in the dry season. There is also the presence of an abundance of floating water hyacinth (*Eichhornia crassipies*) at the edges of the creek in the wet season.

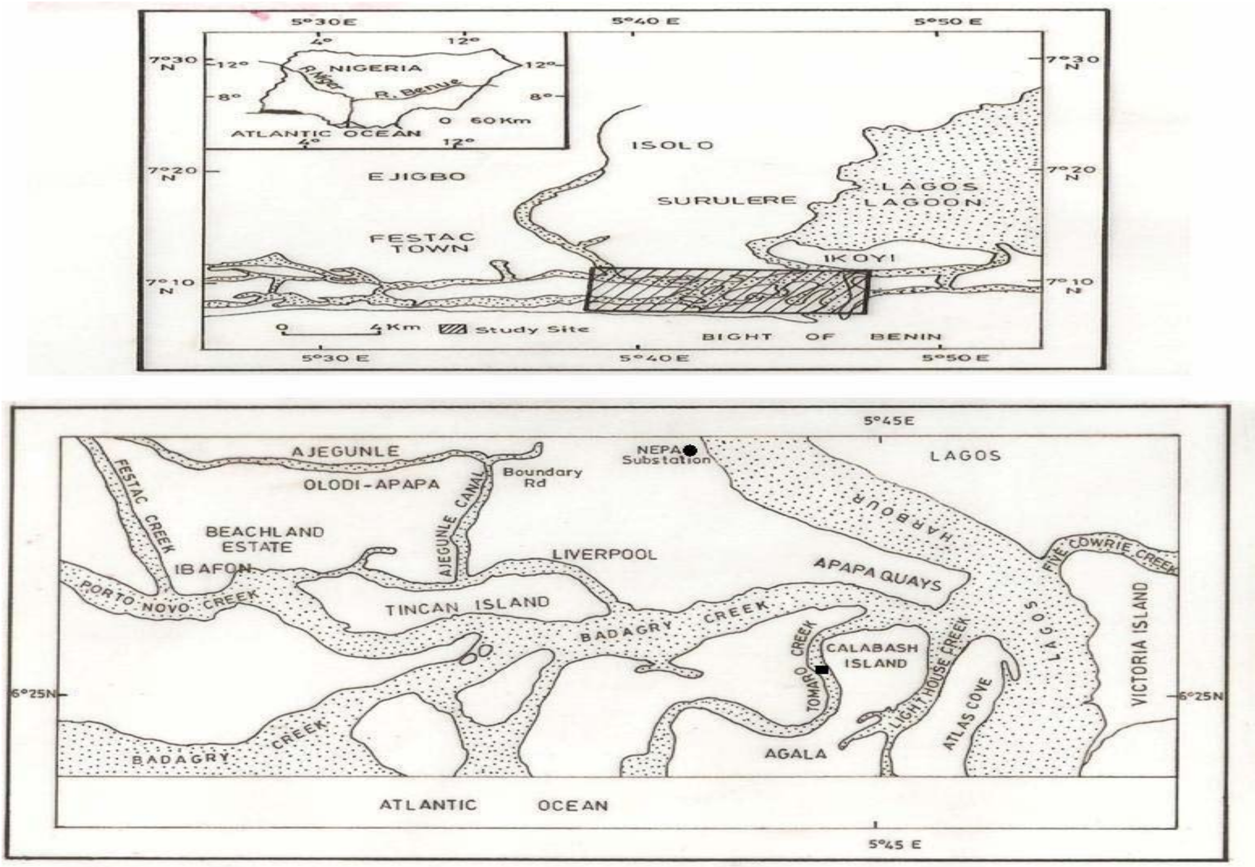

Fig.1: The Apapa area of Lagos showing major Creeks and Sampling site ■

Collection of Water Samples

Monthly surface water samples for physico-chemical analysis were collected for six months (October, 2007 – March, 2008) with 500ml plastic containers with screw cap at the Tomaro creek using an outboard engine powered boat.

Collection of Plankton Samples

A horizontal plankton haul was made on each trip with a standard plankton net of 55µm mesh size towed at low speed (4 knots) for five minutes. The plankton samples were concentrated and stored in 500ml plastic containers (properly labelled showing the time, date of collection and study site). Samples were preserved in 4% unbuffered formalin which was then transferred to the laboratory for further analysis.

Analysis of water quality parameters.

Table 2: Summary of method/device for the estimation of water quality parameters.

	Parameter/ Unit	Method / Device	Reference(s)
1	Air temperature (°C)	Mercury – in – glass thermometer	Nwankwo (1984)
2	Water temperature (°C)	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 (mg/L)	Cole Palmer TDS meter	
7	Total Suspended Solids (mg/L)	Gravimetric method	APHA (1998)
8	Chloride (mg/L)	Argentometric method	APHA (1998)
9	Total hardness (mg/L)	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 (mg/L)	Titration method	APHA (1998)
14	Acidity (mg/L)	Titration method	APHA (1998)
15	Dissolved oxygen (mg/L)	Titration method	APHA (1998)
16	Biological oxygen demand (mg/L)	Incubation and Titration	APHA (1998)
17	Chemical oxygen demand (mg/L)	Titration method	APHA (1998)
18	Nitrate – nitrogen (mgL)	Colorimetric method	APHA (1998)
19	Phosphate – phosphorus (mg/L)	Colorimetric method	APHA (1998)
20	Sulphate (mg/L)	Turbidimetric method	APHA (1998)
21	Silica (mg/L)	Colorimeter (DR2010)	APHA (1998)
22	Calcium (mg/L)	Titrimetric method	APHA (1998)
23	Magnesium (mg/L)	Titrimetric method	APHA (1998)
24	Copper (mg/L)	Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application methods (2002)
25	Iron (mg/L)	Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application methods (2002)
26	Zinc (mg/L)	Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS	Perkin Elmer Application methods (2002)
27	Chlorophyll a (µg/L)	Florometric method	APHA (1998)

Biomass In Terms of Numbers Using Counting Methods

Plankton sample were allowed to settle in the lab for 2hrs and concentrated to 20ml. For each settled sample, 5 drops of well mixed sample were investigated. On each occasion, one drop of sample was thoroughly investigated using the Drop Count Method described by Lackey (1938). For each drop five transect were investigated by moving the stage at different position under a Carl Zeiss monocular microscope.

Zooplankton species were observed, identified and drawn using text. Several relevant keys and illustrations: Newell and Newell (1966), Wimpenny (1966), Olaniyan (1975), Gibbons (2001) and Waife and Frid (2001) were consulted to confirm identification.

Community Structure Analysis

Species diversity index (Shannon-Wiener, 1963), Species richness (Margalef, 1951); Evenness or equitability indices (Pielou, 1975) and Simpson Dominance index were used to estimate the zooplankton biodiversity.

Species Richness Index (d)

This is also known as the species diversity index. The species richness (Margalef, 1951) was given by the equation.

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

Where d = Margalef richness index or Species diversity index, S = Number of species in the population, N = Total number of individuals in species.

Shannon -Wiener Index (Hs)

This was proposed by Shannon-Wiener (1963) and it is given by the equation:

$$Hs = \frac{N \log N - (\sum Pi \log Pi)}{N}$$

Where Hs = Shannon-Weiner diversity index, ∑ = Summation, i = count denoting i^{th} species ranging from 1 to n. Pi = proportion that the i^{th} species represent to the total number of individuals in the Sampling space.

Species Evenness (j)

Species equitability or evenness was determined by the equation:

$$j = \frac{Hs}{\log_2 S}$$

Where j = equitability index, Hs = Shannon-Weiner diversity index, S = number of species in the population.

Simpson's Dominance Index (C)

Simpson's dominance index by Simpson (1949) using the equaton:

$$C = \sum \left(\frac{n_i}{N}\right)^2$$

ni = the no. of individuals in the iths species, Ni = the total no. of individuals.

Correlation Coefficient (r)

The correlation between zooplankton abundance and some environmental variable (Temperature, salinity, total weekly rainfall and nutrient levels (Phosphorus and Nitrates] was determined by Spearman Rank correlation analysis and it is given by the equation:

$$r = \frac{1-6\sum D^2}{n(n^2-1)}$$

Where r = correlation coefficient, $\sum D^2$ = sum of squares of difference of the ranks, n = number of weeks.

RESULTS

The variation of the water quality indices of the Tomaro creek between October 2007 and March 2008 are represented in Table 1. The air temperature variation recorded showed minimal variation and ranged between 27 and 30.5^{0}C. The highest temperature value (30^{0}C) was recorded both in February and March respectively while the lowest value (27^{0}C) was recorded in January.

Table 1: Monthly Variations in the Water Quality Indices at Tomaro Creek (October 2007- March 2008).

PARAMETERS		MONTHS							
		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	MEAN	STD. DEV.
1	Air Temperature (°C)	30.5	30	31	27.8	26	26	28.13	±2.08
2	Water Temperature(°C)	29.5	28.2	29.1	27	30.5	30.5	27.98	±1.64
3	Transparency(cm)	25	61.8	98.5	128.5	174	174	111.17	±44.18
4	pH at 26°C	7.32	7.38	7.33	7.6	7.67	7.53	7.47	±0.15
5	Conductivity (µS/cm)	3270	5730	19930	31000	38700	37300	22655	±15564
6	Rainfall (mm)	87.9	19.5	8.9	74.4	17.6	44.5	24.5	±13.89
7	Total Suspended Solids (mg/L)	32	16	16	102	33	240	73.17	±87.76
8	Total Dissolved Solids (mg/L)	1716	2530	8220	16880	20472	19340	11526.3	±8459.89
9	Salinity(‰)	1.71	3.1	11	17.4	23.2	21.1	12.92	±9.15
10	Acidity (mg/L)	1.8	2.9	6.6	6.5	7.5	7.5	5.47	±2.48
11	Alkalinity (mg/L)	70	70	385	281.2	1190	1255.1	541.88	±541.59
12	Total Hardness (mg/L)	764.5	843	2780	4173	7645	7880	4014.25	±3171.5
13	Calcium (mg/L)	27.8	55.6	170	511.5	2080.1	2001.1	807.68	±970.72
14	Magnesium (mg/L)	170	166.3	574.4	723.9	583.2	590.4	468.03	±238.69
15	Zinc (mg/L)	0.006	0.008	0.02	0.007	0.011	0.022	0.01233	±0.01
16	Iron (mg/L)	0.11	0.14	0.16	0.19	0.1	0.25	0.15833	±0.06
17	Copper (mg/L)	0.002	0.003	0.002	0.003	0.005	0.004	0.0032	±0.00
18	Chloride (mg/L)	725	1450.3	5220	8120	12125	11000	6440.05	±4795.2
19	Nitrate (mg/L)	5	3	3.2	4.8	0.7	4.1	3.466	±1.58
20	Sulphate (mg/L)	25.5	116.5	480	610.2	1112.5	1150	582.45	±477.83

21	Phosphate (mg/L)	1.8	0.6	0.25	3.5	1.1	0.3	1.2583	±1.24
22	Silica (mg/L)	1.6	3.6	2.9	4.2	3.4	3	3.12	±0.87
23	Biochemical Oxygen Demand (mg/L)	80	24	50	24	25	33	39.33	±22.29
24	Chemical Oxygen Demand (mg/L)	260	128	505	118	188	68	211.17	±158.33
25	Dissolved Oxygen (mg/L)	4.2	3.6	4	3.8	5.4	4.8	4.3	±0.68
26	Chlorophyll-*a* (μg/L)	9	15	12	22	16	6	13.33	±5.65
27	Species diversity (S)	2	2	4	7	10	8	5.5	±3.33
28	Species abundance (N)	50	50	125	140	170	275	135	±84.14

The surface water temperature ranged between 25.9 and 30.5^{0}C. The highest temperature value (30.5^{0}C) was recorded in March while the lowest temperature value (25.9^{0}C) was recorded in February. The lowest value for air temperature recorded during the wet season was 30.5°C recorded in October and lowest value during the dry season was 26°C recorded in February and March. The average value is 27.98 and standard deviation of ±1.64. The transparency level showed a very wide range of variations between 25 and 174cm. The transparency level showed that the highest transparency level value of 174cm was recorded in February. The lowest value during the wet season was 25cm recorded in October and 128.5cm during the dry season in January, while the lowest transparency level value of 25cm was recorded in October with an average value is 111.17 and standard deviation of ±44.18. The total suspended solids range between 16 and 240mg/L. The lowest value recorded was both 16mg/L in November and December respectively and highest value recorded 240mg/L was in March. The total dissolved solids steadily increased greatly with the months and the values ranged between 1716 and of 20472mg/L. The highest value of 20472mg/L was recorded in February, while the lowest value of 1716mg/L was recorded in October.

The rainfall data showed a distinct monthly variation ranging between 8.9 and 87.9mm. The highest amount of rainfall 87.9mm was recorded in October while the lowest amount (8.9mm) was recorded in December. The surface water pH showed minimal variations. The highest pH value (7.67) was recorded in February, while the lowest value (7.32) was recorded in October. The surface water acidity also showed monthly variations. The highest acidity value of 7.5mg/L was recorded in March while the lowest acidity value was 1.8mg/L recorded in October. The surface water alkalinity varied throughout the sampling period. The lowest value 70mg/L was recorded in October, while the highest value 1255.1mg/L was recorded in March. The lowest value during the wet season was 70mg/L recorded in October and 281.2mg/L during the dry season in January. Salinity values recorded showed that salinity of the water was low and the values ranged between 1.71 and 23.2‰. The month of October had the lowest salinity value of 1.71 while February had the highest salinity level of 23.2 ‰. The lowest value during the wet season was 1.71‰ recorded in October and 17.4‰ during the dry season in January. The conductivity values showed a very wide range in variations which increased constantly with the months. The highest value of 38700μS/cm was recorded in February while the lowest value of 3270μS/cm was recorded in October.

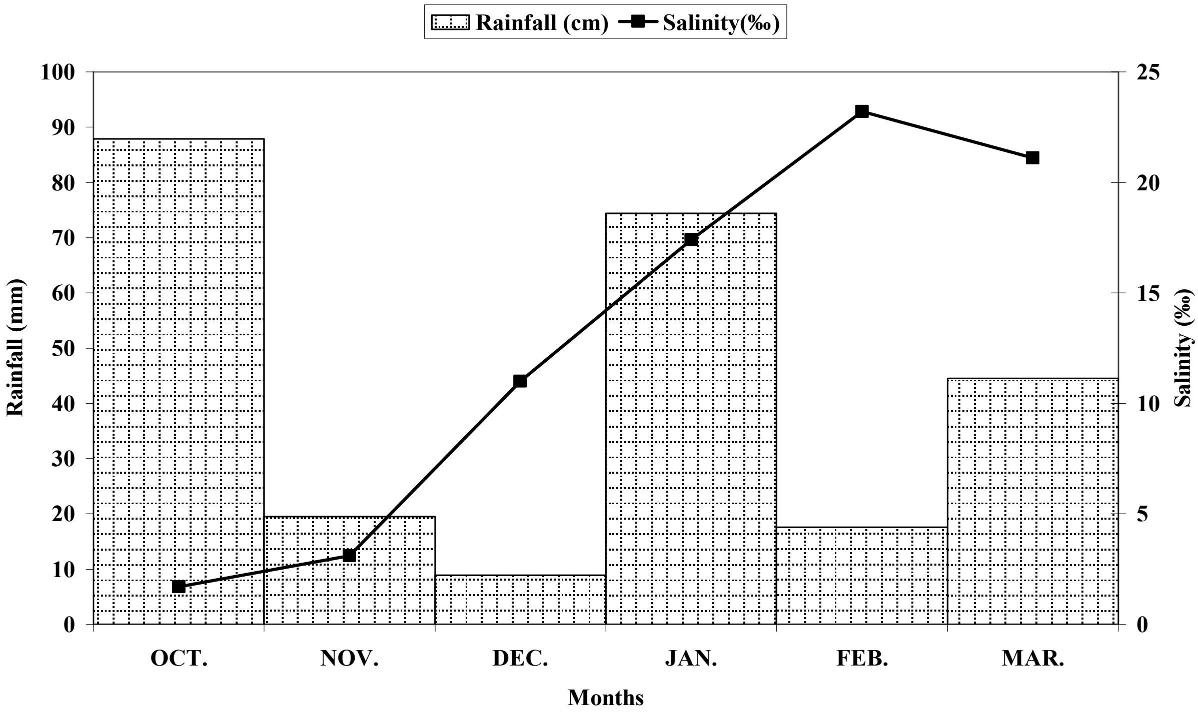

Fig. 5: Monthly variations in Rainfall and Salinity at the Tomaro creek (October, 2007 to March, 2008).

The Dissolved oxygen (DO) showed minimal variations ranging from 3.6 to 5.4mg/L. Lower levels of dissolved oxygen were recorded from November to January. The highest value (5.4mg/L) was recorded in February and the lowest value (3.6mg/L) which was estimated in November. The Biochemical Oxygen Demand was highest at the beginning of the sampling period and decrease subsequently to the end of the sampling period with exceptions in the months of December which had a value of 50mg/L. The lowest value of 24mg/L was recorded in November while the highest value 80mg/L was recorded in October. The highest value of COD, 505mg/L was recorded in December while the lowest value (68mg/L) was recorded in March. The lowest value during the wet season was 128mg/L recorded in November and 68mg/L during the dry season in March. The total hardness values showed a steady increase with each sampling month and ranged between 764.5 and 7880mg/L. The highest value 7880mg/L was recorded in March, while the lowest value 764.5mg/L was recorded in October.

Surface water chloride values showed a steady increase in each month and a wide range of variations. The lowest chloride value of 725mg/L was recorded in October, while the highest value 1450.3mg/L was recorded in November. The calcium level ranged from 27.8 to 2080.1mg/L . The highest value 2080.1mg/L was recorded in February while the lowest value 27.8mg/L occurred in October. The calcium level ranged from 166.3 to 723.9 mg/L. The highest value723.9mg/L was recorded in January while the lowest value 166.3mg/L occurred in November. The nitrate–nitrogen concentrations ranged between 0.7and 5mg/L. The sulphide concentrations varied through 25.5mg/L recorded in October to 1150mg/L recorded in March. The phosphate–phosphorus concentrations showed monthly variations and these concentrations recorded showed that the highest value 3.5mg/L occurred in January, while the lowest value 0.3mg/L occurred in March.

The surface water silica concentrations showed distinct monthly variations. The highest silica concentration (4.2mg/L) was recorded in January, while the lowest concentration (1.6mg/L) was recorded in October. Copper values were between 0.002 and 0.005mg/L with an average value of 0.0032 mg/L . Iron showed fluctuation in concentration between 0.1mg/L to 0.25mg/L with an average value of 0.16 mg/L. Zinc values showed very minimal variations ranging from 0.006 to 0.022mg/L with an average value of 0.012 mg/L. The lowest value during the wet season was 0.02mg/L recorded in December and 0.007mg/L during the dry.

Chlorophyll *a* (µg/L)

Chlorophyll *a* concentration ranged from 6µg/L recorded in March to 22µg/Lrecorded in January. Average chlorophyll *a* concentration for the period of study was 13.33µg/l while standard deviation was ±

5.65. Chlorophyll *a* values were higher in the dry than the wet season.

Zooplankton diversity and abundance

The aspect of zooplankton dynamics species at the Tomaro creek between October, 2007 and March, 2008 is presented in Table 2.

A total of 13 zooplankton genera constituting 18 species were recorded throughout the study period. More taxa were observed in February and March compared to October and November. Two major phyla of zooplankton were identified at the Tomaro creek throughout the sampling period which are the Arthropoda and Cnidaria. The major orders represented were the Order - Copepoda and Order - Siphonophora. Of these, the phylum Arthropoda was the most abundant, accounting for 99% of the total species composition with the phylum Cnidaria recording 1% of the total species composition. Among the Arthropods, *Acartia discaudata* Giesbrecht (Calanoida) had the highest number of species (195 individuals were recorded). *Centropages furcatus* Dana, *Metridia longa* Lubbock (copepoda) ranked lowest with only 10 individuals each. Among the Cnidaria, there were some unidentified jelly fish in the Class - Scyphozoa.

With regard to the juvenile stage, nauplii, zoea, megalop, bivalve, gastropod larvae and fish eggs constituted the juvenile stages collected at the sampling site. The Nauplii larva had the highest number of individuals, accounting for 68% of the total juvenile stages composition while the bivalve and gastropod larva had the lowest number of individuals, accounting for 5% of the total composition respectively.

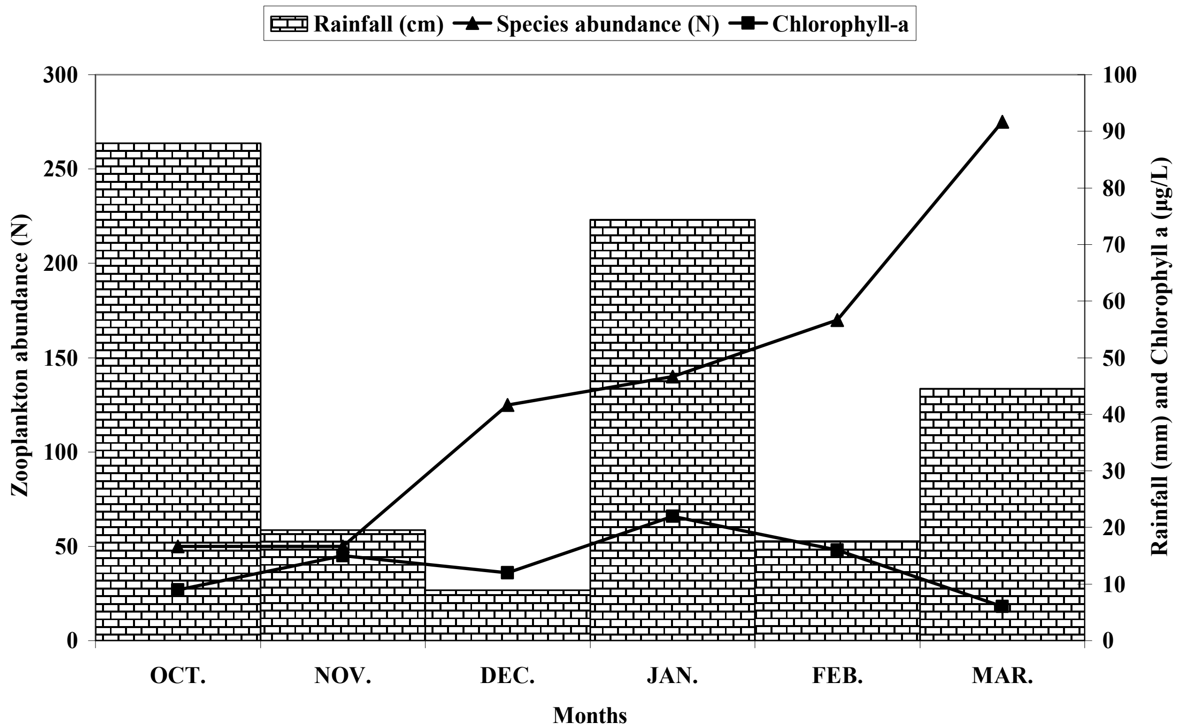

Fig. 10: Monthly variations in Rainfall, Chlorophyll *a* and Zooplankton abundance at the Tomaro creek (October, 2007 to March, 2008).

TABLE 2: SPECIES COMPOSITION AND ABUNDANCE (Cells/ml) OF ZOOPLANKTON AT THE TOMARO CREEK COLLECTED BETWEEN (OCTOBER, 2007 AND MARCH, 2008).

TAXA	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
CLASS: CRUSTACEA						
SUB-CLASS: COPEPODA						
ORDER I: CALANOIDA						
FAMILY: ACARTIIDAE						
Acartia clausii Giesbrecht	20	-	-	-	10	-
Acartia discaudata Giesbrecht	-	10	70	50	25	35

Acartia tonsa Dana	-	40	-	-	20	75
FAMILY: METRIIDAE						
Metridia longa (Lubbock)	-	-	-	10	-	-
FAMILY: PARACALANOIDAE						
Calanus finmarchicus (Gunn.)	-	-	-	-	5	-
Centropages furcatus Dana	-	-	-	-	5	5
Paracalanus parvus Claus	-	-	10	-	60	25
ORDER II: CYCLOPIDA						
Cyclopina longicornis Claus	-	-	-	-	10	-
CLASS: MYSIDACEA						
FAMILY: MYSIDAE						
Mysis sp	-	-	-	-	5	-
JUVENILE STAGES						
Lucifer zoea larva	-	-	10	-	-	-
Megalopa larva	-	-	-	15	10	10
Nauplii larva of Barnacle	-	-	35	40	-	95
Nauplii larva of copepods	-	-	-	-	20	20
Zoea larva	-	-	-	10	-	-
PHYLUM: CNIDARIA						
CLASS: SCYPHOZOA						
ORDER: SIPHONOPHORA						
Unidentified jelly-fish	-	-	-	10	-	-
JUVENILE STAGES						
Bivalve larva	-	-	-	5	-	-
Fish eggs	30	-	-	-	-	-
Gastropod larva	-	-	-	-	-	10
Total species diversity (S)	**2**	**2**	**4**	**7**	**10**	**8**
Total zooplankton abundance (N)	**50**	**50**	**125**	**140**	**170**	**275**

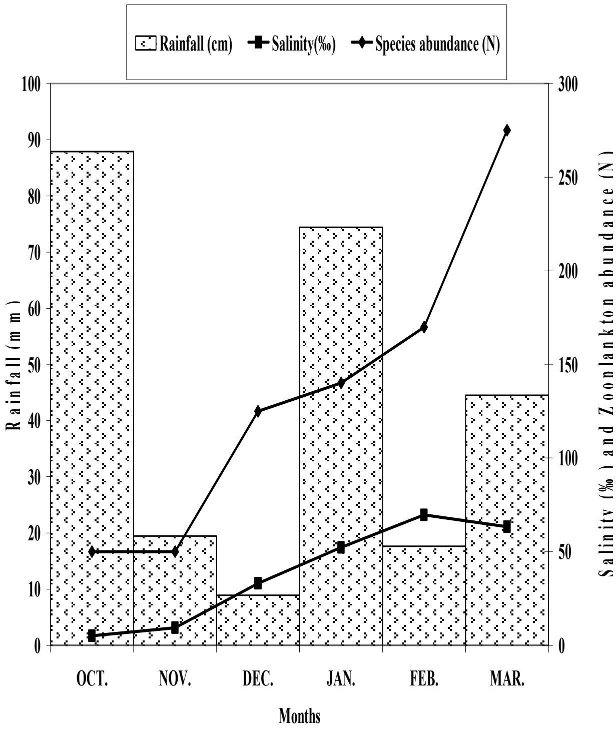

Fig. 11: Monthly variations in Rainfall, Salinity and Zooplankton abundance at the Tomaro creek (October, 2007 to March, 2008).

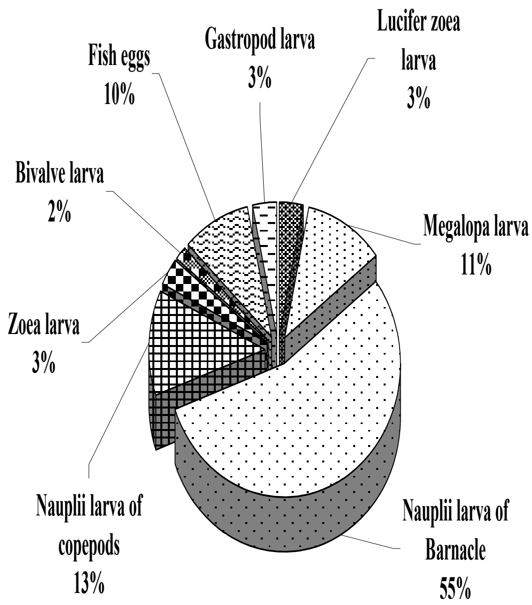

Fig. 13: Relative abundance of juvenile stages at the Tomaro creek (October, 2007 to March, 2008).

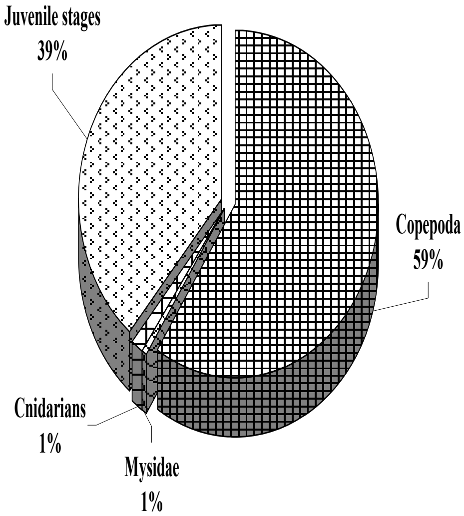

Fig. 12: Relative abundance of zooplankton at the Tomaro creek (October, 2007 to March, 2008).

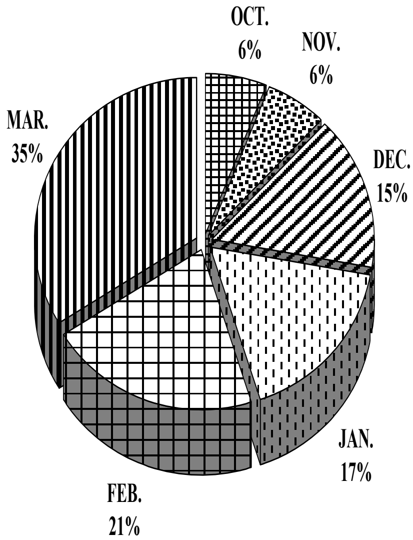

Fig. 14: Monthly distribution and abundance of Zooplankton at the Tomaro creek (October, 2007 and March, 2008).

Community Structure Indices

The indices of Species richness (d), Shannon – Wiener (Hs), Menhinick (D), Evenness (j), and Simpsons' Dominance (C) were calculated for the monthly variation in zooplankton abundance and composition and are presented in Table 3. The Margalef's index was highest (1.75) in February and lowest (0.26) in both October and November, the Shannon - Weiner index was lowest (0.22) in November and highest (0.85) in February. Species richness value ranges between 0.26 and 1.75mg/L. The highest value of 1.75mg/L was recorded in February and the lowest value 0.26mg/L was recorded in October and November, while the average value was 0.89. The diversity index value ranges between 0.22 to 0.85mg/L. The highest value (0.85mg/L) was recorded in February and the lowest value 0.22mg/L was recorded in November, while the average value was 0.55. The evenness / equitability values ranged between 0.72 and 0.97mg/L. The highest value (0.97mg/L) was recorded in October and the lowest value 0.72mg/L was recorded in November, while the average value was 0.83. The Simpsons' Dominance Index value range between 0.06 and 0.68mg/L. The highest value (0.68mg/L) was recorded in November and the lowest value (0.06mg/L) was recorded in February.

Table 3: Zooplankton community composition parameters at the Tomaro creek (October, 2007 to March, 2008).

PARAMETERS	MONTHS							
	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	Mean	Std. Dev.
Total species diversity (S)	2	2	4	7	10	8	5.5	±3.33
Total zooplankton abundance (N)	50	50	125	140	170	275	135	±84.14
Log of Species diversity (Log S)	0.3	0.3	0.6	0.85	1	0.9	0.66	±0.31
Log of zooplankton abundance (Log N)	1.7	1.7	2.1	2.15	2.23	2.44	2.05	±0.29
Shannon-Wiener Index (Hs)	0.29	0.22	0.47	0.72	0.85	0.74	0.55	±0.26
Menhinick Index (D)	0.28	0.28	0.36	0.59	0.77	0.48	0.46	±0.19
Margalef Index (d)	0.26	0.26	0.62	1.21	1.75	1.25	0.89	±0.61
Equitability Index (j)	0.97	0.72	0.78	0.85	0.85	0.82	0.83	±0.08
Simpson's Dominance Index (C)	0.52	0.68	0.4	0.24	0.06	0.22	0.35	±0.22

TABLE 5: SPEARMAN'S CORRELATION COEFFICIENT ASSOCIATIONS FOR SPECIES ABUNDANCE, RICHNESS AND CHLOROPHYLL *a* AT THE TOMARO CREEK (October, 2007 to March, 2008).

	PARAMETERS	CORRELATED		
		ZOOPLANKTON ABUNDANCE (N)	TOTAL SPECIES DIVERSITY (S)	CHLOROPHYLL-*a* (mg/L)
1	Air Temperature (°C)	✓ (-)	✓ (-)	X
2	Water Temperature (°C)	✓ (+)	x	✓ (-)
3	Transparency (cm)	✓ (+)	✓ (+)	X
4	Total Dissolved Solid (mg/L)	✓ (+)	✓ (+)	X
5	Total Suspended Solid (mg/L)	X	✓ (+)	✓ (+)
6	pH	✓ (+)	✓ (+)	✓ (+)
7	Acidity (mg/L)	✓ (+)	✓ (+)	X
8	Alkalinity (mg/L)	✓ (+)	✓ (+)	X
9	Salinity (‰)	✓ (+)	✓ (+)	X
10	Chloride (mg/L)	✓ (+)	✓ (+)	X
11	Conductivity (μS/cm)	✓ (+)	✓ (+)	X
12	Dissolved Oxygen (mg/L)	✓ (+)	✓ (+)	X
13	Biochemical Oxygen Demand (mg/L)	✓ (+)	✓ (-)	✓ (-)
14	Total Hardness (mg/L)	✓ (+)	✓ (+)	X
15	Calcium (mg/L)	✓ (+)	✓ (+)	X
16	Magnesium (mg/L)	✓ (+)	✓ (+)	X

17	Zinc (mg/L)	✓ (+)	X	✓ (-)
18	Iron (mg/L)	✓ (+)	X	X
19	Copper (mg/L)	✓ (+)	✓ (+)	X
20	Nitrate (mg/L)	X	✓ (+)	X
21	Sulphate (mg/L)	✓ (+)	✓ (+)	X
22	Phosphate (mg/L)	X	X	✓ (+)
23	Silica (mg/L)	✓ (+)	✓ (+)	X
24	Chlorophyll *a* (µg/L)	X	X	1
25	Species richness (S)	X	1	X
26	Zooplankton abundance (N)	1	✓ (+)	X

Key:

✓ (+) → Strongly positive (≥ ±0.40)
✓ (-)→ Strongly negative (≤ ±0.40)
x → not strongly correlated

DISCUSSION

The Tomaro creek of South-western Nigeria form part of the numerous ecological niches associated with the Nigerian coastal environment and according to Nwankwo and Akinsoji (1992), these creek and lagoons are linked to the sea through the Lagos Harbour which remains open all through the year. The variation in the water quality indices of the Tomaro creek during the course of the investigation could be attributed to the effect of tidal sea water incursion and, also freshwater input from adjoining rivers and creeks.

Air temperature was high throughout the study period, with the highest value (31^0C) recorded in December. The present observation also revealed a high surface water temperature all through the sampling period. Water temperature is usually high in the tropics. Transparency was observed to increase progressively with the dry season. These confirm the phenomenon that transparency and rainfall are inversely related, with increase in rainfall leading to a decrease in the transparency of the creek water. Furthermore, Nwankwo (1990) highlighted that seasonal variation in transparency in the coastal waters of South-western Nigeria is linked to the rainfall pattern and associated floods. According to Olaniyan (1969), pH is an indicator of environmental condition and the result of chemical condition in an aquatic environment. The study site was alkaline through out the study. According to Nwankwo (1984), high pH values observed in coastal waters of Nigeria may be due to the buffering effects of the sea water.

Salinity which creates horizontal environmental barriers to the Lagos lagoon biota is directly linked to the rainfall pattern (Nwankwo, 1996, 1998). The continued increase in salinity values observed during the investigation was likely due to increased incursion of tidal seawater, coupled with increase in evaporation rate. According to Barnes (1980), the complex variation of surface water salinity in lagoons is not determined by the alteration of wet and dry seasons, but by the nature of seawater and freshwater inflow coupled with the occurrence of strong winds. Barnes (1980) also highlighted the fact that in the wet seasons, lagoons are diluted considerably by freshwater from rain and river systems, while in the dry season, evaporation becomes more prominent. Salinity regimes in the Lagos lagoon have also been related to rainfall distribution (Nwankwo and Amuda, 1993).

It follows that salinity values were low in the creek because of the freshwater discharge from the adjoining wetland through creeklets (Nwankwo, 1991) during the rains. Furthermore, in the dry months, tidal incursion was well noticed inland which raised the salinity of the water considerably. This confirms a report by Olaniyan (1969). However, in October 2007, there was a decrease in the salinity values at the study site possibly due to the effect of rainfall and consequently, increase in freshwater inflow. According Fagade and Olaniyan (1974) and Nwankwo (1996), salinity is an environmental barrier in the distribution of biota. The intrusion of tidal seawater hinterland makes salinity an important factor in the creek (Nwankwo and Amuda, 1993). According to Onyema and Emmanuel (2009) evaporative concentration and reduced or minimal floodwater/river inputs encouraged increases in salinity, chloride, total dissolved solids, total hardness, conductivity and cations values among others in the dry season for the Lekki lagoon.

Conductivity increased with rise in the total dissolved solids and a decrease in the total suspended solids and increases during the dry months. The chloride values observed increased appreciably monthly while the acidity and alkalinity values in the study site showed notable monthly values in October and March. The continued increase in the total hardness values could be due to increase in conductivity values throughout the sampling period. The Calcium and Magnesium concentrations were also high throughout the period of study. The heavy metal concentrations of the study site were low and showed monthly variations throughout the study period.

The nutrient level recorded during the period of investigation was high for sulphate. Most tropical waters have low nutrients values, a feature considered common for natural and polluted waters, but the level of sulphates and nitrates recorded during the study is suggestive of both chemical and organic pollution and nutrient enrichment. The high levels of nitrate-nitrogen and sulphide-sulphur may be due to the effect of direct discharges of pollutants such as municipal sewages and other biodegradable wastes into the coastal waters coupled with the enrichment of adjoining wetlands, creek and subsequent run-offs. This corresponds with the observation of Nwankwo (1993) for the coastal water of south-western Nigeria. Also, Nwankwo (1995) is of the view that storm water channels, creek and creeklets acts as conduits for land based human-induced activities into the coastal waters. The phosphate-phosphorus concentrations were very low throughout the sampling period. Furthermore, according to Nwankwo (1984) and Nwankwo and Akinsoji (1992), rainfall also introduces chelating agents as well as increase the nutrient levels of the lagoons. The silica concentration of the study site was observed to increase appreciably but the values were recorded in the rainy months. According to Nwankwo (1998), Dissolved oxygen decreases with increased temperature and Biochemical Oxygen Demand due to increase metabolic activities of most species probably inducing bacteria and fungi which are common in polluted sites in the Lagos lagoon (Akpata and Ekundayo, 1983) but the relatively high Biochemical Oxygen Demand (BOD) values and the relatively high Dissolved Oxygen (DO) values observed through the investigation may be to the photosynthesis activities which released oxygen.

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) can be used to determine the level of pollution in a water sample. With regard to the COD values were relatively high, probably indicating a high level of pollution within the creek.

The abundance and diversity of species similarly varied with rainfall pattern. More zooplankton taxa were observed in February and March. This may probably be due to the increased rainfall volume in these months which consequently led to an increase in flood effects, a resultant dilution of the water body and an increase in the population of freshwater species. The present observation showed that the number of individuals of the zooplankton species decreased with an increase in the amount of rainfall throughout the period of investigation. This however, corresponds with Hill and Webb (1958), Olaniyan (1969) and Nwankwo (1991, 1993; Onyema, 2003, 2007, 2008) who reported that floods associated with rainfall dilutes the ionic concentration of the coastal waters and breaks down any horizontal, environmental gradient within the lagoon system. However, there was an increase in the abundance and species diversity of copepods and some juvenile stages in February and March. Despite the sharp increase in the salinity of the water, which probably maybe due to the high tolerance of these zooplankton species to high salinity environments. Data on the Species richness index and Diversity index, Equitability and the Simpson Dominance index showed monthly variation in conformity with the zooplankton distribution. High values for the diversity index indicate that the species were more evenly dispersed. The dominance by more species was attributed by very high species diversity and high species richness. Hence it follows that rainfall and salinity are known to regulate the occurrence and distribution of biota in the Tomaro creek. This corresponds to the findings of Olaniyan (1975), Hill and Webb (1958) and Nwankwo (1990) that two physiological factors, rainfall and salinity determine the hydro-climate of the coastal lagoons of South-western Nigeria. Also, it was observed that zooplankton abundance and salinity of the Tomaro creek showed a strong positive correlation ($r = 0.87$).

From the present observations, it is possible that rainfall affects other environmental factors. This confirms the reports from Webb (1960) that rainfall in the tropics is more important than temperature in determining environments. From the observations Biochemical Oxygen Demand ($r= -0.40$) show a strongly negative correlation while salinity ($r= 0.87$) and Dissolved Oxygen ($r= 0.62$) showed a strongly positive correlation. Conductivity and Total Dissolved Solids also showed a strong positive correlation. While zooplankton abundance and water temperature ($r = 0.45$) show a strong positive correlation, indicating that an increase in rainfall consequently lead to decrease in the water temperature.

Arthropods were the most abundant and more diverse group observed while some unidentified jelly-fish, a Cnidarian were frequent individual species observed during the investigation. However, various juvenile stages were also observed, with the nauplii larval stages the more abundant of the stages, having a total number of 95 individuals. Among the Arthropods, *Acartia discaudata, Acartia clausii, Acartia tonsa* (Giesbrecht), *Calanus finmarchicus* (Gunn.), *Centropages furcatus* (Dana) and *Paracalanus parvus* Claus were prevalent.

REFERENCES

Akpata, T.V, Oyenekan, J.A and Nwankwo, D.I (2003). Impact of organic pollution on the Bacterial, Plankton and Benthic populations of Lagos lagoon, Nigeria. *International Journal of Ecology and Environmental Science.* **19**: 73-82.

APHA (1998). *Standard methods for the Examination of water and waste water*, (20th edition). American Public and Health Association. American Waterworks Association and water Environment Federation (WEF). 1270pp.

Barnes, R.S.K (1980). Coastal lagoons. Cambridge University Press, London. 106pp.

Beadle, L.C (1974). The inland waters of tropical Africa: An introduction to tropical Limnology. McGraw Hill Publishing Company, New York. 365pp.

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

Chukwu, L.O and Nwankwo, D.I (2004). The impact of land-based pollution on the hydrochemistry and macrocommunity of a tropical west Africa creek. The *Ekol.* **2**(1-2): 1-9.

Fagade, S.O and Olaniyan, C.I.O. (1974). Seasonal distribution of fish fauna of the Lagos lagoon. *Bull de FAN*. **36:** 244-252.

Gibbons, M.J. (2001). *An introduction to the zooplankton of the Benguela Current Region*. NDB, Western Cape, South Africa. 54pp.

Kusemiju, K, Nwankwo, D.I and Bamisaiye, R.B (1993). The Hydrobiology and Fishes of Opobo channel, River State, Nigeria. *Journ. Sci. Res. Dev.* **1**:74-79.

Lackey, J.B (1938). The manipulation and counting of river plankton and changes in some organisms due to formalin preservation. *U.S Public Heaith Reports.* **63**: 2080-2093.

Margalef, D.F (1951). Diversidad de species en les communideades. Natural public institute of Biology. Barcelonia. **9:** 5-27.

Newell, G.E. and Newell, R.C. (1996). *Marine Plankton*: *A practical guide.* Revised Edition. Hutchinson, London. 225pp.

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

Nwankwo, D.I (1990). Contributions to the diatoms flora of Nigeria. Diatoms of Lagos lagoon and adjacent sea. *Nigeria Journal of Botany*. **3**: 53-70.

Nwankwo, D.I (1991). A survey of the dinoflagellates of Nigeria. Armoured dinoflagellates of Lagos lagoon and associated tidal creeks. *Nigeria Journal of Botany*. **4:** 29- 39.

Nwankwo, D.I. (1993). Cyanobacteria bloom species in coastal waters of South-Western Nigeria. *Archiv fur Hydrobiologie*. **90:** 533-542.

Nwankwo, D.I. (1996). Phytoplankton diversity and succession in Lagos lagoon, Nigeria. *Archiv Fur Hydrobiologie.* **135** (4): 529 – 542.

Nwankwo, D.I (1998). The influence of saw mill wood wastes on Diatom population of Okobaba Lagos, Nigeria*. Nigeria Journal of Botany*. **11**: 16-24.

Nwankwo, D.I and Akinsoji , A (1988). Periphyton algae of a eutrophic creek and their possible use as indicators. *Nigerian Journal of Botany***. 1** ;47-54.

Nwankwo, D.I and Akinsoji, A. (1989). The benthic algal community of a sawdust deposition site in Lagos lagoon. *International Journal of Ecology and Environmental Sciences.* **15**: 197 – 204.

Nwankwo, D.I and Akinsoji, A. (1992). Epiphyte community on water hyacinth, *Eichhornia crassipies* (Mart.) Solms in coastal waters of South-Western Nigeria. *Archiv fur Hydrobiologie*. **124:** 501-511.

Nwankwo, D.I and Amuda, S.A (1993). Epiphytic diatoms of the free floating aquatic macrophytes in a polluted south-west Nigeria creek. International Journal of ecological and Environmental Sciences. **19**: 1-10.

Nwankwo, D.I, Onyema, I.C and Adesalu, T.A (2003). A survey of Harmful Algae in Coastal water of South-western Nigeria. *Journal of Nigerian Environmental Society.* **2**: 241-246.

Olaniyan, C.I.O. (1969). The seasonal variation in the hydrology and total plankton of the lagoons of south-western Nigeria. *Nigerian Journal of Science*. **3**(2)**:** 101-119.

Olaniyan, C.I.O.(1975). *An introduction to West African Ecology.* Heinemann Education Books Ltd., London. 170pp.

Onyema, I.C (2007). The phytoplankton composition, abundance and temporal variation of a polluted estuarine creek in Lagos, Nigeria. *Turkish Journal of Fisheries and Aquatic Sciences.* **7(2)*:***114- 128.

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

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**: 11-24.

Onyema, I.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. *Ecol. Env. And Cons.* **13** (1): 1 – 12.

Pielou, E.C (1975). Ecological diversity. John Wiley and sons, New York. 165pp.

Shannon and Wiener, W (1963). The mathematical theory of communication. University of Illions Press, Urbana. 125pp.

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

Wiafe, G. And Frid, C.L.J. (2001). Marine zooplankton of West African Marine Biodiversity Capacity Building in the West Africa Sub-region. Darwin Initiative Report. 5, Ref. 162/7/451. 48-107.

Wimpenny, R.S. (1966). *The plankton of the Sea.* Faber and Faber Limited, London. 426pp.

9/2/2009

Table 5: Spearman's Correlation coefficient matrix of Water Quality Indices, Chlorophyll-*a* and Zooplankton diversity and Abundance at the Tomaro creek from October, 2007 to March, 2008.

	Air temp.	Water temp.	Transparency	Rainfall	TDS	TSS	pH	Acidity	Alkalinity	Salinity	Chloride	Conductivity	DO	BOD	COD	Total Hardness	Calcium	Magnesium	Zinc	Iron	Copper	Nitrate	Sulphate	Phosphate	Silica	Chlorophyll – *a*	Species diversity (S)	Species abundance (N)
Air temp.	1																											
Water temp.	0.20	1																										
Transparency	-0.73	-0.26	1																									
Rainfall	0.45	0.33	-0.66	1																								
TDS	-0.75	-0.03	0.95	-0.85	1																							
TSS	-0.59	0.6	0.79	-0.18	0.59	1																						
pH	-0.78	-0.37	0.75	-0.9	0.91	0.38	1																					
Acidity	-0.43	0.17	0.89	-0.81	0.91	0.48	0.70	1																				
Alkalinity	-0.76	0.18	0.88	-0.54	0.85	0.59	0.68	0.78	1																			
Salinity	-0.71	-0.01	0.94	-0.85	0.99	0.55	0.88	0.94	0.87	1																		
Chloride	-0.73	0	0.94	-0.82	0.99	0.56	0.87	0.93	0.99	0.99	1																	
Conductivity	-0.69	0.03	0.95	-0.84	0.99	0.58	0.86	0.95	0.86	0.99	0.99	1																
DO	-0.8	-0.17	0.64	-0.4	0.67	0.29	0.6	0..54	0.88	0.7	0.75	0.67	1															
BOD	0.24	0.03	-0.47	0.78	-0.59	-0.24	-0.69	-0.56	-0.39	-0.58	-0.57	-0.58	-0.1	1														
COD	0.65	0.04	-0.38	0.25	-0.38	-0.57	-0.56	-0.03	-0.29	-0.29	-0.29	-0.29	-0.16	0.51	1													
Total Hardness	-0.08	-0.10	0.96	-0.70	0.95	0.64	0.82	0.87	0.97	0.96	0.98	0.96	0.81	-0.5	-0.36	1												
Calcium	-0.86	0.05	0.87	-0.58	0.87	0.59	0.78	0.73	0.98	0.88	0.91	0.86	0.89	-0.45	-0.44	0.97	1											
Magnesium	-0.36	-0.05	0.81	-0.82	0.86	0.44	0.68	0.93	0.56	0.86	0.82	0.88	0.33	-0.48	-0.01	0.72	0.53	1										
Zinc	-0.03	0.79	0.58	-0.08	0.38	0.52	-0.02	0.63	0.6	0.44	0.46	0.46	0.31	-0.09	0.26	0.51	0.44	0.44	1									
Iron	-0.18	0.78	0.63	-0.15	0.42	0.88	0.16	0.47	0.34	0.4	0.38	0.44	-0.09	-0.31	-0.34	0.41	0.28	0.49	0.62	1								
Copper	-0.8	-0.21	0.69	-0.68	0.79	0.36	0.86	0.6	0.83	0.78	0.82	0.76	0.78	-0.66	-0.57	0.84	0.91	0.39	0.14	0.07	1							
Nitrate	0.19	0.34	-0.17	-0.49	-0.34	0..34	-0.42	-0.39	-0.41	-0.41	-0.44	-0.37	-0.59	0.47	-0.09	-0.4	-0.5	-0.13	-0.13	0.45	-0.67	1						
Sulphate	-0.07	0.13	0.96	-0.72	0.96	0.62	0.8	0.91	0.97	0.97	0.98	0.97	0.78	-0.53	-0.3	0.99	0.95	0.76	0.57	0.43	0.82	-0.45	1					
Phosphate	-0.19	-0.58	-0.02	-0.31	0.13	-0.03	0.35	-0.09	0.05	0.05	0	-0.06	-0.25	-0.03	-0.29	-0.1	-0.21	0.25	-0.68	-0.07	-0.11	-0.43	-0.15	1				
Silica	-0.06	-0.12	0.35	-0.79	0.5	0.12	0.62	0.51	0.49	0.49	0.45	0.49	-0.14	-0.93	-0.39	0.32	0.2	0.55	-0.05	0.29	0.43	-0.28	0.36	0.29	1			
Chlorophyll *a*	0.09	-0.65	-0.08	-0.65	0.19	-0.37	0.45	0.14	0.16	0.16	0.11	0.15	-0.28	-0.54	-0.13	-0.08	-0.18	0.30	-0.56	-0.24	0.11	-0.17	-0.05	0.68	0.11	1		
Species diversity	-0.79	-0.15	0.9	-0.85	0.98	0.49	0.93	0.87	0.98	0.98	0.99	0.97	0.77	-0.56	-0.35	0.96	0.9	0.79	0.31	0.26	0.84	-0.46	0.95	0.11	0.84	0.19	1	
Species abundance	-0.65	0.45	0.97	-0.51	0.86	0.84	0.6	0.84	0.87	0.87	0.88	0.88	0.62	-0.40	-0.32	0.92	0.85	0.72	0.72	0.71	0.62	-0.13	0.93	-0.21	0.62	-0.27	0.80	1.