STATISTICAL ANALYSIS OF PLANKTIC FORAMINIFERA OF THE SURFACE CONTINENTAL SHELF SEDIMENTS OFF SOUTHWESTERN NIGERIA

OLÁYÍWOLÁ, M. A.[1] and ODÉBÒDÉ, M.O.[2]
[1]Natural History Museum, Obáfémi Awólówò University, Ilé-Ifè, Nigeria
[2]Department of Geology, Obáfémi Awólówò University, Ilé-Ifè, Nigeria
E-mail: mayiwola@oauife.edu.ng & mashoodade@yahoo.co.uk Tel: +234-8105907780
E-mail: laniyiodebode@oauife.edu.ng & molaniyiodebode@yahoo.co.uknTel: +234-8033535090
([1]Corresponding Author: mashoodade@yahoo.co.uk)
(Received: 6th August, 2013; Accepted: 8th November, 2013)

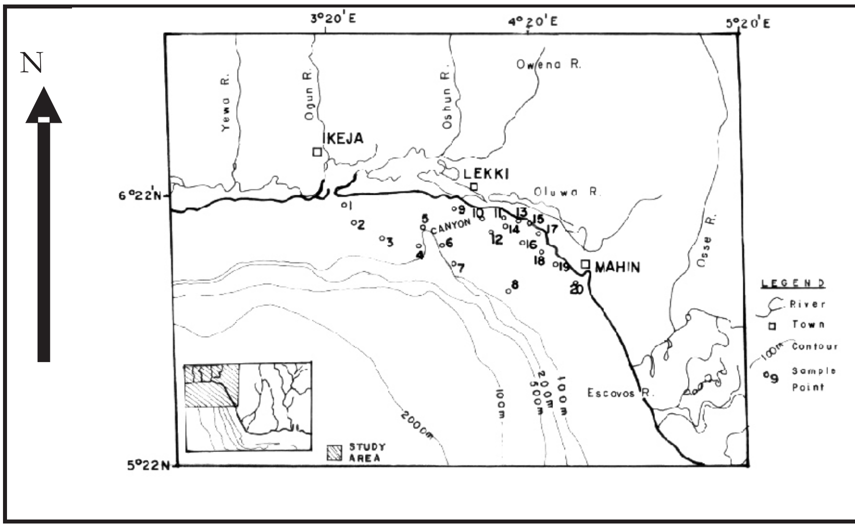
ABSTRACT

Planktic foraminiferal assemblage recorded from selected samples obtained from shallow continental shelf sediments off southwestern Nigeria were subjected to statistical analysis. The Principal Component Analysis (PCA) was used to determine variants of planktic parameters. Values obtained for these parameters were later subjected to PCA for comparison. The PCA was employed to differentiate the planktic species into different reaction groups in order to determine their preferred environmental condition. Species ratio, most especially non-tropical/tropical ratio, proved to be the most reliable ecological/climatic indicator in the study area. The planktic/benthic ratio, species diversity, planktic number and species ratio trends increased oceanwards. Conversely, the planktic species dominance, relative abundances of *Globigerinoides ruber, G. trilobus immaturus* and *Globigerina bulloides* patterns decreased oceanwards. The relative abundances of *Globigerinoides ruber*, *G. trilobus immaturus* and *Globigerina bulloides* as well as planktic species dominance correlated with climatic indicator. However, the climatic indicator did not correlate with P/B ratio, planktic number and planktonic diversity. PCA indicated the clustering of *Globigerina bulloides* abundance and non-tropical/tropical species ratio, ratios of pair of species and planktic *diversity*, and planktic dominance, *G.ruber* and *G. trilobus immaturus* abundances respectively. On the contrary, the P/B ratio and Planktic number stood as outliers. The PCA distinguished eight planktic foraminiferal reaction groups which were dependent upon a complex interaction of abiotic (temperature and salinity) and biotic factors.

Keywords: Statistical Analysis, Planktic, Foraminifera, Continental Shelf, Southwestern Nigeria.

INTRODUCTION

The study area straddles the inner and middle continental shelf off Southwestern Nigerian. It lies between latitudes 3°50' and 6°50' N and longitudes 3°25' and 8°50' E. Situated in the Gulf of Guinea between the eastern boarder of Benin Republic and Western flank of Niger Delta, it is bounded in the north by the marginal barrier island-lagoon complex and in the south by outer continental shelf (Figure 1). It is underlain by lowland, nearly flat and non-consolidated sediments.



Key to Stations

1. = LE1	11. = BE2
2. = LE1A	12. = BE3
3. = LE2	13. = BE7
4. = LE3	14. = BY1
5. = LE4	15. = BY2
6. = LE4A	16. = BY3
7. = LE5	17. = BY4
8. = LE7	18. = BY5
9. = BE1	19. = BY6
10. = BE1A	20. = BN4

Figure 1: Map of the Study Area (modified after Nwilo and Badejo, 2007)

Planktic foraminifera constitute a major component of continental shelf biogenic sediments' microfauna. They live primarily in the pelagic zone and their distribution is controlled by both abiotic and biotic factors. Broecker (1965) suggested that the distribution of planktic foraminifera may not be dependent upon temperature alone, but upon density of the water medium, which in turn is dependent upon temperature, salinity and pressure of that medium. Berger and Piper (1972) also suggested that sedimentation of planktic foraminiferal tests is related to their settling behavior.

However, the distribution of the planktic foraminiferal faunas living in today's ocean is directly related to the distribution of surface oceanic water masses (Bé, 1966, Belyaeva and Saidova, 1967, Ruddiman, 1969). Wilcoxon (1964), Boltovskoy (1964, 1968) and Cifelli (1967) recorded distribution pattern of planktic foraminifera in the Atlantic Ocean similar to the one recorded by Adegoke *et al.* (1971) in the Gulf of Guinea. Li *et al.* (1999) also recorded Holocene planktic foraminiferal assemblages on the Western Australia's southern shelf, which were dominated in the west by tropical forms like *Globigerinoides trilobus, Globorotalia menardii* and *Neogloboquadrina dutertrei* and in east by the temperate species *Globorotalia inflata*.

Moreover, many workers have devised different techniques for analysis of planktic foraminiferal faunas in both surface and deep-sea cores sediment. These are Schott (1935), Ericson *et al.* (1961), Phleger (1960), Emiliani (1964) and Imbrie (1963). Some of these techniques have limitations as some are not as statistically rigorous as others and not all of these are applicable to all sea sediments, for example, if species did not occur in sufficient numbers to permit statistically significant statement to be drawn.

Furthermore, different workers (Odum et al., 1960; Ellison, 1965; Gibson, 1966; Lidz, 1966; Odum, 1969; Berger and Parker, 1970) have proposed different diversity indices. Nonetheless, relative abundances of individual species data represent a closed number system (Chayes, 1960 and Emiliani, 1964), hence their use may receive a lot of critics. A Closed system with few components imposed severe statistical constraints which become less severe as the number of components increases (Krumbein and Graybill, 1966). In an attempt to avoid the statistical constraints imposed by a closed number system, Emiliani (1964) suggested the use of the ratios of the relative abundances of two or more species. A ratio that has been used extensively is the relative abundance of "cold-water" species to relative abundance of "warm-water" species (Boltovskoy, 1965).

Imbrie (1963), Jollife (1986) and Jorissen (1987) have successfully applied multivariate analysis to the characterization and solution of a variety of geological problems. This technique has been proved to be of considerable value in the study of foraminiferal populations.

Yurica and Hiroshi (2002) as well used multivariate analyses to analyze recent planktic foraminiferal species from 52 surface sediments collected from Ryukyu Arc region in the northwestern Pacific Ocean and adjacent East China Sea. R-mode factor analysis was used to classify the planktic foraminiferal species into four reaction groups. Feldberg and Mix (2003) used Q-mode analysis of planktic foraminiferal species abundances in 767 top-core and down-core samples to reveal four statistically independent assemblages. Grimsdale and Van Morkhoven (1955) and Lynts (1971) established that increase in planktic/benthic ratio could be interpreted as a result of three factors. These are increase in the productivity of planktic foraminiferal species, decrease in contribution from the adjoining banks, beaches or shores and differential dissolution of planktic foraminiferal tests. According to Lynts (1971), low planktic/benthic ratios could result from contamination from the influx of shallow-water benthic foraminiferal from the adjoining banks. This could be corroborated by low occurrence of benthic foraminifers such as *Miliolina* and *Textulariina*.

Martinez *et al.* (2007) suggested that a decrease in both temperature and salinity would probably favour an increase in the population density of *G. inflata* while *Neogloboquadrina dutertrei dutertrei* populations were favoured by increasing salinity and temperature values. Marchant *et al.*, (1999) correlated warmer and colder conditions to a higher relative abundance of *N. dutertrei* and *G. inflata* respectively. Kirci-Elmas *et al.* (2007) showed that relative abundance of *Globigerinoides ruber* indicates warm water condition. Jones (1967) found that *G. dutertrei dutertrei* appeared to be mainly influenced by temperature. Ibaraki (2002) established that *Globigerinoides ruber and G. sacculifer* are high salinity tolerant species.

Initial studies and investigations on the physiographic settings of the study area and environs, had been carried out by many workers. Among these are NEDECO (1954; 1959; 1961), Allen and Wells (1962), Allen (1965) and **Altenbach et al. (2003)**.

Most studies on Recent foraminifera in Nigeria have concentrated on benthic forms. These include Fayose (1970), Asseez *et al.* (1974), Adegoke (1975), Adegoke *et al.* (1976), Ramanathan (1981), Salami (1982; 2005), Adegbie and Dublin-Green (1994), Dublin-Green (1996, 1999, 2004, 2005), Oláyíwolá and Odébòdé (2008, 2011); Phillips (2008) and Phillips *et al.* (2012). Little is known about Recent planktic foraminifera of Nigerian Continental Shelf. Notable is the work of Adegoke *et al.* (1971) which carried out a detailed study of the distribution of extant Planktic foraminifera in the modern sediments from the Gulf of Guinea. 22 species and two subspecies were reported and four bathymetry biofacies were delineated based on the planktic foraminiferal distribution and abundance. Additionally, Oláyíwolá (2007) identified both benthic and planktic foraminiferal taxa in the littoral sediments obtained off Southwestern Nigeria. Low occurrence of about 6.8 to 20.0 % and 4.4 to 9.6 % of *Miliolina* and *Textulariina* respectively are recorded in this work, which signified low influx of adjoining beach sediments in the studied area.

The present study determined the trends of the planktic/benthic ratio, planktic species diversity, planktic number, species ratio, relative abundance of individual species, planktic species dominance and non-tropical/tropical species ratio parameters oceanwards and their comparison using PCA. An attempt was made as well, to determine the preferred environmental conditions for the planktic foraminiferal assemblages. This study would enhance paleoenvironmental interpretation of the ancient sediments deposited in the Gulf of Guinea.

MATERIALS AND METHODS

Twenty grabbed samples, used for this work, were supplied by the Nigerian Institute for Oceanography and Marine Research (NIOMR) Lagos. These samples were collected along four transects (LE1 to LE8, BE1 to BE6, BY1 to BY6 and BN4) during the 1989 Inter-governmental Oceanographic Commission (IOC) cruise in the Gulf of Guinea (Figure 1).

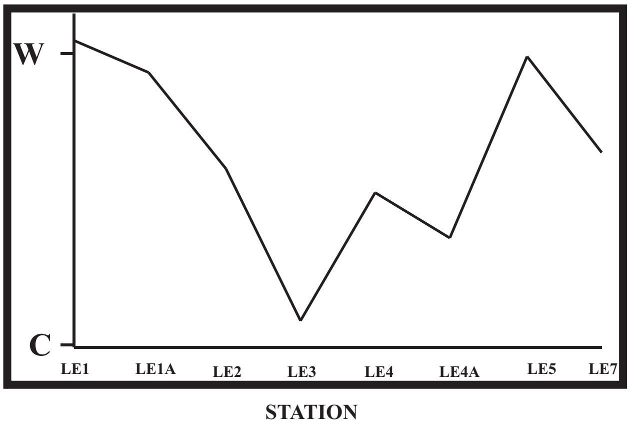
Twenty-five grams of each dried sediment sample was weighed. Following methodology employed by Clark *et al.* (1994) and Dublin-Green (1996, 1999, 2004), samples were processed for foraminifera. The sample residues were spread over a standard picking tray and were scanned under reflected light, binocular microscope. The foraminiferal contents were picked, identified and counted. The identification and taxonomy of the Planktic foraminiferal species were based mainly on the work of Parker (1962), Adegoke *et al.* (1971), Kennett and Srinivasan (1983), Bolli and Saunders (1986), and Loeblich and Tappan (1988).

The percentages of species of each individual were calculated. The Planktic/benthic (P/B) ratio, expressed as the percentages of planktic foraminiferal in the total foraminiferal assemblages, were calculated from the counting data (Grimsdale and Van Morkhoven, 1955; Phleger, 1960; and Boltovskoy, 1965).

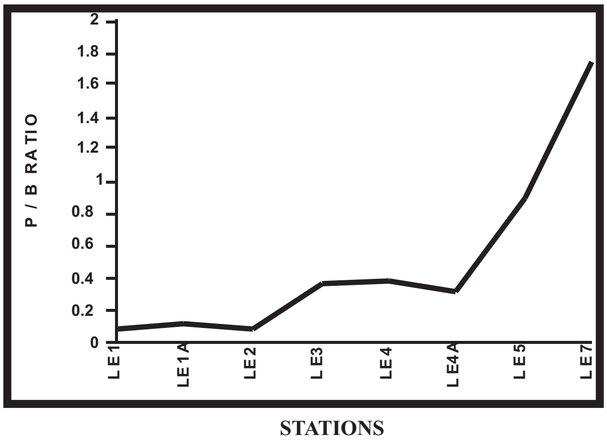
The work of Bé (1966, 1967) and Belyaeva and Saidova (1967) on the zoogeography of planktic foraminifera enables us to make *a priori* decision to group the recovered fauna into non-tropical and tropical species. This gives room for the calculation of the ratio of non-tropical to tropical forms. The resulting curve of this ratio for the present study area was shown in Figure 3A. The ecological/climatic indicator curve of Figure 2A was derived from this curve (Lynts, 1971). The relative abundance data were subjected to Principal Component Analyses (PCA) and diversity analysis using the computer package PAST (Paleontological Statistics software) of

Øyvind *et al*. (2001, 2007). PAST was also employed to plot values of p/b ratios, planktic number, planktic diversity, planktic dominance and relative abundance of planktic foraminifera, and species ratios against sample stations (Figures 2B-2H) and (Figures 3A-3C) respectively.

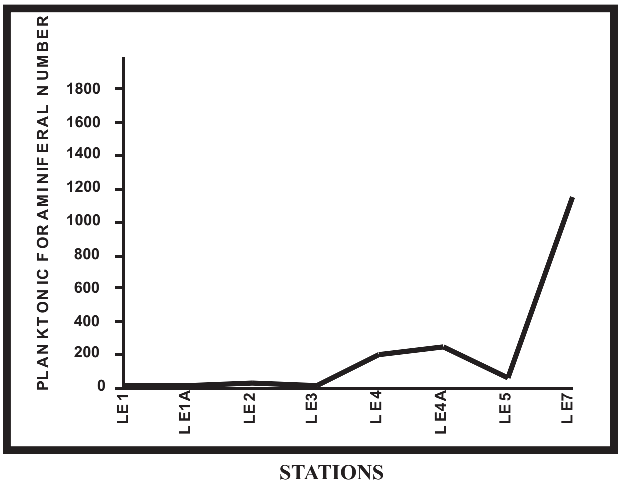
In general, the closed system was composed of eighteen (18) components (species) and was assumed to behave more like an open system. It is also important that one must always keep in mind the restrictions imposed by the closed system. These were taken into cognizance in this investigation.



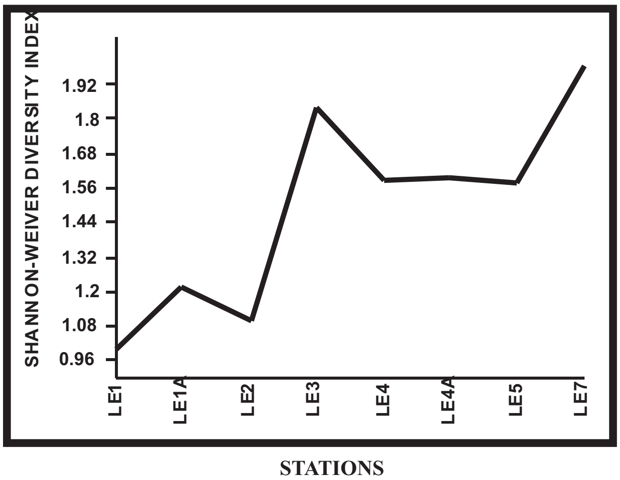
(**A**) Climatic indicator: **'W'**=warmer climates and **'C'**=indicates cooler climates



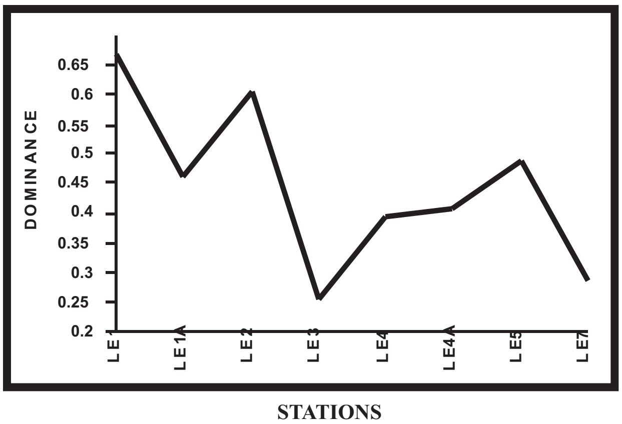
(B) P/B ratio



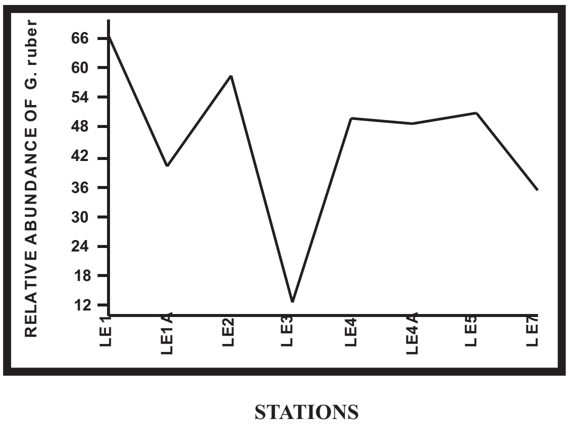
(C) Planktonic Foraminiferal Number



(D) Planktonic Species Diversity

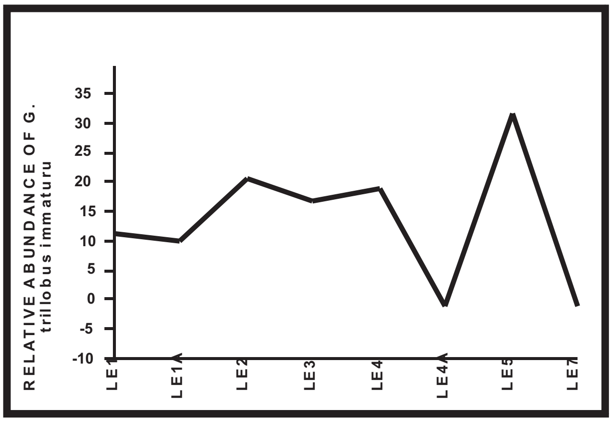


(E) Planktonic Species Dominance



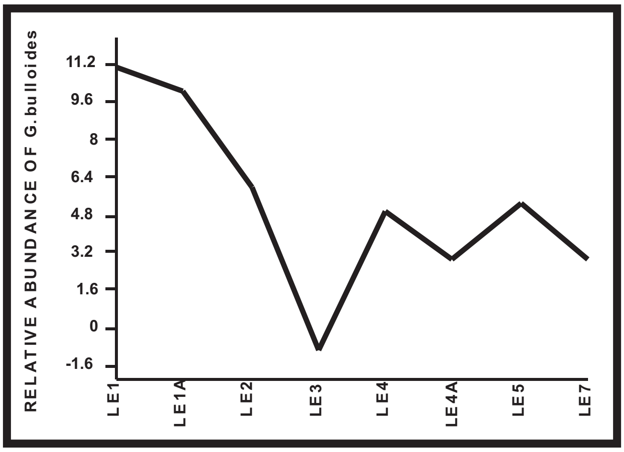
(F) Relative Abundance of *Globigerinoides ruber*

Figure 2: Planktic Foraminiferal Species Analyzed Parameters



STATIONS

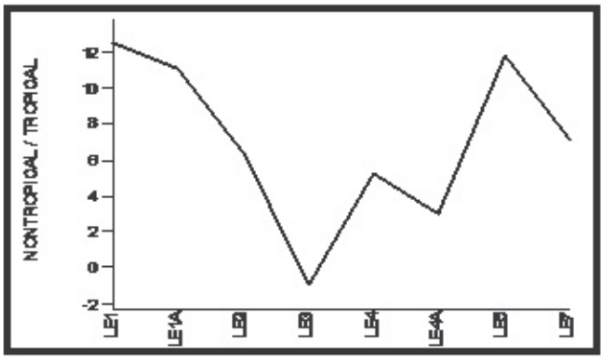
(G) Relative Abundance of *Globigerinoides trilobus immaturu*



STATIONS

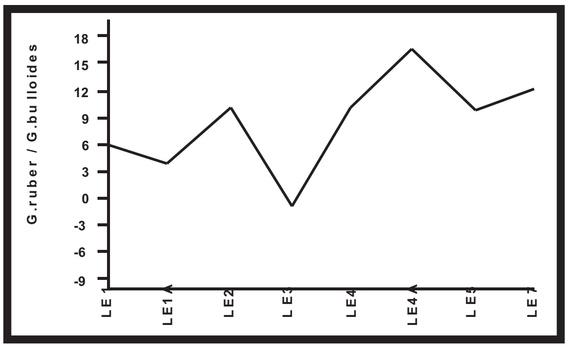
(H) Relative Abundance of *Globigerina bulloides*

Figure 2 (Cont'd): Planktic Foraminiferal Species Analyzed Parameters



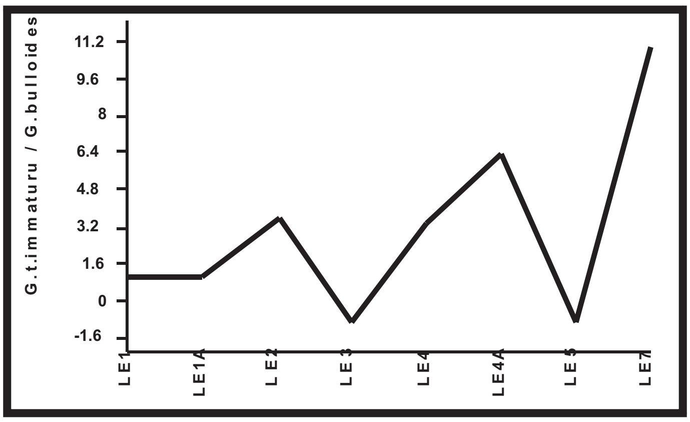
STATIONS

(A) Percentage of Non-tropical/Tropical Planktic Foraminifera



STATIONS

(B) *Globigerinoides ruber/Globigerina bulloides*



STATIONS

(C) *Globigerinoides trilobus immaturus / Globigerina bulloides*

Figure 3: Ratios of Planktic Foraminiferal Species

RESULTS

P/B Ratio

Eighteen planktic foraminiferal species were recorded in sample stations LE1, LE1A, LE2, LE3, LE4, LE4A, LE5 and LE7 which accounted for about 40 % of the total samples collected (Table 1) while sample stations BE1, BE1A, BE2, BE3-BE7, BY1-BY6 and BN4 were without planktic foraminifera. There was a general pattern of increase in the P/B ratio oceanwards from the continent. Low P/B values were recorded at sample stations 0.1 (LE1), 0.12 (LE1A) and 0.09 (LE2). The values then rose steadily from 0.9 (Le2) through 1.7 (LE7). The P/B ratio ranged from 0.09 (LE1) to 1.7 (LE7). The values significantly fluctuated (Figure 2B). The p/b ratio trend did not correlate with the derived climatic indicator, dominance, and relative abundance of individual planktic foraminifera in the study area (Figures 2A, 2B, 2E, 2F, 2G and 2H). The trend showed correlation with planktic foraminiferal number and planktic species diversity (Figures 2B, 2C and 2D). However, PCA indicated independence between the P/B ratio and each of the other planktic foraminiferal parameters investigated (Table 2).

Table 1: Absolute Numbers and Distribution of Total Planktic Foraminifera Fauna off the Lagos Coast, Southwestern Nigeria

Station Number	LE1	LE1A	LE2	LE3	LE4	LE4A	LE5	LE7	BE1	BE1A	BE2	BE3-BE7	BY1-BY6	BN4
Globigerinoides trilobus immaturus	1	1	7	-	34	44	-	361	-	-	-	-	-	-
Globigerinoides rubber	6	4	20	1	100	117	29	404	-	-	-	-	-	-
Globigerinoidess trilobus trilobus	-	-	5	-	20	15	3	74	-	-	-	-	-	-
Orbulina universa	-	-	-	1	-	-	1	10	-	-	-	-	-	-
Neogloboquadrina dutertrei dutertrei	-	-	-	2	14	18	5	100	-	-	-	-	-	-
Globorotalia inflata	-	-	-	-	-	-	-	13	-	-	-	-	-	-
Globorotalia scitula scitula	-	-	-	-	-	-	3	30	-	-	-	-	-	-
Globigerinoides trilobus sacculifer	-	-	-	-	-	-	-	3	-	-	-	-	-	-
Globigerina bulloides	1	1	2	-	10	7	3	33	-	-	-	-	-	-
Globigerinoides conglobatus	-	-	-	-	2	5	-	7	-	-	-	-	-	-
Globigerina menardii menardii	-	-	-	-	-	-	-	44	-	-	-	-	-	-
Globigerina menardii ungulata	-	-	-	-	-	-	-	38	-	-	-	-	-	-
Globigerina menardii cultrata	-	-	-	2	-	-	-	25	-	-	-	-	-	-
Sphaeroidinellopsis seminulina	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Globigerinoides spec. indet.	1	4	-	-	20	32	5	-			-	-	-	-
Hastigerina siphonina	-	-	-	-	-	-	2	-	-	-		-	-	-
Hastigerina aequilateralis	-	-	-	-	1	2	-	-	-	-	-	-	-	-
Globigerinoides elongatus	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Number of Spec/25gm	9	10	34	8	201	240	57	1139	-	-	-	-	-	-

Planktic Number (S)

The planktic foraminiferal number (S) represents the number of planktic foraminifera per gram of sediment ≥ 63 μm. The S values varied from 8 (at station LE3) to 1139 (at station LE7) (Table 1). Samples LE3 and LE7 had the lowest and highest values of S respectively (Figure 2C). Samples at stations LE1, LE1A, LE2 and LE3 had very low values of S. The S values rose from eight (LE3) steadily to 240 (LE4A) then dropped to 57 (LE5) and picked up exponentially to the highest value of 1139 (LE7) (Table 1, Figure 2C). The values of S increased oceanwards from the continent and correlated with P/B ratio and planktic species diversity trends (Figures 2B, 2C and 2D). The trend of S values indicated lack of correlation with the derived climatic indicator, dominance, and relative abundance of individual planktic foraminifera (Figures 2A, 2C, 2E, 2F, 2G and 2H). In addition, PCA result showed lack of correlation between S values and aforementioned planktic parameters that included derived climatic indicator, dominance, and relative abundance of individual planktic foraminifera (Table 2).

Planktic Species Diversity (H)

The Shannon-Weiner diversity index values (H) were very low, ranging from 1.0 (LE1) to 1.9 (LE7) (Figure 2D). H values increased oceanwards, from 1.0 (LE1) to 1.7 (LE1A), then dropped to 1.08 (LE2). Thereafter, the values rose to 1.88 (LE3) and dropped again to 1.68 (LE4) through 1.66 (LE4A) to 1.67 (LE5) and finally rose to 1.9 (LE7). There was no correlation between H trend and the derived climatic indicator, dominance and relative abundance of individual planktic foraminifera (Figures 2D, 2A, 2E, 2F, 2G and 2H).

Table 2: Reordered PCA Loading of Analysis of Relationships between different Parameters Based Upon Ratio of Individual Species (Øyvind et al**., 2001; 2007)**

Planktic Numbers (S)	1.000				
Relative abundance of *Globigerina bulloides*		-0.3066			
Percentage of nontropical/tropical species		-0.0733			
G. ruber/Globigerina. bulloides			0.4498		
G. trilobus immaturus/Globigerina bulloides			0.8801		
Planktic species diversity			0.6324		
Dominance of planktic foraminifera				-0.5032	
Relative abundance of *Globigerinoides ruber*				-0.2001	
Relative abundance of *Globigerinoides t. immaturus*				-0.5851	
P/B Ratio					0.8761

Note: G=Globigerinoides; t=trilobus; Values in the Table 2 indicate correlation coefficients between the variables (rows) and factors (columns).

The trend of planktic species diversity showed correlation with P/B ratio and planktic foraminiferal number (Figures 2B, 2C and 2D). The PCA showed some strong relation between species diversity and ratios of pair of species (*Globigerinoides ruber/Globigerina bulloides* and *Globigerinoides immaturus/Globigerina bulloides*) but failed to reflect any strong relationship with other parameters (Figures 2D, 3B, 3C and Table 2).

Planktic Species Dominance (D)

Dominance (D) values were observed to be generally low. The values ranged from 0.25 (LE3) to 0.67 (LE1) (Figure 2E). The D values decreased oceanwards from 0.67 (LE1) to 0.25 (LE3), rose to 0.47 (LE5) and finally dropped to 0.30 (LE7). The species dominance showed partial relation with the derived climatic indicator and relative abundances of *Globigerina bulloides* and strong relation with relative abundance of *G.ruber* (Figures 2A, 2E, 2F and 2G). The D pattern showed lack of correlation with P/B ratio, planktic species number and species diversity (Figures 2E, 2B, 2C and 2D). However, the result of PCA showed correlation between planktic dominance, relative abundances of *G. ruber* and *G. trilobus immaturus* but did not show strong deviation from other parameters in the study area (Table 2).

Relative Abundance of Individual Species

The highest number of individual species in each sample was 1139 while the lowest number was 8. No planktic foraminifera's individual species was documented in stations BE1, BE1A, BE2, BE3-BE7, BEY1-BY6 and BN4 (Table 1). The numbers of individual of selected species were used to calculate the relative abundance of tropical and non-tropical planktic foraminiferal species in each sample. These values were later plotted against sample stations (Figures 2F, 2G and 2H). The most abundant tropical and non-tropical species selected for illustration were *Globigerinoides ruber* (d'Orbigny) and *Globigerinoides trilobus immaturus* (d'Orbigny) and *Globigerina bulloides* (d'Orbigny) respectively (Table 3). The planktic foraminiferal species indicated significant fluctuations in their respective relative abundance. The relative abundance of *G. ruber* and *G. trilobus immaturus* varied from 12 (LE3) to 66 (LE1) and zero (LE4A) to 34 (LE5) respectively. The relative abundance of *G. ruber, G. trilobus immaturus and G. bulloides* decreased oceanwards from 66 (LE1) through 36 (LE7), 11 (LE1) through 0 (LE7) and 11.2 LE1 through 3.6 (LE7) respectively. The relative abundance of *G.ruber* was related to the derived climatic indicator while those of *G. trilobus immaturus* was not strongly correlated with the derived climatic indicator (compare Figure 2A with Figures 2F and 2G). The PCA indicated correlation of the relative abundance of these species with planktic species dominance but independent of other studied planktic parameters (Table 2). In contrast, *Globigerina bulloides* had the greatest relative abundance of occurrence in non-tropical waters (Table 3). Their relative abundance values varied and fluctuated greatly from 0.0 (LE3) to 11.2 (LE1) (Figure 2H) and were strongly related to the derived climatic indicator (Figures 2A and 2H, Table 2). Although, the result of PCA did not show any strong relation between their relative abundance and other parameters investigated, there was strong correlation with the derived climatic indicator (Table 2).

Ratios of Species

In the present investigation, the planktic foraminiferal fauna was subdivided into tropical and non-tropical forms (Bé, 1966; 1967, Belyaeva and Saidova, 1967) (Table 3). The ratio of two predominantly tropical species, *G.ruber* and *G. trilobus immaturus* to a predominantly non-tropical species, *Globigerina bulloides* was used (Figures 3A, 3B and 3C).The ratio of non-tropical to tropical planktic foraminifera in each sample was illustrated in Figure 3A. The comparison of Figures 3B with 3C showed that ratios with the same species as a denominator had quite similar ratio trends. The PCA also supported this assertion (Table 2). Although the comparison of Figures 3A, 3B and 3C indicated some relationship between the ratios of pairs of species and the ratio of non-tropical and tropical species. These relationships were not as strong as the ratio between species pair (Table 2). The ratios of pairs of species also strongly correlated with the Species diversity (Figures 3B, 3C, 2D and Table 2).

Table 3: Subdivision of Planktic Foraminiferal Species into Tropical and Nontropical Groups (After Bé 1966; 1967).

Species	Distribution
Globigerinoides trilobus immaturus	Tropical
G. ruber	
G. trilobus trilobus	
G. trilobus sacculifer	
G. conglobatus	
Globigerinoides sp.	
G. elongatus	
Orbulina universa	
Neogloboquadrina dutertrei dutertrei	
Globorotalia menardii menardii	
G. menardii ungulata	
G. menardii cultrata	
Hastigerina siphonina	
H. aequilateralis	
Sphaeroidinellopsis seminulina	
Globigerina bulloides	Non-tropical
Globorotalia inflata	
Globorotalia scitula scitula	

Principal Component Analyses (PCA)

The PCA indicated the clustering of the following: *G. bulloides* abundance and non-tropical/tropical species ratio, *Globigerinoides ruber*/*Globigerina bulloides* and *Globigerinoides immaturus*/*Globigerina bulloides* (ratios of pair of species) and planktic diversity, and planktic dominance, *G.ruber* and *G. trilobus immaturus* abundances respectively. In contrast, the P/B ratio and Planktic number stood as outliers (Table 2).

The PCA also delineated eight reaction groups, each of which was highly independent of the others (Table 4). This accounted for 72.0 % of the total variance contained in the data matrix. The reaction groups consisted of planktic foraminiferal species that indicated linear relationships in their distributions within the surface sediments. These reaction groups were later analyzed in terms of the abiotic factors (e.g. temperature and salinity) (Be, 1960; Be and Hamlin, 1967; Jones, (1967,1968)) (Table 5).

DISCUSSION

The continental shelves of southwestern Nigerian might not be a perfect test for some of the planktic parameters illustrated in this study.

Table 4: Reordered PCA Loading of Analysis of Relationships between Planktic Foraminiferal Species Based upon upon Relative Abundance of Species in Each of Sample (Øyvind e*t al*., 2001; 2007)

Globigerinoides trilobus immaturus	0.2853							
Globigerinoides ruber	0.5060							
Globigerinoides trilobus trilobus	0.2436							
Globigerinoides trilobus sacculifer		- 0.1293						
Globigerinoides conglobatus			0.1538					
Globigerinoides sp.			0.1584					
Globigerinoides elongatus				- 0.1293				
Orbulina universa				- 0.9448				
Neogloboquadrina dutertrei dutertrei				- 0.8601				
Globorotalia inflata				- 0.1293				
Globorotalia scitula				- 0.0531				
Globorotalia menardii				- 0.1293				
Globorotalia menardii cultrata				- 0.9442				
Globorotalia sp.				- 0.9238				
Globigerina bulloides					0.5844			
Hastigerina siphonina						- 0.030		
Hastigerina aequilateralis							0.1574	
Sphaeroidinellopsis seminulina								- 0.924

Note: Values in Table 4 Indicate Correlation Coefficients between the Variables (rows) and Factors (columns).

Physiographic settings of the study area characterized by structural features like submarine canyons and fans associated with mudslide and turbidity currents affect the sensitivity of some of the planktic parameters. However, it will be from those parameters, which are less sensitive to the physiographic setting that most of the climatic information would be derived.

P/B Ratio

A steady increase in the trend of P/B ratios (Figure 2B) recorded in this study may be interpreted as a result of the following factors: a decrease in contribution from the adjoining banks (beaches or shores) (Grimsdale and Van Morkhoven, 1955); an increase in the productivity of planktic foraminiferal species; and differential dissolution of foraminiferal tests (Lynts, 1971). Also, an increase in salinity oceanwards may have contributed to the increase in P/B ratio oceanwards. The lack of correlation between the trend of P/B ratios and the climatic indicator (Figures 2A and 2B; Table 2) disqualifies the first factor that is mostly related to climatic conditions. Also, low occurrences of *Miliolids* (6.8-20.0 %) and *Textulariina* (4.4-9.6%) (Lynts, 1971, Oláyíwolá, 2007, Oláyíwolá and Odébòdé, 2008, Oláyíwolá and Odébòdé, 2011) signify that the increase in P/B ratio trend was not as a result of the influx of shallow water benthic foraminifera from the adjoining shore.

Hence, the general increase in the P/B ratio recorded from LE1 through LE7 (Figure 2B) oceanwards may have probably resulted from a real increase in productivity or differential dissolution of foraminiferal tests and increase in salinity oceanwards.

Table 5: Preferred Change of Depth, Temperature and Salinity For Species Occurring in Surface Sediments of Study Area. [Environmental Data from 1) Bandy, (1964), 2) Bé (1960), 3) Bé and Hamlin (1967), 4) Jones (1967), 5) Jones (1968), and 6) Nikolaev *et al.* (1998)].
Note: NA= Not Available Data.

Species	Preferred Depth Range(m)	Preferred Temperature Range (°C)	Preferred Salinity Range (‰)	Reference(s)
Globigerinoides trilobus immaturus				
Globigerinoides ruber	0-100	24.0-25.2	35.98-36.78	4
Globigerinoides trilobus trilobus	35-49	NA	NA	5
Globigerinoides trilobus sacculifer	0-100	24.6-28.8	35.98-36.78	4
Globigerinoides conglobatus	100-200	20.7-25.2	36.28-36.48	4
Globigerinoides sp	NA	NA	NA	NA
Globigerinoides elongatus	NA	NA	NA	NA
Orbulina universa	25-74	17.6-27.7	36.14-36.55	4, 5
Neogloboquadrina dutertrei dutertrei	25-49	19.1-24.8	36.13-36.49	3, 4
Globorotalia inflata	NA	13-17	36.40-36.60	2, 3
Globorotalia scitula	NA	NA	NA	NA
Globorotalia menardii	NA	NA	NA	NA
Globorotalia menardii cultrata	25-49	17.6-27.7	36.14-36.67	4,5
Globorotalia sp.	NA	NA	NA	NA
Globigerina bulloides	0-38	12-14	36.40-36.60	2, 3, 4
Hastigerina siphonina	100-150	20- 23	NA	1
Hastigerina aequilateralis	7-29	10-28	NA	1
Sphaeroidinellopsis seminulina	25-75	28-30	NA	6

Planktic Number

Planktic foraminiferal number could also be expected to be influenced by physiographic setting, in as much as it is dependent upon both reproductivity and rate of sedimentation. The increase in planktic foraminiferal number oceanwards could be interpreted to be as a result of increase in reproductivity. Sedimentation is strongly related to climatic condition.

The lack of correlation between planktic foraminiferal number and climatic indicator recorded (compare Figures 2A and 2C), indicates that climatic condition would have very little effect on planktic number in the study area. It also indicates that the rate of sedimentation could not have been the cause of increase in planktic number oceanwards. This is because the rate of

Planktic Species Diversity

Physiographic setting of the studied area may not have caused the increase in planktic species diversity oceanwards from sample station LE1 through LE7 because physiographic setting would not directly influence any parameter based upon taxonomic criteria. Changes in species diversity may be expected to result from shift in diversity gradients corresponding to shift in distribution of surface water masses during the geologic past. Differential dissolution of planktic foraminiferal test could also be responsible for species diversity changes. This is corroborated by poor preservation of some of the specimens of planktic foraminiferal tests recovered in the studied surface sediments. It is, therefore, believed that the shift in the distribution of surface water mass and differential dissolution of planktic foraminiferal test could be responsible for the species diversity changes observed in the studied sediments. Lack of correlation between species diversity and climatic indicator indicates that changes in climate have little or no effect on the planktic species diversity.

Planktic Species Dominance

Changes in planktic species dominance trend oceanwards are probably not caused by physiographic setting of the studied area because the computation was based upon taxonomic criteria. Correlation between species dominance trend and climatic indicator means changes in climate will affect the planktic species dominance. For example a drop in temperature from warm to cold (Figure 2A) led to decrease (0.65 to 0.25) in planktic foraminiferal species dominance for sample stations LE1 to LE3 (Figure 2E). This is interpreted as more and more planktic foraminiferal species are dominating the samples in question. On the other hand, a rise in temperature from cold to warm resulted in increasing species dominance form 0.25 to 0.5 for sample stations LE3 to LE5 (Figures 2A and 2E) respectively which means less and less planktic species are dominating these samples.

Relative Abundance of Individual Species

Planktic foraminiferal species in the study area display fluctuations in their respective relative abundances oceanwards (Figures 2F, 2G and 2H). The relative abundances of the species of *Globigerina bulloides* and *globigerinoides ruber* show strong correlation with derived climatic indicator respectively (compare Figure 2A, with Figures 2F and 2G). This implies that changes in climatic condition lead to changes in the relative abundance of these species.

However, fluctuations in relative abundances of these and other species must be related to factor(s) other than the climatic condition. *Globigerinoides ruber* is known to prefer a deeper and/ or colder habitat (Table 5) and preference for narrow water temperature and salinity range. These suggest that fluctuations in relative abundance of *G. ruber* species (Figure 2F) may be related to changes in both water temperature and salinity regimes. *Globigerinoides trilobus immaturus* occurrs in the same reaction group with *G. ruber* (Table 2). This indicates that the distribution of *G. trilobus immaturus* may also be influenced by water temperature and salinity. *Globigerina bulloides* is generally considered to be a sub-polar to cold temperate species. The depth, temperature and salinity preferences of this species are given in Table 5 with characteristic narrow water temperature and salinity range. This suggests that increase in the relative abundance of *G. bulloides* may be caused by decreasing water temperature and salinity and vice versa.

Ratio of Species

The comparison of Figure 3B with 3C shows that ratios with the same species as a denominator have quite similar ratio trends. Lack of correlation between pairs' species ratios and climatic indicators (Figures 3B, 3C and 2A; Table 2) indicates that a change in the ratios of pair of species is independent of climate change. The ratio of non-tropical to tropical planktic foraminifera in each sample, illustrated in Figure 3A, is designated as the derived climatic indicator (Figure 2A) which reveals the climatic events in the study area. Inflections in the curve toward a greater percentage of tropical forms are interpreted to indicate ameliorating climatic conditions associated with warm events (Figure 2A). Conversely, the inflections in the curve toward a greater percentage of non-tropical species are indication of deteriorating climatic conditions associated with glacial events.

Principal Components Analyses (PCA)

The PCA divided planktic foraminiferal assemblages recovered from surface shelves' sediments into eight reaction groups (Table 4). These reaction groups were analyzed in terms of the abiotic factors that they were reacting to. This analysis was based upon the preferred depth, temperature and salinity ranges given in Table 5.

The first reaction group is made up of *Globigerinoides trilobus immaturus, G. ruber* and *G. trilobus trilobus* (Tables 4 and 5). From limited ecological information given in Table 5, it could be suggested that this group reacted to changes in temperature and salinity regime. This group has narrow temperature range and wide salinity range. This possibly indicates that the group had restricted temperature tolerance and less restricted salinity tolerance. *Globigerinoides trilobus sacculifer* stood alone as the second reaction group (Tables 4 and 5). *G. trilobus sacculifer* reacted to both temperature and salinity regimes. Therefore, increase in temperature and salinity favoured increase in populations in this group.

The third reaction group consisted of *Globigerinoides conglobatus* and *Globigerinoides* sp. (Tables 4 and 5). *G. conglobatus* had rather restricted salinity tolerances and less restricted temperature tolerances. Hence, the change in salinity resulted in the change in population of this group. *Globigerinoides elongatus, Orbulina universa, Neogloboquadrina dutertrei d., Globogerina inflata, Globogerina scitula, G. menardii, G. menardii cultrata and G. sp.* formed the fourth reaction group (Tables 4 and 5). It could be tentatively suggested from limited ecological information that this group reacted to changes in both the temperature and salinity regimes. *Orbulina universa* had rather restricted salinity tolerances and less restricted temperature tolerances. The population densities of *N. dutertrei dutertrei* were influenced more by salinity than temperature. Accordingly, decreased temperature and a slight decrease in salinity, would probably favour an increase in the population density of *G. inflata*, while *N. dutertrei dutertrei* populations increased with increasing salinities and temperature. *Globigerinoides menardii cultrata*, also depended primarily on salinity, because it had a rather broad temperature tolerance.

The fifth reaction group consisted of one species, *Globigerinoides bulloides* (Tables 4 and 5). This group appeared to react to both temperature and salinity regimes. Consequently, decreasing temperature and salinity favoured an expansion of the populations of *G. bulloides*. *Hastigerina siphonina* made up the sixth reaction group. The population density was influenced by temperature changes (Tables 4 and 5). This reaction group had little tolerance for temperature change and thus, slight decrease in temperature favoured an increase in the population of *Hastigerina siphonina*.

Conversely, *Hastigerina aequilateralis,* the seventh reaction group had wide temperature range (Tables 4 and 5). Hence, change in temperature might have little or no effect on the population density of this group. The eighth reaction group comprised *Sphaeroidinellopsis seminulina,* which was influenced by narrow temperature gradient (Tables 4 and 5). Therefore, a slight decrease in temperature resulted in the increment of the population density of this group.

CONCLUSIONS

A steady increase in the planktic/benthic ratio, planktic species number and planktic species diversity trends oceanwards was observed from this study. These trends may have probably resulted from a real increase in reproductivity, differential dissolution of foraminiferal tests and shift in the distribution of surface water mass and not as a result of climatic changes. Conversely, planktic dominance and abundances of *G. ruber*, *G. trilobus immaturus* and *Globigerina bulloides* patterns decreased oceanwards. This may have been caused by climatic condition of the study area.

Also, the planktic species dominance (D), relative abundances of *Globigerinoides ruber* and *Globigerina bulloides* and ratios of species, most especially non-tropical / tropical ratio, show some relationship with derived climatic indicator.

The relative abundances of planktic foraminiferal species and planktic dominance are dependent upon complex interactions of both biotic and abiotic factors. The Planktic/benthic ratio, planktic number and planktic species diversity, on the other hand, did not show any relationship with the derived climatic condition. Hence, these factors cannot be used successfully as climatic indicators in the study area. In general, the derived climatic indicator of the study area reflects both deteriorating (i.e. cold) and ameliorating (i.e. warm) conditions.

PCA distinguished eight planktic foraminiferal reaction groups in surface continental shelves' sediments, of the study area. Fluctuations in the population densities of planktic foraminiferal species in these reaction groups were caused, generally, by at least two abiotic factors namely temperature and salinity. However, biotic factors too play very important roles in influencing the population density changes of the planktic foraminiferal species.

ACKNOWLEDGEMENTS

We are grateful to the Nigerian Institute of Oceanography and Marine Research (NIOMR), Lagos that supplied the research samples and the anonymous reviewers whose comments have significantly improved the quality of this paper. We appreciate research grants to the senior author by the Nigerian Mining and Geosciences Society and Nigerian Association of Petroleum Explorationists.

REFERENCES

Adegbie, A. T. and Dublin-Green, C. O. 1994. Foraminifera Faunal of the Gulf of Guinea near Shore sediments, In: *Proceedings of the First Symposium of Intergovernmental Oceanographic Commission for East Atlantic*; 1; pp. 13-126.

Adegoke, O. S. 1975. Foraminiferal fauna of the polyhaline lagoons of the Gulf of Guinea. *Jour. Mining and Geology*, 12 (1&2), pp. 1 - 8.

Adegoke, O. S., Dessauvagie, T. F. J. and Kogbe, C. A. 1971. Planktic Foraminifera in Gulf of

Guinea Sediments. *Micropaleontology*, 17, (2), pp. 197 – 213.

Adegoke, O. S., Omatsola, M. E. and Salami, M. B. 1976. Benthic Foraminifera Biofacies of the Niger Delta. *Maritime Sediments*, Spec. Publication 1, pp. 279 – 292.

Allen, J.R.L. 1965. Late Quaternary Niger Delta and Adjacent Areas: Sedimentary Environments and Lithofacies. *Bulletin AAPG,* 49 (5), pp. 547 – 600.

Allen, J. R. L. and Wells, J. 1962. Holocene Coral Banks and Subsidence in the Niger Delta. *Jour. Geology*, 70, pp. 381- 397.

Altenbach, V. A., Lutze, G. F., Schiebel, R. and Schonfeld, J. 2003. Impact of interrelated and interdependent ecological controls on benthic foraminifera: An example from Gulf of Guinea. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 197, pp. 213-238.

Aseez, L. O., Fayose, E.A. and Omatsola, M. E. 1974. Ecology of the Ogun River estuary, Nigeria. *Palaeogeography, Palaeoclimatology and Palaeoecology,* 16, pp. 243 – 260.

Bandy, O.L. 1964. Cenozoic Planktonic Foraminifera Zonation. *Micropaleontology*, 10, no. 1, pp. 1-17.

Bé, A. W. H. 1960. Ecology of Recent planktonic foraminifera. Part 2- Bathymetric and seasonal distributions in the Sargasso Sea off Bermuda. *Micropaleontology*. 6, no. 4, pp. 373-392.

Bé, A. W. H. 1966. Distribution of Planktic Foraminifera in the world Oceans. (Abstract). *International Oceanogr. Congr.*, 2nd. Moscow.

Bé, A. W. H. 1967. *Foraminifera. Families globigerinidae and Globorotaliidae.* Cons. Perm. Internat. Expl. Mer. Zooplankton, Sheet 108; pp. 1-8; text-figs. 1-31.

Bé, A. W. H. and Hamlin, W. H. 1967. Ecology of Recent planktic foraminifera. Part 3- Distribution in the North Atlantic During the summer of 1962. *Micropaleontology*; 13(1); pp. 87-106, text figs. 1-41.

Belyaeva, N. V. and Saidova, Kh. M. 1967. *Foraminiferovye poyasa microvogo okeana.* Priroda, n. s., no. 1, pp. 117-118.

Berger, W. H. and Parker, F. L. 1970. Diversity of foraminifera in deep-sea sediments. *Science*; 168 (3937); pp. 1345-1347; text-figs. 1-2.

Berger, W. H. and Piper, D.J. W. 1972. Planktonic Foraminifera: Differential Settling, Dissolution, and Redeposition. *Journal of Limnology and Oceanography*, 17(2), 275-287.

Bolli, H.M. and Saunders, J. B. 1986. Oligocene and Hollocene Low Latitude Planktic Foraminifera. In: Bolli, H. M. and Saunders, J.B. and Perch-Nielsen, K. (Eds.) *Plankton Stratigraphy*, Cambridge University Press, Cambridge, pp. 155-262.

Boltovskoy, E., 1964. Distribution de los foraminiferas planctonicos vivos en el Atlantico ecuatorial, parte qeste (Expedition "Equalant"). *Argentina, serv. Hidrogr. Naval.,* No H. 639, pp. 1 –54, pls. 1- 4, text–figs. 1- 4.

______1965. Los foraminiferos recientes. Biologia, métodos de studio. Applicaciòn oceanograficá, EUDEBA (Editorial Universitaria de Buenos Aires). Pp. 1-510, text-figs. 1-114.

______1968. Living planktonic foraminifera of the eastern part of the tropical Atlantic Rev. *Micropal;* 11(2), pp. 85 –98. pls. 1 –2, text-figs. 1-2.

Broecker, W. S. 1965. Isotope geochemistry and Pleistocene climatic record. In: Wright, H. E., and Frey, D. G. Eds., *The Quaternary of the United State.* Princeton, N. J.: Princeton Univ. Press; pp. 737-753; text- figs. 1-7.

Chayes, F. 1960. On correlation between variables of constant sum. *Jour. Geophys. Res.*; 65; no. 12; pp. 4185-4193.

Cifelli, R. 1967. Distributional analysis of North Atlantic Foraminifera collected in 1961 during cruises 17 and 21 of the R/V Chain. *Cushman Found. Foram. Res., contr.,* 18(3), pp. 118-127, text-figs. 1 – 4.

Clark, F., Patterson, R. and Fishbein, E. 1994. Distribution of Holocene Benthic foraminifera from tropical Southwest Pacific Ocean. *Journal of Foraminifera Research,* 24(4), pp. 241-267.

Dublin-Green, C. O. 1996. Seasonal distribution of benthic foraminifera in the Bonny Estuary, Niger Delta. *Geologie de l'Afrique et de l'Atlantique sud:* 12th Coll. Micropaléontologie Africaine, Mémoir 16, pp. 175 - 183.

Dublin-Green, C .O. 1999. Benthic foraminiferal biotopes in the Bonny Estuary, Niger Delta. *Journal of Mining and Geology,* 35(2), pp. 269-277.

Dublin-Green, C. O. 2004. Recent benthic foraminifera from the Bonny estuary, Niger Delta, Nigeria. *Journal of Mining and Geology,* 40(1), pp. 85-90.

Dublin-Green, C. O. 2005. Benthic foraminifera as pollution indicators in the Bonny estuary, Niger Delta. *Journal of Mining and Geology*, 41(2), pp. 229 – 236.

Ellison, R. L. 1965. Diversity of benthic foraminifera (abstract). *Geol. Soc. Amer.,* Spec. Paper, no. 82; p. 55.

Emiliani, C. 1964. Paleo-temperature analysis of the Caribbean cores A254-BR-C and CP-28. *Geol. Soc. Amer., Bull.*; vol. 75; no.2; pp.129-144; text-figs. 1-7.

Ericson, D. B., Ewing, M., Wollin, G. and Heezen, B. C. 1961. Atlantic deep-sea sediment cores. *Geol. Soc. Amer., Bull.* vol. 72; no. 2; pp. 193-286; pls. 1-3; text-figs. 1-50.

Fayose, E. A. 1970. Preliminary Account of the Distribution of Recent Foraminifera off the Bight of Benin, Tarkwa Bay, *Bull. Inst. Fr. Afr.* Noire, A. 3, pp. 594-606.

Feldberg, M. J. and Mix, A. C. 2003. Planktic foraminfera, sea surface tempeature, and mechanisms of oceanic change in the Peru and south equitorial currents, 0-150 ka BP. *Paleoceanography*; vol.18 (1); pp.1 -16.

Gibson, T. G. 1966. Some unifying characteristics of species diversity. *Cushman Found. Foram. Res.*, 17, pp. 117 – 124.

Grimsdale, T. F. and van Morkhoven, F. P. C. M. 1955. The ratio between pelagic and benthic foraminifera as a means of estimating depth of deposition of sedimentary rocks. *Proceedings of World Petroleum Congress*, 4th, Rome. Sect. 1/D4, pp. 473-491.

Ibaraki, M. 2002. Responses of planktic foraminifera to the emergence of the Isthmus of Panama. *RevisItbaa Mraekxi icana de Ciencias Geológicas*, vol. 19(3) pp. 15 2-160.

Imbrie, J. 1963. Factor and vector analysis programs for analysing geologic data. *U. S. office Naval Res. Geogr. Branch.* Task No. 389-135. Tech. Rept. no. 6, pp. 1-83. text-figs. 1-2.

Jollife, I. T. 1986. *Principal Component analysis.* Springer-Verlag, New York.

Jones, J. I. 1967. Significance of distribution of planktic foraminifera in the Equatorial Atlantic Undercurrent. *Micropaleontology*, 13(4), pp. 489-501, text – figs. 1 –36.

Jones, J. I. 1968. The relationship of planktic foraminiferal populations to water masses in the western Caribbean and lower Gulf of Mexico. *Bull. Mar. Sci.*; vol. 18; no. 4; pp. 946-982. text-figs. 1-16.

Jorissen, F. J. 1987. The distribution of benthic foraminifera in the Adriatic Sea. *Marine Micropaleontol,* 12, pp. 21-48.

Kennet, J. P. and Srinivasan, M. S. 1983. *Neogene Planktic Foraminifera A Phylogenetic Atlas.* Hutchinson Ross Publishing Company, Stroudsburg, Pennsylvania. pp. 1 – 263.

Kirci-Elmas, E., O. Algan, I. Özkar-Öngen, U. Struck, A. V. Altenbach, E. K. Sagular, and A. Nazik, 2007. Palaeoenvironmental Investigation of Sapropelic Sediments from the Marmara Sea: A Biostratigraphic Approach to Palaeoceanographic History during the Last Glacial Holocene. *Turkish Journal of Earth Sciences*; Vol. 17; pp. 129–168.

Krumbein, W. C. and Graybill, F A. 1966. *An introduction to stastical models in geology.* New York: McGraw-Hill, pp. 1-475.

Li, Q., James, N. E., Bone, Y., McGowrn, B. 1999. Plaeoceanographic significant of recent foraminiferal biofacies on the western shelf of Western Australia: A preliminary study. *Palaeogeography, Palaeoclimatology, Palaeoecology;* 147; pp101-120.

Lidz, L. 1966. Deep-sea Pleistocene biostratigraphic, *Science.* Vol. 154, no. 3755; pp.1448-1462; text-figs. 1-5.

Loeblich, A. R. and Tappan, H. 1988. Foraminiferal *Genera and their Classification.* Van Nostrand Reinhold. New York, pp. 970.

Lynts, G. W. 1971. Analysis of the Planktonic Foraminiferal Fauna of Core 6275, Tongue of the Ocean, Bahamas. *Micropaleontology.* Vol. 17, no. 2, pp. 152-166. The Micropaleontology Project, Inc.

Marchant, M., Hebbln, D. and Wefer, G. 1999. High resolution planktic foraminferal record of the last 13,300 years from the upwelling area off Chile. *Marine Geology*; 161; pp. 115-128.

Martinez, J. I., Mora, G., Barrows, T, T. 2007. Paleoceanographic conditions in the western Caribbean Sea for the last 560 kyr. as inferred from planktonic foraminifera. *Marine Micropaleontology* 64, 177–188.

NEDECO (Netherlands Engineering Consultants), 1954. *Western Niger delta, report on investigation*, The Hague, 143 pp.

________1959. *River studies and recommendations on improvement of Niger and Benue,* Amsterdam, 1000 pp.

______1961. *The waters of the Niger delta*, The Hague, 317 pp.

Nikolaev, S.D., Oskina, N.S., Blyum, N.S. and Bubenshchikova, N.V. 1998. Neogene–Quaternary variations of the 'Pole–Equator' temperature gradient of the surface oceanic waters in the North Atlantic and North Pacific. *Global and Planetary Change*; vol. 18, pp. 85–111.

Nwilo, P. C. and Badejo, O.T. 2007 Impacts and Management of oil spill pollution along the Nigerian coastal Areas. (http://www.fig.net/pub/pub36/chapters/chapter_8).

Odum, E. P. 1969. The strategy of ecosystem development. *Science*; vol. 164; no. 3877; pp. 262-270; text-figs. 1-2.

Odum, H. T., Cantlon, J. E. and Kornicker, L. S. 1960. An organizational hierachy postulate for the interpretation of species-individual distributions, species entropy, ecosystem evolution, and the meaning of a species-variety index. *Ecology;* vol. 41; no. 2; pp. 395-399; text-figs. 1-3.

Ọláyíwolá, M. A. 2007. A study of littoral foraminiferal fauna of the sediments off the Lagos coast, Southwestern Nigeria. Unpublished M. Phil. thesis; Obáfémi Awólówò University, Nigeria; p. 175.

Ọláyíwolá, M. A. and Odébòdé M. O. 2008. Foraminiferal Ecology of Southwestern Nigeria's offshore littoral sediments: benthic fauna's diversity indices / pattern. In: Salami, A. T., Ofoezie, I. E. and Awotoye, O. O. (eds.). *Proceedings of the 1st Annual Conference of the Institute of Ecology and Environmental Studies,* Obáfémi Awólówò University, Nigeria, pp. 113-121.

Ọláyíwolá, M. A. and Odébòdé M. O. 2011. Foraminiferal Distribution of Southern Nigerian's Offshore Littoral Sediments: Benthic Faunal Diversity Indices and Patterns. *Ife Journal of Science* Vol. 13, No. 1, pp. 45-56.

Øyvind, H., David, A. T. H., and Ryan, P. D., 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeologia electronica, 4 (1); pp. 49. (http://www.folk.uio.no/ohammer/past/).

Øyvind, H., David, A. T. H., and Ryan, P. D., 2007. PAST: Paleontological Statistics Software Package for Education and Data analysis. Ver. 1-67, pp. 83. (http://www.folk.uio.no/ohammer/past/).

Parker, F. L. 1962. Planktic foraminiferal species in Pacific sediments. Micropaleontology 8, 219–254.

Phleger, F. B., 1960. *Ecology and Distribution of Recent Foraminifera*, John Hopkins Press, Baltimore, Md., 297 pp.

Phillips, O. A. 2008. Beach ecology characterization using benthic foraminifera: The Kuramo and Bar beaches, Lagos Nigeria. In: Salami, A. T., Ofoezie, I. E. and Awotoye, O. O. (Eds.). *Proceedings of the 1st Annual Conference of the Institute of Ecology and Environmental Studies*, Obáfémi Awólówò University, Nigeria, pp. 122-138.

Phillips, O. A., Falana, A. O. and Oláyíwolá, M. A. 2012. Assessment of Environmental Impact on Benthic Foraminiferal Distribution in Lagos Lagoon, Nigeria. *Journal of Mining and Geology,* 48 (1): pp. 71–81.

Ramanathan, R. M. 1981. Ecology and distribution of Foraminifera in Cross River Estuary and Environs off Calabar, Nigeria. *Journal of Mining Geology,* 18 (1), pp.154- 162.

Ruddiman, W. F. 1969. Recent planktic foraminifera: Dominance and diversity in North Atlantic surface sediments. *Science.* Vol. 164(3884); pp. 1164-1167; text-figs.1-3.

Salami, M. B. 1982. Bathyal benthic foraminiferal biofacies from the Nigerian sector of the Gulf of Guinea (West Africa). *Revista Española de Micropaleontología,* 14, pp. 455-461.

Salami, M. B. 2005. *Age and Environmental indication of ancient sedimentary rocks. Inaugural Lecture Series,* 174. Obafemi Awolowo University Press Ltd., 45 pp.

Schott, W., 1935. Die Foraminiferen in dem Pondcd sediments of the Mid-Atlantic Ridge aquatorialen Teil des Atlantischcn Ozeans. between 22" and 23" north latitude. Bull. Deut. Atl. Exped. Meteor 1925-1927 3(3B): *Geol. Sot. Amer.* 80: 1163-1190. 43-134.

Wilcoxon, J. A. 1964. Distribution of foraminifera off the Southern Atlantic Coast of the United States. *Cushman Found, Foram. Res., Contr.* L5 (1), pp. 1-24, text – figs. 1-14.

Yurika, U. and Hiroshi U. 2000. Distribution and Oceanographic Relationships of modern planktic foraminifera in the Ryukyu Arc region, northwest Pacific Ocean. *The journal of Foraminiferal Research,* 30 no 4, pp. 336-360.