International Journal of Scientific & Engineering Research, Volume 8, Issue 7, July-2017
ISSN 2229-5518

Baseline study of Estuarine Oceanographic Effects on Benthic foraminifera in Qua Iboe, Eastern Obolo and Uta Ewa/Opobo River Estuaries, Southeastern Nigeria

Thomas A. Harry, Clement Bassey, Paul A. Udofia, Saviour Daniel
Department of Geology, Akwa Ibom State University, Mkpat Enin, AKS- Nigeria
Corresponding author: tharry.tom@gmail.com; thomas.harry@aksu.edu.ng

Abstract- A total of 428 living benthic foraminiferal species (286 calcareous benthics and 142 agglutinated) which were retrieved from 60 sediment samples from Qua Iboe River, Eastern Obolo River and Uta Ewa/Opobo river estuaries were analyzed to establish a relationship between oceanographic effects on their distribution within the coast. Foraminiferal abundance and diversity as well as oceanographic parameters were measured and monitored over a period of three months. Characterization of the benthic foraminiferal assemblages, oceanographic-estuarine properties, living foraminifera and water depth was carried out and the relationship between foraminiferal distribution and estuarine oceanographic properties achieved by utilizing a set of statistical methods, including Q and R mode clustering, Pearson correlations, Principal Component Analysis (PCA), species rarefaction and multivariate regression linear modeling. Rarefaction analysis with 95 % confidence show the following results: 32 taxa from > 200 species (Eastern Obolo), 15 taxa from ≤ 125 species (Qua Iboe) and 4 taxa from ≤ 25 species (Uta Ewa). This gives maximum average specimens and taxa expected in the area which shall hereby serve as a baseline for future studies. The species diversity of the study areas shows a clear pattern of distinct disparities. Based on maximum average species distributions, Uta Ewa/Opobo River estuary shows minimum diversity compared to Qua Iboe and Easter Obolo/Opobo river estuaries. This work serves as a reference material for understanding paleobiogeography, biostratigraphy, paleoecology in paleoenvironmental reconstructions and petroleum exploration.

Index Terms— *Foraminifera, Paleoecology, oceanographic conditions, statistical methods, baseline*

1 Introduction

THE organisms utilized in this study are foraminifera. These are protozoans with shells that are usually composed of either secreted calcium carbonate (calcareous foraminifera) or sediment particles collected and bound together by the organism from the surrounding environment (agglutinated foraminifera). Foraminifera live in marine environments from the deepest ocean floor to the intertidal salt marshes that are found behind barrier islands or in the margins of estuaries. Several researchers have utilized foraminifera as a tool for paleo environmental reconstruction including paleoecology and marine biostratigraphy. Living population and surface sediment assemblages can be used to assess the current state of benthic ecosystem (Pati and Patra, 2012). Foraminiferal distribution is known to have a patchy nature (Barras et al, 2010; Griveaud et al, 2010) and they live throughout the upper 10 cm of sediments (Ozarko et al, 1997). Ponar Van vine grab and hand held corer was used in the bottom sediment sampling across the shore at every established transect. Oceanographic parameters were measured at every station to acquire more information about the water column. Foraminiferal species respond well in stations and months with favourable water physiochemical properties. However, according to Wang and Murray (1983) the tidal strength of an estuary usually reflects the amount of foraminiferal test transported from the open sea. Also, water chemistry has influenced the distribution pattern of living foraminifera, while the hydrodynamics control the dead assemblages (Wang and Murray, 1983).

1.1 Location and Physiography

Qua Iboe, Eastern Obolo and Uta Ewa / Opobo River estuaries are part of southern coastal waters of Nigeria. (Foster et al, 1983). The study area is located within the Niger Delta Basin. This basin is situated on the continental margin of the Gulf of Guinea in equatorial West Africa lying between Latitudes 30 and 60 N, and longitudes 50 and 80E. Imo and Bonny rivers flow into Uta Ewa / Opobo estuary while Qua Iboe River flow from Abia State through Onna and Eket Local Government Areas (Etesin et al., 2013). The Qua Iboe River estuary is in proximity to Exxon Mobil Crude oil effluent processing and treatment facility. The three river estuaries generally flow on alluvium of coastal plain sands (Recent in age) and empty into Atlantic Ocean. The study area has both wet and dry seasons characterized by its subtropical climate. Although there is always rain, the atmospheric temperature is high all through the year. The relative humidity is generally on the peak during the rainy season and low at dry season. Moreover, the area is situated within the hot humid tropical rain forest belt of Nigeria. The dominant vegetation in this ever-green rain forest comprises mangrove, raffia palms, grass and Nypa palms. They cluster on the river banks and creeks, hence serve as a shelter in marine environment for fish, foraminifera and other numerous organisms.

Fig. 1: Map of the study area showing sample locations

2 Methodology

2.1 Field Procedures

The following field parameters were obtained in situ from August, 2014 for a period of 4-5 months: dissolved oxygen (DO), electrical conductivity, pH, water transparency, surface water temperature, and salinity and water depths.

Langrangian method was used for real time measurement of surface tidal current velocity and direction at Uta Ewa terminal (NNPC petrol filling station) and Eastern Obolo's Bridge head (Okorombkho village). Stop watch was used to measure the time it takes a floating object on surface water to traverse a pre-measured distance of 10m along the tidal channel. This process was repeated thrice every 15 minutes for 12 hours per day. Specifically, the direction of flow at both the ocean coastline (South Atlantic Ocean) and tidal channels was determined using compass clinometers. Therefore, the velocity of the current measured was obtained by dividing the distance covered (10m) by the time taken and multiplied by 0.7, a constant factor for converting surface tidal current velocity to obtain bottom water current velocity (Emeka et al., 2010; Antia et al., 2012). Bottom sediment samples with replicates, for microfauna samples were collected at each location, on monthly basis. A total number of 60 sediment samples were collected. A specialized Ponar and Van vine grab were used to collect bottom sediment at equal intervals from one end of the shoreline across the shore to the other end. A greater depth was obtained by hand held when used at intertidal environment. A solution of rose Bengal and formaline was immediately added to the sediments to selectively stain the living cells (Walton, 1952). The pigmentation on the cells distinguished the living foraminifera from the fossil forms.

.

2.2 Laboratory Procedures

Foraminifera were quantified and identified using intermediate sieve fraction from GEOTOP (2010) systematic measures. 25ml of wet sediment for fauna analysis was routinely washed with sieve sizes of 63 or 45 micron. The residue was dried in oven at a temperature of 500C for 24hrs. The dried samples were studied under binocular microscope. The fauna were wet picked, stored and counted. The red or brown pigmentation of the forms was used as a means differentiating living foraminifera from the dead forms. In general, a bright stain inside more than half of the test was the criterion for a specimen to be considered as alive (Dijkstra et al, 2013; De Stigter et al., 1998; De Stigter et al., 1999). For agglutinated foraminifera the presence of stain in the aperture was an extra criterion to be used for living forms. This analysis was carried out in the Micropaleontology Laboratory, Geology Department, Akwa Ibom State University, Nigeria. Specimens were identified down to species level following the generic classification of Loeblich and Tappan (1987), Mikhalevich (1980, 2004), Sen Gupta et al (2002, 2003), and the holotype descriptions of Ellis and Messina (1940–1978) with other related foraminiferas databases.

The obtained oceanographic parameters such as dissolved oxygen, electrical conductivity, pH, water transparency, surface water temperature, salinity and water depth were clustered by Past computer software. The data were standardized by their different measurement equipment directives. The electrical conductively was the only data excluded by some model due to its high magnitudes. Apart from the absolute figures used in periodic analysis, by univariate statistics the mean parameters in a month per sample were obtained. This was used to cluster with the biotic data to delineate their responses in a particular sampling period. The sum of the average data was also calculated to achieve the mean representations of the sites in the study area (Usoro et al.,2015).

Q and R-mode cluster analysis using different data matrices which aids in general taxonomic, quantitative and qualitative comparison were prepared for the three study locations. Comparison with models for oceanographical and ecological interpretation was done. This enhanced the determination of the baseline in both benthic foraminifers' assemblage and physiochemical characteristics. 'Jaccard's Coefficient of Association' suitable for environmental analysis (N. Dijkstra et al, 2013) was also applied in this work. The main modes of variations within the abiotic variables were defined using Principal Component Analysis (PCA) (Davis, 2002; Harper, 1999). Absolute abundances were standardized and normalized before clustering was applied to increase the importance of the less abundant species (Manly, 1997, Dijkstra et al, 2013). The same was applied to the Multivariate linear regression model used to define mainly the relationship and perhaps characteristics of species and water quality. The relation between abiotic variables and benthic foraminiferal assemblage as well as between stations/locations was established with a Pearson correlation matrix. Q- and R-mode clustering, PCA, linear model and the Pearson correlation matrix were performed using the statistical program PAST (Hammer et al., 2001).

3 Results

6.1 Hydrodynamics

AThe hydrodynamics and the state of ecosystem are responsible for the distribution of foraminifera in tidal channels and related rivers estuaries system. The tidal range of the three study locations are mesotidal and semidiurnal in their characterization. The tidal pattern information used in this work for Qua Iboe River estuary was according to Antia et al (2012) and Emeka et al (2010) and real time measurements were carried out in Eastern Obolo and Uta Ewa/Opobo River estuaries during the course of this research respectively. At all the locations,waves were generated by winds and boats.

Results show that the maximum surface ebb tidal current velocities for Neap and Mean in Eastern Obolo are 0.142m/s, 0.284m/s. For Uta Ewa/Opobo, the maximun ebb tidal current velocity for Neap was 0.172m/s (fig. 2). This implies that Uta Ewa/Opobo river estuary empties into the oceanic water from its basin faster than Eastern Obolo River. This has some resultant effects on maintaining the physical, biological and chemical properties of the esturine system. From the estuarine oceanographic property analysis below, due to the rich source of river recharge, Uta Ewa/Opobo recorded more of alkaline water pH. As a result of this, PCA positively correlated salinity on both percentage variances along Eastern Obolo Estuary. It was observed that fresh water foraminifera species (e.g Reophax ssp) dominated Uta Ewa/Opobo.

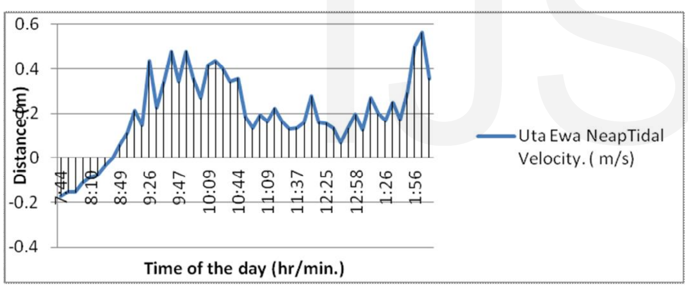

Fig. 2: Surface tidal current velocity at Eastern Obolo River Estuary. Neap tide NNPC Petrol Filling station, Uta Ewa Terminal.

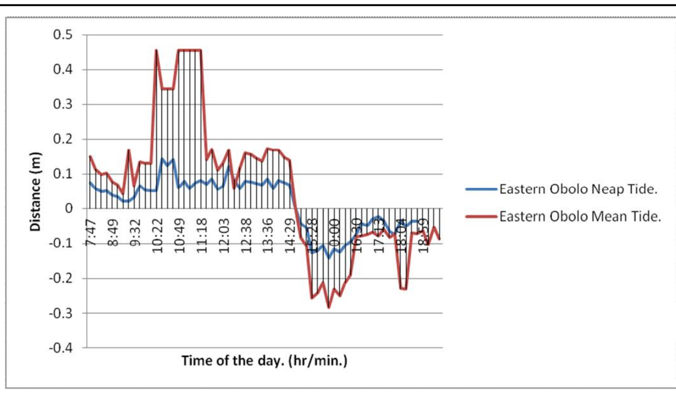

Fig. 3: Surface tidal current velocity at Eastern Obolo River Estuary. Neap and Mean Tide at Okorombokho Bridge.

Qua Iboe River estuary is a mixed energy environment; hence, influenced by tide and wave. It has the topmost peak in recycling time than Uta Ewa/Opobo River estuary. To this effect, the average dissolved oxygen was a little.
sponse of species in Qua Iboe River and Uta Ewa/Opobo River. Moreover, in Eastern Obolo, the maximum bottom flood tidal current velocities for Mean and Neap are 0.321m/s and 0.060m/s, and maximum bottom tidal current velocities of Neap for both flood and ebb in Uta Ewa/Opobo are 0.333m/s, 0.120m/s (Fig. 2). The disparity between 0.060m/s and 0.333m/s Neap bottom flood tidal velocities of both locations, entails more about the mixing energy, supply and time of river/ocean relationship. This relationship may enhance the supply of few foreign species of foraminifera, perhaps through upwelling process as encountered in Uta Ewa/Opobo estuary. It is observed that the trend of this southern coastal waters indicates that it is a significant area of upwelling. This affects the stability and sustainbility in characterization of the ecosystem. Though the primary productivity is boosted, changes in water quality has led to a deterioration of species density and diversity

3.2 Oceonographic Parameters

In general, the mean dissolved oxygen varies in Qua Iboe (9.12-13.6 mg/l), Eastern Obolo (7.15-9.82 mg/l) and Uta Ewa/Opobo (7.3-8.7 mg/l). Salinity was on a general decrease ranging from 2.0 ppt to about 10ppt, however, there was an appreciable elevation in salinity at the mouth of the estuaries in some months. Although not computed, Uta Ewa/Opobo River estuary water column was too turbid. In terms of opaque water quality, Eastern Obolo mean water transparency of 13.8m was recorded as the closest to Uta Ewa/Opobo River and Qua Iboe River with about 1.3m level of light penetration. In the month of August a pH of 8.1 at 17.4m depth was recorded for Qua Iboe River system. In September, mean water pH (7.25) with decrease mean depth of about 9.12m was recorded. At Eastern Obolo, the mean pH ranges from 6.1 to 6.6 and depth 10.2m and 12.2m respectively. On a general note, Uta Ewa/Opobo River estuary (mean pH 6.5) was observed to have similar depth variation, may be due to seasonal sand mining in the area. Also to this effect, the two locations were mostly influenced by tidal and wave energy. This enhances their sedimentation and accommodation processes.

3.3 Benthic foraminiferal Assemblages

Total of 428 living benthic foraminiferal species with 286 calcareous and 142 agglutinated, were identified in the samples of the three study stations. In addition to the above number, out of 60 sediments sample collected and analyzed, 1, 136 dead foraminifera were obtained. It is to be noted that dead species were not included in this analysis. The rarefaction analysis of species summarizes both the taxa and specimen distribution of the study areas (fig. 4). This algorithm is used from Krebs (1989). Rarefaction analysis with 95 % confidence, (fig. 4) show the following results: 32 taxa from > 200 species (Eastern Obolo), 15 taxa from ≤ 125 species (Qua Iboe) and 4 taxa from ≤ 25 species(Uta Ewa).

This give maximum average of specimens and taxa expected in the area, and shall hereby serve as a baseline for future studies. The species diversity of the study area shows a clear pattern with distinct disparities (Fig. 5). With regards to maximum average of species distributions, Uta Ewa / Opobo River estuary shows less diversity compared to Qua Iboe and Eastern Obolo. Uta Ewa / Opobo recorded the highest species dominance index (Fig. 6). Also, Qua Iboe species dominance index is nearly in the same range with Uta Ewa / Opobo but with slight elevation. All study locations species assemblage description below is based on maximum numbers of species collected and calculated from each sample station. In addition, the Shannon index 'H' chart (Fig.7) confirms the species diversity profile characteristics of the three study areas.

3.3.1 Qua Iboe River Estuary

H. germanica, L. cylindricus, A. glabratus and T. globigeriniformis are mainly the attributes of the location species assemblages. Other important members include *Bolivina lowmani , H. pilulifera, Recurvoides turbinatus and Rhizammina grilli* . The less recurring species encountered include H. rugosa and H. depressula. Other species of this location are reported with details in species association clustering analysis below.

3.3.2 Eastern Obolo River Estuary

The species assemblage of this location shares a little similarity with Qua Iboe River estuarine system. *Globigerinoides spp., Elphidium subgranulosum, P. challengeri and S. socialis* are the recurring dominant species. However, *Bolivina semicostata, Neoconorbina spp., T. inflata, P. variabilis, H. nipponica and P. japponicum* are also common within the area. Other low density species like H. rancocasensis, T. comprimata, B. crassatina, F. elongata, and R. turbinatus were represented.

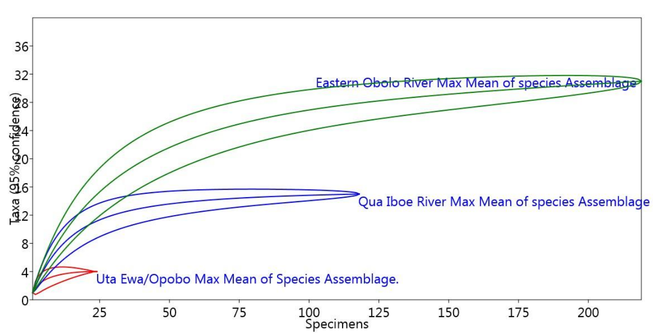

Fig. 4: Show individual foraminifera species rarefaction of the study areas.

ketienziensis made this species assemblage and the location a significant future case study due to its paleontological significance. *S. aduncus, C. rudis, Frondicularia elongata, and H. normani* made up the assemblage *and T. globigeriniformis* is the only species here that appear in the other three study areas.

3.4 Oceanographic Characteristics

The oceanographic characteristics of the study area were analyzed by different models using Q-mode clustering such as Principal Component Analysis (PCA); and other related statistical measures. Based on different data variables, correlation and coefficient values were plotted to help delineate the baseline oceanographic conditions. The variances below (fig.8) compares the real time characteristic of study locations. However, PCA 1 explained 81.8 % variance indicating high positive correlation to Surface water temperature and

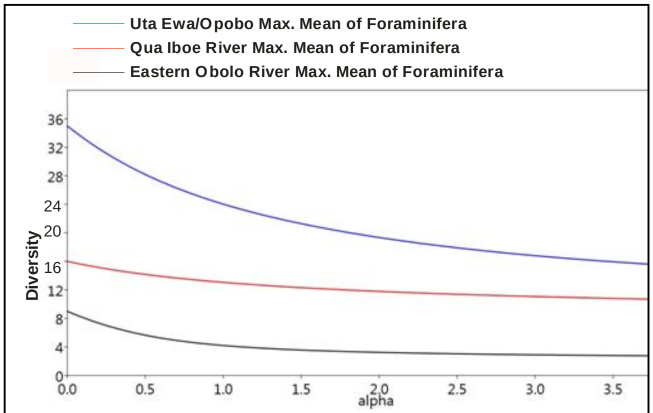

Fig. 5: Diversity profile of foraminifera species distribution in Qua Iboe, Eastern Obolo and Uta Ewa / Opobo River estuaries

transparency with high intermediate salinity while PCA 2, explained 81.1 % variance show high positive correlation to 'DO', salinity, and pH with low depth. It also negatively correlated to surface water temperature and transparency. Therefore, high composition in salinity variable correlated to both variances.

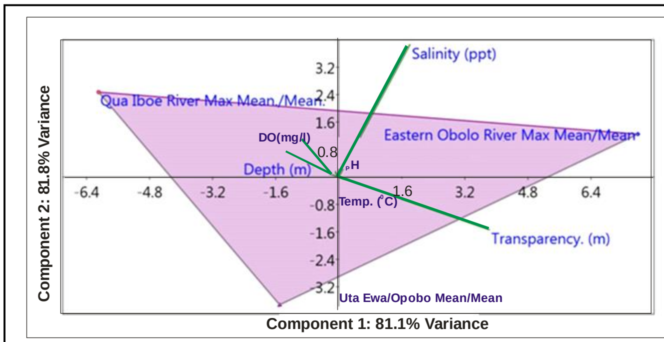

Fig. 8: Principal component analysis, PCA (Q-mode) of sample stations in oceanographic variables space; Qua Iboe, Eastern Obolo and Uta Ewa / Opobo River Estuaries. Diversity profile of foraminifera species distribution in Qua Iboe, Eastern Obolo and Uta Ewa / Opobo River estu-

From the PCA, Eastern Obolo River recorded high oceanographic water quality than Qua Iboe River; while Uta Ewa / Opobo was least in terms of oceanographic water quality.

3.5 Foraminiferal associations: R-mode Clustering

A total of 428 living benthic foraminiferal species (286 calcareous and 142 agglutinated) which were identified and obtained from 60 sediment samples of three study areas were analysed using univariate and multivariate statistical methods. By the application of univariate statistical method, the maximum numbers of foraminifera species across the sample station roll was obtained. This help to calculate the average maximum number of species in a particular location. R-mode clustering grouped this average maximum number of living benthic foraminiferal of Qua Iboe, Eastern Obolo and Uta Ewa/Opobo River Estuaries into different sub-assemblages or associations. The outcome of the three study locations clustering produced two major species associations; *Hemirobulina-B. semicostata and L. cylindricus-H. rugosa*. The first has the following two distinct sub associations namely *Hemirobulina-Saccamina and Globigerinoides spp.-B. semicostata*. The second association has two sub associations: *A. lessonii-Loeblichopsis and R. elongata-H. rugosa*

3.5 Foraminiferal Habitat relationships: Multivariate Regression (Linear Modeling)

Linear regression was performed using R-mode resemblance function in one algorithm, and standard (least-squares) regression other than "Reduced Major Axis" method. The Least-squares regression keeps the x values fixed, and it finds the line that minimizes the squared errors in the y values (Hammer et al, 2001). The linear model only included the dominant species that is species with a relative abundance of > 5% in at least one sample. (Dijkstra, N. et al, 2013). The following results were obtained through the application model and principal component analysis, PCA fitted to find relationships between abiotic variables and the benthic foraminiferal species and associations.The linear model (R-mode) outcome of these data together with the maximum average numbers of forams species (R-mode clustering species associations/assemblages) are hereby used to delineate the response in the community structures. This analysis clearly boasted the understanding of inference extent in species' average response to average water column physiochemical conditions of the three study area. The same was applicable with the PCA clustering analysis in this present study.

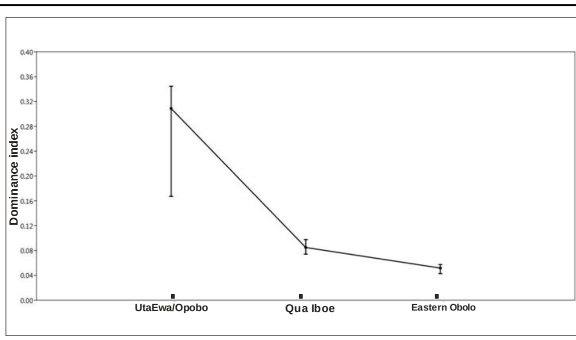

Fig. 6: Shows Dominance index (DI) of foraminifera distribution in Qua Iboe, Eastern Obolo and Uta Ewa/Opobo River estuaries

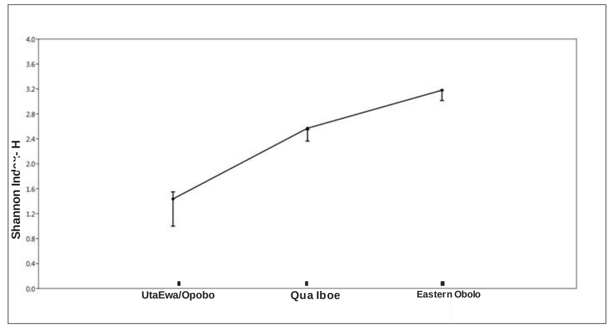

Fig. 7: Shows Shannon Index- H of foraminifera distribution in Qua Iboe, Eastern Obolo and Uta Ewa/Opobo River estuaries

Qua Iboe River estuary mean water column characteristics and species response levels are as follows:

- o Slightly low dissolve oxygen 'DO' (≤ 11.2mg/l), neutral water pH, low salinity (≤ 7ppt), normal water temperature (27oC), below intermediate depth (11m) and low water transparency (2m).
- o *E. subgranulosum-T. globigeriniformis sub association: Cornuspira involvens* is the only specie fitted by the regression model with low positive response.
- o *Loeblichopsis-Cyclocibicides sub association: Haynesina germanica and Loeblichopsis cylindricus* indicated moderate positive response. *Amphistegina lessonii* show slightly intermediate response; with below average positive responses to *Ammonia parkinsoniana, Ammodiscus glabratus and Bolivina lowmani. Hyperammina rugosa, Hyperammina elongata, Haynesina depressula, Recurvoides turbinatus, Rhizammina grilli and Carterina spiculotesta* all show low positive responses. Other forms are not clustered by the model.

However, Eastern Obolo River estuary mean water column characteristics and species response levels are as follows:

a. Very low water transparency (≥ 14m), slightly moderate salinity (≤ 13ppt), neutral water pH, low dissolves oxygen (≤ 9.3 mg/l), slightly low depth (≤ 10m) and water temperature (27-28oC) are indicated by regression model.

- *E. subgranulosum-T. globigeriniformis sub association*: high positive response species are *B. semicostata and E. subgranulosum*. Also, *Globigerinoides spp. and Rosalina bradyii* response positively above average measures. *T. globigeriniformis and Planorbulina variabilis* indicated moderate positive responses. *Pseudononion japponicum, Neoconorbina spp. and Saccamina socialis* are in below average positive response group and *Vaginulinopsis baggi, Hemirobulina rancocasensis, Tiphotrocha comprimata, Ammobaculites minuta, Conlophragmium spp., Hyperammina friabilis, Botelina labyrinthica, Ammobaculites linea, Hanzawaia nipponica and Ammonia ketienziensis* all showed low positive responses.
- *Loeblichopsis-Cyclocibicides sub association: only Hormosina pilulifera* indicated a positive response below the meas-

ured average variations. It was noted that *Cornuspira involvens, Loeblichopsis.*

cylindricus show low positive response. Besides, many other of this group were not fitted especially A. parkinsoniana- C. verniculata sub assemblage.

Also, Uta Ewa/Opobo River estuary mean water column characteristics and species response levels are as follows :

- Low 'DO'(≤ 9.0 mg/l), acidic water pH (≤ 6.2) and low salinity (4 ppt).
- E. subgranulosum-T. globigeriniformis sub association: Reophax guttifer indicated moderate positive response, while Reophax elongates show just slight intermediate overlaps. On the other hand, Subreophax monile and chrysalogonium rudis have low positive response. Also, Subrophax aduncus and Ammonia ketienziensis indicated very low responses. Significantly, many member of this team were not fitted by the model.
- Loeblichopsis-Cyclocibicides sub association: no other member of this group was fitted by the linear model except Amphistegina lessonii with zero index response.

4 Discussion

The species diversity of the study areas shows a clear pattern with distinct disparities. Based on maximum average species distributions, Uta Ewa/Opobo River estuary shows minimum diversity compared to Qua Iboe and Easter Obolo/Opobo river estuaries.This characterization of the three locations was based on the maximum mean numbers (instead of max. numbers) of foraminifera species per location versus average water column conditions respectively. The PCA 1 explained 70.6 % variance and 2 explained 29.3 % variance. The mode of variation changes from Eastern Obolo to Qua Iboe and decreases down to Uta Ewa/Opobo River estuarine system. Species association/assemblages resulted from the calculated maximum average numbers of jaccard's cofficient. However, with jaccard's cofficient of association, component 1 indicated positive cofficient (≥ 0.24) for *Rosalina bradyii, Saccamina socialis, Globigerinoides spp., Trochammina inflata, Elphidium subgranulosum* with salinity (< 0.16) and with cofficient value (≥ -0.08) negatively correlated with Reophax guttifer of *E. subgranulosum-T. globigeriniformis* sub association with 'DO', pH, and depth (< -0.08) . Also the same component 1 and coefficient value (≥ -0.08) correlated positively with no species of *Loeblichopsis-Cyclocibicides* sub association but negatively correlated with *Ammodiscus glabratus, Ammonia parkinsoniana, Bolivina lowmani and Amphistegina lessonii*. PCA 2, indicated no positive correlation with *subgranulosum-T. globigeriniformis* sub association with coefficient value of ≥ 0.24, rather it positively correlated with *Ammodiscus glabratus, Hormosina pilulifera, Bolivina lowmani and Haynesina germanica of Loeblichopsis-Cyclocibicides sub association*. Eastern Obolo River recorded high oceanographic water quality than Qua Iboe Rive, while Uta Ewa/Opobo was least in terms of oceanographic water quality.

5 Conclusion

This study presents the baseline and pre-impacted state of the estuarine oceanographic characteristics of the benthic foraminifera in Qua Iboe River, Eastern Obolo, Uta Ewa and Opobo River Estuaries. Foraminiferal associations were identified by R-mode clustering. Q-mode clustering was used to define the characteristics of both abiotic and biotic variables. Multivariate linear regression, Principal component analysis, Pearson correlation, Rarefaction and other model were used to define the data of this research work. The measured oceanographic parameters in the study area indicated the following mode of variations in decreasing order of magnitudes: Uta Ewa/Opobo, Qua Iboe and Eastern Obolo River estuaries. Similar variation was attributed to their species diversity. Also, the numbers of taxa in each follow the same trend above. But in species density contrast, Qua Iboe estuary took the ground level, while Uta Ewa/Opobo and Eastern Obolo estuaries top the table. There was no pronounced variation in both biotic and abiotic properties between the month of August at Eastern Obolo and September at Qua Ibo River respectively. Moreover, species have varying affinity to set of physiochemical measure, but with a better positive response to moderate setting classes. The energy settings of Eastern Obolo favour the benthic foraminifera species due to low bottom tidal current velocity. Significantly, Qua Iboe and Uta Ewa/Opobo estuary are high mixed energy environments with no or fewer shelter marine areas.

References

Antia, V.I., Emaka, N. C., Ntekin, E. U., & Amah, E. A. (2012). Grain size Distribution and Flow Measurements in the Qua Iboe River Estuary and Calabar Tidal River, S.E. Nigeria. European Journal of Scientific Research, 67(2), 223-239.

Appeltans, W., Bouchet, P., Boxshall, G.A., De Broyer, C., de Voogd, N.J., Gordon, D.P., Hoeksema, B.W., Horton, T., Kennedy, M., Mees, J., Poore, G.C.B., Read, G., Stöhr, S., Walter, T.C., Costello, M.J., 2012. World Register of Marine Species (WoRMS).

Barras, C., Fontanier, C., Jorissen, F., Hohenegger, J., (2010). A comparison of spatial and temporal variability of living benthic foraminiferal faunas at 550 m depth in the Bay of Biscay. Micropaleontology 56, 275-295.

Davis, J.C., 2002. Statistics and Data Analysis in Geology, 3rd ed. John Wiley & Sons Inc, New York. de Stigter, H.C., Jorissen, F., Van der Zwaan, G.J., 1998. Bathymetric distribution and microhabitat partitioning of live (Rose Bengal stained) benthic foraminifera along a shelf to deep sea transect in the southern Adriatic Sea. Journal of Foraminiferal Research 28, 40-65.

De Stigter, H.C., Jorissen, F., Van der Zwaan, G.J., (1998). Bathymetric distribution and microhabitat partitioning of live (Rose Bengal stained) benthic foraminifera along a shelf to deep sea transect in the southern Adriatic Sea. Journal of Foraminiferal Research 28, 40-65.

De Stigter, H.C., van der Zwaan, G.J., Langone, L., (1999). Differential rates of benthic foraminiferal test production in surface and subsurface sediment habitats in the southern Adriatic Sea. Palaeogeography, Palaeoclimatology, Palaeoecology 149, 67-88.

Dijkstra, N. (2013) Benthic foraminifera as indicators of natural variability and anthropogenic impact. Environmental change in the SW Barents Sea and Hammerfest Harbor; A dissertation for the degree of Philosophiae Doctor.

Emeka, N. C., Antia, V. I., 14pong, A. J., Amah, E. A., and Ntekim, E. U. (2010). A study on the Sedimentary of Tidal Rivers: Calabar, and Great Kwa, S. E. Nigeria. European Journal of Scientific Research, 47(3), 370-386.

Ellis, B.E., Messina, A.R., 1940–1978. Catalogue of Foraminifera American Museum of Natural History, New York.

Etesin, U., Udoinyang, E. and Harry, T. (2013). Seasonal Variation of Physico-chemical Parameters ofWater and Sediments from Iko River, Nigeria. Journal of Environment and Earth Science, 3(8) : 96 - 110

Foster C. A, Swain F. M., Petters S.W., (1983). Late Paleocene Ostracoda from Nigeria. Revista Espanola De Micropaleontologia., vol.xv, num. 1,pp103-166.
Griveaud, C., Jorissen, F.J., Anschutz, P., (2010). Spatial variability of live benthic foraminiferal faunas on the Portugese margin. Micropaleontology 56, 297-322.

Hammer, Ø., Harper, D.A.T., Ryan, P.D., (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1): 9 pp.

Harper, D.A.T., 1999. Numerical Palaeobiology. John Wiley & Sons Inc, New York.

Krebs, C.J. 1989. Ecological Methodology. Harper & Row, New York.

Loeblich, A.R., Tappan, H., (1987). Foraminiferal genera and their classification. Van Nostrand Reinhold Co, New York.

Manly, B.F.J., 1997. Randomization, Bootstrap and Monte Carlo Methods in Biology. Chapman and Hall, New York.

Mikhalevich V.I.(2004). On the heterogeneity of the former Textulariina (Foraminifera) / / Proc. 6 Intern. Workshop Agglutinated Foraminifera. Grzybowski Foundation Spec. Publ. V. 8. P. 317 to 349.

Mikhalevich V.I.(1980). Available at www.foraminifera.edu / projectdatabase
Nigerian Meteorological Station (NIMET), (2012). Cross River State Climate Data. Calabar, Cross River State..

Ozarko, D., Patterson, R.T., and Williams, J.F.L., (1997). Marsh foraminifera from Nanaimo, British Columbia (Canada): Implications of infaunal habitat and taphonomic biasing: Journal of Form-iniferal Research, v. 27, no. 1, p. 51–68.

Pati, P. and Patra, P. K. (2012). Benthic Foraminiferal Responses to Coastal Pollution: a Review. International Journal of Geology, Earth and Environmental Sciences ISSN: 2277-2081 (Online). An Online International Journal Available at http: / / www.cibtech.org / jgee.htm.

Sen Gupta, B.K. (2002). Modern Foraminifera. (http: / / books.google.com / books?id=k-3tUnxw- lgCpg=PA16&ipg).
Sen Gupta B. K. (2003), Systematics Classification of modern Foraminifera Modern Foraminifera. Kluwer Academic Publishers.

Schönfeld, J., 2012. History and development of methods in Recent benthic foraminiferal studies. Journal of Micropalaeontology 31, 53-72.

Usoro M. Etesin, Aniefiok E. Ite, Thomas A. Harry, Clement E. Bassey, Edet W. Nsi. Assessment of Cadmium and Lead Distribution in the Outcrop Rocks of Abakaliki Anticlinorium in the Southern Benue Trough, Nigeria. Journal of Environment Pollution and Human Health. Vol. 3, No. 3, 2015, pp 62-69. http: / / pubs.sciepub.com / jephh / 3 / 3 / 2

Wang, P. & Murray, J. W. (1983). The use of foraminifera as indicators of tidal effects in estuarine deposits. In: Wang, P., Distribution of Foraminifera in Estuarine Deposits: A comparison between Asia, Europe and Australia. Tokyo: Terra Scientific Publishing Company, 71-83.

Walton, W.R., 1952. Techniques for recognition of living foraminifera. Contribution from the Cushman Foundation of Foraminiferal Research 3, 56–60.J.S. Bridle, "Probabilistic Interpretation of Feedforward Classification Network Outputs, with Relationships to Statistical Pattern Recognition," *Neurocomputing—Algorithms, Architectures and Applications,* F. Fogelman-Soulie and J. Herault, eds., NATO ASI Series F68, Berlin: Springer-Verlag, pp. 227-236, 1989. (Book style with paper title and editor)