Technical Publication of Nigerian Institute for Oceanography and Marine Research (NIOMR) Lagos Nigeria, Volume 1, November 2008.

TECHNICAL PUBLICATION

OF THE
NIGERIAN INSTITUTE FOR OCEANOGRAPHY AND MARINE RESEARCH (NIOMR)
LAGOS, NIGERIA

VOLUME 1
NOVEMBER 2008

TECHNICAL PUBLICATION

OF THE
NIGERIAN INSTITUTE FOR OCEANOGRAPHY AND MARINE RESEARCH (NIOMR)
LAGOS, NIGERIA

VOLUME 1

NOVEMBER 2008

All enquiries to:
The Nigerian Institute for Oceanography and Marine Research (NIOMR)
P.M.B 12729
3 Wilmot Point Road
Victoria Island
Lagos
Tel: 234 (1) 17642276
E-mail: niomr@linkserve.com.ng
Web site: www.niomr.gov.ng

ISBN 078-2345-116

Printed by:
Mich-Bamidele Nigeria Limited
9 Ayoade Street
Bajulaiye Somolu
Lagos
Tel: 08023034880

Contents

Preface

The Nigerian Institute for Oceanography and Marine Research (NIOMR) established in November 1975 by the Research Institute Establishment Order of 1975 has the responsibilities to conduct research into the resources and geological/geophysical, chemical and physical characteristics of the Nigerian territorial waters and the high seas. NIOMR also conducts research to fish utilization as well as Extension and Liaison Services. Since the establishment of NIOMR, a total of 35 occasional papers and 109 technical papers had been published to expose the research findings of the Institute to various stakeholders. These technical papers were previously published as standalone papers. In order to improve the quality, publication and circulation of scientific information from the Institute NIOMR's Technical Committee was set up in June 2007.

I am happy to note that the new Technical Publication Committee has coordinated the publication of this new NIOMR Technical Paper Series as volumes. Each Volume which may consist of 5 or more papers will be subsequently published on a half yearly basis. The papers in this new series have been critically peer reviewed both internally and by external scientists. I hope that with the release of this maiden technical paper series, NIOMR scientists will seize the opportunity to make their research findings available to the scientific community, educational, government and private stakeholders. It is my believe that this publication and subsequent editions, will further extend the frontiers of knowledge and contribute to the body of scientific information needed for the socio-economic development and sustainable management of Nigeria's marine coastal environment and resources.

Dr. A. O. Ayinla
Executive Director/CEO
17 April 2008

FROM THE PUBLICATION COMMITTEE'S TABLE

The new NIOMR Technical publication series will be published on a half yearly basis. This first volume contains eight papers which have been critically reviewed by both internally and externally recognized scholars. The papers in this maiden volume cover a wide variety of subjects related to NIOMR's research mandate from Marine Resources and Fisheries, Physical/Chemical/Biological Oceanography, Geology/Geophysics, and Fish utilisation departments.

NIOMR is grateful to all reviewers and contributors for their cooperation.

Dr. Larry Awosika
Chairman NIOMR Technical Publication Committee
15th November 2008

GLACIAL AND INTERGLACIAL VARIABILITY OF THE NIGER RIVER DISCHARGE INTO THE GULF OF GUINEA

Adegbie Adesina

Nigerian Institute for Oceanography and Marine Research,
P.M.B. 80108, Victoria Island, Lagos State, Nigeria.

ABSTRACT

Stable oxygen isotope ($\delta^{18}O$) ratios of planktonic foraminifera *Globigerinoides ruber* (pink) and *Globigerinoides sacculifer* from Niger fan deep sea sediments have revealed the variability of the Niger river discharge into the Gulf of Guinea for the last 245,000 years. Analysis of Meteor core GeoB 4901-8 (02°40.7'N, 006°43.2'E: water depth 2184 m), showed glacial and interglacial climatic oscillations in the Late Quaternary over the tropical eastern Atlantic. During glacial periods, the oxygen isotope values are high and very low during interglacials. High negative $\delta^{18}O$ values of *G. ruber* (pink) up to -3.2‰ were recorded in these sediments, this value is very low when compared with the $\delta^{18}O$ *G. ruber* (pink) record from the Congo fan. Similarly, low values up to -2‰ during interglacials were recorded in the difference between the oxygen isotope values ($\Delta\delta^{18}O$) between shallow-dwelling planktonic foraminifera *G. ruber* (pink) and *G. sacculifer*. Apart from indicating oscillating climatic conditions in the Late Quaternary, very low values of $\delta^{18}O$ ratios of *G. rubber* (pink) also record periods of surface ocean freshening. The $\Delta\delta^{18}O$ (*G. ruber* - *G. sacculifer*) record gives credence to the fact that there was significant increase in the Niger river discharge during warm periods.

Keywords: *glacial and interglacial, Niger fan, Stable oxygen isotope, planktonic foraminifera, Fe/Ti ratios, Africa climate change.*

1. INTRODUCTION

Paleoenvironmental conditions over Africa have been a subject of interest among earth scientists. Many studies have been conducted to unravel what the African climate was like especially in the Quaternary. Continental studies on lake levels (Street and Grove, 1976), sand dunes (Sarnthein, 1978) and also on marine sediments (Adegbie et al., 2003; Pastouret et al., 1978; Schneider et al., 1997; Zabel et al., 2001) have all shown that the African climate and paleoenvironment are influenced and may be controlled by a suite of complex processes. It is known that the African monsoon strongly influence the African terrestrial climate on one hand and also the surface water hydrography of the surrounding marine realm on the other hand. These are recorded in paleoceanographic and paleoenvironmental proxies such as oxygen, nitrogen and carbon isotopes, alkenones, etc. Unfortunately not much has been done in correlating between the African monsoons and precipitation changes. More studies are therefore needed in order to correlate between the African monsoonal precipitation changes during glacial and interglacial periods.

Such correlations can better be done with the study of deep-sea cores close to the continent that could provide continuous record for several thousand year (kyr) cycles. The Niger deep sea core provides such opportunity. Oxygen isotopes of planktonic foraminifera from the Niger deep sea fan sediments were analysed to provide paleoenvironmental information that allows reconstruction of precipitation changes and sea surface hydrography in the basin. The paper further discusses the history of the Niger river discharge into the tropical east Atlantic surface ocean under the influence of varying climatic conditions during the past 245, 000 years.

2. HYDROGRAPHY

The modern hydrography of the Gulf of Guinea where the Niger Delta fan is located is tightly coupled to the regional atmospheric circulation of the region and could be best described in relation to the general hydrographic and atmospheric conditions of the eastern equatorial South Atlantic. Peterson and Stramma, (1991); Wefer *et al.*, (1996), described in details the hydrography of surface and subsurface waters of the South Atlantic. In the tropical east Atlantic, the surface warm currents comprise the Guinea Current (GC) which runs parallel to the west coast of Africa, the south equatorial current (SEC) which runs in the opposite direction, and the Angola current (AC) which runs southwards along the southeastern coast of the Atlantic (Fig. 1). The cold surface waters are the Benguela Coastal Current (BCC) and the Benguela Oceanic Current (BOC). They respectively transport cold nutrient-rich waters coming from the low latitudes of southern Africa and the Indian ocean towards the southeastern coast and the open central gyre. Other currents are the subsurface South Equatorial Counter Current (SECC) and the Equatorial Under Current (EUC). The combination of local and remote wind forcing is said to be responsible for the large variability of the surface currents in the south Atlantic (Richardson and Walsh, 1986). Owing to the Coriolis force, air moving from the subtropical high pressure area to the equatorial low pressure zone is diverted to the west of the equator. Thus, the SE-trades emerge. The EUC is a fast-flowing undercurrent extending between 5°N and 5°S parallel to the equator in water depth of 50-125 m (Peterson and Stramma, 1991). The current runs throughout the year and is present along the entire equatorial Atlantic.

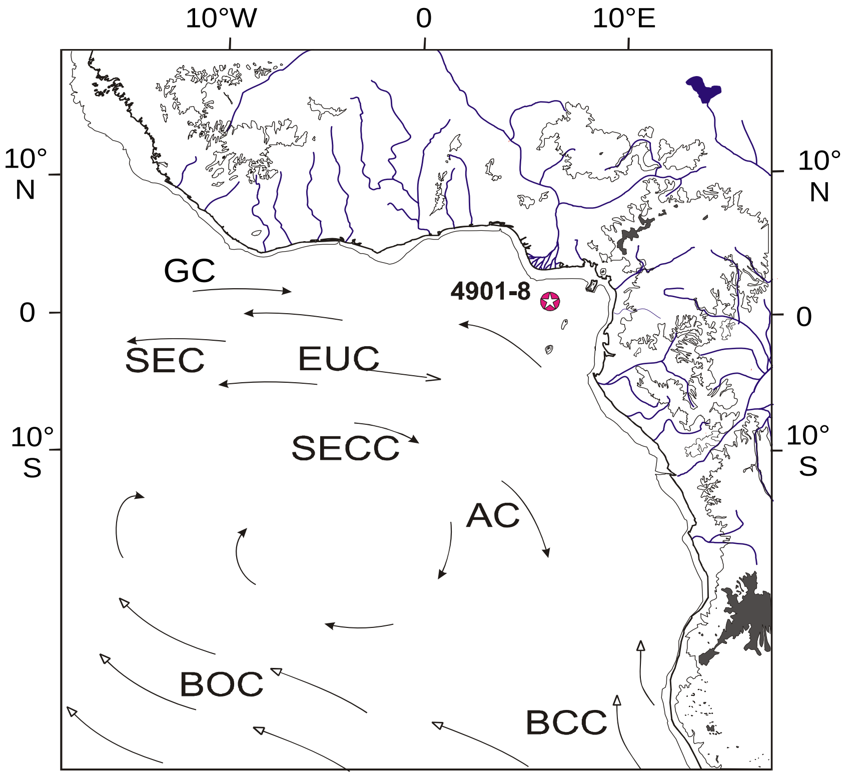


Figure 1: Location of GeoB 4901-8 and the current pattern in the Gulf of Guinea

The interactions of these currents coupled with the strong influence of the southeast trade winds as already mentioned above might cause the shoaling of the thermocline and the nutricline and sometimes result in oceanic upwelling (Schneider et al., 1994). Coastal upwelling signals has been well documented in the Angola basin (Voituriez and Herbland, 1981) so also are seasonal upwelling cells reported (Diedhiou et al., 1998) along the coast of West Africa and near the coast of Gabon.

3. MATERIALS AND METHODS

Sediment samples from gravity core GeoB 4901-8 (02°40.7'N, 006°43.2'E) at water depth of 2184 m, taken from the Niger deep sea fan were analysed. The core was retrieved during the first leg of RV Meteor Cruise Nr. 41 (M41/1). Core recovery technique is well described in (Schulz et al., 1998).

The core was sampled at 5 cm intervals. During sampling, 10 cm^3 syringe samples were taken. The core samples were wet-sieved over a sieve combination of 150 and 63µm mesh sizes and dried overnight at 50°C in the oven. The dried weights of each sieve (> 150 and 63µm) were taken. For each sample, an average of thirty specimens of *G ruber* (pink), twelve specimens of *G sacculifer* (without final chamber) between the sizes of 350 and 400 µm and six specimens of *Cibicides wuellestorfi* of sizes > 250 µm were picked. Only tests that are undamaged were selected for isotope measurements.

The stable oxygen isotope ($\delta^{18}O$) record of epibenthic foraminifera *Cibicides wuellerstorfi* (*C. wuellerstorfi*) was used for the reconstruction of the age model (Fig. 2) because it best correlates with the SPECMAP than the $\delta^{18}O$ record of *G ruber* and *G. sacculifer*. Although the $\delta^{18}O$ records of *G. ruber* and *G. sacculifer* show typical Late Quaternary pattern, they also strongly record local changes in surface water temperature and/or salinity especially in the last interglacial. This made the $\delta^{18}O$ record of *C. wuellerstorfi* the best choice for establishing the age model. Using the AnalySeries 1.1 software programme (Paillard et al., 1996), the $\delta^{18}O$ record of *C. wuellerstorfi* was correlated with the widely used marine oxygen isotope stages (MIS) of the SPECMAP $\delta^{18}O$ stack (Imbrie et al., 1984). Isotope ratios are measured using a Finnigan MAT 251 micromass spectrometer connected to a Kiel Automated Carbonate Device. The carbonate test is reacted with concentrated orthophosphoric acid at 75°C. Isotopic results are presented in per mil ($^0/_{00}$) using the standard isotopic delta notation (δ) relative to the Pee Dee Belemnite (PDB) scale. Conversion to the international PDB scale was done using the NBS-18, NBS-19 and NBS-20 standards. Typical analytical precision of isotopic measurements of calcite at the University of Bremen laboratory is better than ±0.07 $^0/_{00}$, for $\delta^{18}O$.

4. RESULTS

Sediment samples recovered from GeoB 4901-8 are fine-grained hemipelagic mud of foraminifera ooze with varying amounts of clay and nannofossils. The core gives an age model that date back to MIS 8.0 with an age of about 245,000 years before present (Fig. 2). Sedimentation rates are moderately high reaching a maximum of 12 cm/1000 years in cold conditions and as low as 5 cm/1000 years during interglacials.

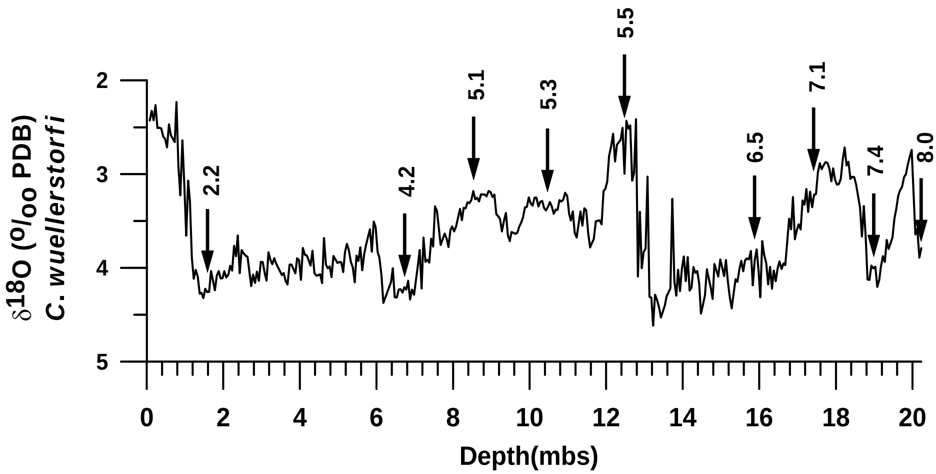


Figure 2: Age model of core GeoB 4901-8. Arrows show the marine oxygen isotopic events used as stratigraphic control points.

Figure 3 shows the results of the stable oxygen isotope records plotted against time. An average of 3‰ and 2.7‰ amplitude change were observed in the records of *G. ruber* (pink) and *G. sacculifer* respectively, representing highly varied hydrographic changes in the Gulf of Guinea for the past 245 kyr. The Holocene and other interglacial periods penetrated by this core show a marked decrease in the $\delta^{18}O$ values of these two species. High negative $\delta^{18}O$ values of *G. ruber* (pink) up to -3.2‰ per mil were recorded in these sediments. Also, the $\delta^{18}O$ record of *G. ruber* (pink) shows unusual distinct four peaks in MIS 5 which might be caused by surface water freshening (Fig. 3).

5. DISCUSSION

5.1 Changes in Surface Water Hydrography

Considering the location of core GeoB 4901-8 on the Niger fan (Fig. 1) it is expected that the $\delta^{18}O$ records of *G. ruber* (pink) will not only respond to global ice volume changes but also to changes in continental rainfall intensity. This specie of planktonic foraminifera is well known to inhabit very shallow water depth and could tolerate relatively large changes in temperature (16-31°C) and salinity (22-49‰) (Hemleben et al., 1989). It is also known to flourish during increased river discharge (Pastouret et al., 1978; Schneider et al., 1997). Zabel et al., (2001) attributed the low carbonate content (0.1-36.1 wt %) of the sediments from this Niger fan core to the dominance of terrigenous materials that are mainly supplied by the Niger river. Peaks of low $\delta^{18}O$ values of *G. ruber* (pink) up to -3.2 ‰ observed in the Holocene as well as other interstadials of warm periods penetrated by this core indicate significant hydrographic changes due to fresh water dilution by the Niger river. These values when compared with those observed at the Congo fan (Schneider et al., 1997) and the Niger delta (Pastouret et al., 1978) could be interpreted as periods of large surface water freshening.

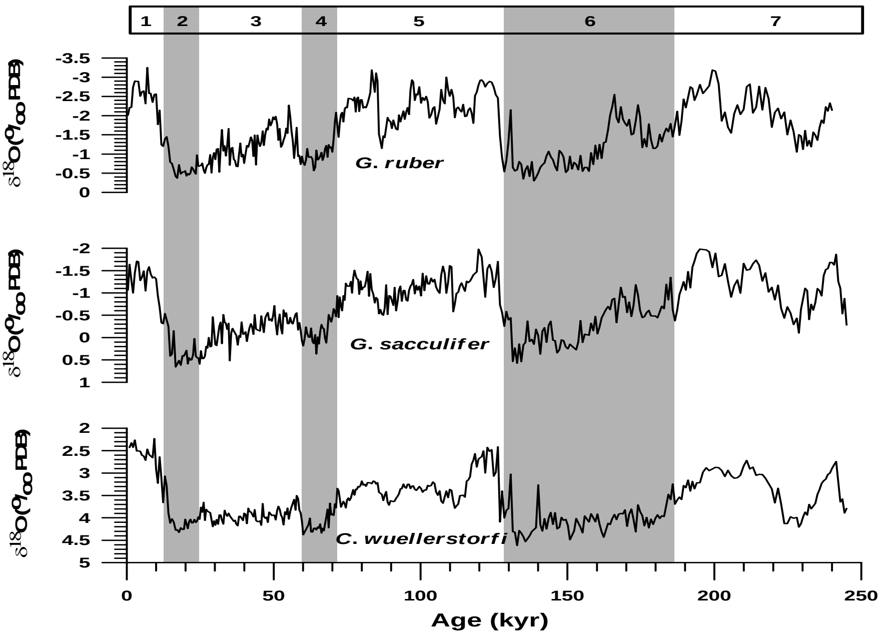


Figure 3: Stable oxygen isotope ($\delta^{18}O$) values for *Globigerinoides ruber* (pink), *Globigerinoides sacculifer* and *Cibicides wuellerstorfi* plotted on the age scale.

Variations in the local hydrography could also be inferred from the measured $\Delta\delta^{18}O$ (*G. ruber* – *G. sacculifer*). Analysis of plankton tows, core top samples and culture experiments (Erez and Luz, 1982; Fairbanks et al., 1982; Mulitza et al., 1998) already discussed the vital effect, temperature sensitivity, habitat depth and temporal distribution pattern of these species. Both species are said to be tropical and shallow dwelling living in the upper water column and could tolerate wide range of sea surface temperatures and salinities (Hemleben et al., 1989). Nevertheless despite the similarities these species still exhibit differences in isotopic signal down-core (Fig. 3 and 4). Although *G. ruber* (pink) tend to record more negative $\delta^{18}O$ values than *G. sacculifer*, both are known to record $\delta^{18}O$ values lighter than the average 1.5‰ annual $\delta^{18}O$ value known for the Holocene.

Using the $\delta^{18}O$ difference between shallow and deep-living planktonic foraminifera to decipher surface water stratification. Mulitza *et al*., (1997) recorded a difference of up to ~3‰ in the tropics. Evidence from core-top studies (Duplessy *et al*., 1991; Mulitza *et al*., 1998) show that most of the shell material from *G. ruber* and *G. sacculifer* are secreted in the mixed layer of the ocean. In the Niger fan core, the $\Delta\delta^{18}O$ values vary between -2.21‰ and –0.16‰ with an average offset of about 2‰ dominantly resulting from temperature and salinity changes in the upper water column. If the global ice volume effect is assumed to be negligible, on one part, this difference may indicate changes in the seasonal distribution pattern of the species, in which case $\Delta\delta^{18}O$ values might be a function of seasonal fluctuations in Sea Surface Temperature (SST) (Mulitza *et al*., 1998). Secondly, due to the location of the core, $\Delta\delta^{18}O$ signal may indicate local salinity changes due to surface water freshening by the Niger river discharge. An average of 2‰ $\Delta\delta^{18}O$ value recorded between these species is not expected to be solely caused by SST changes.

5.2 Climatic Implications

Comparison of the $\Delta\delta^{18}O$ signals with orbital insolation at latitude 10°N (Fig. 4) a position where the low pressure cells over central Africa sits during boreal summer shows that at periods of maximum insolation, there is corresponding high spikes in $\Delta\delta^{18}O$ values. The variation in the intensity of the summer insolation more or less corresponds with amplitude of the $\Delta\delta^{18}O$ for the late Quaternary. This shows the sensitivity of the surface ocean hydrography to changes in atmospheric conditions on the African continent. During warm climatic conditions for example in MIS 3, 5 and 7, $\Delta\delta^{18}O$ values are significantly more negative sometimes up to –2.3‰ showing significant surface water freshening due to increased Niger river discharge into the Gulf of Guinea. It is therefore reasonable to say that periods of warm interglacial conditions are accompanied with wet conditions as contrasted with periods of cold and dry glacial climatic periods.

6. CONCLUSIONS

Very high negative $\delta^{18}O$ values up to –3‰ recorded for the shallow dwelling planktonic foraminifera *G. ruber* (pink) indicate large freshwater discharge from the Niger river, marked by high precipitations and significant salinity reduction over the drainage area mostly during interglacial periods. Although the absolute amount of change in sea surface temperature and salinity cannot be fully established with the $\Delta\delta^{18}O$ (*G. ruber* – *G. sacculifer*) record, the 2.3‰ $\delta^{18}O$ change between these species is high. Since SST is known to be fairly constant in this tropical part of the ocean (Zabel et al., 2001), high value of $\Delta\delta^{18}O$ is thereby suggested to be due to increased river input causing surface water freshening. The climate over central and western Africa as recorded in the stable oxygen isotope composition of *G. ruber* and *G. sacculifer* tests when compared with the SPECMAP shows alternating glacial and interglacial climatic conditions averaging 50,000 year duration.

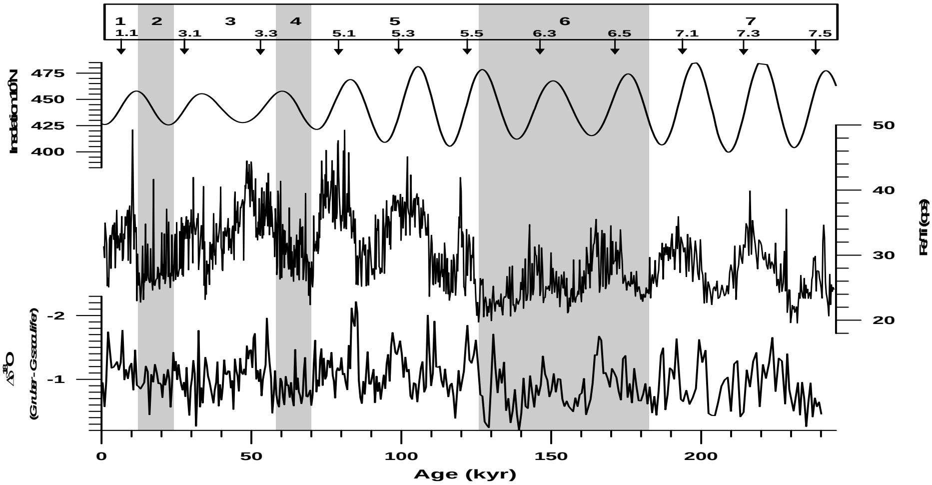


Figure 4: Downcore variations of Δδ18O (G. ruber – G. sacculifer) versus Fe/Ti ratio and insolation at 10°N. The Fe/Ti ratio indicates enhanced or less chemical weathering by high (interstadials) or low (stadials) terrigenous Fe input.

ACKNOWLEDGEMENTS

I am grateful to Prof. Ralph Schneider and Dr. Helge Arz for their discussions. The Master and crew of RV Meteor (M41/1) are acknowledged for their technical support during coring operations. Thanks to Monica Segl, and B. Meyer-Schack for laboratory assistance at the University of Bremen.

REFERENCES

Adegbie, A.T., Schneider, R.R., Rohl, U. and Wefer, G., 2003. Glacial millennial-scale fluctuations in central African precipitation recorded in terrigenous sediment supply and freshwater signals offshore Cameroon. Palaeogeography, Palaeoclimatology, Palaeoecology, 197: 323-333.

Diedhiou, A.S., Janicot, S., Viltard, A. and de Felice, P., 1998. Evidence of two regimes of easterly waves over West Africa and the tropical Atlantic. Geophys. Res. Let, 25: 2805-2808.

Duplessy, J.C. et al., 1991. Surface salinity reconstruction of the North Atlantic Ocean during the last glacial maximum. Oceanologica Acta, 14(4): 311-324.

Erez, J. and Luz, B., 1982. Temperature control of oxygen-isotope fractionation of cultured planktonic foraminifera. Nature, 279: 220-222.

Fairbanks, R.G., Sverdlove, M., Free, R., Wiebe, P.H. and Bé, A.W.H., 1982. Vertical distribution and isotopic fractionation of living planktonic foraminifera from the Panama Basin. Nature, 298: 841-844.

Hemleben, C., Spindler, M. and Anderson, O.R., 1989. Modern Planktonic Foraminifera. Springer-Verlag, Berlin.

Imbrie, J. et al., 1984. The orbital theory of pleistocene climate: support from a revised chronology of the marine d18O record. In: A.L. Berger, J. Imbrie, J.D. Hays, J. Kukl and J. Saltzman (Editors), Milankovitch and climate. Reidel Publishing Company, Hingham, pp. 269-305.

Mulitza, S., Dürkoop, A., Hale, W., Wefer, G. and Niebler, H.-S., 1997. Planktonic foraminifera as recorders of past surface-water stratification. Geology, 25(4): 335-338.

Mulitza, S., Wolff, T., Pätzold, J., Hale, W. and Wefer, W., 1998. Temperature sensitivity of planktonic foraminifera and its influence on the oxygen isotope record. Marine Micropaleontology, 33: 223-240.

Paillard, D., Labeyrie, L. and Yiou, P., 1996. Macintosh program performs time-series analysis. EOS, Transactions, AGU: 77-379.

Pastouret, L., Chamley, H., Delibrias, G., Duplessy, J.C. and Thiede, J., 1978. Late Quaternary climatic changes in Western Tropical Africa deduced from deep-sea sedimentation off the Niger delta. Oceanologica Acta, 1(2): 217-232.

Peterson, R.G. and Stramma, L., 1991. Upper-level circulation in the South Atlantic Ocean. Prog. Oceanog., 26: 1-73.

Richardson, P.L. and Walsh, D., 1986. Mapping climatological seasonal variations of surface currents in the tropical Atlantic using ship drifts. Journal of Geophysical Research, 91(C9): 10,537-10,550.

Sarnthein, M., 1978. Sand deserts during glacial maximum and climatic optimum. Nature, 271: 43-46.

Schneider, R.R., Müller, P.J. and Wefer, G., 1994. Late Quaternary paleoproductivity changes off the Congo deduced from stable carbon isotopes of planktonic foraminifera. Palaeogeogr., Palaeoclim., Palaeoecol., 110: 255-274.

Schneider, R.R., Price, B., Müller, P.J., Kroon, D. and Alexander, I., 1997. Monsoon related variations in Zaire (Congo) sediment load and influence of fluvial silicate supply on marine productivity in the east equatorial Atlantic during the last 200,000 years. Paleoceanography, 12(3): 463-481.

Schulz, H.D., cruise and participants, 1998. Report and preliminary results of METEOR-Cruise M 41/1, Malaga - Libreville, Berichte, Fachbereich Geowissenschaften, Universität Bremen, Bremen.

Street, F.A. and Grove, A.T., 1976. Environmental and climate implications of Late Quaternary lake level fluctuations in Africa. Nature, 261: 385-390.

Voituriez, B. and Herbland, A., 1981. Primary production in the tropical Atlantic Ocean mapped from oxygen values of Equalant 1 and 2 (1963). Bull. Mar. Sci., 31: 853-863.

Wefer, G. et al., 1996. Late Quaternary surface circulation of the South Atlantic: The stable isotope record and implications for heat transport and productivity. In: G. Wefer, W.H. Berger, G. Siedler and D. Webb (Editors), The South Atlantic - Present and Past Circulation. Springer, Berlin, pp. 461-502.

Zabel, M. et al., 2001. Late Quaternary variations in terrigenous input on the Niger Fan-Implications for central African climate change. Quaternary Research, 56: 207-217.

STRUCTURE OF AQUACULTURE MARKET IN PERI-URBAN ZONE OF LAGOS STATE, NIGERIA

Adeogun, O. A., O. A. Ayinla; A. Oresegun; H. K. Ogunbadejo; O. R. Oguntade; Alhaji Tanko; M. B. Hamzat and Megbowon, I.

Nigerian Institute for Oceanography and Marine Research
Victoria Island, Lagos.

ABSTRACT

The knowledge about the extent to which fish markets are structured is crucial for the success of commercial liberalization policies. This study presents an analytical framework for the market structure including descriptive analysis of the market network of aquaculture industry in the peri-urban zone of Lagos State, Nigeria. The results of the step-wise regression model shows that distance to rail, air export and other markets all combined to explain 78.6 percent total variation in dependent variable (quantity). Results in the latter case show that the effect of some structural factors appears to be strong in the measure of market structure. The policy makers may use this information to prioritize infrastructure budgets and allocate more funds to increase the degree of integration and development of market institutions designed to link peri-urban fish producers with the rapidly growing urban markets.

Keywords: *Market, structure, peri-urban, aquaculture.*

1. INTRODUCTION

The production of seafood by aquaculture is growing rapidly in many parts of the world. According to the United Nations Food and Agriculture Organization (FAO, 2003), one-quarter of the world's total seafood production of 130 million metric tonnes (mt) per year is now produced by aquaculture. A substantial portion of the world's total aquaculture production occurs in the countries of Southeast Asia especially China. FAO FISHSTAT Plus observes that aquaculture has the potential to grow significantly in Sub-Saharan Africa (SSA). The SSA contribution of 72,334 tonnes to the African total in 2003 was a mere 0.13 percent of the world total. While Nigeria is reported to have maintained its leading position in terms of volume 30,677 tonnes and value US$77,253, 000 (Hecht, 2006), FAO (2006) reports that Nigeria doubled its production from 15,000 tonnes in 1994 to over 45,500 tonnes in 2006. The observed shifts have been attributed to changes in market demand (Shimang, 2005). In terms of price, there is a significant change in the price of fish. Nigeria is reported to have the highest average urban fish price of around US$4.10 per kilogram (Hecht, 2006). It would be interesting to relate the evolution of the Nigerian aquaculture industry to fish price coupled with declining supply from capture and rising demand for fish products. According to Shimang (2005), the major jump in production during the period of 1988 – 1989 from 6,000 tonnes to 25,000 tonnes, was linked with an increase in the price of fish at that time. Here, we analyze the potential for the future expansion of aquaculture in Lagos State, Nigeria, and also consider how this potential might be constrained by infrastructure, notably fish market. There are several reasons to study this specific market.

First, the contribution of food fish from peri-urban to urban zones often goes unnoticed and curiously, little attention has been paid to understanding the complementary relationship between market supply chain in peri-urban and urban zones. Urban and peri-urban agriculture are increasingly understood as the key to guaranteeing food security, especially for the most vulnerable – children and women (Iaquinta and Drescher, 2001). Urbanization as we all know affects all sectors of food supply system. As urban population increases, more food needs to be transported and distributed to cities. Changing food habits of urban dwellers modify the food production systems in rural and peri-urban areas. On the production side, rural and peri-urban agriculture become more market oriented, i.e. more input-oriented and less diverse in terms of variety of product (Waibel and Schmidt, 2000). Second, the seafood market is a relatively simple market. It is well defined and well structured compared to a market economy (NIOMR, 2006).

Third, the lack of adequate infrastructure is most often advocated as the principal reason for the poor progress of aquaculture product marketing (Brummett, 2005). According to Brummett, "market failures are posited to lie chiefly behind the failure of aquaculture to develop beyond a subsistence oriented scale. The positive impact of market incentives on the scale and intensity of fish production is clearly established through a comparative analysis of two groups of fish producers differentiated by the location of their market in either the peri-urban or rural zones of southern Cameroon. In the peri-urban domain, prices were 48 percent higher, the number of buyers was three times greater, and the average purchase per customer was nearly double that of the rural domain. In response to these structural differences, producers in the peri-urban domain sold 300 percent more fish per harvest, were 72 percent more productive per unit area and had 11 times the production scale of producers in the rural domain. There appears to be an urgent need to connect rural producers to urban markets in order to foster the growth of aquaculture in SSA".

However, the market chain of commercial farmers in the country differs widely and depends entirely on the product, scale of operation and the target market. The chain for fish from commercial farms sold in peri-urban or urban markets is from producer to buyer or wholesaler / retailer to consumer. Market structure is also important for the farmers. If their product competes in large market, increased aquaculture production will have only a limited price effect. This may make it easier for the industry to grow than in the case where there are few or no substitutes, and the farmers have to create the market for their product.

Fourth, our empirical example will focus on catfish. This has two main reasons. The most important is that catfish is clearly the most studied and cultivated seafood species when it comes to market knowledge in Nigeria. In fact, it is the only species where there is substantial academic literature on the topic. Moreover, it is also in many ways the species for which most innovations have taken place technologically as well as market wise. African catfish is the species which most likely has experienced most of the potential market interaction and structure. Hence, we examined the structure of aquaculture market in peri-urban zones of Lagos State, Nigeria.

2. ANALYTICAL PERSPECTIVE

Previous studies regarding market structure of seafood have tended to focus on the following: product specific factors such as ease of preparation, taste, appearance and health (Richardson *et al.,*; 1993; Engle and Kouka, 1995; Wessels, *et al.,*1996); socioeconomic, demographic lifestyle factor (Kinnucan and Venkateswaran, 1990; Kinnucan, *et al.,* 1993; Herrmann, *et al.*, 1994; Nauman *et al.*, 1995; Gempeaw, *et al.,* 1995; Nayga and Capps, 1995; Cortez and Senauer, 1996); economic factor (Cheng and Capps, 1988; Burton, 1992; DeVoretz and Salvanes, 1993; Asche, 1996); aggregate seafood consumption levels and characteristics, e.g. the National Food Survey in the UK; fish marketing and credit (Lem, *et al*., 2004); and fish marketing analysis (Pomeroy and Trinidad, 1995).
Analyses of each of these groups of factors have been dominated by several different disciplines, each using its own analytical approach. While economists tend to focus on the relationships among prices, quantities and income, studies of the influences of socioeconomic factors have been dominated by marketing perspective. Analysis of how product attributes and lifestyle factors are perceived by consumers has been carried out under social psychology perspective. The orientation of the present study is the structure of catfish market and how structure influences the performance of the industry in order to make a contribution to the improved marketing of catfish in the State.

3. DATA

The data regarding fish market structure was collected from markets situated within the peri-urban zones of Lagos State, Nigeria using structured questionnaire between June 2003 and December 2005. The zones are Badagry, Ikorodu, Eti-Osa, Ojo and Epe or Far East (Figure 1).

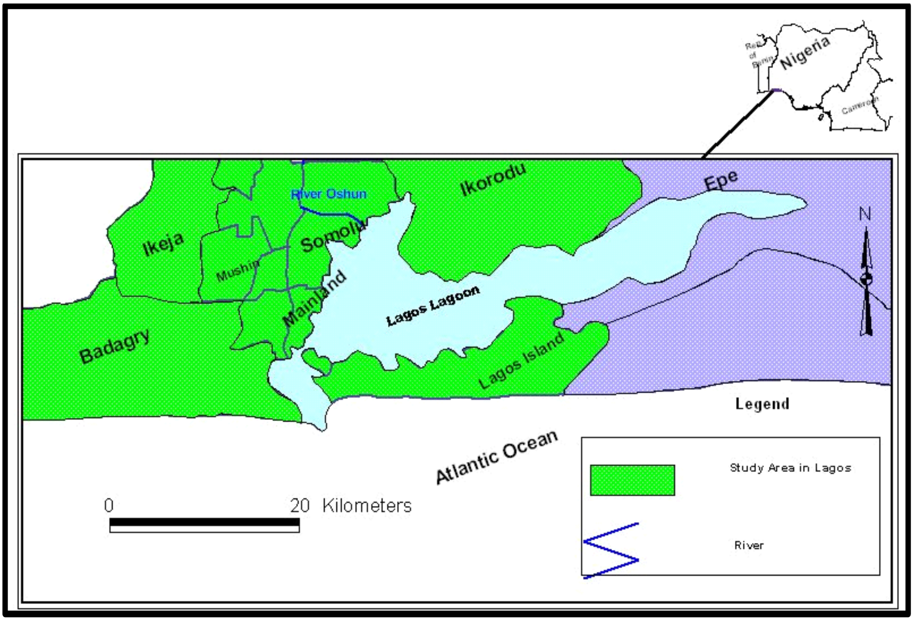


Figure 1: Administrative map of Lagos State showing study areas

The interview comprised questions regarding market participants, channels, arrangement, number of buyers and sellers at each market level, volume of trade handled by each buyer/seller, entry barrier (capital cost, scale economies, marketing costs and margins. The markets were randomly selected. The target population included all categories of farmed fish traders irrespective of age and gender. Eleven markets were studied (Table 1) and these were located and identified with the aid of Geographic Positioning Satellite (GPS).

Table 1: Distribution of fish market sampled in Peri-urban zone, Lagos State

ZONE	MARKET	COORDINATE
Badagry	Alagbata Ikoga Moba	6° 25.448´N; 3° 50.908´E
	Agbalata Western zone	6° 26.194´ N; 3° 0.947´ E
Epe (Far East)	Epe	6° 36.779´ N; 3° 42.380´ E
Ikorodu	Igbogbo	6° 35.512´ N; 3° 31.015´ E
	Owode	6° 36.648´ N: 3° 30.794´ E
Ojo	Morogbo	6° 30.005´ N; 3° 05.854´ E
	Okokomaiko	6° 28.276´ N; 3° 11.313´ E
Eti-Osa	Olorunseyi	6° 30.658´ N; 3° 36.963´ E
	Badore	6° 30.655´ N; 3° 36.966´ E

Source: Field survey, 2005

4. EMPIRICAL ANALYSIS

Information collected were coded and incorporated into database using Statistical Package for Social Science (SPSS) software. Descriptive statistics were employed to describe the respondents in the chains, their operations and performance, using means, modes and percentages. Since descriptive approach contains little statistical analysis and reaches conclusion regarding performance and efficiency based on the researcher's subjective assessment, the study also proceeded to employ industrial organization approach which is a standard tool for the analysis of markets. This theory tells us that the market structure determines market conduct and thereby sets the level of market performance. Regression analysis was used to identify structural factors affecting market development in the zone. The model specification was as follows:

$$\Phi_t = f\ (d_1, d2, d_3, d_4, e_i) \qquad - \qquad (1)$$

$$\Phi_t = \beta_o + \beta_1 d_1 + \beta_2 d_2 + \beta_3 d_3 + \beta_4 d_4 \qquad - \qquad (2)$$

where,

Φ_t is the quantity supplied to a market at a point in time; β_o is the intercept; β_1- β_4 are the parameters to be determined; d_1 to d_4 represents market distance to the main road, rail, air-export to other markets respectively and e_i is the stochastic disturbance.

5. RESULTS AND DISCUSSION

The results in Table 2 indicate the nature and characteristics of market in the peri-urban zones of Lagos State. Ten (90.9 percent) out of the market surveyed were mixed retails and wholesales with various goods, foods and services while one representing 9.1percent was mixed goods and food only. There is no specific market devoted for the sales of fish. The opening day for each market varies from one location to another. Findings revealed that nine (81.8 percent) of the market open every day; weekly market and every four to six days markets had 9.1 percent each. One major common characteristic of these markets was that, the markets opened as early as 7.00am to 7.00pm. The catfish markets sampled usually opened for business from 2.00pm and closed around 8.00 pm each day except Sunday when most farms did not open for business.

Table 2: Market characteristics in Peri-urban zone, Lagos State

MARKET CHARACTERISTICS	FREQUENCY	PERCENTAGE (%)
Market type		
Mixed goods and food	1	9.1
Mixed retails and wholesales	10	90.1
Mixed food	0	0.0
Fish market only	0	0.0
Open Day		
Daily	9	81.8
Weekly	1	9.1
Every 4 – 6 days	1	9.1
Rotational	0	0.0

Source: Field survey, 2005

Table 3 depicts the findings on the structure and infrastructures obtained in the study areas. Almost all the markets ten (90.9 percent) in the peri-urban zone were open to sky. Various traders were seen displaying the wares openly while the traders sometimes used umbrella as a shade during rainy or hot season (Fig. 2). Modern shopping malls or stalls were generally lacking. Because of the open nature of the markets, many infrastructures such as water supplies, toilets, electricity, washing facilities storage facilities were absent. Packaging of catfish was non-existence. Fish were either consumed fresh as 'pepper soup' or smoked.

Fig. 2: A typical open to sky market in Ojo Local government

Table 4 illustrates the products forms and sources. Fishermen and fish farmers formed the bulk of the major producers and suppliers of fish to most markets in the peri-urban zone. Studies showed that capture fisheries contributed 72.7 percent of fish supplied while farmed fish contributed 27.3 percent. Various kinds of fish, species, forms, quantity and quality were found in the study areas. Fresh fish was the most frequent accounting for 63.6 percent and processed fish which include whole fish whether round or gutted, sliced, frozen, smoked and fried accounted for 36.4 percent. Live fish in which 54.5 percent traders marketed were also seen in all the markets.

Table 3: Infrastructure facilities obtained in Peri-urban zone, Lagos State

STRUCTURE AND INFRASTRUCTURE FACILITIES	FREQUENCY	PERCENTAGE (%)
Market structure		
Open to sky	10	90.9
Partly covered	1	9.1
Stall	0	0.0
Shopping mall	0	0.0
Water supplies		
Yes	1	9.1
No	10	90.9
Ice provision		
Yes	2	18.2
No	9	81.8
Storage (Cold room/refrigerator)		
Yes	2	18.2
No	9	81.8
Packaging		
Yes	1	9.1
No	10	90.9
Toilet		
Yes	1	9.1
No	10	90.9
Washing facilities		
Yes	3	27.3
No	8	72.7
Electricity		
Yes	4	36.4
No	6	54.6

Source: Field survey, 2005

Table 4: Product forms and sources in Peri-urban zone, Lagos State

PRODUCT FORM AND SOURCES	FREQUENCY	PERCENTAGE (%)
Source		
Capture	8	72.7
Farmed/culture	3	27.3
Quality		
Fresh	7	63.6
Processed	4	36.4
Whole fish (Round and Gutted)		
Fresh	8	72.7
Dried	3	27.3
Sliced into portion		
Fresh	7	63.6
Dried	4	36.4
Fillet		
Fresh	Not Available	
Dried		
Bundled/basket/unsorted mixture		
Fresh	2	18.2
Dried	9	81.8
Live		
Yes	6	54.5
No	5	45.5
Frozen		
Yes	9	81.8
No	2	18.2
Fried		
Yes	2	18.2
No	9	81.8
Smoked		
Yes	11	100
No	0	

Source: Field survey, 2005

5.1. Market channel

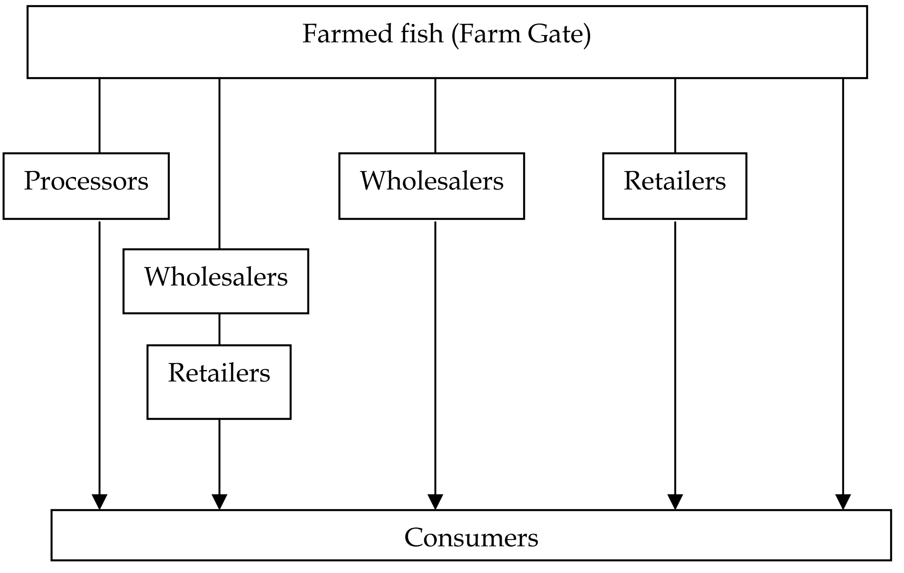


Fig. 3: Market channel of fish products

Figures 3 show the flow of fish and fish products from the producers to the final consumers. Wholesales are the major sources through which fish products are channeled to the consumers in all the markets surveyed. Only a few consumers or retailers had direct access to the producers. Fish distribution channel from the peri-urban zone to urban zone also assumes a significant importance in the areas studied. Live catfish were transported from peri-urban to urban zone with various means of transportation. The percentage distribution from the zones was however not investigated in this study.

5.2. Market Structure

Bain (1968) defined market structure as characteristics of the organization of a market which seem to influence strategically the nature of competition and pricing behaviour within the market.

Most of the markets sampled can be described as oligopolistic, as the number of sellers of products was not so large that individual contributions are negligible. This finding was also reported by Pomeroy and Trinidad (1995) and Lem, *et al.*, (2004). Potential barriers exist due to product differentiation (quality and species), capital requirement, scale economies and institutional factors. Capital barrier may serve as an entry barrier to those who cannot afford capital outlay to enter the market. Pomeroy (1989) and Scheid and Sutinen (1981) noted that initial capital costs provide a restrictive entry barrier especially for small-scale fishermen. Institutional factors can be in form of membership before the commencement of the business.

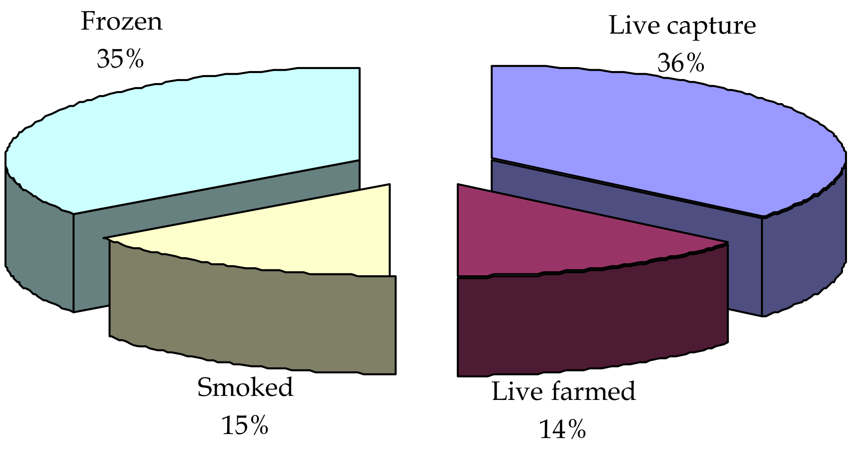


Fig. 4: Percentage distribution of traders by product form

Figure 4 above reveals the distribution of the traders according to the products forms traded in the markets. The percentages of traders engaged in live capture fisheries were found to be 36 percent compared with live farmed fish of 14 percent. Traders selling frozen fish accounted for 35 percent while smoked fish mainly from capture represented 15 percent.

5.3. Structural Factors affecting Fish Trading in the Zone

The results of the step-wise regression model are presented in Table 6. With respect to equation 2, distance to rail, air export and other markets all combined to explain 78.6 percent total variation in dependent variable (quantity). This finding showed that the regression equation has a very high explanatory power and the regression line is a 'good fit'. The F- and t-statistics were also found to be highly significant ($p>5$). In terms of signs and magnitude, only distance to air export conformed to the *a priori* expectation while the other two variables were negative. In the study carried out by Goletti and Farid (1994) on the structural factors affecting rice market integration in Bangladesh, the effect of some structural factors appeared to be strong across different specifications of the measure of market integration. As expected, distance negatively affected market. Road infrastructure has a positive and significant effect and rail density also have an unexpected negative effect especially for long-term multiplier.

Hence, identifying road infrastructure, rail, air export and linkages with other markets in production could be the most important factors affecting the development of aquaculture market in Lagos State especially in peri-urban areas. A few policies emerge as a way of developing the markets distribution support services. First, there is an indication towards investing on road, rail, air and market. Second, since fish is a highly perishable commodity, distance between farm gate and market should be reduced, alternatively, a strategy for facilitating the access of producers/marketers to urban markets should be put in place. This will result in an expansion and intensification of the industry while attracting new entrants.

Table 6: Results of stepwise regression analysis – Linear function

Independent variable	Regression coefficient	R^2	R^{-2}	F-ratio	t-statistics
Constant	2447.63 (958.03)				
d_2	-906.75** (340.59)	0.698	0.622	9.241	2.662
d_3	961.08** (335.44)	0.386	0.318	5.668	2.865
d_{mkt}	-103.37** (34.27)	0.850	0.786	13.211	-3.016

Figure in parenthesis are standard error of the coefficients.
** Significant at 5% level.

6. CONCLUSION

This study had provided a formal analysis of the structure of aquaculture markets in peri-urban zone of Lagos State, Nigeria. A basic finding of this research was that the organization of the markets cannot be described as being perfect as the number of sellers of products is not so large that individual contributions are negligible. Market barriers existed in all the markets studied. Some of the potential entry barriers were due to demand a condition which ranges from product differentiation to capital requirements. The relation between market and structural factors was also explored. Some policy implications have been drawn from this study. Policy makers may use results from this study to apply policies in a more efficient manner. Government has a crucial role to play in creating the enabling environment for the development of market-driven aquaculture. This includes provision of necessary infrastructures as well as road improvement since fish is a perishable commodity.

ACKNOWLEDGEMENT

This research formed part of the DFID funded research project - Aquaculture and Urbanization in SSA: Resource utilization, market development and poverty targeting issues associated with emerging Peri-urban (PU) and Urban (U) Aquaculture in Nigeria (DFID Project No. R8287), through the WorldFish Centre. We appreciate the support of Dr. Krishen Rana of the Institute of Aquaculture, University of Stirling, Scotland. We thank the Extension Officers of Lagos State Agricultural Development Authority for support during the survey implementation.

REFERENCES:

Asche, F.,1996. A system approach to the demand for salmon in the European Union. *Applied Economics*, 28, p. 97-101.

Bain, J.S., 1968. Industrial organization. 2nd Edition, John Wiley and Sons, New York.

Brummett, R., 2005. *Final Technical Report. Development of integrated aquaculture-agriculture systems for small-scale farmers in the forest margins of Cameroon* (NRE9800 605/522/003-Implementing agency: WorldFish Centre. 31p

Burton, M. 1992. The demand for Wet fish in Great Britain. *Marine Resource Economics*. Vol. 7 (2), p. 57-66.

Cheng, H. and Capps, O. Jr., 1988.Demand analysis of fresh and frozen finfish and shellfish in the United States. *American Journal of Agricultural Economics*. Vol. 70 (3), p. 533-542.

Cortez, R., and Senauer, B. 1996. Taste changes in the demand for food by demographic groups in the United States: A nonparametric empirical analysis. *American Journal of Agricultural Economics*. Vol. 78, p. 280-289.

DeVoretz, D.J., and Salvanes, K.G., 1993. Market Structure for farmed salmon. *American Journal of Agricultural Economics*. Vol. 75, p. 227-233

Engle, C.R. and Kouka, P.J., 1995. Potential consumer acceptance of canned Bighead Carp: A structural model analysis. *Marine Resource Economics*. Vol. 10, p. 101-116

FAO (2003). The State of World Fisheries and Aquaculture 2003. Rome: Food and Agriculture Organisation of the United Nations.

FAO FISHSTAT Plus In: Hecht, T., 2006. *Regional review on aquaculture development for Sub-Saharan Africa*. FAO Fisheries Circular No. 1017/4, FAO 96p

FAO, 2006. Nigeria leads Sub-Saharan Africa in fish farming business. *The Punch*, Wednesday, September 6, 2006, p. 3.

Gempeaw, C.M., Bacon, J.R., Wessels, C.R. and Manalo, A., 1995. Consumer perceptions and aquaculture products. *American Journal of Agricultural Economics*. Vol. 77 (5), p. 1306-1312.

Goletti, F.R. Ahmed and Farid, N., 1994. Structural determinants of market integration. The case of rice markets in Bangladesh. *Developing economies* (forthcoming)

Hecht, T., 2006. *Regional review on aquaculture development for Sub-Saharan Africa*. FAO Fisheries Circular No. 1017/4, FAO 96p.

Herrmann, R.O., Rauniyar, G. P., Hanson, G.D. and Wang, G., 1994. Identifying frequent seafood purchasers in the Northeastern U.S. *Agricultural and Resource Economics Review*, p. 226-235.

Iaquinta, D. L., and Drescher, A., 2000. "More than the spatial fringe: An application of the Peri-urban Typology to planning and Management of Natural Resources, Rural – Urban Encounters", Development Planning Unit International Conference, Managing the Environment of the Peri-urban Interface, University College, London, 9-10 November 2001.

Kinnucan, H.W., and Venkateswaran, M., 1990. Effects of generic advertising on perceptions and behaviour: The case of catfish. *Southern Journal of Agricultural Economics*, p.137-151

Kinnucan, H.W., Nelson, R.G., and Hiariey, J., 1993. U.S. preferences for fish and seafood: An evoked set analysis. *Marine Resource Economics*. Vol. 8, p. 273-291.

Lem, A., Tietze, U., Ruckes, E., Anrooy, R.van, 2004. Fish marketing and credit in Viet Nam. FAO *Fisheries Technical Paper* No. 468, Rome, 174p.

Nauman, F.A., Gempesaw, C.M., Bacon, J.R., and Manalo, A., 1995. Consumer Choice for Fresh Fish: factors affecting purchase decisions. *Marine Resource Economics*. Vol. 10, p.117-142

Nayga, R.M. Jr., and Capps, O. Jr., 1995. Factors affecting the probability of consuming fish and shellfish in the away from home and at home markets. *Journal of Agricultural and Applied Economics*. Vol.27, (1), p. 161-171.

NIOMR, 2006. Market development, fish and fish products marketing in Urban and Peri-urban zones of Lagos. *Technical Report*, 35p

Pomeroy, R.S.,1989. *The economics of production and marketing in a small-scale fishery: Matalom, Leyte*, Philippines. ICLARM

Pomeroy, R. S., and Trinidad, A. C., 1995. Industrial organization and Market Analysis: Fish marketing. In: *Prices, products, and people: Analyzing Agricultural Markets in Developing Countries* (J. S. Gregory, ed.). Lynne Rienner Publishers, London, 493p.

Richardson, N. J., Shepherd, R., and Elliman, N.A., 1993. Current attitudes and future influences on meat consumption in the U.K. *Appetite*. Vol. 21, p. 41-51

Scheid, A.C. and Sutinen, J.G., 1981. The structure and performance of wholesale marketing of finfish in Costa Rica. In: *Small scale fisheries in Central America: Acquiring information for decision making* (J.G. Sutinen and R.B. Pollnac, eds.). International Centre for Marine Resource development, University of Rhode Island, RI, USA

Shimang, G.N., 2005. Country strategy updates: In: Hecht, T., 2006. *Regional review on aquaculture development for Sub-Saharan Africa*. FAO Fisheries Circular No. 1017/4, FAO 96p

Waibel, H., and Schmidt, E., 2000. Feeding Asian Cities – Food Production and processing issues. Regional Seminar, FEEDING ASIAN CITIES, 27-30 November, 2000, Bangkok

Wessels, C.R., Kline, J., and Anderson, J.G., 1996. Seafood safety perceptions and their effects on anticipated consumption under varying information treatments. *Agricultural and Resource Economics Review*. N0. 25, p.12-21.

THE UTILIZATION OF SORGHUM HUSK IN THE NUTRITION OF TILAPIA (OREOCHROMIS NILOTICUS)

Aladetohun, N. F.

Federal college of Fisheries and Marine Technology,
Victoria Island, Lagos.

ABSTRACT

Five iso-nitrogenous diet with a mean crude protein content of 27.72% were formulated to contain 0%, 25%, 50%, 75% and 100% substitution levels of sorghum husk replacing yellow maize respectively in the diets of *Oreochromis niloticus*. *O. niloticus* average weight of 21.6g was reared in hapas stacked in concrete tanks for 10 weeks. Feeding was carried out twice daily at 5% total body weight. At the end of the experimental Treatment trials, the highest weight gain of 16.65g was recorded in Treatment 1 (0% sorghum husk). This was followed by treatment 2 (25% sorghum husk) with a mean weight gain of 14.04g. The specific growth rate was highest in Treatment 1 with 6.50%/day followed by Treatment 2 with 5.3%/day and the lowest in Treatment 5 with 2.20%/day. The protein intake per week was highest in Treatment 1 (3.88/day) and lowest in treatment 5 (3.30/day). The protein efficiency ratio decreased with increase in the level of sorghum husk ranging from 4.29 in Treatment 1 to 1.56 in treatment 5. The analysis of variance showed significant difference ($P < 0.05$) in the feed Treatment on the growth of Tilapia (*O. niloticus*). Among the diets with sorghum husk, diet 2 has the highest growth performance while diets 4 and 5 showed very low growth performance and nutrient utilization. Sorghum husk diets performed fairly well as a feedstuff and inclusion rate of 25% or even 50% could replace yellow maize in Tilapia diet.

Keywords: *Sorghum husk, Tilapia, Utilization, Nutrition.*

1. INTRODUCTION

Aquaculture or aqua-farming is the husbandry of aquatic plants and animals such as fin fish, shell fish, algae, kelp and seaweed. Its practice range from the propagation of aquatic organisms under complete human control to the manipulation of at least one stage of the life of an aquatic organism e.g. rate of growth, reproduction and feed conversion efficiency.

Aquacultural importance cannot be over emphasized since it provides man with readily available fish for consumption. According to Dada (2003), fish contributes about 40% of total dietary protein of the average Nigerian and major supply is from the capture fisheries. However, while industrial fisheries declined from 36,226 tonnes in 1991 to 23308 tonnes in 2000, aquaculture production increased from 15,804 tonnes in 1991 to 56,720 tonnes in 2000 (FDF, 2000).

Nigerian aquaculture production in 2000 including culture-based fisheries in coastal and inland waters showed that tilapia production was highest among the other fish species captured with 14,388 tonnes while fresh water cat fish (*Clarias gariepinus, C. anguillaris, Heterobranchus sp)* had 9,385 tonnes and Brackish water cat fish (*Chrisichythis nigroigitatus, carps, Hererotis niloticus, Mullets, Parachanna obscura and other fishes*) had 8,003 tonnes. In 2005, Global aquaculture production of O. *niloticus* was 1,700 metric tonnes (FAO, 2005).

Tilapia (including all species) is the second most important group of farmed fish after carp, and the most widely grown of any farmed fish. In 2004 tilapia moved up to the eighth most popular seafood in USA global production and is projected to increase from 1.5 million tonnes in 2003 to 2.5 million tonnes by 2010 with a sales value of more than UE $5 billion. (FAO, 2005).

O. niloticus usually grow rapidly on formulated feeds with lower protein levels and tolerate higher carbohydrate levels than many carnivorous farmed species e.g. *Clarias* spp. It can breed easily and their hardiness and adaptability to a wide range of culture systems has led to the commercialization of tilapia production in more than 100 countries. (USDA) 2001.

In developing countries however, manures and agricultural by-products are used to produce tilapia (USDA, 2001). Yellow maize is one of the major food crops known. It is processed into cereals, cornflakes, pap and other food product for human consumption. There is competition on the use of maize for animal feed and the need to find substitutes for maize. The use of sorghum husk will not allow for any competition with human food because it is an agricultural by-product not utilized by human beings.

The objective of this study is to investigate the performance of *O. niloticus* fingerlings on graded levels of sorghum husk substituted diet as an appropriate and cheap feed stuff ingredient for tilapia.

2. MATERIALS AND METHOD

The experiment was carried out at the National Institute for Freshwater Fisheries Research (NIFFR) New Bussa in Niger State for a period of 10 weeks. Ten hapas, each of dimensions 1m x 1m x 1m were used. Each hapa was kept in place in the concrete ponds with surface area of 100m^2 (10m x 10m). The water quality (temperature, pH, salinity, dissolved oxygen, conductivity, and turbidity) was checked with the aid of Horiba Water Quality Checker U22XD.

The fish used for the experiment were obtained from NIFFR fishponds. They were acclimatized for 24 hours before they were used for the experiment.

One hundred and fifty tilapia (*O. niloticus*) fingerlings were selected with body weights ranging from 20 to 25 grammes. The fish were assigned 15 individuals per unit to each of the five dietary treatments. The experimental set up is shown in figure 1.

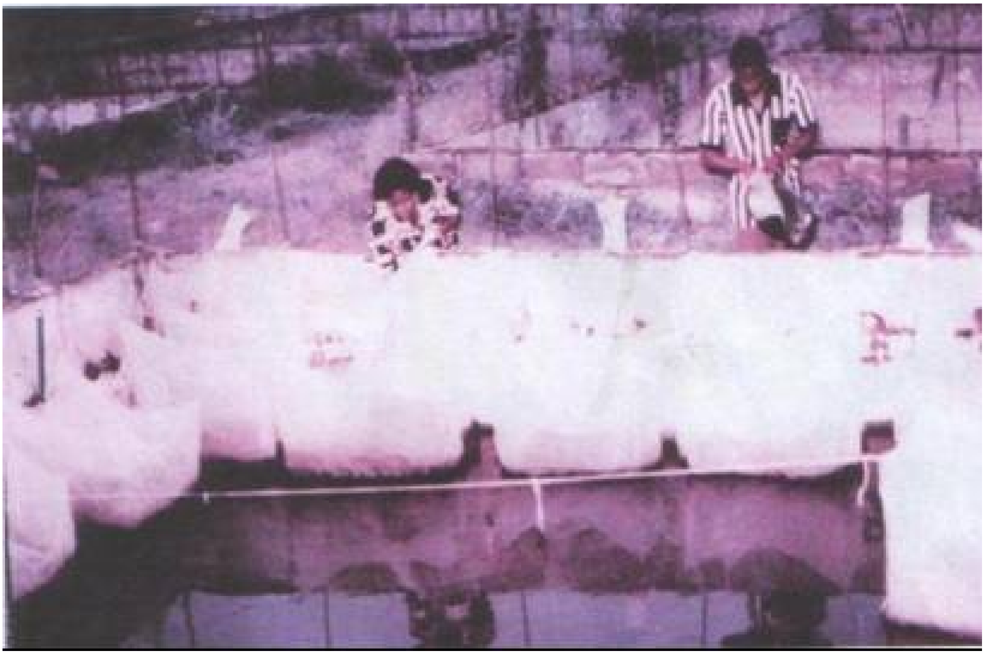


Figure 1: The set up of Experimental Unit

Feed ingredient, sorghum husk were collected from Eagle Flour Mill, Ibadan. The brewers' wastes (spent grains) were collected from Nigerian breweries, Ibadan. Blood meal, fishmeal, mineral, premix, yellow maize and groundnut cake used were supplied by Nigerian Institute for Freshwater Fisheries Research, New Bussa, Niger State.

Five diets were formulated to contain 0%, 25%, 50%, 75% and 100% sorghum husk in replacement of yellow maize in the basal diet. The control diet was the one containing 100% yellow maize without sorghum husk inclusion. The formulations are shown in Table 1.

Table 1: Percentages Composition of Experimental Diets

TREATMENTS					
INGREDIENTS	**I**	**II**	**III**	**IV**	**V**
Groundnut cake (kg)	15.12	15.12	15.12	15.12	15.12
Blood Meal (kg)	7.61	7.61	7.61	7.61	7.61
Fish Meal (kg)	12.37	12.37	12.37	12.37	12.37
Yellow Maize (kg)	43.90	32.92	21.95	10.98	0.00
Sorghum husks (kg)	0.00	10.98	21.95	32.92	43.90
Brewer's waste (spent grain) (kg)	10.00	10.00	10.00	10.00	10.00
Oysters shell (kg)	2.5	2.5	2.5	2.5	2.5
Oil (kg)	6.0	6.0	6.0	6.0	6.0
Mineral/Vit. Premix (kg)	2.5	2.5	2.5	2.5	2.5
Total ( )	100	100	100	100	100
% Substitution sorghum Husk	0%	25%	50%	75%	100%

The experimental fish were fed twice daily at 5% body weight. The quantities of feed were then adjusted weekly in accordance with weight gain of fish.

3. GROWTH AND NUTRIENT UTILIZATION INDICES

3.1 Means weight Gain per Week (g/week)

This was estimated from the total weight gain divided by the number of weeks of the experiment.

3.2 Mean Weight Gain per day (g/day)

This was determined by finding the difference in weights before and after experiment and dividing by the number of experimental days.

3.3 Total Percentage Weight gain (%)

This was calculated from the formula:

$$\frac{\text{Weight gain}}{\text{Initial Weight}} \times \frac{100}{1}$$

3.4 Mean Weight Gain (g)

This was determined by finding the difference between the initial and final weight (g) of experimental fish i.e.

3.5 Specific Growth Rate (SGR) (%)

Specific growth rate was calculated using formula:

$$\frac{\text{LOG e W2} - \text{LOG e W1} \times 100}{\text{T2} - \text{T1}}$$

Where:

LOGeW1	=	Logarithm of Initial weight
LOGe2	=	Logarithm of Final weight
T1	=	Initial time in Wk
T2	=	Final Time in Wk

3.6 Gross Efficiency of Food Conversation (%)

$$= \frac{1}{\text{Feed Conversation Ratio}} \times 100$$

3.7 Feed Conversation Efficiency

$$= \frac{\text{Weight gain}}{\text{Food eaten}}$$

3.8 Protein Efficiency Ratio (PER)

$$= \frac{\text{Net Weight Gain}}{\text{Protein intake (g)}}$$

3.9 Protein intake

$$= \text{Food Consumption} \times \frac{\text{Percentage Protein}}{100}$$

3.10 Total Feed intake

= Summation of the total rate of feed fed per week

3.11. Production Protein Value (PPV)

$$= \frac{\text{Final Percentage Protein} - \text{Initial Percentage protein}}{\text{Protein Intake}}$$

Experimental results were subjected to the Analysis of variance. Computer (SPSS) Statistical Package for Social Scientists was used for the analysis of correlation and regression on the growth and nutrient utilization parameters at Computer Science Department, University of Ibadan.

4. RESULT

The result of the proximate composition of experimental diets is presented in Table 2

Table 2: Proximate Composition of Experimental Diets

PARAMETERS (%)	I	TREATMENT DIETS			
		II	III	IV	V
Moisture	7.52	7.60	7.90	7.80	6.98
Ether Extract	8.98	9.86	9.72	9.56	10.10
Crude protein	27.69	27.25	26.81	28.32	28.55
Ash	14.40	15.01	14.32	16.15	16.20
Fibre	10.10	11.42	11.81	13.06	13.57
N.F.E.	31.31	28.86	29.44	24.00	24.50

4.1 Calculated on dry weight basis (%) weight

The average percentage crude protein value was 27.27% with the maximum value 28.55% and minimum value 26.81% in diet 3 and 5 respectively. The fibre content ranged from 10.10% to 13.57% with minimum value being 10.10% in diet 1 and maximum value 13.57% in diet 5 respectively (Table 2). The nutritional composition of sorghum is presented in Table 3.

Table 3: Nutritional Information on Sorghum

Dry matter	94.00%
Total Digest Nutrients	83.00%
Net Energy for Lactation	0.87 meal/lb
Net Energy for Metabolism	0.92 meal/lb
Crude Protein	34.40%
Crude Fat	9.50%
Crude Fibre	12.70%
Ash	0.16%
Calcium	0.74%
Potassium	0.38%
Magnesium	0.19%

Source: (USDA 2001)

The highest weight gain of 16.65g was recorded in treatment 1 (0% sorghum husk). This was followed by treatment 2(25% sorghum husk) with a mean weight gain 14.04g. The lowest mean weight gain of 5.15 was recorded in treatment 5 (100%0 sorghum husk). There was a decrease in mean weight gain with increase in levels of sorghum husk inclusion as shown in Fig. 1. There was a negative correlation co-efficient (r = -0.98) in the mean weight gain.

The equation for correlation co-efficient is:

$$Y = 1661.0087 - 0.98\ 15X$$

Total percentage weight gain was highest in treatment 1 (0% sorghum husk) with 83.25% and least in treatment 5 (100% sorghum husk) with a value of 24.52%. There was a significant difference (P < 0.05) between the total percentage weight gain in treatments 1,2,3,4 and 5 (0% sorghum husk 25%, 50%, 75% and 100% sorghum husk) respectively.

There was a negative correlation co-efficient r = - 0.97, between treatment 1 (6.50g/week), treatment 4 (2.30% week) and treatment 5 (2.20g/week). The equation for the correlation co-efficient is Y = 629.9203 – 0.9691X. There was significant difference (P < 0.05) between the specific growth rate and the levels of sorghum husk in the diets.

The protein intake per week was highest in treatment 1 (3.88g/day) and reduced to 3.30g.day) in treatment 5. There was a negative correlation (r = -0.80) between the levels of sorghum husk inclusion and the protein intake for treatments 1,2,3,4 and 5. The equation for correlation co-efficient is Y = 391.0009 – 08042X. However there was no significant difference (P > 0.05) between the protein intake in treatment 1 (3.88g/day), treatment 2 (3.65g/day), treatment 4 (3.50/day, treatment 5 (3.30g/day).

The protein efficiency ratio decreased with increase in the level of sorghum husk. The values were 4.29 for treatment 1, 3.85 for treatment 2, 2.60 for treatment 3, 1.63 and 1.56 for treatment 4 and 5 respectively.

There was a negative correlation co-efficient (r = - 0.97) between the levels of sorghum husk inclusion and the protein efficiency ratio. Equation for correlation co-efficient is Y = 432.1488 – 0.9699 x.

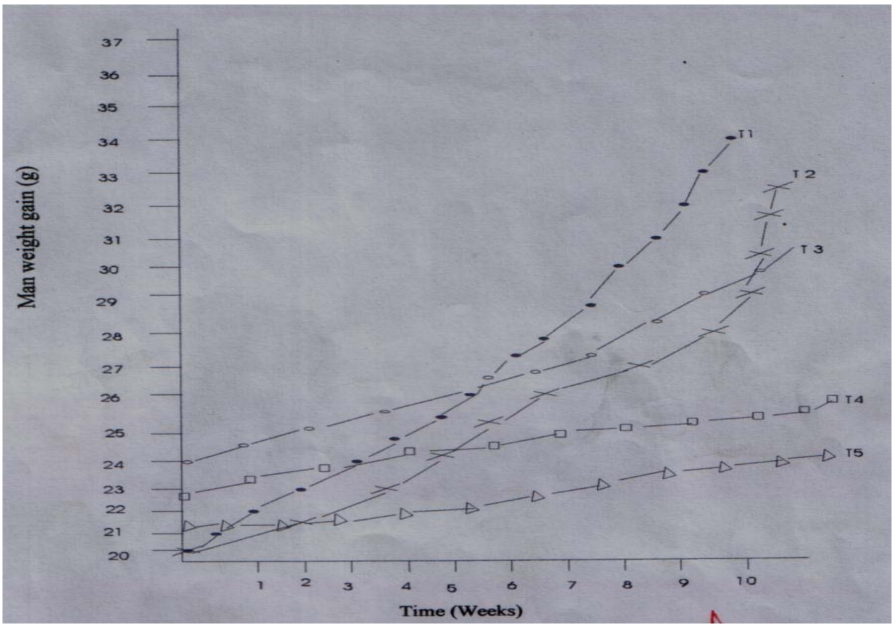


Figure 2: Mean Weight Gain of Fish Treatment 1 to 5

KEY:
• ——• (T1) % Sorghum Husk
X —— X (T2) 25% Sorghum Husk
0 —— 0 (T3) 50% Sorghum Husk
□ —— □ (T4) 75% Sorghum Husk
◄——► (T5) 100% Sorghum Husk

Table 4: Summary of Growth and Nutrient Utilization in Tilapia (*Oreochromis niloticus)*

PARAMETERS	TREATMENTS DIETS				
	1	2	3	4	5
Experimental Days	70	70	70	70	70
No. of Fish Stocked	15	15	15	15	15
Survival Percentage (%)	100	100	100	100	100
Average Initial Weight (g)	20.00	20.00	24.50	22.50	21.00
Average Final Weight (g)	36.65	34.04	34.68	28.20	26.15
Average Weight Gain (g)	16.65	14.04	10.18	5.72	5.15
Mean Wt Gain per Day (g)	0.238	0.201	0.145	0.082	0.074
Mean Wt. Gain/Week (g)	1.665	1.404	1.018	0.572	0.515
Total Percentage Wt. Gain (g)	83.25	70.20	41.55	25.42	24.52
Specific Growth Rate (%/Week)	6.50	5.35	3.50	2.30	2.20
Total Feed Intake (g)	1400.83	1338.61	1459.43	1258.38	1167.2
Feed Conversion Ratio	84.13	95.3	143.4	200.8	249.6
Gross Efficiency Food	1.19	1.05	0.70	0.50	0.40
Food Efficiency Conversion (%)	1.19	1.05	0.70	0.50	0.40
Protein Intake (g/day)	3.38	3.65	3.91	3.50	3.30
Protein Efficiency Ratio	4.29	3.85	2.60	1.63	1.56
Productive Protein Value (P.P.V.)	3.35	2.23	2.02	2.22	2.06

There was no fish mortality throughout the experimental period and survival rate was 100%. Similarly, no symptoms of infections and diseases were observed.

5. DISCUSSION

The main factor in the digestibility of the feed in this investigation was the fibre content of the feed. Falaye (1988) recommended that the fibre content of Tilapia diets should not be more than 10%. There was increase in the fibre content after incorporating the sorghum husk into the diets. The fibre content was 10.0% in diet 1, 11.42% in diet 2, and 11.81%, 13.66%, 13.57% in diet 3, 4 and 5 respectively. The best feed was Diet 1, which had the lowest fibre content while diet 5 with the highest fibre content had poor performance. Similar results were obtained by Ojo (1985), where inclusion of various levels of cocoa husk elevated fibre contents in the diets. Omojola (1989) reported that the inclusion of various levels of rice bran elevated fibre contents slightly. The fibre content in sorghum husk is higher than that of rice bran.

The protein level of the feed fell within the limits recommended for efficient utilization of dietary protein by Viola *et. al.,* (1987), who recommended 24% - 30% crude protein levels for tilapia species. The mean weight gain, specific growth rate, mean weight gain per week, and total percentage weight gain decreased with increase in levels of sorghum husk. Decreasing trend of performance of the experimental fish (*O. niloticus*) may be attributed to the increasing levels of fibre content on the feed, which depressed the utilization of feed ingredients (Omojola 1989). Longe and Adetola (1983) observed that in layers, excreta weights of birds fed high fibre feeds were higher than control birds fed low fibre diets. They remarked that increased stool weight was often accompanied by feacal excretion of nutrients. Shiau *et al* (1988) reported that high fibre content in feed has been shown to decrease utilization by hastening gastric emptying time in tilapia.

It has been reported that tilapia can utilize fibrous feed materials very well (Viola *et. al.*, 1988). However, Falaye (1988) recommended that fibre content should not be higher than 10% for Tilapia diets. The poor performance observed in diets 4 and 5 therefore may be due to high fibre contents (13.06% and 13.57%). This probably may explain the reason for higher performance of fish given diets 1 and 2 respectively. Lovell (1979) reported that the amount of protein present in feed does not determine its utilization by fish. Despite the fact that the protein content of sorghum husk is slightly higher than that of yellow maize, fish in diets containing 0% and 25% Sorghum husk levels performed better than that in 75% and 100% sorghum husk substitutions levels with higher protein.

The productive protein value did not show any definite trend with the level of sorghum husk inclusion. Falaye (1988), did not observe any significant difference in protein deposition in his experiment using cocoa husk. Shiau *et. al.,* (1988) observed no difference in the protein content of fish fed graded levels of carboxymethyl cellulose. This was attributed to iso-nitrogenous nature of the diets. No mortality was recorded throughout the period of the trial. A 100%

survival was recorded. This could be due to good handling and management throughout the period of the experiment.

6. CONCLUSION

Sorghum husk diets performed fairly well as a feedstuff. The highest growth performance was recorded in diet 2, followed by diet 3, but diets 4 and 5 showed very low growth performance and nutrient utilization.

There was no mortality recorded throughout the experimental period. Similarly, no symptoms of infections and diseases were observed.

It could be recommended that 25 percent or even 50% sorghum husk could replace yellow maize in tilapia (*O. niloticus*) diet.

ACKNOWLEDGEMENT

I am grateful to the Executive Director of NIOMR, Dr. O. A. Ayinla; Dr. A. Oresegun and Dr. Pat Anyanwu of NIOMR respectively for their assistance.

REFERENCE

Dada B. F. (2003): Contribution of Fisheries to employment, National Economy and food Security in Nigeria. A paper delivered at FISON Public Lecture.

Falaye A. E. (1988): Utilization of Cocoa Husk in the Nutrition of Tilapia (*O. niloticus* Trewavas) Ph.D. Thesis University of Ibadan pp. 80–83

FAO 2003, Aquaculture Bulletin: The Domestic Fish Production Sector in Nigeria Fisheries 2000.

FDF (2000): The Domestic Fish Production sector in Nigerian Fisheries, 2000.

Longe, O. G., J. A. Adetola (1983): Metabolisable Energy Values of some Agricultural Wastes and Industrial by products for

Layers and the Effects of these Ingredients in Gut Dimensions J. Anim Prod. Res (1983) 3 (1) pp. 1 – 13

Lovell, R. T (1979): Formulating Diets for Aquaculture Species Feedstuffs: 51; pp. 29 – 32.

Ojo, I. O. (1985): Substitution of Yellow Maize with Cocoa Husk in Supplement Diets for Tilapia (*O. niloticus*) M.Sc Project University of Ibadan, Ibadan. 94p.

Omojola, V.A. (1989): The Utilization of Rice Bran in the Nutrition of Tilapia (*O. niloticus*) M. Sc Project, University of Ibadan. Pp 70.

Shiau S.V., Yu, H. L., Hiva, S., Chen S. V. and Hsus S. J. (1988): The Influence of Carboxymethyl Cellulose on Growth, Digestion, Gastric Emptyingtime and Body Composition of tilapia. Aquaculture 70. pp 345 – 354.

USDA 2001 United States Department of Agriculture Buyers Guide. July 11, 2001 Volume 73 (29): 30 – 31

Viola, S. ; Arieli, Y. and Zohar, G. (1988): Animal Protein Free Diets for Hybrid Tilapia (*O. niloticus x O. aureus*) in Intensive Culture. Pp 115 – 125

DETERMINATION AND CONTROL OF AMMONIA AND pH LEVELS IN AN INTENSIVE CATFISH FARM USING WATER RECIRCULATION SYSTEM

Anyanwu, P.E., Ebonwu, B.I., Hamzat, M.B., Ihimekpen, F., Okoro, B., Ayaobu-Cookey, I.K., Matanmi, M.A. and E. S. Afolabi.

Nigerian Institute for Oceanography and Marine Research,
PMB 12729, Lagos.

ABSTRACT

A study was carried out to determine ammonia and pH levels and measures of control in an intensive catfish farm using water recirculation system. A commercial extruded floating feed containing 42% crude protein was fed to the fish. The results revealed that ammonia ranged from 3.0 to 40.0 mg/l during the three months study period while pH ranged from 5.4 to 7.0. pH levels were low being in the acidic range while ammonia levels were high. Regular flushing of the sedimentation tank and introduction of fresh water reduced the level of ammonia in the system.

Keywords: *Ammonia, pH, catfish culture, water recirculation system, control.*

---

1. INTRODUCTION

Good water quality ensures good growth, reproduction and survival of all aquatic organisms including fish. Ammonia is the major nitrogenous waste product from fish. It occurs in two forms in water, the ionized ammonia ($NH_4{}^+$ and NH_3. $NH_4{}^+$) and the unionized ammonia (NH_3) that is toxic to fish. The two forms together called Total Ammonia (TAN) exit in the following equilibrium:

$$NH_4^+ \leftrightarrow NH_3 + H^+$$

Temperature and pH affect the form of ammonia predominant at any given time in an aquatic system (Swann, 1997). As pH and temperature rise, the equilibrium shifts to the right, resulting in an increase in the concentration of unionized ammonia (NH_3). Low pH and temperature will shift the equilibrium to the left (Boyd, 1979). Toxic unionized ammonia can be converted to harmless nitrate by biological nitrification, as illustrated in the equation below.

$$NH_3 + 1.5\,O_2 \rightarrow H^+ + H_2O + NO_2 \quad \text{---- Stage 1}$$

$$2NO_2 + O_2 \rightarrow 2NO_3 \quad \text{---- Stage 2}$$

Nitrification is a two-stage aerobic process. The first stage is the conversion of ammonia to nitrite by Nitrosomonas bacteria and the second stage is the conversion of nitrite to nitrate by Nitribacter bacteria (USEPA 1975, WPCF 1983). pH on the other hand is the measure of the hydrogen ion (H^+) concentration. It is the degree to which water is either acidic or basic. pH also affect many other water quality parameters and the rates of many biological and chemical processes. The desirable range of pH for fish culture is from 6.5–8.5. Levels below 4 or above 11 cause fish mortality.

Aquaculture recirculation system is an intensive system employing high stocking densities (>300fish/m^3) as well as use of high quality complete diets. There is reduction in water usage when compared to continuous flow-through systems. However major water quality problem in recirculation aquaculture usually result from excessive ammonia production causing fish mortality and poor growth (Boyd, 1979 and Helene *et al*. 1997). The amount of ammonia in the system depends on equilibrium between its rate of production, oxidation by bacterial activity, and the water exchange rate (Carpenter, 1967 and Meade, 1985). Nitrifying bacteria are very important in WRS aquaculture units because they remove ammonia from the system for a successful culture operation. Considering the high stocking rates and intensive feeding in recirculation systems, it is very important to monitor and control the levels of ammonia and pH in the water.

The objective of this work was to determine the levels of ammonia and pH under intensive catfish production in a water recirculation system and adopt measures for their control.

2. MATERIALS AND METHODS

The experiment was carried out in the indoor water recirculation system (WRS) catfish farm of Nigerian Institute for Oceanography and Marine Research, Victoria Island, Lagos from April to June, 2007. The facility operated the standard Dutch model system for production of African catfish and comprised of six fibre glass fish tanks measuring $3m^3$ each, one bio-filtration unit measuring $25m^3$, two surface water pumps (1hp) each, sedimentation tank unit measuring $3.6m^3$ and pump tank measuring $3.5m^3$. The bio-filtration medium used was polypropylene plastic "block" material. Holland strain of *C. gariepinus* was reared in 4 fibre glass tanks each measuring $3m^3$. The total number of fish stocked including juveniles and broodstock was 3,902 at the beginning of the experiment. Mean body weights ranged from 8.59 to 1,113.0g in the four tanks while total fish biomass was 91.30kg. The fish were reared for 3 months and were fed Dizengoff feed, an imported extruded commercial floating diet containing 42% crude protein level at 2–4% body weight daily. A total of 255.06kg of feed was fed to the fish.

Water quality analysis particularly ammonia (NH_3) and pH were carried at out daily at 8.00 hours using Colombo mini water test kit (Aquadistri BV Model). Water and atmospheric temperatures were also determined using mercury-in-glass thermometer. Water for analysis was collected from the sedimentation tank which received the effluent water from the fish rearing tanks.

3. RESULTS

The values of ammonia and pH recorded in the sedimentation tanks for three months (April to May 2007) are presented in Tables 1, 2 and 3. The measures undertaken to control these critical water quality parameters are also indicated. For the month of April, pH ranged from 5.6 to 6.8 while ammonia ranged from 5 to 10 mg/l. For May and June 2007, pH varied from 5.4 to 7.0 and 5.8 to 7.0 respectively while ammonia ranged from 5 to 40 mg/l and 5 to 30.0 mg/l respectively. Air and water temperatures varied from 23^{o}C to 27^{o}C and 25^{o}C to 29^{o}C respectively.

pH levels were low being on the acidic range and did not vary widely whereas ammonia levels were high and fluctuated greatly. The results are presented in Fig. 1. Major water quality control measured taken was flushing of the water treatment unit and introduction of freshwater. This measure controlled the level of ammonia but had little or no effect on pH.

Table 1: pH and Ammonia Levels in the Sedimentation Tank (April 2007)

DATE	pH	AMMONIA (mg/l)	MEASURES TAKEN TO CONTROL WATER QUALITY
1/4/07	5.6	5.0	Fresh water was introduced into the tank
2/4/07	6.2	5.0	Continuous introduction of fresh water in the tank
3/4/07	6.2	10.0	Continuous introduction of fresh water in the tank
4/4/07	6.4	10.0	Draining of the tank from the bottom for 10 minutes and scrubbing of the tank
5/4/07	6.6	5.0	Continuous addition of fresh water and flushing of sedimentation tank
6/4/07	6.6	5.0	Continuous addition of fresh water and flushing of sedimentation tank
7/4/07	6.6	5.0	Flushing of sedimentation tank
9/4/07	6.8	10.0	-
10/4/07	6.8	10.0	Flushing of sedimentation tank
11/4/07	6.6	10.0	-
12/4/07	6.8	10.0	-
13/4/07	6.8	10.0	Flushing of sedimentation tank, washing of pump tank and refreshing with fresh water
14/4/07	6.6	5.0	-
16/4/07	6.2	5.0	-
18/4/07	5.8	5.0	Partial flushing of sedimentation tank due to shortage of water
20/4/07	5.6	5.0	Partial flushing due to water shortage
25/4/07	5.6	10.0	Flushing of sedimentation tank
27/4/07	5.6	5.0	-
30/4/07	5.6	5.0	-

Table 2: pH and Ammonia Levels in the Sedimentation Tank (May 2007)

DATE	pH	AMMONIA (mg/l)	MEASURES TAKEN TO CONTROL WATER QUALITY
2/5/07	5.6	10.0	-
4/5/07	5.8	10.0	-
7/5/07	6.4	10.0	Washing and flushing of pump and sedimentation tanks.
9/5/07	6.0	5.0	Power / generator failure. Feeding was not carried out to prevent water fouling.
10/5/07	6.5	40.0	Flushing of sedimentation tank
11/5/07	5.6	10.0	-
12/5/07	5.4	10.0	Flushing of sedimentation tank
14/5/07	6.4	5.0	-
16/5/07	6.2	10.0	Flushing of sedimentation tank
17/5/07	6.4	10.0	-
18/5/07	6.6	20.0	Flushing of sedimentation tank
20/5/07	6.2	10.0	-
21/5/07	6.4	30.0	Flushing of sedimentation tank
22/5/07	6.6	10.0	-
23/5/07	6.4	10.0	Flushing of sedimentation tank
24/5/07	6.2	5.0	Flushing of sedimentation tank
25/5/07	6.2	5.0	-
27/5/07	6.6	10.0	-
28/5/07	7.0	30.0	Flushing of sedimentation and pump tanks
30/5/07	6.2	10.0	Flushing of sedimentation tank

Table 3: pH and Ammonia Levels in the Sedimentation Tank (June 2007)

DATE	pH	AMMONIA (mg/l)	MEASURES TAKEN TO CONTROL WATER QUALITY
1/6/07	6.4	10.0	Flushing of sedimentation tank and washing of pump tank.
2/6/07	6.6	10.0	-
3/6/07	6.6	10.0	-
4/6/07	6.6	10.0	Flushing of sedimentation tank.
5/6/07	6.8	10.0	-
6/607	6.8	30.0	Flushing of sedimentation tank.
7/6/07	6.8	10.0	-
8/6/07	6.4	10.0	Flushing of sedimentation tank.
9/6/07	6.8	10.0	Partial flushing of sedimentation tank due to shortage of water
10/6/07	6.6	30.0	Flushing of sedimentation tank.
11/6/07	6.8	20.0	Flushing of sedimentation tank and washing of pump tank.
12/6/07	6.6	5.0	-
13/6/07	6.4	5.0	-
14/6/07	6.4	30.0	Flushing of sedimentation tank.
15/6/07	6.0	5.0	-
16/6/07	6.2	10.0	Flushing of sedimentation tank.
17/6/07	5.8	10.0	-
18/6/07	6.0	10.0	Flushing of sedimentation tank
19/6/07	6.4	10.0	Flushing of sedimentation tank
20/6/07	6.8	5.0	Flushing of sedimentation tank
21/6/07	6.5	3.5	Flushing of sedimentation tank
22/6/07	6.4	5.0	Flushing of sedimentation tank
23/6/07	6.4	10.0	-
24/6/07	6.6	10.0	Partial flushing of sedimentation tank due to shortage of water
25/6/07	6.6	10.0	Flushing of sedimentation tank
26/6/07	6.8	5.0	-
27/6/07	6.8	10.0	Flushing of sedimentation tank and washing of pump tank
28/6/07	7.0	5.0	No flushing but rained from morning till evening.
29/6/07	6.6	5.0	Power failure, no flushing and heavy rainfall.
30/6/07	6.8	5.0	Heavy rainfall and flushing was not carried out due to shortage of water

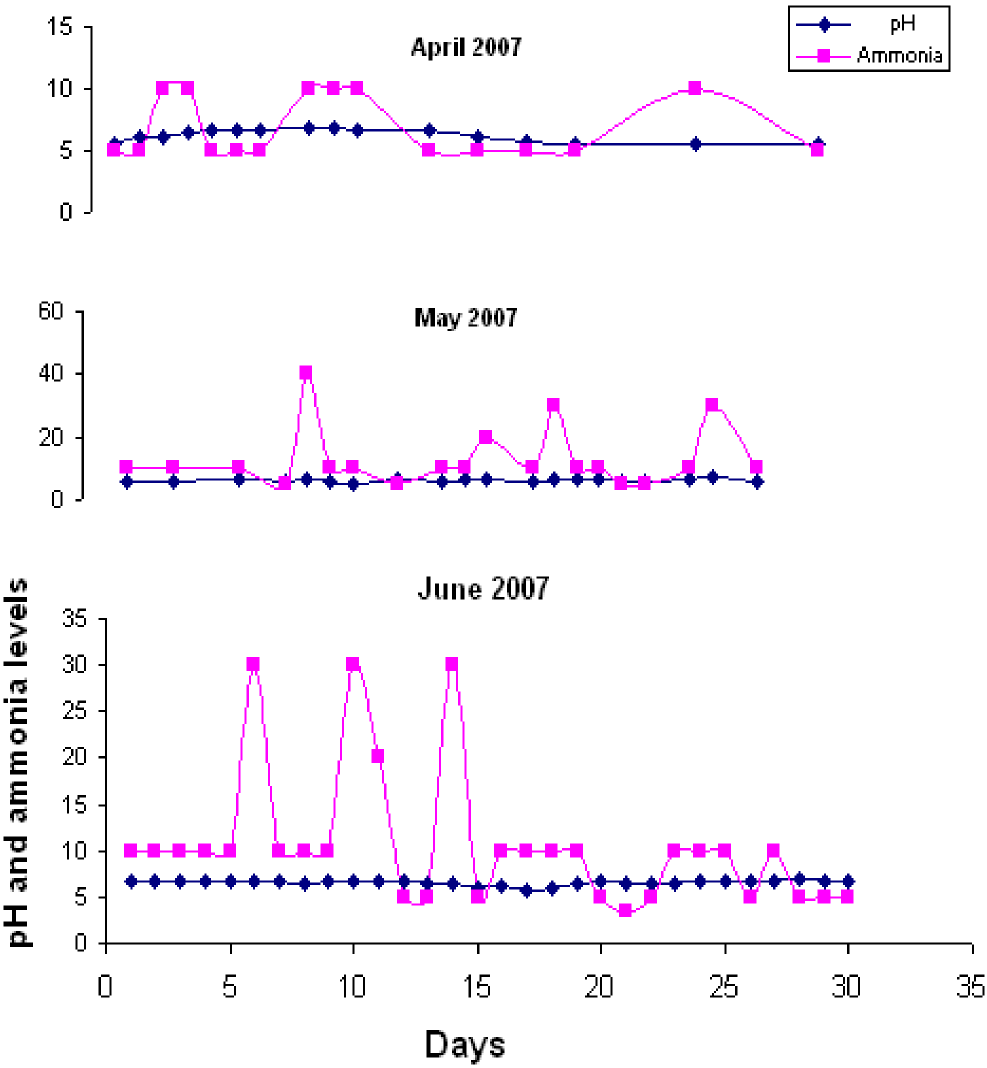


Fig 1. pH and ammonia levels in the sedimentation tank

4. DISCUSSION

In closed water recirculation aquaculture system, ammonia removal is a critical factor for successful culture operations. In the NIOMR WRS system operating the Dutch model of WRS, a trickling biological filter containing polypropylene filter media is used for biological nitrification of ammonia. As effluent water is pumped into the bio-tower, nitrifying bacteria attached to the media surfaces will convert ammonia to nitrate.

Toxicity levels of ammonia according to Tucker and Robinson (1990) vary from species to species. EIFAC (1973) reported that toxic levels of ammonia for short exposure lie within 0.6 - 2.0 mg/l. Colt *et al* (1975) quoted by Boyd (1979) reported that the 96hr LC_{50} of NH_3 for Channel catfish at 30^oC was 3.8mg/l. Oellermann and Hecht (1993) observed that the LC_{50} toxicity values of unionized ammonia for *C. gariepinus* and the *Heterobranchus longifilis* X *C. gariepinus* hybrid are approximately 6.5 mg/l and 9.10 mg/l respectively. These values indicate an extremely high tolerance when compared to LC_{50} values for other teleost species.

However high levels of ammonia occur in recirculation aquaculture systems where values over 40mg/l have been recorded (Fleuren and Alakija, pers. com.). Ammonia levels of 5 to 40 mg/l obtained in this study were similar to those obtained by Fleuren and Alakija as well as other WRS catfish farms in Lagos State (Ebonwu, pers. comm.). Fish species suitable for ultra-high density aquaculture should have high ammonia tolerance.

Nitrification process is an acid forming process according to Swann (1997) and therefore in closed system, the water must be buffered to prevent a decline in pH. In this study, pH obtained was in the acid range of 5.4–7.0. Rapid pH changes of 0.5–1.0 unit will significantly reduce bio-filter ammonia and nitrite conversion efficiency (Cutler and Crump, 1933, Bisogni and Timmons, 1991). A rapid increase in ammonia will be observed in the system until bacteria adapt to the need conditions (Wheaton *et. al.*, 1991).

Temperature and pH affect the concentration of un-ionized ammonia in aquatic systems. The concentration increases with increase in temperature and pH as shown in Table 4. If anaerobic condition occurs de-nitrification will commence thereby converting nitrate back to ammonia (Lees, 1952 and Atlas and Bartha, 1987). Regular washing of the distribution plate to ensure uniform distribution of circulated water through the bio-filter block can minimize or control anaerobic condition. Also, loss of time during power failure should be minimized to avoid die-off of bacteria in the bio-filter. Alternative power supply must be provided to ensure continuous circulation of water.

Table 4: Percentage of Total Ammonia that is Un-Ionized at various Temperatures and pH. (Swann Ladon, 1997)

Ph	**12.2°C (54°F)**	**16.7°C (62°F)**	**20°C (68°F)**	**23.9°C (75°F)**	**27.8°C (82°F)**	**32.2°C (90°F)**
7.0	0.2	0.3	0.4	0.5	0.7	1.0
7.4	0.5	0.7	1.0	1.3	1.7	2.4
7.8	1.4	1.8	2.5	3.2	4.2	5.7
8.2	3.3	4.5	5.9	7.7	11.0	13.2
8.6	7.9	10.6	13.7	17.3	21.8	27.7
9.0	17.8	22.9	28.5	34.4	41.2	49.0
9.2	35.2	42.7	50.0	56.9	63.8	70.8
9.6	57.7	65.2	71.5	76.8	81.6	85.9
10.0	68.4	74.8	79.9	84.0	87.5	90.6

N/B:
To determine un-ionized ammonia concentration, multiply total ammonia concentration by the percentage which is closest to the observed temperature and pH of the water sample. For example, if Total ammonia concentration of water sample is 5.0 mg/l at pH 9 and temperature of 20°C (68°F), the concentration of un-ionized ammonia will be 5.0 mg/l Total ammonia X 28.5%. This will give 1.43mg/l of un-ionized ammonia.
Growth rates of fish have been known to decrease at high ammonia concentrations. Long term exposure of fish to reversed ammonia concentration gradients leads to varied manifestations of chronic and acute toxicity both of which result in cytological damage to gill

tissue and the liver. Thus nitrifying bacteria are very important in WRS aquaculture units because ammonia and other nitrogenous metabolites must be removed from the system for successful culture operations (Muir, 1981). A major control of ammonia levels adopted in this study was daily flushing of sedimentation tank and refilling with freshwater which lowered ammonia levels below 10 mg/l in April 2007 contrary to higher levels of 5 – 40mg/l obtained for May 2007. High levels of ammonia occurred usually when sedimentation tank was not flushed regularly as shown in Tables 1 to 3.

Ammonia levels were also lowered due to effect of rain water on the water treatment unit as observed from 28th–30th June, 2007. Despite that the sedimentation tank was not flushed for 3 days, ammonia levels did not rise above 5.0 mg/l. The water treatment unit was located outside in the open and exposed to rainfall. Filling with freshwater kept ammonia levels low, an important management tool for control of water quality in intensive systems.

REFERENCES

Atlas, R.M. and R. Bartha. 1987. Microbial Ecology: Fundamentals and Applications. Menlo Park C.A; Benjamin Cummings.

Bisogni, J.J. and M.B. Timmons. 1991. Control of pH in closed recycled aquaculture systems. Engineering aspects of Intensive Aquaculture. Proceedings from the Aquaculture symposium held at Cornell University, Ithaca, NY. April 4–6, 1991.

Boyd, C.E. 1979. Water Quality in warm water fish ponds. Agricultural Experiment Station, Auburn University, Alabama, USA. 359p.

Carpenter**.** P. L. 1967. Microbiology. Philadelphia: W.B. Saunders.

Cutler, D.W. and I.M. Crump. 1933**:** Some aspects of physiology of certain nitrite forming bacteria. Annals of Applied Biol. 20: 291 – 296.

EIFAC. 1973. European Inland Fisheries Advisory Commission. Water quality criteria for European fresh water fishes. Report on Ammonia and Fisheries. Water Res. 7: 101 – 122.

Helen, M., Bernad, M., Jeanne, G. and Eric, V. 1997. Modelling fish mortality due to urban storm run-off. Interacting effects of hypoxia and ammonia. Journal of the International Association on Water Quality. 31 (2): 2 – 11.

Lees, H. 1952. The biochemistry of the nitrifying organisms. Biochemical Journal 52: 134 – 139.

Meade, J. W. 1985. Allowable ammonia for fish culture. The Progressive Fish Culturist. 47: 135 – 145.

Muir J.F. 1981: Recirculated Water systems in aquaculture. Recent Advances in Aquaculture, Muir, J.F. and R.J. Roberts. Eds. London: Croom Helm.

Oellermann, K.K. and Hecht, T. 1993: The aquaculture potential of a catfish hybrid *Heterobranchus longifilis* male X *Clarias gariepinus* female in Southern Africa. p. 129 – 134. In: Hecht, T., Britz, P.(eds). Proceedings of the Second Congress of the Aquaculture Association of Southern Africa, Rhodes University, Grahamstown. South Africa. 8 – 11 September, 1992.

Swann, L. 1997. A fish farmer's guide to understanding water quality. Aquaculture Extension. Indiana Sea Grant Program, Fact Sheet AS-503.7p. http://www. ansc.purdue.edn/aquanic

Tucker, C. S. and E.H. Robinson. 1990. Channel Catfish farming Handbook. N.Y.Van Nostrand Reinhold.

USEPA (U.S. Environmental Protection Agency). 1975. Process design manual for nitrogen control. Washington. D.C: USEPA, Office of Technology Transfer.

Wheaton, F. W., J.N. Hochheimer, G.E. Kaiser and M.J. Krones. 1991. Principles of biological filtration. Engineering aspects of Intension Aquaculture. Proceeding from the Aquaculture Symposium, Ithaca, N.Y: Cornell University, April 4-6, 1991.

WPCF (Water Pollution Control Federation). 1983: Nutrient Control. Manual of Practice: Pub. No. FD – 7, Washington, D.C. Water Pollution Control Federation.

3D BATHYMETRIC MODEL OF AVON CANYON IN THE WESTERN NIGERIA CONTINENTAL SHELF AND RESULTING WAVE REFRACTION PATTERNS

Awosika, Larry F.

Nigerian Institute for Oceanography and Marine Research Lagos

---

ABSTRACT

Avon canyon located offshore the western Nigeria continental shelf is the largest of the three major canyons (Avon, Mahin and Calabar canyons) offshore Nigeria. Using available bathymetric data, a 3D bathymetric model of the western Nigeria continental shelf and the Avon canyon was achieved. Also, using two different deep water wave conditions (wave heights, directions, period, fetch and the modelled bathymetry) a Linear Wave Propagation Model RCPWAVE was employed to model wave refraction patterns. Interpretation of bathymetric data and the 3D models reveal the V shape configuration of the canyon which meanders along its axis in a net easterly direction. The canyon head is amphitheatre-shaped with steep rims. Several gullies occur along the shelf east and west of the canyon. The two wave refraction models show that although most of the wave energy is refractively trapped on the offshore canyon rim, a small fraction of the wave energy 'tunnels' across the canyon. The two wave refraction models also show how the steep bottom features of Avon canyon break up a wave train into complex patterns with waves larger at the flanks of the canyon and smaller at the head of the canyon. The wave crests bend sharply over the canyon walls. Other large scale refraction of waves is also noticed along the coast due to sand shoals near the coast. The Wave refraction patterns have implication for the breaking wave energy which invariably have concomitant impacts on the shoreline. The results of this study hence will be useful for the understanding of the waves dynamics, erosion and flooding risks assessment along the western Nigeria coast. This is so considering the rapid

development of the Methanol plant, an oil refinery, the Olokola port city, housing estates and other heavy industries close to shore.

Keywords: *Canyon, continental shelf, wave refraction, bathymetry, Nigeria.*

1. INTRODUCTION

Avon canyon is located offshore the western Nigeria continental shelf which is bordered by a Barrier lagoon coastal complex. It is the biggest canyon of the three major canyons (Avon, Mahin and Calabar canyons) located offshore the Nigerian continental shelf. The precise setting of the Avon canyon and other canyons offshore Nigeria is presented in Figure. 1 (GEBCO digital atlas, 2003).

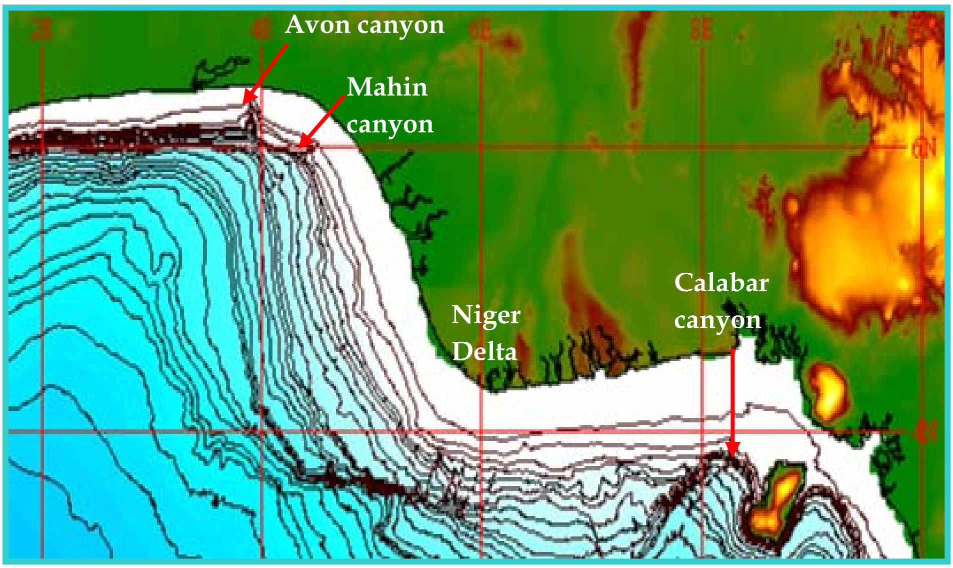


Figure 1. Bathymetric configuration of the Nigerian Continental shelf (GEBCO digital atlas, 2003). (Contour interval 100m)

The nature of the Nigeria continental shelf has been documented by Allen (1964 and 1965); Allen and Wells (1962); Stonely (1966); Burke (1972); Merki (1972); Awosika, (1988, 1990), and others. The Nigerian continental shelf is narrow ranging from 35km in the west to over 75km off the Calabar estuary. The shelf off the western shelf between Lagos and Lekki town east of Lagos averages about 30km in width. The western shelf widens to about 62 km. Farther to the east and off Calabar, the shelf widens to 75km. The general shape and morphology of canyons in the continental margins has been described by several authors, notable ones include Daly (1936); Kuenen, (1952); Shepard and Dill (1966), Burke,(1972); Belderson and Kenyon (1976); Clarke and Pickering, (1996), Twichell and Roberts (1982); Babonneau *et al*., (2002) amongst others. The general morphology of canyons in continental margins is shown in Figure 2.

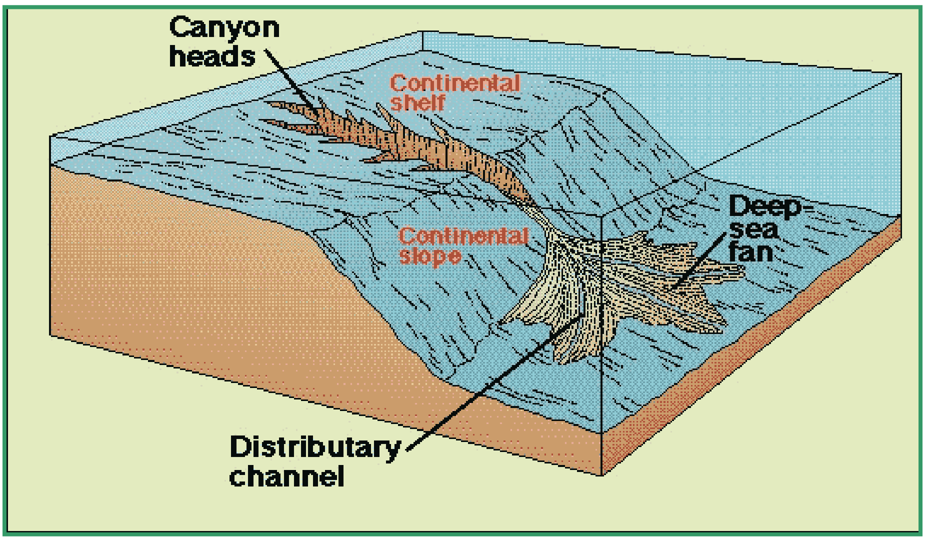


Figure 2. Submarine canyon – fan system.
(After http://www.geology.wmich.edu/kominz/C4turbiditycurrent.gif, 2004)

The presence of the Avon Canyon east of Lagos was first documented on the British Admiralty Chart, (1862). The chart shows shallow tributary valleys leading into the canyon, within 4 to 6km of the coastline and in water depths of less than 50 m. Allen (1964) reported the presence of the Avon canyon around longitude 3° 55' 00''E and latitude 6° 10' 00''N, as a V shaped canyon.

The occurrence of canyons in the continental shelf result in the refraction of waves which causes changes in the wave energy and the angle of wave approach which, subsequently influence longshore current parameters and intensity of breaking waves. Wave refraction can result in convergence or divergence of the wave energy producing changes in wave height as well as wave direction in the nearshore environment (Figure 3).

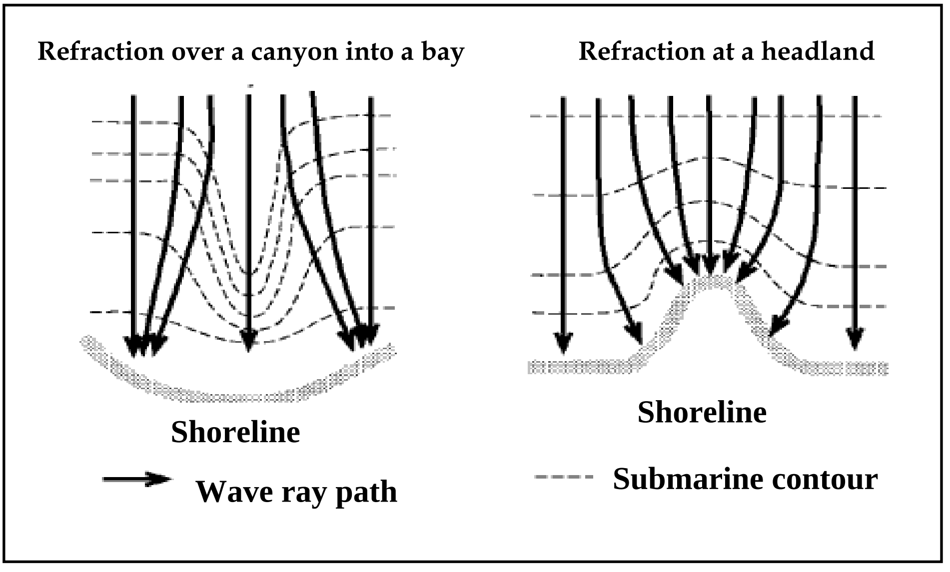


Figure 3. Typical wave refraction patterns over canyon and headland.

Refraction of waves propagating over submarine canyons result in strong along-coast changes in the heights and directions of waves. The changes in wave height and direction along the shoreline result in complex surf and swash zone circulation, including converging alongshore flows, jets, eddies, and gigantic rip currents.

The primary purpose of this study is to understand the propagation of waves over the realistic bottom topography of the Avon canyon and hence understand the patterns of wave breaking on the adjoining shoreline.

2. STUDY METHODOLOGY

In understanding wave refraction patterns along the study area and subsequent effects of breaking waves on the shoreline the following analysis was undertaken:

2.1 3D bathymetric model of the Western Nigeria continental shelf with particular reference to Avon canyon.

Bathymetric data from the Nigerian Institute for Oceanography and Marine Research (NIOMR) cruises in the western Nigerian continental shelf, undertaken between 1985 and 1988 (Figures 4 and 5) on board R/V SARKIM BAKA and the Intergovernmental Oceanographic Commission of the Central Eastern Atlantic (IOCEA) cruise in the Gulf of Guinea of 1994 was collated (Awosika *et al.*, 1994) Bathymetric depths from these database were digitised using the program 'Profortran'. Using a computer program "SURFER", a 3 dimensional (3D) bathymetric chart of the continental shelf to the east of Lagos was achieved.

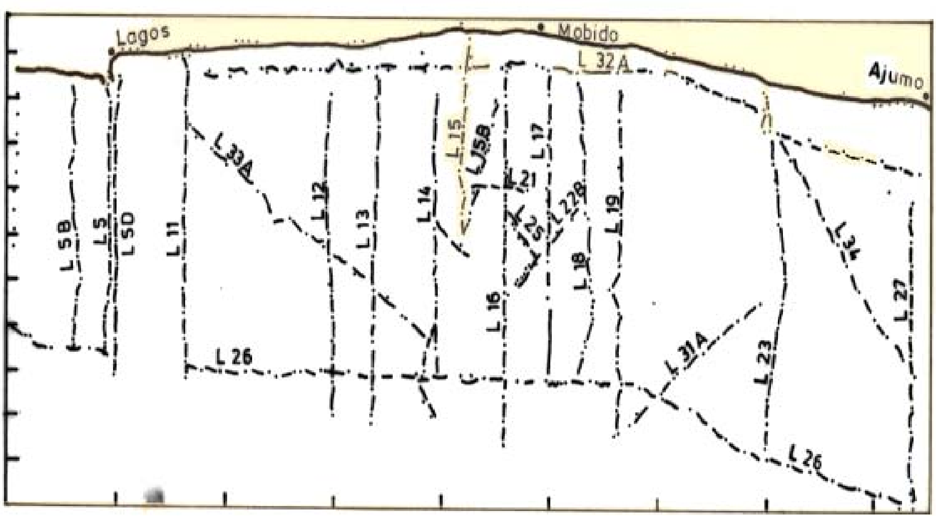


Figure 4. Bathymetric sounding lines along the Western Nigerian Continental Shelf (After Awosika et al., 1990).

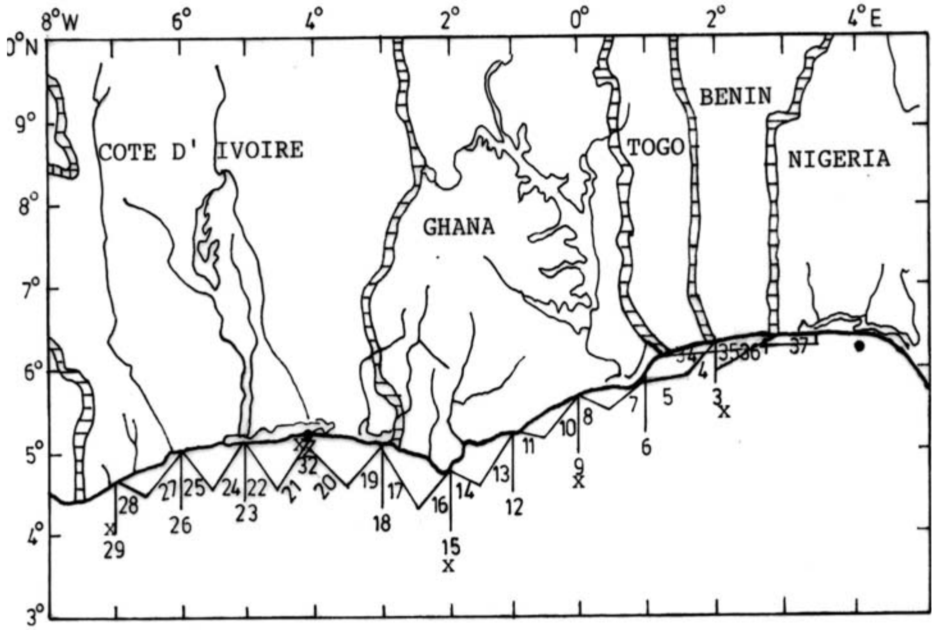


Figure 5. Bathymetric sounding lines and sediment sampling stations during IOCEA Cruise in the Gulf of Guinea (After Awosika *et a*l., 1994).

2.2 Wave refraction model

A Linear Wave Propagation Model RCPWAVE was employed in understanding the wave refraction patterns along the study site. The RCPWAVE is a computer model developed by the United States Army Corps of Engineers as tool for solving the open coast wave propagation problem. The model also contains algorithm which estimates wave conditions inside the surf zone.

Two types of models were made with varying inputs as shown in Table 1.

i. depth values were taken from digitised bathymetric map;

ii. actual depth values were provided for each cell of a grid comprised of cells in the x-direction and cells in the y-direction;

iii. the aerial extent of model covers 45km in the y-direction and 125km in the x-direction;

iv. a fetch of 150km was approximated for the model; and

v. deep water wave conditions (wave heights) of 1.8m and 2.0m were used for model numbers WFM1 and WRM 2 respectively.

Table 1. Data inputs used in the RCPWAVE models.

MODEL NUMBER	DEEP WATER WAVE HEIGHT (m)	DEEP WATER WAVE DIRECTION (DEGREES)	WAVE PERIOD (SEC)	WIND DIRECTION
WRM. 1	1.8	225	6	Southwest
WRM. 2	2.0	225	13	Southwest

3. RESULTS

3.1 Bathymetric models

Interpretation of computer generated bathymetric map (Figure 6) and the 3D models (Figures 7 and 8) reveal the bathymetric configuration of the Avon canyon and the adjoining continental shelf.

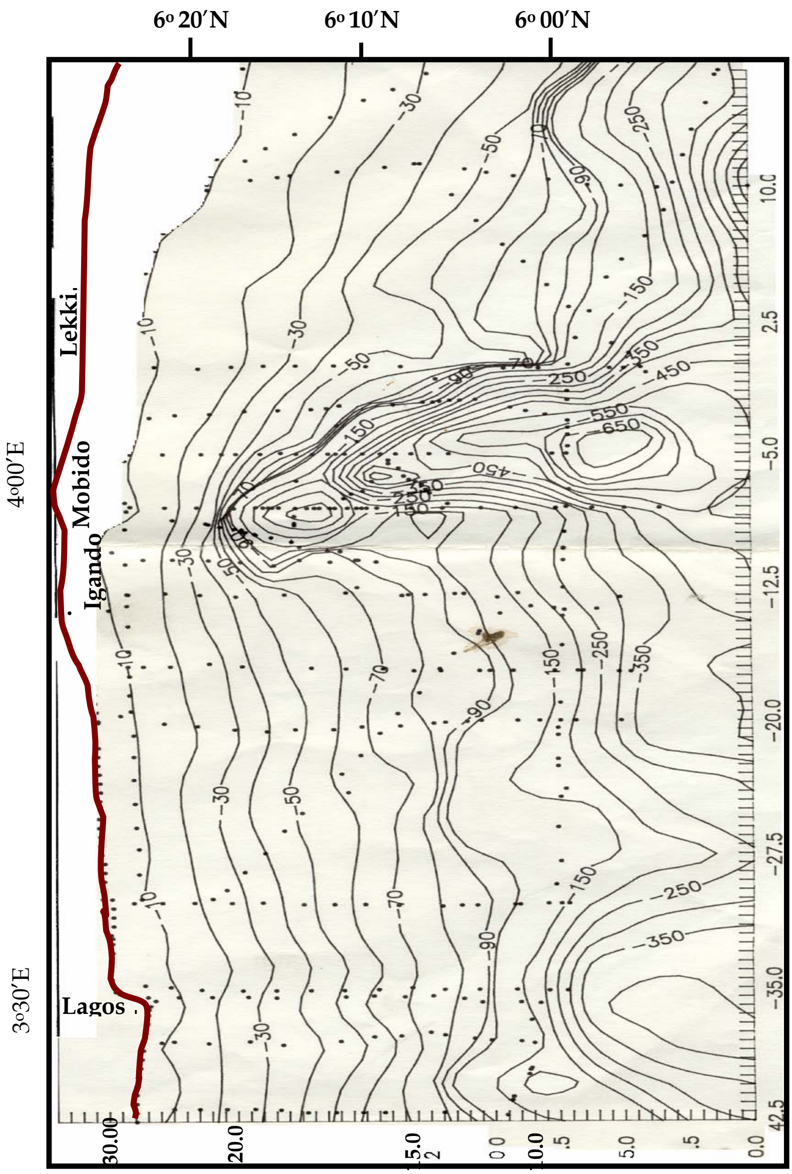


Figure 6. Computer generated bathymetric map of the Western Nigeria Continental shelf. (Dots denote digitised points)

In plan view, the canyon shows a V-shaped configuration. The canyon meanders along its axis in a net easterly direction. The canyon head is amphitheatre-shaped with steep rims. Several gullies occur along the shelf east and west of the canyon. These gullies are more prominent within the shelf break west and east of the canyon (Figures 7 and 8).

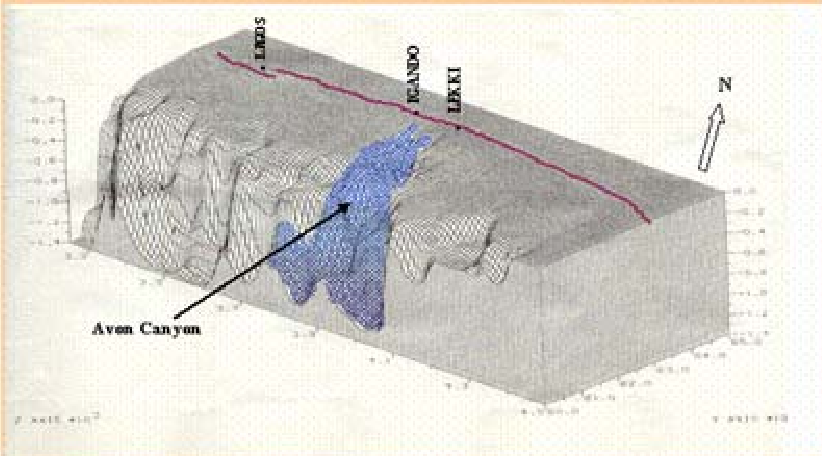


Figure 7. 3D bathymetric model of the Avon canyon (Looking from the southwest)

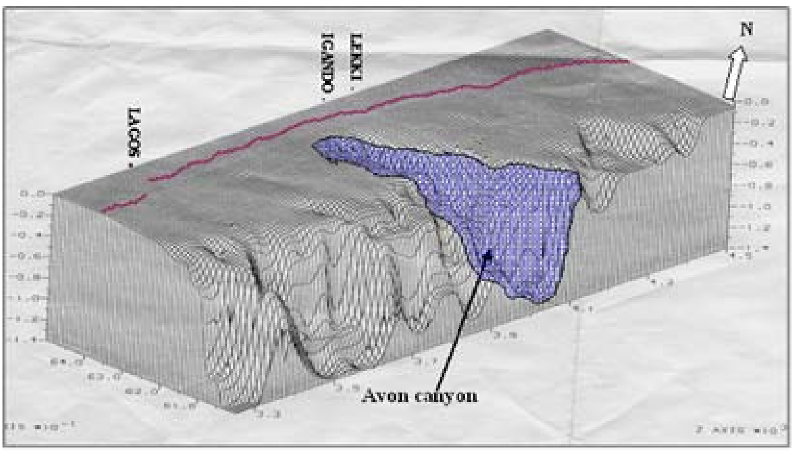
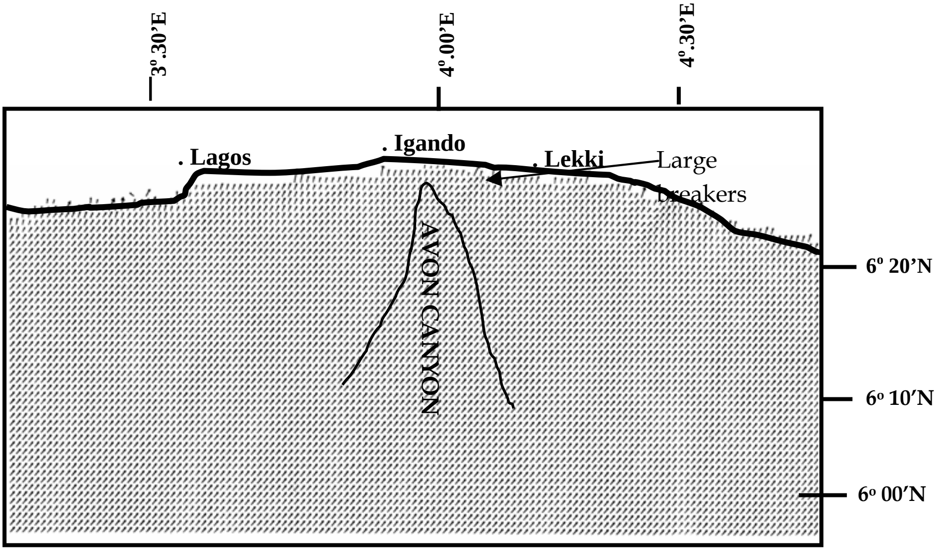


Figure 8. 3D bathymetric model of the Avon canyon (looking from the southeast)

3.2. Wave refraction

The two wave refraction models (Figures 9 and 10) show how the steep bottom features of Avon canyon break up a wave train into complex patterns under different wave conditions (WR I and WR 2).

Figure 9 showing deep water wave condition of 1.8m, direction of 225° and period of 6 seconds represent normal to average met-ocean conditions in the shelf. This model shows the refraction of waves in the shelf and the Avon canyon especially. The large breakers east and west of the head of the canyon are the result of the wave refraction.



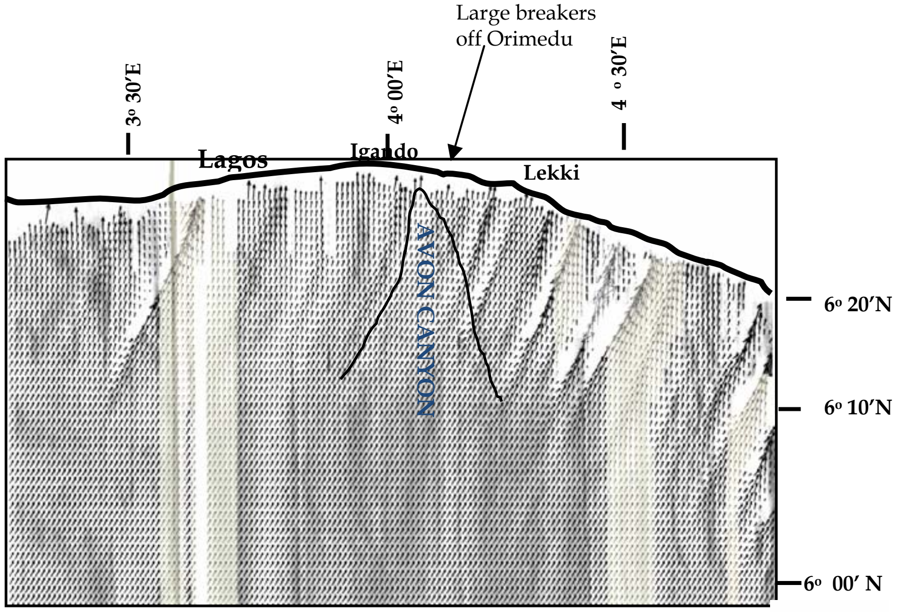
(Deepwater wave conditions: height -1.8m, direction - 225°, period - 6.0sec)

Figure 9. Wave refraction diagram (Model WFM.1) offshore western Nigeria using Regional Coastal wave propagation model.

Generally, the wave energy is refractively trapped on the offshore canyon rim, while a small fraction of the wave energy 'tunnels' across the canyon. It is evident that the waves are larger at the flanks of the canyon and are smaller at the head of the canyon.

The waves fan out, resulting in divergence (low waves) over the head of the canyon and convergence (high waves) on either side. The wave crests bend sharply over the canyon walls.

Figure 10 with deep water wave height of 2m, direction of 225^{o} and period of 13 seconds represents stormy conditions at sea. Again waves are refracted due to the canyon. The waves are however larger than the normal conditions. The refraction of waves are very pronounced within the head of the canyon with resulting low breaking waves off the Avon canyon head. Large breaking waves are also observed east and west of the canyon head. Large scale refraction of waves is also noticed within the nearshore zone due to sand shoals.



(Deep water wave conditions: height - 2m, direction - 225.0°, period - 13.0 sec)

Figure 10. Wave refraction diagram (Model WFM.2) offshore western Nigeria using Regional Coastal Processes wave propagation model.

Variations in wave height can be recognized by the prominence of the wave crests on either side of the canyon compared to the crests directly over the canyon and by the variation in the width of the surf zone. The degree of wave convergence and divergence in these models are indicated by the width of the lines designating wave crests.

5. DISCUSSION

Wave refraction is a key process affecting the distribution of wave energy and power, and hence the potential for coastal flooding, erosion and sediment transport along the shoreline. Wave refraction results from a change in local wave propagation speed due primarily to local depth changes. As waves slow down in shallow water, wave-length reduces and wave height increases. Submarine canyons have the effect of focusing waves into the regions on either side of the canyon. These observations can be explained qualitatively by the effect of refraction over the complex bathymetry (Munk and Traylor, 1947).

Wave transformations are important processes to consider in coastal flood studies, especially where long period swell is prevalent, and where coastal morphology focuses wave action on the coast. Most energy in nearshore waters comes from wind-generated waves and tidal currents. The dispersion of water, pollutants, nutrients, and sediments near the coast and the formation and erosion of sandy beaches are some of the common results of nearshore energy dissipation.

The two wave refraction models (Figures 9 and 10) show how the steep Avon canyon bathymetric configuration (Figures 7 and 8) can break up a wave train into complex patterns. It is evident that the waves are larger at the flanks of the canyon and are smaller at the head of the canyon. The refracted waves result in large breakers east and west of the canyon with smaller breakers off the immediate head of the canyon. Littoral observations of wave dynamics show large breaking waves due to refraction offshore Igando and Orimedu villages (Ibe *et al*., 1993). The source of energy for coastal erosion and sediment transport is wave action. Large breakers pounding the coast especially sandy coast, usually result in high rates of erosion. Understanding the underlying coastal processes and the relationship of the beach with the offshore bathymetry and waves is critical to understanding and controlling coastal erosion.

The Avon canyon area and the adjoining continental shelf are presently being developed rapidly. Industries like the Methanol plant, an oil refinery, the Olokola Free trade zone and port city east of the Avon Canyon (a joint project between Ondo, Ogun States, Chevron Nigeria Limited and the Nigerian National Petroleum Corporation) and other heavy industries are presently planned for the area very close to shore. The nearshore area will be dredged to make way for large vessels to serve these coastal infrastructures. The bathymetric configuration of Avon canyon and resulting wave refraction and breaking wave patterns will have concomitant effects on coastline stability as regards erosion. This will definitely play important roles on the viability and environmental sustainability of these projects.

6. CONCLUSION

Canyon topography produces dramatic changes in wave energy over alongshore distances of only a few hundred meters resulting in complex nearshore circulation, sediment transport and deposition. The funnel shaped bathymetric configuration of canyons coupled with gravity currents optimize canyons as sediment conduits to the deeper part of the ocean. The results of this study hence will be useful for the understanding of the waves dynamics, erosion and flooding risks assessment along the western Nigeria coast. This study and other ocean dynamics study will be needed to comprehend the regional oceanographic and sedimentary system necessary for planning and decision-making of the coastal projects along the Lekki- barrier lagoon coastal system.

ACKNOWLEDGEMENTS

The author is grateful to the Intergovernmental Oceanographic Commission (IOC of UNESCO for funding this study. Many thanks go to the Professor Mike Collins and other staff members of the Geology Department of the Southampton University UK for assistance provided.

REFERENCES

Allen, J. R. L., (1964): The Nigerian Continental Margin: Bottom sediments, submarine morphology and geological evolution. Marine Geology, Vol. 1 p. 289-332.

Allen, J. R. L., (1965): Late Quaternary Niger Delta, and adjacent areas: Sedimentary environments and lithofacies Am. Assoc. Petrol. Geol. Bull. 49, p. 547-600.

Allen, J. R. L. and Wells, J. W., (1962): Holocene coral banks and subsidence in the Niger delta. J. Geol., 70: p.381-397.

Awosika, L. F., (1990): Coral Bank Obstructions to trawling in the middle to outer continental shelf east and west of Lagos. NIOMR Pub. No.57, 13p.

Awosika, L. F., Ibe, A.C., Oyewo, A. and Ibe, C.E. (1994). Navigational and surveying techniques employed during the first IOCEA cruise in the Gulf of Guinea. In proc. International symposium on the results of the first IOCEA cruise in the Gulf of Guinea, 17-20 May 1994. Pub Centre for Environment and Development in Africa. p 14-18.

Babonneau, N., Savoye, B., Cremer, M. and Klein, B., (2002). Morphology and architecture of the present canyon and channel system of the Zaire deep-sea fan. Marine and Petroleum Geology. Vol. 19, p. 445-467.

Belderson, R. H. and Kenyon, N. H., (1976). Long-range views of submarine canyons. Marine Geology, Vol.22, p.M69-M74.

British Admiralty charts, (1862). Published by the British Hydrographic Office London UK.

Burke, K. C. B., (1972). Longshore drift, submarine canyons, and submarine fans Am. Assoc. Petrol. Geol. Bull. 56, p. 1975-1983.

Clarke, J. D. and Pickering, K. T., (1996): Architectural elements and growth patterns of submarine channels: applications to hydrocarbon exploration. Bulletin of the AAPG, V. 809, No 2, p.194-221.

Daly, R. A., (1936). Origin of submarine "canyons." Am. J. Sci., 31: p. 401–420.

GEBCO DIGITAL ATLAS 2003 Centenary Edition, (2003). Published on behalf of the Intergovernmental Oceanographic Commission and the International Hydrographic Organisation by the British Oceanographic Data Centre. Natural Environmental Research Council UK.

Ibe, A.C., Awosika, L.F. and Ibe, C. E. (1993) Factors responsible for varying granulometric characteristics of sediments from the western Nigeria coastline. Coastlines of western Africa, Coastal zone 93. Ed. Larry Awosika, Chidi Ibe and Peter Schroder. Pub. American Association of civil engineers N.Y., N. Y.

Kuenen, P. H., (1952). Classification and origin of submarine canyons. Koninkl. Nederl. Akademic Van Wetenschappen Amsterdam, Series B: Physical Sciences 55(5) p.464-473.

Merki, P., (1972). Structural geology of the Cenozoic Niger Delta. In: African Geology (Eds T. F. J. Dessauvagie and A. J. Whiteman), Ibadan University Press, p. 635-646.

Munk, W. H. and Traylor, M. A. (1947). Refraction of ocean waves: A process linking underwater topography to beach erosion. J. Geology, LV(1), 1-26.

Shepard, F. P. and Dill, R. F., (1966): Submarine Canyons and other Sea Valleys: NY: Rand McNally, 1966, 381p.

Stonely, R., (1966): Niger Delta region in the light of the theory of continental drift. Geol. Mag. 103, p. 386-397.

Submarine canyon – fan system (2004). http://www.geology.wmich.edu/kominz/C4turbiditycurrent.gif

Twichell, D. C., and Roberts, D. G., (1982): Morphology, distribution and development of submarine canyons on the US Atlantic continental slope between Hudson and Baltimore. Geology, Vol. 10, p.408-412.

OSCILLATING SURFACE CURRENT PATTERNS OFFSHORE THE WESTERN NIGER DELTA NIGERIA: IMPLICATIONS FOR OIL SPILL AND NUTRIENT TRANSPORT

Awosika, Larry F. and Folorunsho, Regina

Nigerian Institute for Oceanography and Marine Research
Victoria Island, Lagos Nigeria

ABSTRACT

Near surface currents collected with an Acoustic Doppler Current Profiler (ADCP) and Davis drifter deployed off Benin - Escravos river estuary in the western Niger Delta showed along shelf oscillating current patterns. The along-shelf current patterns showed long period oscillations. These oscillating current patterns confirm the current reversals which characterise the Guinea current which had earlier been described as a predominantly west to east moving current. Understanding these oscillating surface currents in the Niger Delta could enhance oil spill transport, nutrient and phytoplankton (the main source of food for fish) distribution and transport systems.

Keywords: *Bathymetry, Continental shelf, Niger Delta, Barrier-lagoon, Nutrients, Phytoplankton, Ocean currents, Oil spill, Oscillating currents.*

1. INTRODUCTION

The western Nigeria coast (the area of study) is composed of three main geomorphic zones (Figure 1), the barrier-lagoon coast, the Mahin coast and the western Niger Delta. The barrier- lagoon coast consists of a strip of sandy barrier bar backed by the Lagos and Lekki lagoons and several tortuous creeks. The Mahin mud coast east of the barrier lagoon coast is composed of muddy coast devoid of sand.

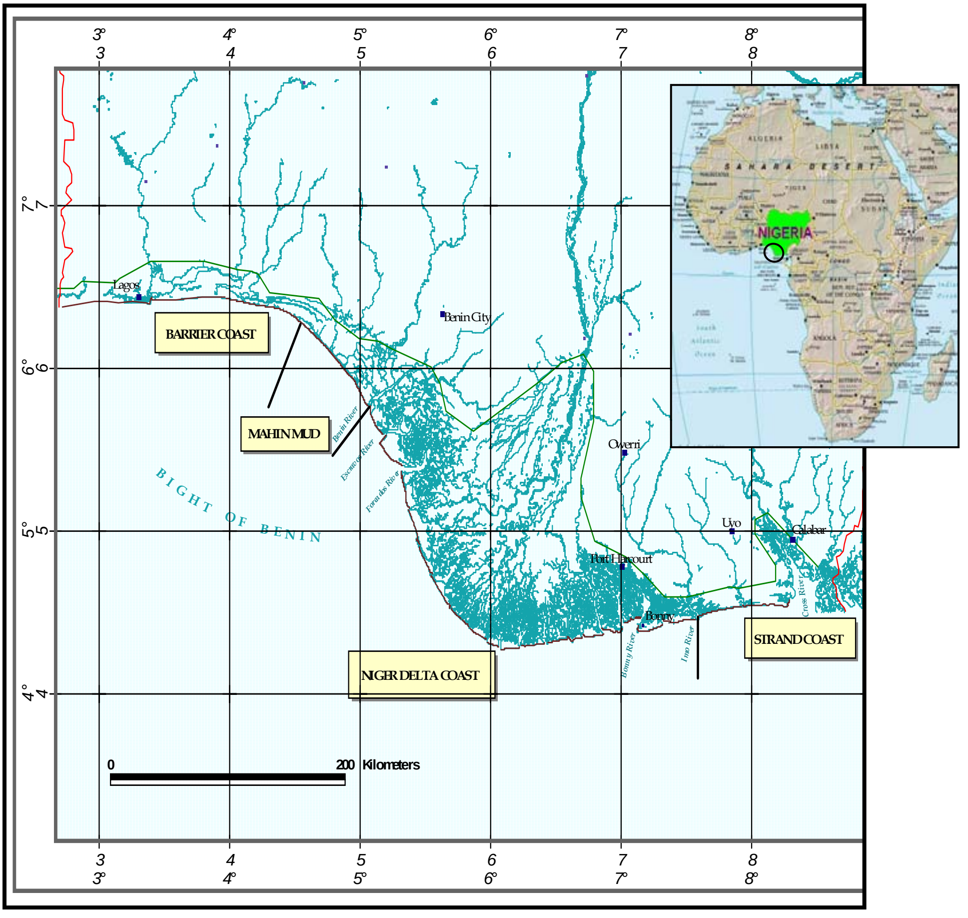


Figure 1. Map showing the different geomorphological zones along the Nigerian coast. (Awosika, *et..al.* 2002)

The Niger Delta is a fan-shaped sedimentary environment located between longitudes 5º00′.00″E and 7º40'.00″E (Benin River in the west and Imo River). Probably the second largest delta in the world, it covers an area estimated at about 20,000sq.km (Allen, 1965). Barrier islands with beach ridges rim the seaward margin of the Niger Delta for about 480 km. Allen (1965) recognised 20 major barrier islands in the Niger Delta separated by deep tidal channels (estuaries). Major river estuaries within the western Niger Delta include Benin, Escravos, Forcados, Ramos, Dodo, Pennington, Sangana, Middleton, Kulama and Nun.

1.1 Offshore bathymetry

Offshore bathymetry in the study area consists of isobaths almost parallel to the coastline (Figure 2). The nearshore 0-45 m is generally gently sloping with wide intertidal zone of over 1.5km along the Mahin mud coast. The shelf breaks at about 100m but with terraces especially offshore the Niger Delta. The bathymetry is grooved by the Avon, Mahin and the Niger Delta canyons (Figure 2).

1.2 Tides

Tides within the study area are semi-diurnal with two inequalities. Swells produced by the southwesterly winds approach the barrier-lagoon and the Niger Delta coast in a southwesterly direction, however along the Mahin mud coast waves arrive parallel to the coastline (Figure 2).

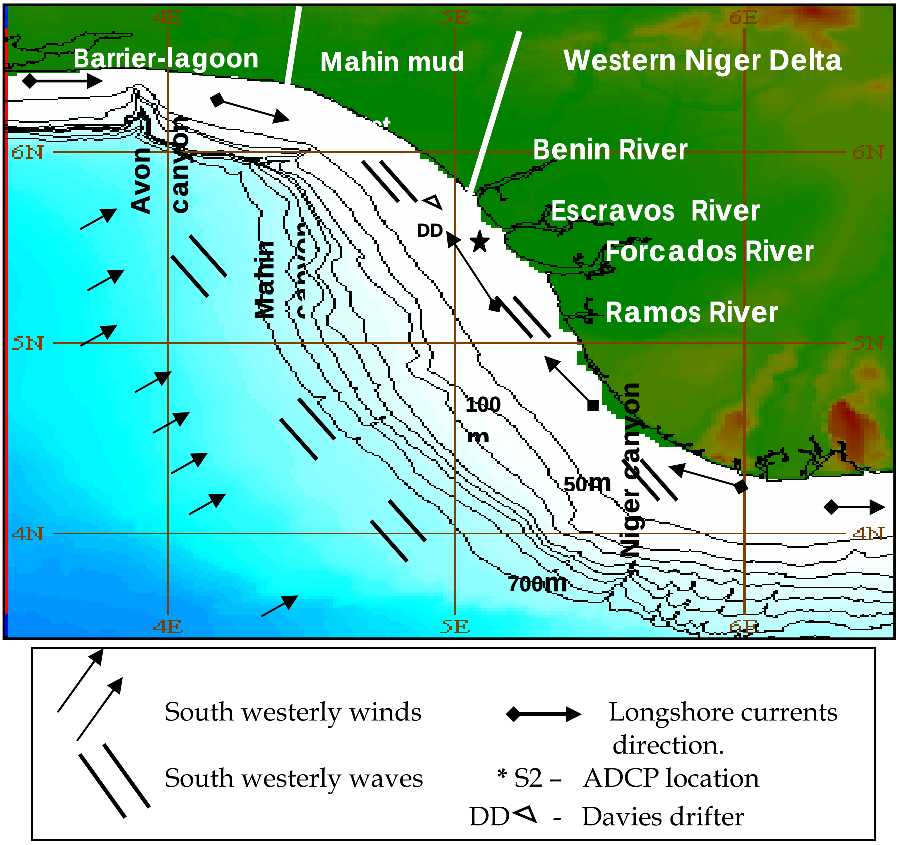


Figure 2. Bathymetric map of the study area with patterns of prevailing oceanographic forces.

1.3 Waves

Waves affecting the study area are wind generated and approach the coastline from a south westerly direction. Swells generally approach the coastline from a south/south-westerly direction most of the year (Figure 2). Waves approach also from south/ south-westerly direction, with oblique angles of between 3^{o} to 15^{o}. Winds are generally on-shore southwesterlies during the northern summer, with an average speed of 4 to 6m/s. This is due to the northwesterly-southeasterly trend of the Mahin mud coast. Tidal range here is between 1.5 to 2m. Between Forcados and Escravos in the Niger Delta, tidal range is from 1.4 to 1.8m (Awosika *et. al.*, 2005).

The semi-diurnal nature of the tides generates tidal currents, which are in phase with tidal cycles. Elevated water, close to shore during the two daily high tides generally assists the waves to progress more inshore wards. Maximum tidal current velocities during high tides along the low lying coast of the Mahin coast were found to be about 2.5m/sec (Ibe, *et al.*, 1984). Stronger tidal currents exceeding 5m/sec at the inlet/ocean intersection have been found to occur during ebb tides. High water at Forcados is 1hr 13 minutes later than at the bar. Low water at Forcados is 1hr. 30 minute later than at the bar. Flood and Ebb streams usually run for about 3hrs after High and Low water respectively.

2. STUDY METHODOLOGY

An acoustic current Doppler profiler (ADCP) was installed offshore Escravos river at station S2 (Figure 2) in water depth of about 15m off the Benin River (longitude 04°55′ 3.31″E and latitude 05°45′ 0.13″N. The records collected by this ADCP spanned 25/07/2000 to 26/07/2000, 30/10/2000 to 05/11/2000 and 04/02/2001 to 06/02/2001 (Evans Hamilton Inc 2001). Surface ocean currents in the northwestern Niger Delta were monitored from 28 July, 2000 to 20 August, 2000 using a surface drifter (Davies Drifter) which contained GPS unit for tracking its position. The Drifter was deployed off the Benin River at longitude 4.92°E and latitude 5.88°N (Figure 2) on 26 July 2000 and transmitted its positions and current speed to the ARGOS satellite until 20 August 2000. Both the ADCP and drifter data were analysed to determine direction of movement and speed.

3. RESULTS

3.1 Current patterns from Acoustic Doppler current profiler (ADCP)

Current rose plots (Figures 3A and 3B) from the ADCP at station S2 showed mean velocities of 12cm/s (0.12m/s) which are predominantly east-west. Percent occurrence of these directions is over 20%. The along-shelf currents predominate over the across-shelf current component.

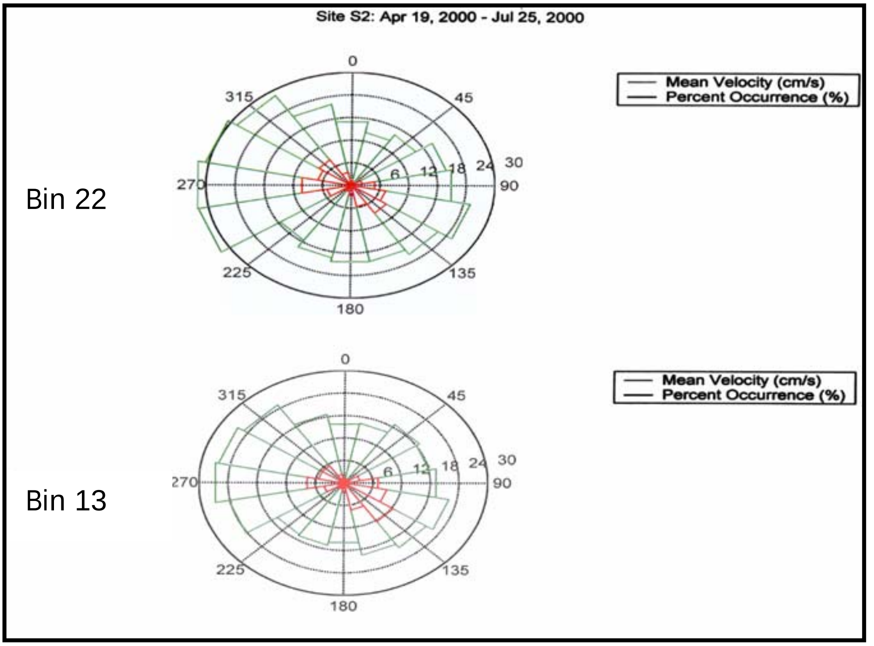


Figure 3A. Current polar plots for station S2 (15.8m water depth) between 19 April 2000 and 25 July 2000. (Evans Hamilton 2001). Bin 13 is 7.3m above sea bed and bin 22 is 11.8m above sea bed.

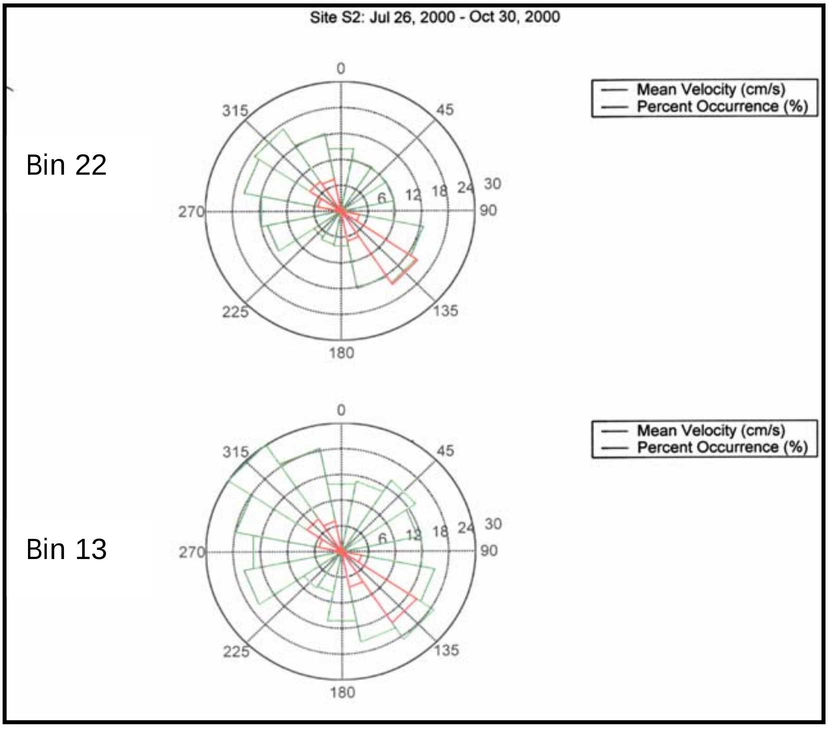


Figure 3B. Current polar plots for station S2 (15.8m water depth) between 26 July, 2000 and 30 October, 2000. Bin 13 is 7.3m above sea bed while bin 22 is 11.8m above sea bed.

These oscillations presented in the polar plots are also presented in stick plots (Figures 4A and 4B). Oscillation periods were found to range between 10 to 14 days which are more persistent during the rainy season months of June to September.

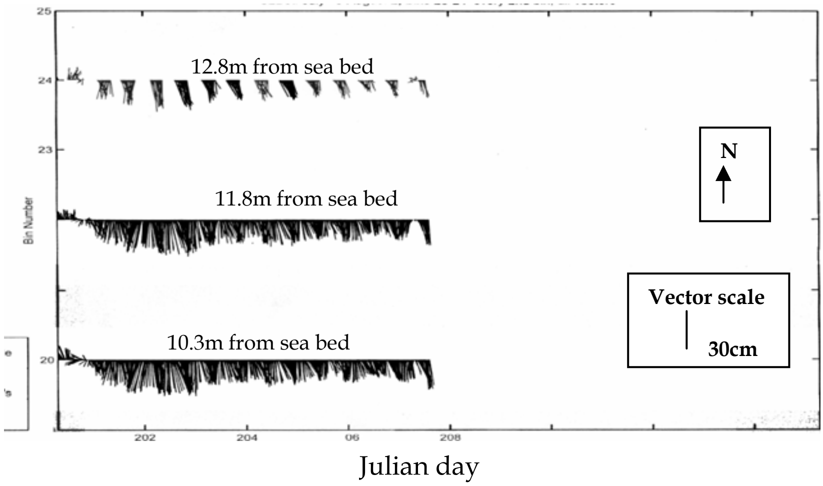


Figure 4A. Stick plots of currents at station S2 (July 8- August 2, 2000)

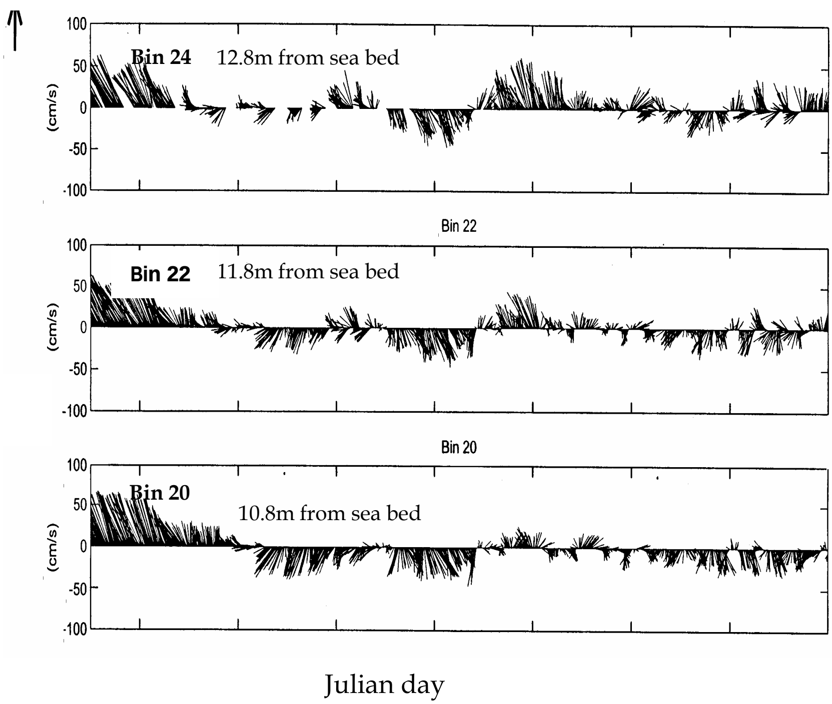


Figure 4B. Stick plots of currents at station S2 (August 10 - August 25, 2000)

3.2. Drifter number 26122 trajectory – 26/7/00 to 20/8/00

Drifter no 26122 movement are well depicted in figure 5 and table 1. The Drifter after deployment on 26/07/00 moved southeastward along-shelf for three days, then reversed and moved rapidly northwestward along-shelf for 2 days with speed ranging from 25.2cm/sec in the south, to 56.4cm/sec in the north close to the deployment location.

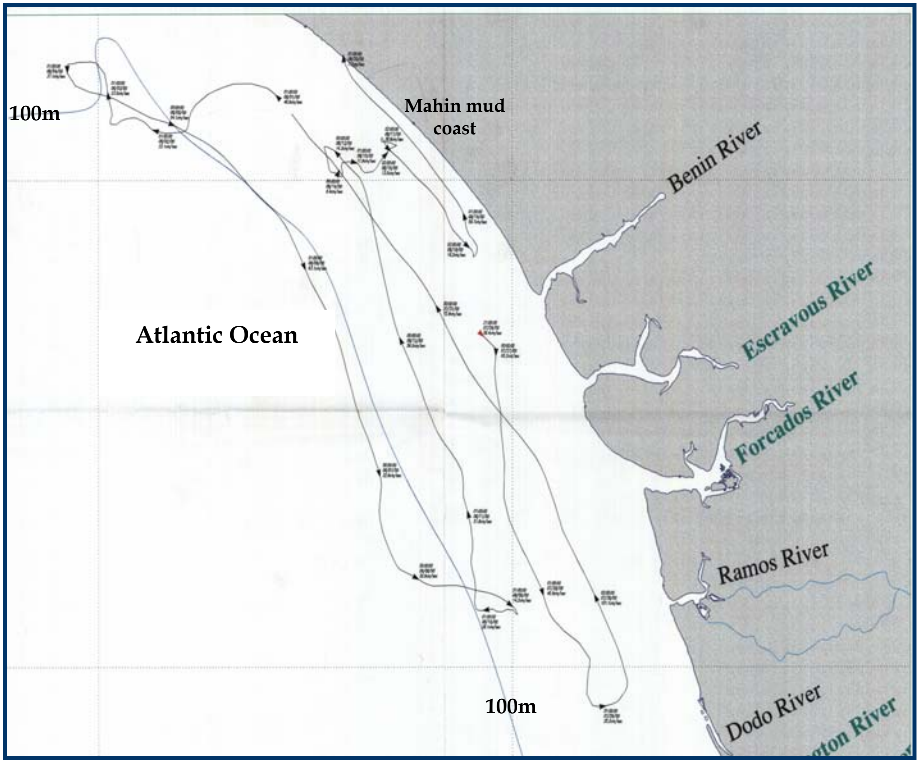


Figure 5. Trajectory of drifter No 26122 deployed off the Benin River estuary in the western Niger Delta. (Evans Hamilton Inc 2001)

Table 1. Davis drifter trajectories (07/26/00 to 08/20/00)

DAYS	DATE	TIME	DIRECTION OF MOVEMENT			CURRENT SPEED (cm/sec.)
				Long. (E)	Lat. (N)	
1	07/26/00	21:00	South-easterly	4.9200	5.880	56.4
2	07/27/00	00:00	Southerly	4.9599	5.6382	65.2
3	07/28/00	01:00	Southerly	5.0706	5.1603	40.9
4	07/29/00	01:00	Easterly	5.2107	4.9182	25.2
5	07/30/00	02:00	North-westerly	5.2938	5.1369	101.1
6	07/31/00	00:00	Northwesterly	4.8222	5.7309	72.9
7	08/01/00	01:00	Westerly	4.4382	6.1665	46.9
8	08/02/00	01:00	Westerly	4.1442	6.1995	22.1
9	08/03/00	01:00	Northwesterly	4.0248	6.1686	23.5
10	08/04/00	01:00	South	3.9249	6.2358	37.1
11	08/05/00	00:00	Southeasterly	4.1712	6.1173	54.1
12	08/06/00	01:00	Southeasterly	4.4940	5.8290	63.1
13	08/07/00	00:00	Southeasterly	4.6755	5.4036	32.9
14	08/08/00	00:00	Southeasterly	4.7595	5.1870	30.9
15	08/09/00	01:00	East	4.9893	5.1327	14.2
16	08/10/00	01:00	West	4.9425	5.1189	28.1
17	08/11/00	01:00	North	4.8948	5.3073	51.8
18	08/12/00	00:00	North	4.7319	5.6649	59.5
19	08/13/00	00:00	Northwest	4.5801	5.0507	14.3
20	08/14/00	00:00	Northeast	4.5750	6.0090	8.4
21	08/15/00	01:00	East	4.5750	6.0090	11.9
22	08/16/00	02:00	East	4.6878	6.0477	13.5
23	08//17/00	02:00	East- north	4.6947	6.0684	38.8
24	08/18/00	02:00	South	4.8858	5.8695	16.2
25	08/19/00	01:00	Southeast	4.8858	5.9193	59.7
26	08/20/00	01:00	Northeast	4.5921	6.2445	7.7

The drifter then moved towards shore for less than a day, and then slowly moved northwestward along-shelf again for 3 days almost parallel to the coastline but staying predominantly outside the inner shelf of water depth of 20m. Current speed along this trajectory varied from about 25.2cm/sec to about 101.1cm/sec south of the Forcados River and decreasing to 72.9cm/sec off Benin River and 46.9cm/sec along the Mahin mud coast (Figure 5). The drifter trajectory changed direction and moved farther out to sea across the 100m isobath in the Avon canyon staying along the western part of the Avon canyon. This trajectory took 3 days with speed ranging from 22.1cm/sec to a maximum of 54.2cm/sec.

From here, the drifter then reversed and moved rapidly southwestward along-shelf for 4 days in deeper waters of more than 100m isobath with speed ranging from 63.1cm/sec in the north to 30.9cm/sec in the south. From here the drifter turned south eastward inside the 100m isobath for one day, then moved along-shore for 3 days, then headed southwest ward for a day and then back north westward for 2 days.

4. DISCUSSION

Coastal ocean currents along the entire Gulf of Guinea consist of the Guinea current, which is an extension of the North Equatorial Counter current (Figure 6). The Guinea current runs above an undercurrent which is thought to be a westward flowing extension of the northern branch of the Equatorial undercurrent which splits into two branches after impinging upon the African continent at Sao Tome Island.

The Guinea current has been earlier documented as a predominantly west to east moving ocean current: (NEDECO 1961, Longhurst 1962, Richardson and Reverdin (1998), Ibe and Awosika (1981), Awosika *et al.*, (1994) amongst others. However, the observed along-shelf current patterns in this study showed long period oscillations which illustrate the large along-shelf extent that the water traveled along the Nigeria continental shelf. Current reversals observed in this study occur most frequently at the beginning and end of the rainy season. Longhurst, (1962) observed similar current reversals.

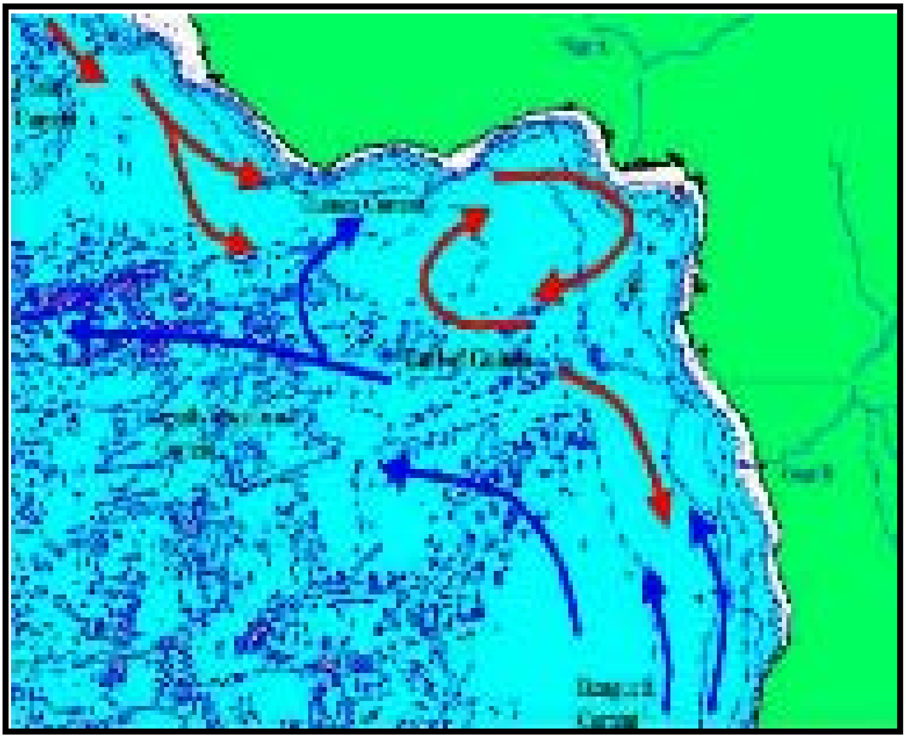


Figure 6. Gulf of Guinea showing prevailing ocean currents

Richardson and Reverdin (1998) observed that the Guinea current can obtain velocities close to 100 cm s^{-1} near 5°W. Richardson and Reverdin (1998), who used buoys to investigate the Guinea Current, found that during fall (November-January) and spring (April-June) the buoy trajectories showed a direct connection between the NECC and the Guinea Current.

While this study has documented seasonal surface current oscillation, the cause or causes of such oscillations still remain subject of debate. Longhurst (1962), Ingham 1970 and Boisvert (1967) attributed the reversal in current direction during the minima to change of variations in the flow of the North Equatorial Countercurrent, the Canary Current, and the Benguela Current and to the weakening of the easterly winds). However, Collin (1988) suggested that the presence of a westward current at the surface near the coast could be due to the surfacing of the Ivorian undercurrent and the seaward displacement of the Guinea Current and not due to the reversal of the Guinea Current. Another explanation, proposed by Ingham (1970), was that the apparent reversals are actually caused by cyclonic eddies between the current and the coast. While no agreement has been reached on the direct cause or causes of the observed oscillating along-shelf surface currents offshore the western Nigerian coast, the implications of the oscillating currents for management of oil spill and nutrient circulation is apparent.

5. IMPLICATIONS OF OSCILLATING CURRENTS ON OIL SPILL AND NUTRIENT TRANSPORT

Oil spill and nutrient transport in the ocean are influenced by a combination of dynamic forces including wind speed and velocity, air and water temperature, tides and currents. To effectively respond to oil spills as well as understand surface movements of nutrients in the ocean, scientists must gather critical chemical, oceanographic, climatic, and on-scene environmental data.

Many Oil spills have occurred along the Nigerian coast either through accident or through sabotage. In many cases, forecasting the movement of oil spill in the Niger Delta is often hampered by insufficient data, particularly in the first few hours of the release. Detailed spill data (location, volume lost, product type) are often sketchy and environmental data (wind and current observations and forecasts) are often sparse or unavailable. This in many cases has led to loss of time, and inefficient oil spill response efforts. The pattern of current oscillations observed in this study should enhance the knowledge of oil spill transport and efforts to combat future oil spills. Knowing the trajectory of the spill gives decision-makers critical guidance in deciding how best to protect resources and direct cleanup.

Almost half of the Earth's biological production stems from microscopic, one-celled plants called phytoplanktons that grow in the surface layers of the ocean. Nutrients like phosphorus and nitrogen are carried by rivers to the sea. There they fertilize the cold waters and promote the growth phytoplanktons. These feed zooplanktons which are eaten by small fishes which in turn are eaten by larger fishes and on up the food chain. These micro organisms are free-drifting organisms, "weak- swimmers", with their distribution in the sea mainly controlled by ocean currents rather than their swimming. The distribution and movements of nutrients are invariably linked to fish availability in the ocean. The Niger delta as well as the Mahin mud coast is known to be good fishing grounds. This is due to the availability of nutrients brought down by the numerous rivers of the Niger Delta. The result of this study should also help in the understanding of nutrients and phytoplankton transport, and hence fish migratory patterns. Such knowledge should contribute to sustainable exploitation of fisheries resources.

6. CONCLUSION

Though Ingham (1970) pointed out that the data on which the concept of current reversals is based are either point observations or isolated sections perpendicular to the coastline, which do not clearly depict current reversals in the alongshore direction, this study confirmed that the Guinea current is characterised by oscillations or reversals. These oscillating currents which have fortnightly patterns will still need to be further studied to throw more light on the cause or causes of the observed oscillations.

REFERENCES

Allen, J. R. L., (1965). Late Quaternary Niger delta and adjacent areas: sedimentary environments and lithofacies. AAPG. Bull. V.49, V.I, p.289-332.

Awosika, L. F. and Ibe, A. C (1994). Geomorphic features of the Gulf of Guinea shelf and littoral drift dynamics. In Proc. International symposium on the results of the first IOCEA cruise in the Gulf of Guinea, 17-20 May 1994. Pub Centre for Environment and Development in Africa. p.21-27.

Awosika, L. F., Collins, M. and Clay, A. T., (1994). Clay mineralogy variations in the Gulf of Guinea and implications for sediment transport dynamics. In Proc. International symposium on the results of the first IOCEA cruise in the Gulf of Guinea, 17-20 May 1994.

Awosika L. F., Folorunsho, R., Dublin-Green C. O and Imevbore V.O (2000). Review of the coastal erosion at Awoye and Molume areas of Ondo State. A consultancy report for Chevron Nigeria Limited. 75p.

Awosika, L.F., Dublin-Green, C. O., Folorunsho, R., Adekambi, M. A and Adekoya E. A (2005). Escravos, Forcados and Ramos River Estuaries and adjourning Continental Shelf: Transport Dynamics. A consultancy report for Exxon Mobil October 2004

Binet, D., (1997): Climate and pelagic fisheries in the Canary and Guinea currents 964- 1993: The role of Trade Winds and the Southern Oscillation. Oceanologia Acta, 20, 177-190.

Boisvert, W.E., (1967): Major currents in the North and South Atlantic Ocean between 64°N and 60°S, *Tech. Rep. Hydrogr. Off. Wash.*, TR-193, 92 p.

Burke, K., (1972). Longshore drift, submarine canyons and submarine fans in the development of the Niger delta. AAPG Bull. V.56, p. 1975 - 1983.

Colin, C., (1988). Coastal upwelling events in front of Ivory Coast during the FOCAL program. Oceanologia Acta, 11, 125-13.

Evan Hamilton, Inc. (2001): Nigeria OPTS Shallow Water Current Measurement Survey; Data Reports 3 and 4.

Hisard, P., C. Henin, R. Houghton, B. Piton, and P. Rual, (1986): Oceanic conditions in the tropical Atlantic during 1983 and 1984. Nature, 322, 243-245.

Ingham, M.C., (1970): Coastal upwelling in the northwestern gulf of Guinea. Bulletin of Marine Science, 20, 1-34.

Longhurst, A. R., (1962). A review of the oceanography of the Gulf of Guinea. Bull. Inst. France Afri. noure, V.24, p.633-663.

NEDECO (1961). The waters of the Niger Delta. The Hague, 317p.

Philander, S. G. H., (1979b). Upwelling in the Gulf of Guinea. Journal of Marine Research Vol.37. p.23 - 33.

Picaut J., and Verstraete J. M., (1979). Propagation of a 14.7 day wave along the northern coast of the Gulf of Guinea. Journal of Physical Oceanography. Vol.9, p.136-149.

Richardson, P.L. and G.Reverdin, (1998). Seasonal cycle of velocity in the Atlantic North Equatorial Countercurrent as measured by surface drifters, current meters, and ship drifts. Journal of Geophysical Research, 92, 3691-3708.

THE AUGUST 1995 STORM SURGE EVENT ON VICTORIA-LEKKI BEACH, LAGOS - MODELLING OF THE SPATIAL EXTENT ALONG THE GULF OF GUINEA COAST

Folorunsho, Regina

Nigerian Institute for Oceanography and Marine Research,
PMB 12729, Victoria Island, Lagos.

ABSTRACT

The Victoria/Lekki beach is part of the Barrier/lagoon coastal morphological system that stretches from Badagry in the west to around Agerige village east of Lekki beach. This coastal complex is very fragile as it is composed of narrow, low lying; sandy barrier bar backed by the Lagos and Lekki lagoons. Over the past decade 20 storm events have been documented along the Victoria beach in Lagos. The most devastating of these was on the 17th August 1995. Data (water levels, barometric pressure, wind speed and direction) collected at the Global Level of the Sea Surface (GLOSS) station in Lagos were analysed to understand the associated characteristics of the storm surge. Since no data was available to show the spatial extent of the storm surge in the area and especially in the Gulf of Guinea (GOG), the Norwegian POM-Based Storm Surge Forecasting model was employed. Result of the model showed the spatial extent of the storm surge in the Gulf of Guinea as well as the intensity of the associated water levels. This study provides a foundation toward the understanding of the annual storm surge experienced in the Victoria beach in Lagos as well as the spatial extent of the storm in the GOG region.

Keywords: *Storm surge, Tides, Erosion, Atmospheric pressure, Barrier/lagoon*

---

1. INTRODUCTION

The Victoria Island-Lekki beach (Fig. 1) in Lagos, is part of the Barrier/lagoon coastal system that stretches from Badagry in the west to around Agerige village east of Lekki beach. The barrier lagoon coastal system consists of beach ridges (Figure 1) fronted by a very narrow beach with foreshore gradient of about 1:50 (Awosika *et. al.*, 2000). Beach crest elevation is between 1-2m

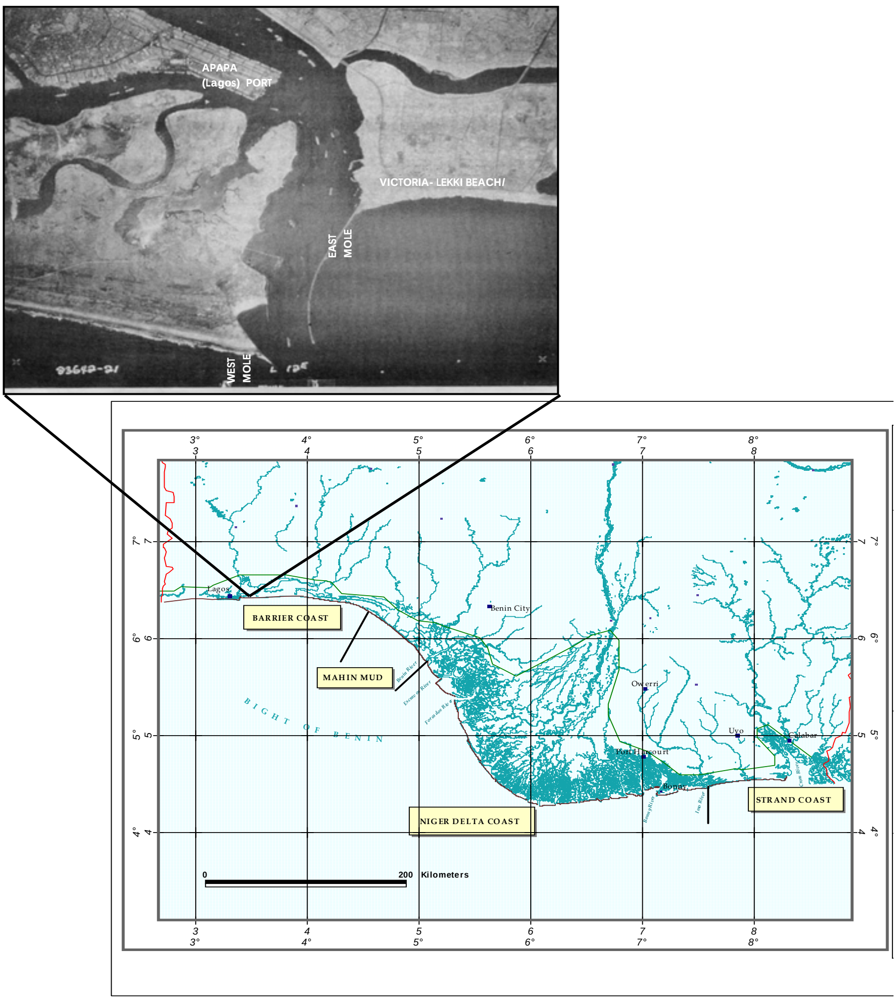


Figure 1. The Location of the Study area (Victoria-Lekki Beach) Lagos (After Awosika *et. al.*, 2000a).

above mean low low water. The beaches are subjected to high-energy waves, resulting in the formation of characteristically steep beach profiles, (Awosika *et. al.*, 1995).

The Bar Beach on Victoria Island has been the scene of very active erosion in the past five decades as a result of the construction in 1912 of the east and west moles, meant to stop the silting of the Commodore channel leading to the Lagos Ports (Awosika, *et. al.*, 1995). Storm surge events have been recorded along the Victoria-Lekki beach coast annually between April to June and August to October (Awosika *et. al.*, 2000). The storm surges usually have devastating effects on low lying coastal areas of the Victoria - Lekki beach in Lagos. One of the most devastating of these occurred on the 17th August 1995 and flooded a large part of the Victoria Island beach. On this day, a sudden rise of the sea level resulted in high waters that over topped the beach, flooding the adjacent streets of Ahmadu Bello Way and beyond (Figure 2). The surge characterized by high waters reaching over 4m high (2m above normal high tide) lasted for more than 24 hours.

2. OBJECTIVES OF THE STUDY

Storm surges in the Gulf of Guinea are usually meteorologically induced. The meteorological forces in this respect are those of wind and pressure gradients. The main objectives of this study are two fold. The first is to analyse the August 1995 storm surge parameters collected by the Next Generation Water Level Measurement System (NGWLS), installed at the jetty of the Nigerian Institute for Oceanography and Marine Research (NIOMR), (Longitude $03^0$24′44″E and Latitude $06^0$25′24″N). The NGWLMS, which is one of the designated Global Level of the Sea Surface (GLOSS) stations is an acoustic tide gauge, equipped with an ancillary sensor for measuring wind speed and direction, gust and barometric pressure.

The second objective is modelling of the spatial extent of the storm surge in the Gulf of Guinea (GOG) in the absence of any other record data from any station in the region. Data used was from the European Centre for Medium-range Weather Forecasts (ECMWF). Such a study will help the understanding of the spatial extent and intensity of the storm surge and future storm surges that could be recorded at tidal stations either in Lagos or other stations in the region.

Figure 2: Flooding due to Storm Surge of the Victoria/ Lekki beach on the 17th August 1995.

3. METHODOLOGY

The data collected by the NGWLMS included water levels, wind speed and barometric pressure. The data which covered from 1st to 31st August 1995 was first anaylsed to understand the characteristics of the storm surge parameters. Since no record of the storm surge was available from any other station in the region a spatial model of the storm surge was simulated. The model utilized the Norwegian Princeton Ocean Model (POM)-Based Storm Surge Forecasting Model (MIPOM) with 10-km horizontal resolution to derive water level variations due to atmospheric forcing (Øyvind Saetra, 2005). Atmospheric forcing (wind and pressure) data for August 1995 were also obtained from the European Centre for Medium-range Weather Forecasts (ECMWF) and processed using a LINUX based computer. The data input into the model consist of wind at 10 meter height (U10) and pressure. Bathymetric data used for the model was compiled from ETOPO 2. DIANA visualization software was used to plot the result of the water levels.

4. RESULTS

4.1 Analysis of storm surge parameters

Data analyzed from the NIOMR NGWLMS consisted of water levels before, during and after the storm surge (1st August and 31st August, 1995). The tidal series (Figure 3) show a predominantly semi-diurnal with two inequalities and tidal ranges of between 1 and 1.5m above the zero level of the tide gauge, (Awosika *et. al.*, 2000). From the tide gauge records, the onset of the storm on 9 to 16th August consisted of water levels averaging 2.2m above the zero level of the tide gauge, when the tidal cycle coincided with the onset of spring tide (Fig. 3). This part of the tidal record is in line with the normal tidal cycle characteristic of the Victoria-Lekki barrier lagoon system.

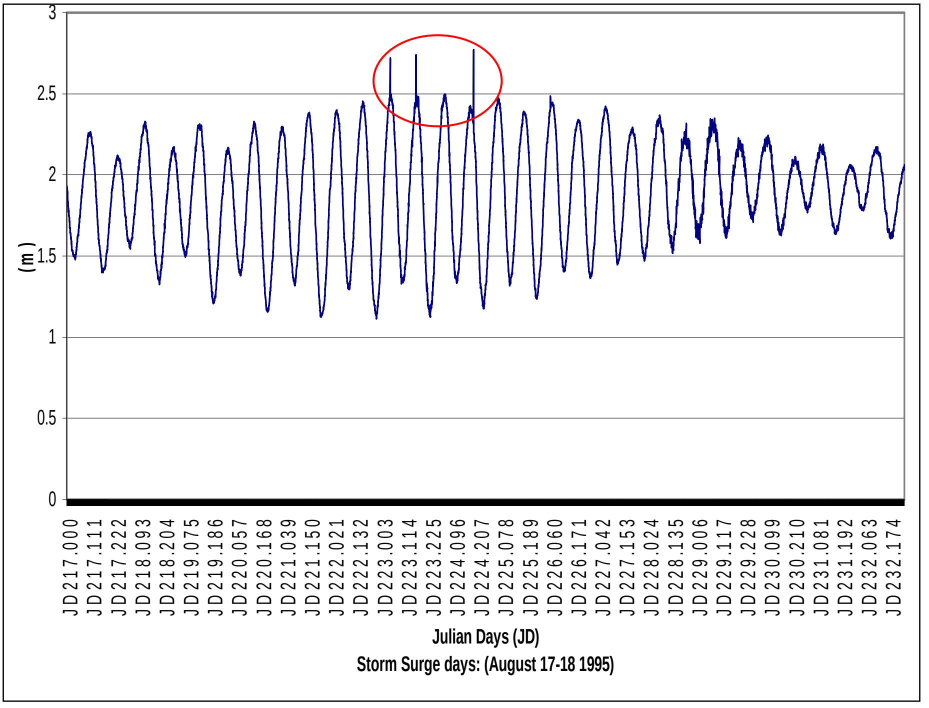


Figure 3. Tide Gauge records of Sea surface oscillations 5th – 26th August 1995. The Red circle highlights the spikes of increased water level during the storm

The spikes in the tidal signature from the 17th August 1995 represent the storm surge. From the records, a 2.5 m high water level was suddenly increased to about 3.0 m above the zero level of the tide gauge with the surge depicted as spikes. Water levels again started receding as from the 18th August to about 2 m. on the 26th August (Figure 3).

Analysis of the NGWLMS barometric pressure record before the storm, revealed a high pressure of 1014 mb and a low pressure of 1009 (Fig 4). The pressure range between 1st and 12th August was about 5 mb. On the 13th August 1995, a significantly low pressure of about 1008 mb developed and was followed by a sudden increase in the barometric pressure to about 1015 mb on the 17th August 1995 when the surge was experienced. The pressure range between the sudden depression on the 13th August and the significant increase in pressure on the 17th August was about 7 mb. On the 18th of August, after the surge, a relatively high barometric pressure of about 1010 mb was recorded.

Analysis of wind data from the tide gauge revealed a relatively high wind velocity of about 6.7 m/s on the 9th August 1995. Wind velocity varied between 3.9 and 6.0 m/s from the 10th to 17th August. During the storm event of 17th August, wind velocity was about 5.1 m/s with a north westerly direction (Table 1 and Figure 5).

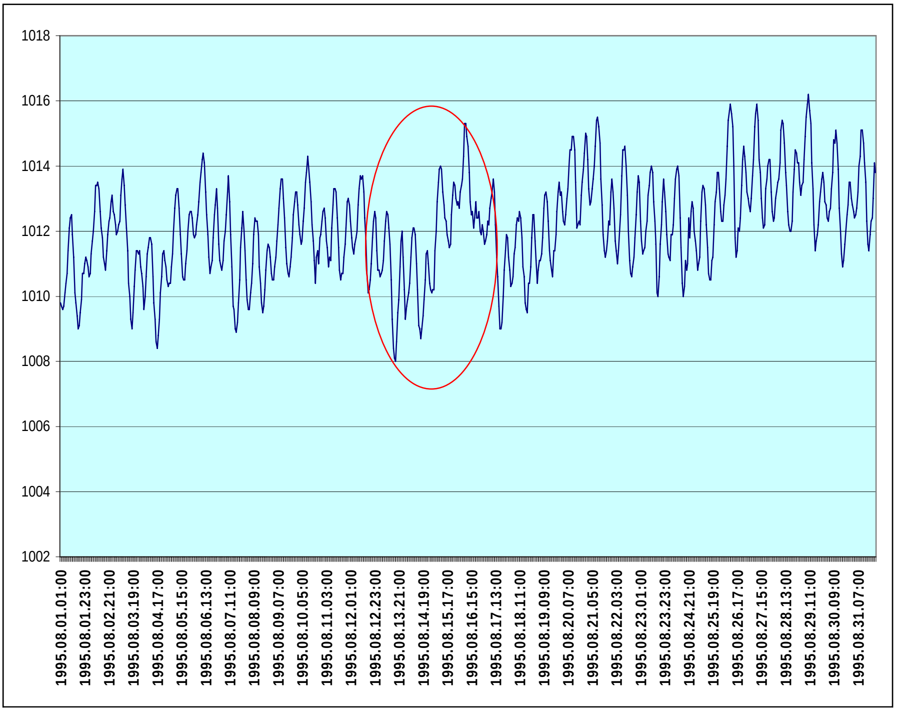


Figure 4. Barometric pressure between 1st August and 31st August 1995. The red circle highlight the sudden depression and increase in pressure records.

Table 1: Wind speed and direction from 9th to 20th August 1995 during the August storm surge.

Date in August 1995	Wind Direction $(^0)$	Wind Speed ms^{-1}
9th August	242 (SW)	6.7
10th August	308 NNW	3.4
11th August	283 NW	5.3
12th August	242 SW	4.9
13th August	244 "	5.3
14th August	266 "	5.2
15th August	254 "	4.0
16th August	306 NW	3.4
17th August	311 "	5.1
18th August	255 SW	4.0
19th August	248 SW	3.9
20th August	345 NNW	6.6

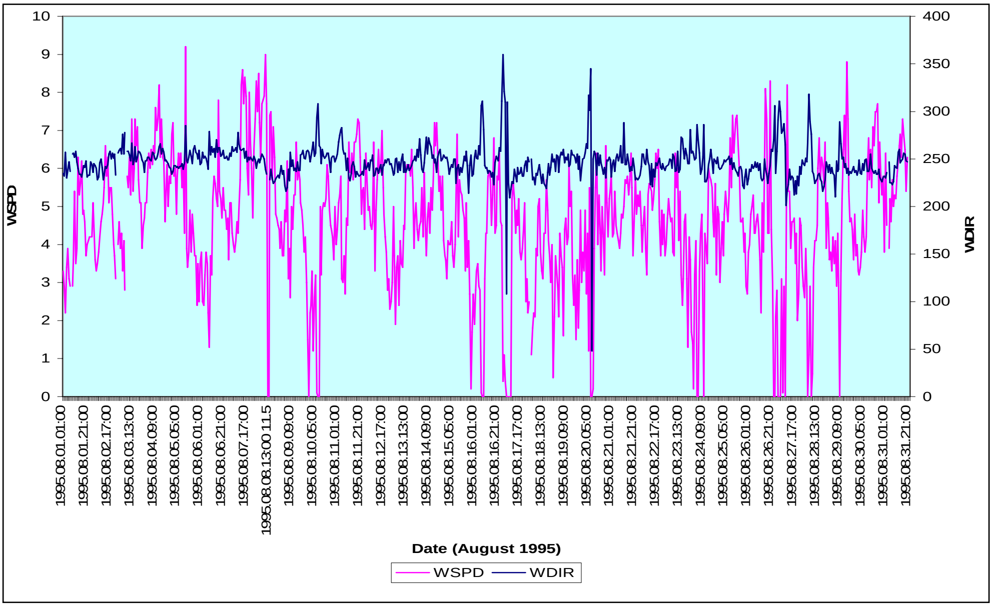


Figure 5. Time series of wind speed/directions, (August 1st through August 31st 1995).

4.2. Modelled Spatial Extent

As already noted above, the storm surge area extent data or information was not available. The Norwegian Princeton Ocean Model was therefore used to compute the area extent of the storm surge on Victoria Island in particular and the GOG in general. The general elevations of the water level on 9th, 13th, 15th and 18th are shown in (Figure 6 to 8). Figure 6 shows the situation at the onset of the storm surge. From this figure, it can be noted that the water level during the onset of the storm was about 2.5m above the zero level of the tide gauge.

On the 13th and 15th of August a 2.5m water level can also be observed over a more extensive area from Cote d'Ivoire to Cameroon in the Gulf of Guinea on the 13th August (Figure 7).

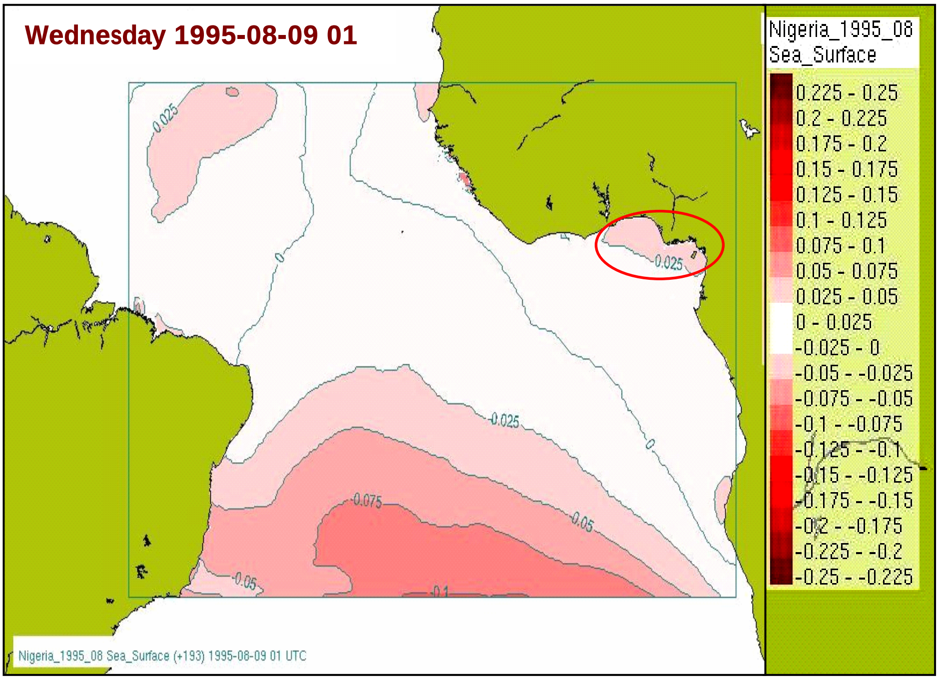


Figure 6: Sea Surface Elevation on the 9th August 1995. Surface elevation (approx 5cm).. Red circle shows sea surface elevation around the study area.

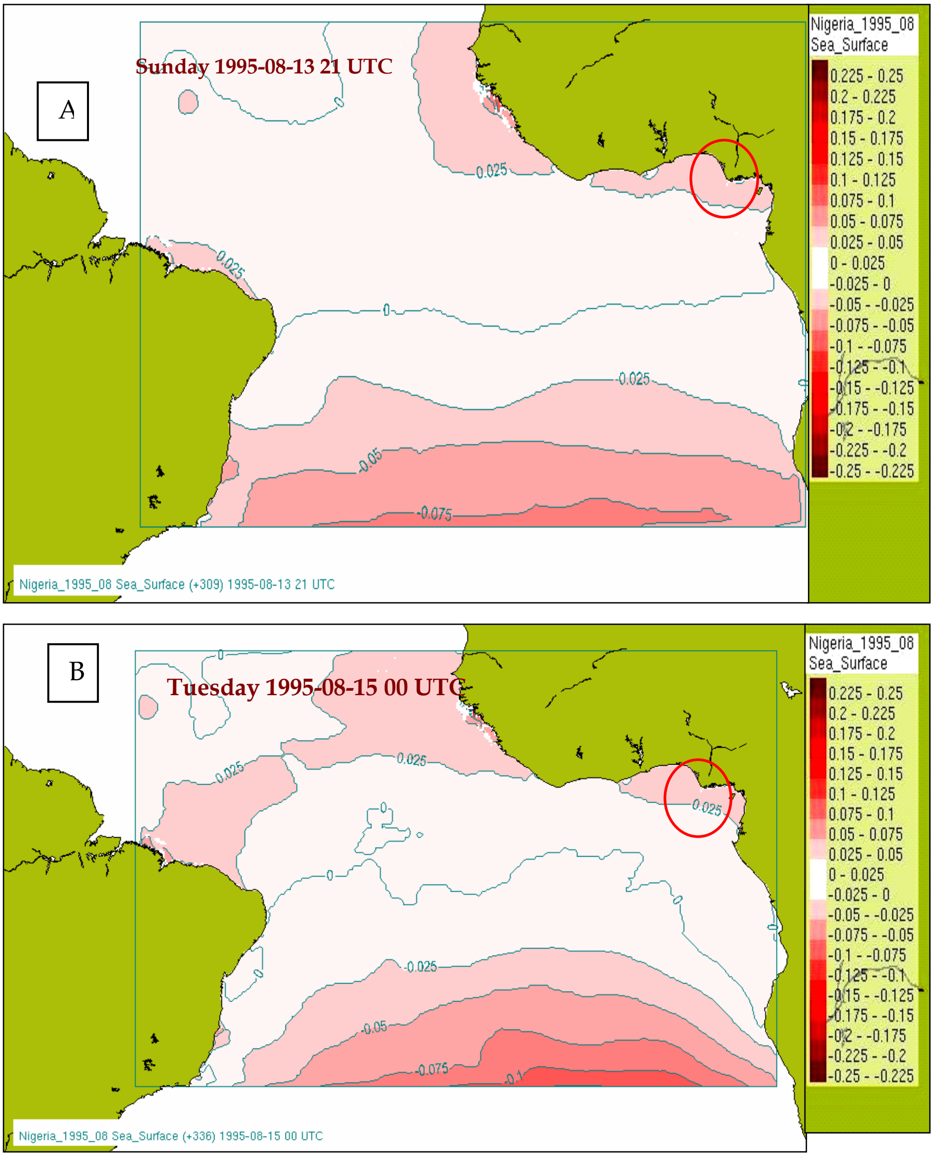


Figure 7: Sea Surface Elevation on A, 13th August 1995; B, 15th August 1995. Red circle shows sea surface elevation around the study area.

The highest water level of above 4.0m can be observed on the 17th August at approximately 06 Coordinate Universal Time (UTC) when the surge occurred. On this day the result showed a wider coverage from Cote d' Ivoire to Angola in the Gulf of Guinea area (Figure 8). By 05 UTC on the 18th August, receding water level of zero was observed to cover the entire GOG coastal area and even the open sea (Figure 9).

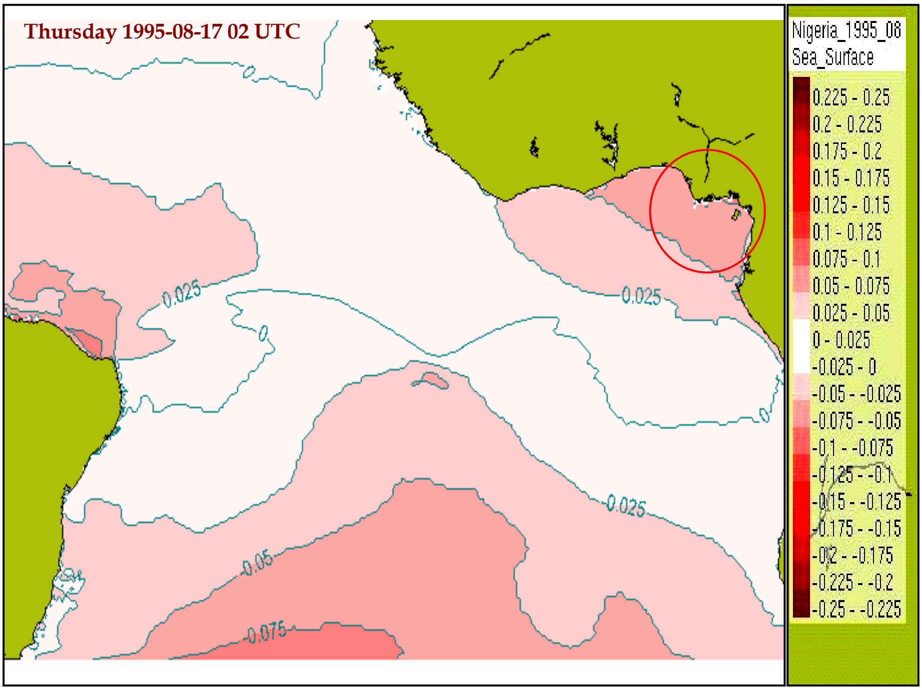


Figure 8: Sea Surface Elevation on the 17th August 1995. Red circle shows sea surface elevation around the study area with a peak surge of about 10cm

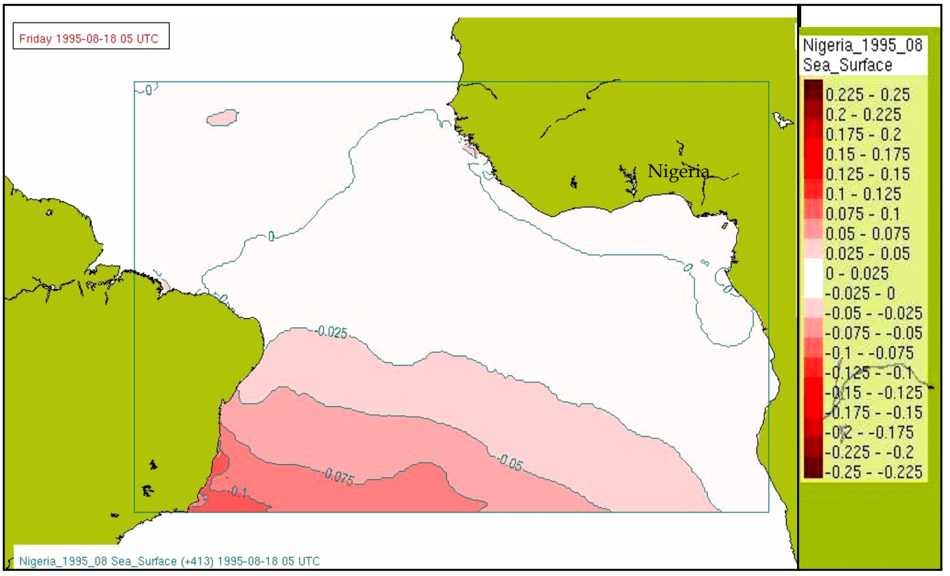


Figure 9: Near normal Sea Surface Elevation around the study area on the 18th August 1995

5. DISCUSSION

Storm surge events in the Gulf of Guinea have been recorded at the Nigerian Institute for Oceanography and Marine Research (NIOMR) by usingthe NGWLMS between 1992-1997. Unfortunately this station was washed off during a storm surge which occurred in 2000. The data collected at NIOMR formed an important source of database for this annual storm surge experienced along the Victoria beach in Lagos. The non operation of other GLOSS designated stations along the Gulf of Guinea was a handicap towards understanding the spatial extent of the annual storm surges as well as the intensity of the associated astronomical water levels. The results of this study revealed a surge of more than 10cm of water at the GOG (Figure 7) on the 17th August when massive flooding was experienced. A similar result of a sudden rise of about 4.0 m water level can be noted on the NGWLMS chart.

A good link is evident between the onset of the surge and depression in the barometric pressure. The rise in water level after a sudden depression (5-7 mb) in pressure, 96 hours before the surge is noteworthy. In a study reported by CIRIA (1996), it was noted that the sudden fall in barometric pressure (depressions) causes a corresponding rise in water level. Tomczak *et. al*. (1994) also noted that in fluids and gases, pressure gradients produce flow from regions of high pressure to regions of low pressure, while in another study Øyvind Saetra (2005) concluded that 1 mb drop in pressure corresponds to 1 cm rise in sea level. These observations could then mean that the sudden depression (5 – 7 mb) in pressure as observed on the barometric pressure between 13th and 17th August 1995 could have resulted in the sudden flow of water from a high pressure zone to the Gulf of Guinea (Figure 9).

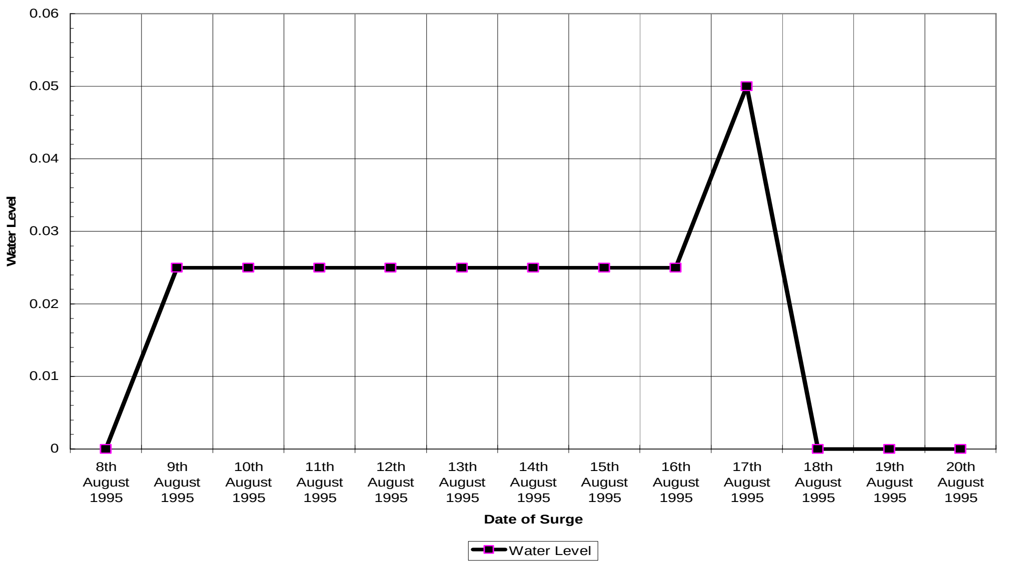


Figure 10: Water surge histogram of August 1995 in the GOG

Wind velocity associated with the August 1995 storm surge during and after was relatively low. This could imply that wind was not significantly responsible for the increased water levels that characterized the surge.

6. CONCLUSION

Examination of the Norwegian POM-Based Storm Surge Forecasting Model (MIPOM) results and analyzed data from tide gauge from NIOMR jetty has contributed significantly towards the understanding of the factors likely to have caused the August 1995 storm surge as well as the spatial extent of the storm surge. The MIPON model has provided a means of quantifying the intensity of the August 1995 surge as well as the possible spatial extent of the storm surge. This study has shown the need for more operational GLOSS stations in the GOG region to ensure that storm intensity and spatial extent of future storm surges are adequately documented. Such documentation will enhance regional database necessary for the formulation, and implementation of a pragmatic flooding and erosion control in most low-lying coastal areas and the GOG at large.

ACKNOWLEDGEMENTS

I acknowledge with thanks the enormous assistance received from Drs. Øyvind Saetra and Jon Albretsen during this study at the Project Office of the International Oceanographic Data and Information Exchange (IODE), Oostende, Belgium.

REFERENCES

Awosika, L. F., A. C. Ibe and C. E. Ibe (1993). Anthropogenic activities affecting sediment load balance along the West African coastline. In proceedings Coastlines of western Africa, Coastal zone 93. Pub. American Association of civil engineers N.Y., N. Y.

Awosika L. F., (1995): Storm Surge of August 1995 and Flooding of the Victoria Island on 17 August 1995. An unpublished paper.

Awosika, L. F., Dublin-Green, C. O., Folorunsho, R., Adekoya, E.A., Adekanmbi, M. A. and Jim-Saiki, J. (2000). Study of main drainage channels of Victoria and Ikoyi Islands in Lagos Nigeria and their response to tidal and sea level changes. CSI-UNESCO Special Report.

Awosika L. F., Folorunsho, R., Dublin-Green C. O and Imevbore V. O., (2000a): Review of the coastal erosion at Awoye and Molume areas of Ondo State. A consultancy report for Chevron Nigerian Limited. 75p.

Folorunsho, R., and L. F. Awosika; (1995): Meteorological Induced Changes Along the Nigerian Coastal Zone and Implications for Integrated Coastal Zone Management Plan. Proc. Int. Conf. "Coastal Change 95" BORDOMER – IOC Bordeaux 1995, 804 – 811.

Folorunsho, R. (2004): Environmental Consequences of Meteorological factors Affecting Ocean Dynamics along the Gulf of Guinea. An unpublished PhD Thesis.

Simm, J. D., Brampton, A. H., Beech, N. W., and Brooke, J. S., (ED) 1996: Beach Management Manual. CIRIA, UK.

Tomczak, M. and Godfrey J. S. (1994). Regional Oceanography: An Introduction. Pergamon

Øyvind Saetra (2005): Experiments on MIPOM: a Norwegian POM-Based Storm Surge Forecasting Model. Group D Report. IODE (UNESCO/IOC International Oceanographic Data and Information Exchange Commitee) and JCOMM (Joint WMO/IOC Commission for Oceanography and Marine Meteorology) and hosted by the UNESCO/IOC Project Office for IODE in Ostende, Belgium

DEMONSTRATION TRIALS OF TRAWL NETS WITH TURTLE EXCLUDER AND BYCATCH REDUCTION DEVICES IN THE COASTAL WATERS OFF LIMBE, CAMEROON.

[1]Solarin, B. B., [2]Moth-Poulsen, T. M, [2]Carr, A., [3]Njifonjou, O, and [4]Meke-Soung, P. N.

[1]Nigerian Institute for Oceanography and Marine Research, Lagos, Nigeria.
[2]Fishery Industry Division, FAO, Rome, Italy.
[3]Station de Recherches Halieutique et Oceanographie, Limbe (SRHOL), Cameroon.
[4]Ministry of Livestock, Fisheries and Animal Husbandries; Service Provincial des Peches du Littoral Douala (SPPLD), Cameroon.

ABSTRACT

The report contains the results of sea demonstration trials on the performance of trawl nets fitted with turtle excluder device (TED) and bycatch reduction devices (BRD) as compared to traditional trawl net fitted with diamond mesh codend. The overall analysis indicated that 90^{o} turned BRD codend (T90) caught 11.8 kg or 31.6% of the total shrimp catch, square mesh window (SMW) caught 9.8kg or 26.0% as compared to 9.5kg or 25.5% by traditional diamond mesh codend. TED trawl net caught 6.2 kg or 16.60% shrimps apparently due to faulty geometrical configuration. However analysis of variance (ANOVA) showed no significant difference ($P>0.05$) between the shrimp caught by the different codends. The quantity of commercial fish recorded was 109.3kg or 24.4% by TED net, 125.30kg or 28.0% by T90 codend, 104.0kg or 23.2% by SMW and 109.0kg or 24.4% by traditional trawl net. The TED and BRD nets caught slightly lower quantity of trash fish compared to the traditional net with the corresponding values of 91.0kg or 22.7% by the TED net, 70.8kg or 17.7% by T90, 112.0kg or 28.0% by SMW and 126.3kg or 31.6% by the traditional net. ANOVA showed significant difference ($P<0.05$) between the commercial and trash fish caught by the different trawl net codends. By visual inspection, the quality of the catch in TED net as well as the BRD codends was relatively better than the traditional diamond mesh codend which retained a lot more debris. Based on the complementary roles of installing TED and BRD in the same trawl net, recommendations are proffered in order to minimize shrimp loss, optimize operational efficiency and thereby facilitate better compliance by the industrial fishermen.

Keywords: *Trawl nets, Turtle excluder device, Bycatch reduction devices*

---

1. INTRODUCTION

On tropical shrimp grounds, turtles and some non target fish particularly juveniles occur and are found together. The reduction of incidental catch of turtles and unwanted fish in shrimp trawls is thus regarded as a priority issue in the global efforts to develop more responsible fishery practices (Eayrs, 2005; Alverson *et. al*., 1994; Andrew & Pepperell, 1992).

Turtle excluder devices (TED) are installed in shrimp trawl nets as a management tool to reduce fishery related sea turtle mortality. This is a critical component of sea turtle recovery efforts by trawler fishermen in Europe, North and South America, Canada, S. E. Asia and Australia. In 1996 TED became a precondition and regulatory requirement for export of shrimps to USA markets. The Nigerian Institute for Oceanography and Marine Research, Lagos, in collaboration with Federal Department of Fisheries developed the locally made TED for adoption by industrial fishermen. Nigeria was certified respectively in 1998 and 2007 among other 18 nations, to export all categories of and species of shrimps to USA based on satisfactory compliance by operators in the fishing industry. In shrimp trawling for every kilogram of shrimp caught up to 20kg or more of other fish are inadvertently captured and killed as recorded by observers on board commercial vessels in the coastal waters off Lagos Nigeria and Douala Cameroon. Discard of shrimp by-catch have also been a global concern.

Activities under the Global Environment Facility (GEF), United Nations Environment Programme (UNEP) and Food and Agriculture Organization (FAO) shrimp fisheries project include the introduction of By-catch reduction devices (BRDs) and proper use of TEDs to mitigate the problems of by-catch and sea turtle incidental catch in shrimp trawl nets.

Sea demonstration trials that were conducted in Cameroon as satellite State to Nigeria involved all the stake holders in the fishing companies as well as Research and Fishery officers.

2. MATERIALS AND METHODS

BRD codends with relatively simple designs and low cost implication were designed and constructed with locally available materials. They included square mesh window (SMW) made of 50 mm mesh netting attached to a 47mm diamond mesh codend (Fig. 1). The 90^{o} turned or gentle codend (T90) was constructed with 47 mm diamond mesh netting that had been orientated or turned from normal to transverse run of netting (Fig. 2). The third net was the traditional trawl net with 47 mm diamond mesh codend. The 4th trawl net was fitted with bent rod TED grid placed in a cylindrical-shaped codend extension (140 – 160 meshes circumference by 60 meshes length) in order to conform to existing regulation as shown in Plate 1. TED grid (Plate 2) was specifically designed and constructed to a large extent in accordance with stipulated U. S. A. standards as stated by Mitchell *et. al*. (1995) and Eayrs (2005).

The traditional and BRD trawl nets as well as the TED fitted trawl net were attached at random to the commercial fishing vessels with 23.5m length-over all (LOA) and 840 horses power (HP). All the 4 nets were towed or trawled simultaneously in parallel with each other in the coastal waters off Limbe, Cameroon between 16th and 22nd April 2007.

During the out-reach session involving Managers, Captains and fishermen of fishing companies, there were a total of 4 demonstration trials at a trawling speed of 2.5-2.7 knots in 25–60 m water depth. The trawling time per haul was approximately one hour.

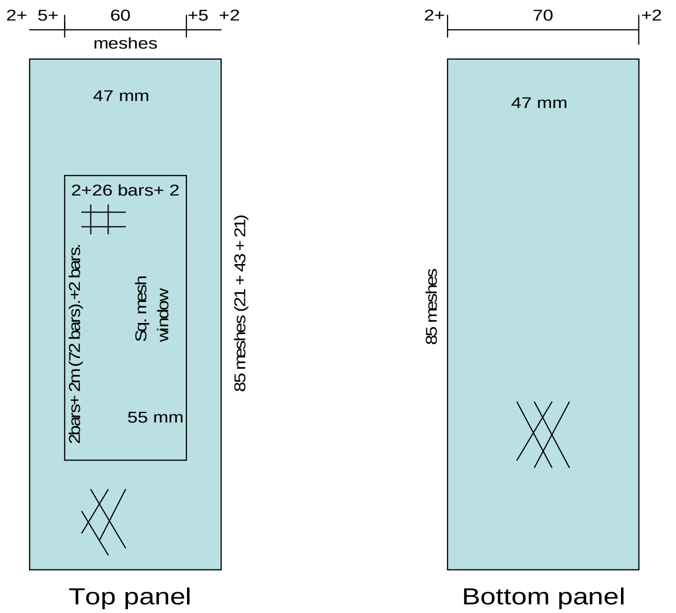


Fig. 1. Square mesh window (SMW) codend

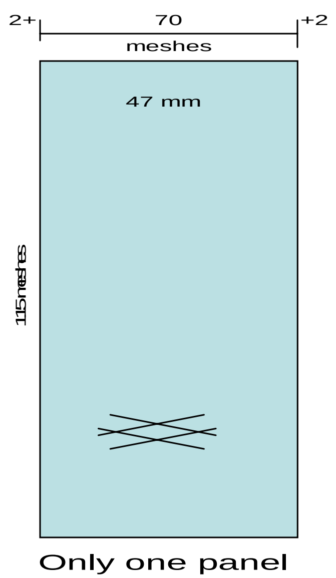


Fig.2 T90 codend (90° turned meshes)

Plate 1. TED grid fixed in Codend Extension

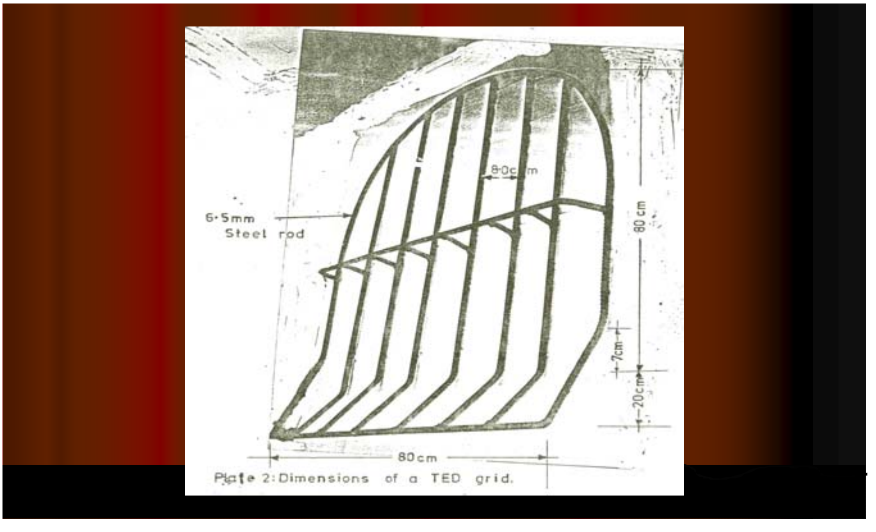


Plate 2. Dimensions of a locally fabricated TED grid

3. DATA COLLECTION AND ANALYSIS

The catch in each of the codends (e.g. the diamond mesh codend of the traditional net and the BRD codends or the TED design option was separately emptied on to the deck one after the other in order to prevent a mix up. The catch in each codend was sorted into 4 major categories viz.: shrimps, fish of commercial value, cuttle fish & crabs and trash fish.

The catch composition was weighed (kg) and identified to species level according to Schneider (1990). Percentage weight composition was determined and recorded accordingly. Length frequency measurement of representative samples of the fish composition was also taken and recorded in the laboratory.

4. RESULTS

The target shrimps included pink shrimp *Penaeus notialis*, guinea shrimp *Parapenaeopsis atlantica*, tiger shrimp *Penaeus kerathurus* and the giant tiger shrimp *P. monodon* all of which constituted 4.21% by weight of the total catch.

The multi-species bycatch was made up of 25 species belonging to 20 families and dominated by the Sciaenids (croakers), Carangidae (caranx), Cynoglossidae (soles), Haemulidae (grunters/big eye), Polynemidae (threadfins), Trichiuridae (hairtails/silver fish), Dasyatidae (rays), Sphyraenidae (barracuda), Drepanidae, Clupeidae (mainly represented by shad), Sphyraenidae (sharks), Sepiidae (cuttle fish) and Portunidae (crabs) which constituted 50.60 % of the total catch by weight.

The trash fish made up mainly of juveniles and immature specimens of commercially important species e.g. croakers which were less than 25cm (TL) constituted 45.91% of the total catch by weight.

Tables 1 - 4 show the weight and the corresponding percentage composition of shrimps and bycatch caught by each of the trawl net codends. As shown in Table 5, the overall analysis indicated that T90 codend caught 11.8kg or 31.6% of the total shrimp catch, SMW caught 9.8 kg or 26.0% as compared to 9.5kg or 25.5% by traditional diamond mesh codend. TED trawl net caught 6.2kg or 16.60% shrimps apparently due to faulty geometrical configuration.

The quantity of commercial fish recorded was 109.3kg or 24.4% by TED net, 125.30kg or 28.0% by T90 codend, 104.0kg or 23.2% by SMW and 109.0kg or 24.4% by traditional trawl net. The TED and BRD nets caught slightly lower quantity of trash fish compared to the traditional net. The corresponding values were 91.0kg or 22.7% by the TED net, 70.8kg or 17.7% by T90 , 112.0kg or 28.0% by SMW and 126.3kg or 31.6% by the traditional net. However ANOVA showed no significant difference (P>0.05) between the shrimp catch but showed significant difference (P<0.05) between the commercial and trash fish caught by the different trawl net codends.

Table 1.. Catch by weight of fish and shrimps in haul one.

Species	TED only	T90	SMW	Trad.
Shrimp	2.4	2.0	2.0	2.0
Com. fish	20.3	0.5	20.0	12.0
Trash	48.0	5.0	43.0	45.0
Total	70.7	7.5	65.0	59.0

Table 1a. Catch by weight (% of traditional)

Species	TED only	T90	SMW	Trad.
Shrimp	120.0%	100%	100.0%	2.0
Com. fish	169.0%	4.0%	166.7%	12.0
Trash	107.0%	11.0%	95.6%	45.0
Total	120%	13%	110.2%	59.0

Table 1b. Catch (kg) by category within tow (%of total catch per tow)

Species	TED only	T90	SMW	Trad.
Shrimp	3.0%	27.0%	3.0%	3.0%
Com. fish	29.0%	7.0%	31.0%	20.0%
Trash	68%	67%	66%	76.0%
Total	100%	100%	100%	100%

Table 2. Catch by weight (kg) of fish and shrimps in haul 2

Species	TED only	T90	SMW	Trad.
Shrimp	1.7	2.0	2.5	2.8
Com. fish	74.0	82.0	50.0	54.0
Trash	27.0	26.8	25.5	34.0
Total	102.7	110.8	78	90.8

Table2a. Catch by weight (% of traditional)

Species	TED only	T90	SMW	Trad.
Shrimp	61.0%	71.0%	89.0%	2.8
Com. fish	137%	152.0%	93.0%	54.0
Trash	79.0%	79.0%	75.0%	34.0
Total	113%	122%	86%	90.8

Table 2b. Catch by category within tow (% of total catch per tow)

Species	TED only	T90	SMW	Trad.
Shrimp	2.0%	2.0%	3.0%	3.0%
Com. Fish	72.0%	74.0%	64.0%	59.0%
Trash	26.0%	24.0%	33.0%	37.0%
Total	100%	100%	100%	100%

Table 3. Catch by weight of fish and shrimps in haul 3

Species	TED only	T90	SMW	Trad.
Shrimp	1.5	5.2	3.7	3.6
Commercial	5.0	17.0	17.0	21.0
Trash	9.0	19.0	23.5	25.3
Total	15.5	41.2	44.2	49.9

Table 3a. Catch by weight (% of traditional)

Species	TED only	T90	SMW	Trad.
Shrimp	42.0%	144.0%	102.8%	3.6
Com. Fish	24.0%	81.0%	81.0%	21.0
Trash	36.0%	75.0%	92.9%	25.0
Total	31%	83%	88.6%	49.6

Table 3b. Catch by category within tow (% of total catch per tow)

Species	TED only	T90	SMW	Trad.
Shrimp	10.0%	13.0%	8.0%	7.0%
Com. Fish	32.0%	41.0%	38.0%	42.0%
Trash	58.0%	46.0%	53.0%	51.0%
Total	100%	100%	100%	100%

Table 4. Catch by weight of fish and shrimp in haul 4.

Species	TED only	T90	SMW	Trad.
Shrimp	0.6	2.6	1.6	1.1
Com. fish	10.0	25.8	17.0	22.0
Trash	7.0	20.0	20.0	22.0
Total	17.6	48.4	38.6	45.1

Table 4a. Catch by weight (% of traditional)

Species	TED only	T90	SMW	Trad.
Shrimp	55.0%	236.0%	145.0%	1.1
Com. fish	45.0%	117.0%	77.0%	22.0
Trash	32.0%	91.0%	91.0%	22.0
Total	39%	107%	86%	45.1

Table 4b. Catch by category within tow (% of total catch per tow)

Species	TED only	T90	SMW	Trad.
Shrimp	3%	5%	4%	2%
Com.fish	57%	53%	44%	49%
Trash	40%	41%	52%	49%
Total	100%	100%	100%	100%

Table 5: Total catch by weight of fish and shrimp in hauls 1- 4

Species	TED only	T90	SMW	Trad.
Shrimp	6.2	11.8	9.8	9.5
Com. fish	109.3	125.3	104.0	109.0
Trash	91.0	70.8	112.0	126.3
Total	206.5	207.9	225.8	244.8

Table 5a: Catch by weight (% of traditional)

Species	TED only	T90	SMW	Trad.
Shrimp	65.0%	120.0%	103.0%	100.0% (9.5kg)
Com. fish	100.0%	115.0%	95.4%	100.0% (109.0kg)
Trash	72.0%	56.0%	88.7%	100.0% (126.3kg)
Total	84.4%	84.9%	92.2%	100%

Table 5b: Catch by category within tow (% of total catch per tow)

Species	TED only	T90	SMW	Trad.
Shrimp	3.0%	5.7%	4.4%	3.9%
Com.fish	52.9%	60.3%	46.0%	44.5%
Trash	44.0%	34.0%	49.6%	51.6%
Total	100%	100%	100%	100%

5. DISCUSSION

Trawl nets with BRD codends were more selective and caught much lower volume of trash fish compared to diamond mesh codend as indicated by Briggs (1992), Broadhurst (2000), Broadhurst *et. al.* (1997 and 1999), Kendall (1990) and Watson *et. al.* (1986). By visual inspection, the fish caught by BRD codends appeared cleaner which made sorting to be easier or less laborious. It required a lot more time to sort the fish caught by traditional diamond mesh codend into different categories because of large quantities of debris and trash fish.

The BRD codends are capable of releasing a lot more bycatch or trash fish than the traditional diamond mesh codend with little or no reduction in shrimp catch. This gives credence to the fact that BRD codends are better options to solve by-catch problem and the need to adopt any one of them in order to drastically reduce the quantity of juveniles and immature species in commercial shrimp trawling as indicated by Foster (2000), Broadhurst and Kennelly (1996), Broadhurst (1998) and Broadhurst *et al*. (1999). Increase in mesh size of codends should allow a lot more small size fish to escape as indicated by Solarin (1989). It is very important to fix the window at an appropriate distance of about 1.5 m from the exterior end of the codend. It is expected that the pack of fish in the codend should effectively stem down the current speed and thereby give the finfish ample chance to escape. The square mesh window should be hauled carefully in order to prevent shrimp falling off during haul back delay.

As indicated by Mitchell *et. al.* (1995) and Eayrs (2005) research and development to improve TED performance have been pursued rigorously. The grid should be maintained at an angle of inclination of 45^o-55^o . With very low TED angle e.g. 30^o the flap cover does not close properly and shrimps are lost. With high grid angle e.g. 70^o the flap cover closes the exit opening tightly and prevents discharge of debris.

The future trend and development will involve a pragmatic and holistic approach to the modification of the trawl net by the introduction of a combination of Turtle Excluder and By-catch Reduction technologies. The interaction of stake holders to educate, inform, sensitize and create a lot of awareness as well as capacity building and skills acquisition in TED and BRD designs should be on a continuous basis and uninterrupted in order to meet and update the standard requirements and also synergize the BRD and TED technologies. The selected BRD codends combined effectively well with TED installed in the codend extension.

ACKNOWLEDGEMENTS

This Research work was funded by Global Environment Facility (GEF) in collaboration with United Nations Environment Programmes (UNEP) and Food and Agriculture Organisation of the United Nations (FAO) for implementation. Free vessel time provided by the Fishing Companies is gratefully acknowledged.

REFERENCES

Alverson, D.L., Freeberg, M. H., Murawski, S.A. & Pope, J.G. 1994. A global assessment of fisheries by-catch and discards. FAO Fisheries Tech Pap. 339, 235pp.

Andrew, N.L. & Pepperell, J. G. 1992. The by-catch of shrimp trawl fisheries. Oceanogr Mar. Biol. Ann. Rev. 30 : 527 – 565.

Briggs, R. P. 1992. An assessment of nets with a square mesh panel as a whiting conservation tool in the Irish Sea Nephrops fishery. Fish. Res. 3: 133 – 152.

Broadhurst M. K. 1998. Bottlenose dolphins, *Tursiops truncates*, removing by-catch from pawn trawl codends during fishing in New South Wales, Australia. Marine Fisheries Review 60 (3): 9-14.

Broadburst, M.K. 2000. Modifications to reduce by-catch in prawn trawls. A review and framework for development. Reviews in Fish Biology and Fisheries. 10: 27 – 60

Broadhurst, M. K. & Kennelly S.J. 1996. Rigid and flexible separator panels in trawls that reduce the by-catch of small fish in the Clarence River prawn- trawl fishery, Australia Mar. Freshwater Res. 47: 991-8.

Broadhurst, M. K., Kennelly S.J. & Doherty G.O. 1997 Specifications for the construction and installation of two by-catch reducing devices (BRDs) used in New South Wales prawn trawl fisheries. Mar. Freshwater Res. 48: 485-9

Broadhurst M. K., R. B. Larsen, S. J. Kennelly & Mc Shane P. E. 1999 Fishery Bulletin 97 (3): 434 – 448

Broadhurst, M. K., S. J. Kennelly & Eayrs, S. 1999. Potentials of flow-related effects of square mesh panels for increasing the escape of unwanted fish through square-mesh panels – Flume tank experiments. Fish Bull. 97: 1-8.

Eayrs, S. 2005 A guide to by-catch reduction in Tropical shrimp trawl Fisheries FAO Rome Italy 110 pp.

Foster, J. J. 2000. Strategies for the development of selective fishing Technology. FAO Fisheries report FIIT/R588 Suppl.

Kendall, D. 1990. Shrimp retention characteristics of the Morison soft TED; a selective webbing exclusion panel inserted in a shrimp trawl Net. Fish Res. 9, 13 – 21.

Mitchell, J. F., Watson, J. W., D. G. Foster & Caylor R. E. 1995. The turtle Excluder Device (TED): A guide to better performance. NOAA Technical memorandum NMFS-SEFSL-366, 35pp.

Schneider, W. 1990. FAO species identification sheets for fishery purpose. Field guide to the commercial marine resources of the Gulf of Guinea. FAO Rome 268pp.

Solarin, B. B. 1989. Mesh selectivity of monofilament (polyamide) gillnets for the bonga (Ethmalosa fimbriata) in Lagos Lagoon, Nigeria. J. Cons. Int. Explor. Mer, 46: 109-110.

Watson, J. W., Mitchell, J. F. & Shah, A. K. 1986. Trawling efficiency Device: a new concept for selective shrimp trawling gear. Mar. Fish. Rev.48(1): 1-9.