FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

UNRAVELING THE MYSTERIES OF AQUATIC BIODIVERSITY: THE GOOD, THE BAD AND THE UGLY

By

PROF. FRANCIS OFURUM ARIMORO
B.Sc, M.Sc (Jos), PhD (Abraka), MZSN, MFBAN
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INAUGURAL LECTURE SERIES 67

30TH AUGUST, 2018

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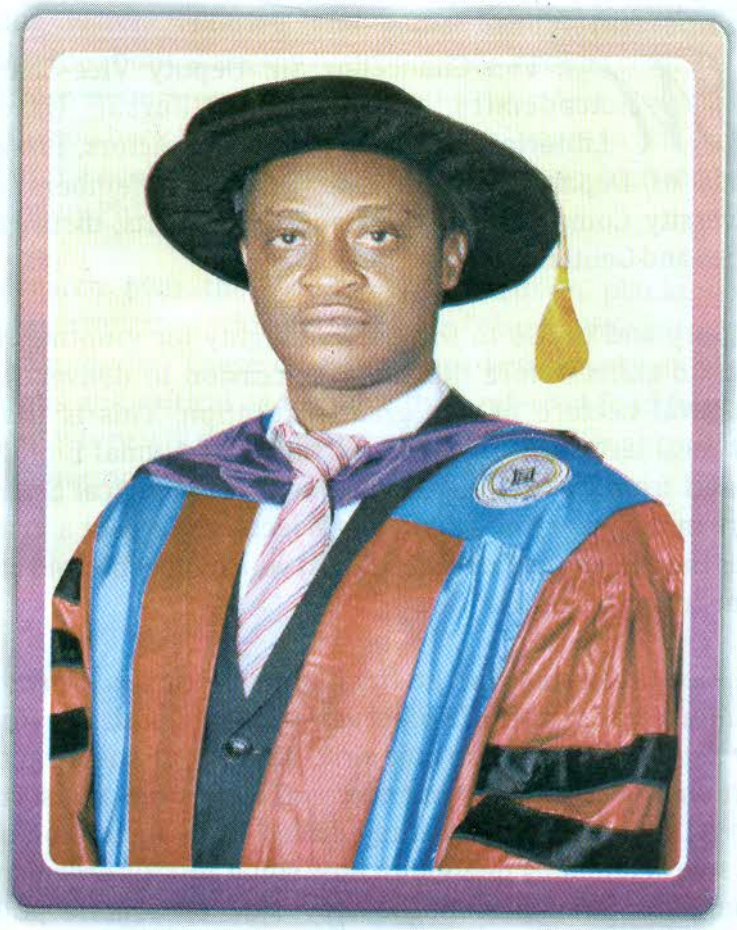

Prof. Francis Ofurum Arimoro

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PREAMBLE

Mr. Vice-Chancellor Sir, Deputy Vice-Chancellor Academics, the Registrar, Bursar, University Librarian, Deans of Schools, Directors, Professors, Heads of Departments, Erudite Scholars, Members of the University Community, invited guests, students, distinguished Ladies and Gentlemen.

All glory and praise to the Lord Almighty for granting me the grace to stand before this august occasion to deliver the 67th Inaugural Lecture of this great institution. This is the **First** inaugural lecture from the Department of Animal Biology and **second** from the defunct Department of Biological Sciences. I share in the view that an inaugural lecture is a debt a Professor owes the University Community and which must be paid at some point during his career.

The Vice-Chancellor Sir, the titled of my lecture is '***Unravelling the Mysteries of Aquatic Biodiversity: The Good, The Bad and The Ugly***'. I chose this topic first because of some mysteries surrounding aquatic biodiversity and ecosystem and second to unravel the immense benefits derived from aquatic biota. The bad side of it mainly deals with how some aquatic organisms are harmful to humans and the ugly side of aquatic pollution resulting to destruction of ecological habitats.

I started off my early primary school days in Orogodo Primary School, Agbor in Delta state. The school got her name from the popular Orogodo River that flows through the town. The people of Ika land place much value on this river and their riparian areas.

Indeed the river forms part of the peoples' collective consciousness; It is entwined with Ika history, folklore, art, traditions, and literature. This river continues to provide drinking water, fisheries, and game habitat that sustained communities built along the riverbanks. As a young child, I derive pleasure in swimming and playing in the river. As feat would have it, I returned back to this river after several years to undertake a study of the ecology of the macroinvertebrates which led to the award of my PhD in 2007.

My research over the years has focused on plankton and macroinvertebrates, which I think of as "*charismatic microfauna and macrofauna*." These organisms are key players in aquatic food webs and critical as they are the preferred food for many fish. My lecture will therefore unravel the mysteries surrounding these unique organisms.

INTRODUCTION

BIODIVERSITY

The term *biological diversity, or biodiversity, originated in the study of terrestrial* ecosystems. One formal definition for biodiversity is "the variety and variability among living organisms and the ecological complexes in which they occur" and "encompasses different ecosystems, species, genes, and their relative abundance" (Angermier and Karr, 1994).

Aquatic biodiversity can be defined as the variety of life and the ecosystems that make up the freshwater, tidal, and marine regions of the world and their interactions. Aquatic biodiversity encompasses freshwater ecosystems, including lakes, ponds, reservoirs, rivers, streams, groundwater, and wetlands. It also consists of marine ecosystems, including oceans, estuaries, salt marshes, seagrass beds, coral reefs, kelp beds, and mangrove forests. Aquatic biodiversity includes all unique species, their habitats and interaction between them. It consists of phytoplankton, zooplankton, aquatic plants, insects, fish, birds, mammals, and others. It is the number of different native species, or species richness. Over 1.4 million identified species live on earth, and experts estimate that as many as another 10 million to 100 million unidentified species may exist (Helfrich *et al.* 2009). Generally, habitat heterogeneity supports higher diversity of life. Coastal estuaries and mangrove swamps, for example, are "edge" ecosystems that link salt- and freshwaters and trap nutrients that allow them to support a rich diversity of aquatic plants and animals.

Marine, coastal and inland areas support a rich assortment of aquatic biological diversity that contributes to the economic,

cultural, nutritional, social, recreational and spiritual betterment of human populations. Life originated in the world's oceans and over the millennia has spread inland and evolved into the diverse forms used today by a variety of stakeholders, including commercial and artisanal fishers, fish farmers, developers and tourists (Pawar, 2016).

DIVERSITY OF AQUATIC ECOSYSTEMS IN NIGERIA

The finite natural resource base shared by 180 million humans and unknown number of plants and other animals is estimated as 923,700 km^2 of land excluding the coastal region. Approximately 125,471 km^2 of Nigeria land mass is covered by the waters of the nation's major rivers, lakes, ponds and pools (Oribhabor 2016). The landmass of Nigeria is enclosed between latitudes 4°16'-13°52' N and longitudes 2°49'-14°32' E and being 1100 km on a North/West axis (Figure 1). Nigeria stretches from the border with Benin Republic to the Eastern border with the Cameroon Republic. The country is a West African maritime State with a coastline that is about 853 km, long. The Nigerian coastal zone can be defined as the area which extends from the shelf break, inland to the limit of tidal influence. This coastline is interrupted by a series of estuaries, which open into an extensive lagoon system in Lagos and Ondo States. In Lagos State, the creeks, floodplains, lagoons and rivers account for approximately 22% of the 790 km^2 land mass. There are at least twenty-two estuaries from Benin River in Delta State coastal region to Cross River in Akwa Ibom State. The Nigerian coastal zone is generally low lying, resulting in extensive wetlands and mangrove swamps. Nigerian had the largest area of mangrove forest in Africa.

BIODIVERSITY IN THE AQUATIC ECOSYSTEMS OF NIGERIA

Nigerian aquatic ecosystems are characterized with diverse species of plants and animals. Unlike the terrestrial habitats, animals in the oceans are found at all depths, so that the total

habitable space of a 4 km (average) deep ocean is 1,263,804 km^3. It is therefore reasonable to assume that Nigeria's aquatic flora and fauna biodiversity is higher than that of the terrestrial habitats. The total fauna of the World is comprised of 25 phyla of which 24 phyla are invertebrates. The phylum Chordata consists of the non-vertebrate and vertebrate chordates. Invertebrate species diversity is much higher in the aquatic ecosystem than in the terrestrial ecosystem. The significance of greater protection to the aquatic ecosystems cannot be over-emphasized, since its diverse fauna is of great economic and social importance. A summary of the faunal biodiversity of Nigeria aquatic ecosystems is shown in Table 1. There are at least 2570 faunal species.

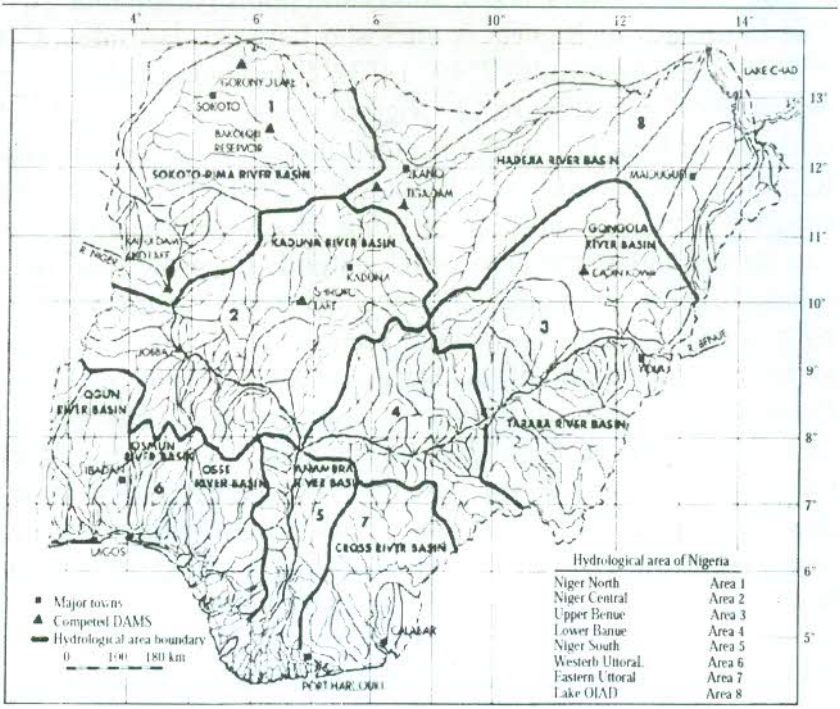


Fig. 1. The Hydrology map of Nigeria (Ita 1993).

Table 1. Species diversity of Nigerian aquatic fauna (Numbers represent the minimum)

Phyla	Classes	No. Of Species
Protista	Mastigophora (103, Ciliophora(18), Rhizophora(196) and Sporozoa (18)	335
Cnidaria	Anthozoa(1), Hydrozoa(3) and Scyphozoa(2)	6
Platyhelminthes	Cestoda(12) and Trematoda(30)	42
Acanthocephala		6
Nematoda		15
Rotifera	Digononta(4) and Monogonota (193)	197
Annelida	Hirudinea (6), Oligochaeta(18) and Polychaeta (101)	125
Arthropoda	Arachnida (5), Crustacea(Branchiopoda (102), Branchiura (4), Cirripedia (4), Copepoda (92), Malacostraca(154), Ostracoda (91) and Insecta (280)	732
Mollusca	Amphineura (1), Cephalopoda (23), Gastropoda (120) and Bivalvia (101)	245
Echinodermata		3
Chaetognata		2
Chordata	Protochordata (3), Pisces (824), Amphibia (28), Reptilia (13), Aves (73), Mammalia (3)	944

Unidentified species account for 8% of the total *(Egborge, 1994)*

THE VALUE OF BIODIVERSITY

So why study Biodiversity? Each aquatic species from a tiny bacterium to a blue whale is unique. It is not size, but the genetic composition of plants and animals that makes all life forms special. Each species has its own inherent genetic library that codes its ability to survive in changing environments. The huge variety of species and genes represents a living library of options to adapt to changes, to develop immunity to diseases, and to pass improved fitness on to future generations. Life is indeed fascinating.

Sustaining biodiversity is essential to the health of our environment and to the quality of human life. We depend on many aquatic plants and animals, and their ecological functions, for our survival. For example, we use surface waters and their inhabitants to help process our waste products. Each day, aquatic organisms (bacteria and fungi) continually break down harmful toxins and nutrients that we flush into our sewage systems or discard directly into our rivers and streams.

Aquatic biodiversity are sources of medicine, food, energy,

shelter, and the raw materials that we use and need. Although we seldom recognize them, each aquatic species has an important role in making our lives easier, healthier, and more productive. Every living organism has an important role to play, and many are indispensable.

Freshwater species provide important ecosystem services. For example, the production of clean drinking water depends on the functions provided by many freshwater species yet this is rarely recognized. A single freshwater bivalve may filter more than seven litres of water a day –without keystone species such as these maintained in river systems the water would not be as pure.

ANTHROPOGENIC IMPACT ON THE NIGERIAN AQUATIC ECOSYSTEM

The biodiversity of the Nigerian aquatic ecosystems is increasingly being destroyed or depleted by persistent threat of aquatic pollution resulting from intense human activities such as indiscriminate use of fertilizers and pesticides in agriculture; industrialization; urbanization; pressure due to rapid population growth; malutilization and mismanagement of natural aquatic resources; dam, road and bridge construction; irrigation; draining and filling of wetlands. The negative environmental and social impacts of these projects are becoming evident and cannot be ignored if we are to avoid the sorts of problems which they have brought in other parts of the World (Oribhabor 2016).

Pollution from point and diffuse sources is a major problem throughout Africa and particularly in Nigeria were legislation intended to protect the environment is weak and not fully implemented. Point source pollution from industries, slaughter house wastes and sewage discharge are a common feature over

the entire region. Several rivers are in such poor condition that fisheries have collapsed, also reported is drastic reduction in the diversity of aquatic invertebrates (Arimoro and Osakwe 2006; Arimoro and Ikomi 2008, Arimoro *et al* 2015). Lagoons and wetlands have become a sink to discharges, including excavated sand, heavy metals and other chemicals from wastes fuels and machineries. Owing to seasonal distribution of rainfall, the lagoon system and creeks experience seasonal flooding which introduces a lot of detritus, nutrients as well as pollutants arising from land based activities including domestic and industrial effluents, urban storm runoff, agricultural activities (Chukwu and Nwankwo 2003). Being largely an oil producing nation the attendant effect of oil pollution and petroleum impacts have been eminent on the entire freshwater biota. Invertebrates and fishes have shown drastic reductions in both abundance and taxonomic richness occurring at sites downstream spills (Chukwu and Nwachukwu 2005, Arimoro *et al* 2018).

Mr. Vice Chancellor Sir, I will like to ask us a question here. Reflecting on the title of this Inaugural lecture can we say that this crude oil pollution being experienced in Nigeria is Good, Bad or Ugly? Your guess perhaps is the same as mine.

BENEFITS OF BIOMONITORING FOR SUSTAINABILITY

Assessing the ecological 'health' of rivers and streams is a fundamental and increasingly important water management issue worldwide and, as a consequence, a vast array of biological monitoring approaches has been developed especially in Europe and North America. Apart from South Africa, however, studies of biomonitoring in developing in Sub-Saharan Africa, including Nigeria, isstill far from sufficient (Arimoro and Ikomi 2009). Biological monitoring approaches are essential to achieving the goals of ecological sustainability, which espouse protection of biodiversity and the maintenance of essential ecological processes and life support systems (Karr, 1991). Recognizing the

existence of natural geographic variation in species distribution and abundance is an important consideration in the development of biomonitoring programmes, particularly at large spatial scales (Karr 1991; Resh *et al* 1995; Bunn and Davies 2000). Invertebrates dominate the world's ecosystems, and there are immense challenges to addressing their conservation needs. In Nigeria, Aquatic Ecologists have to wrestle with a number of impediments in order to advance the science of biomonitoring. These include:

(1) lack of knowledge about macroinvertebrate fauna and their tolerance values, especially during the aquatic, immature stages;

(2) the scarcity of research programs and formal training opportunities for biomonitoring offered in universities;

(3) the shortage of high-quality microscopes and other necessary equipment; and

(4) limited government understanding and support for field of invertebrate conservation is growing, and filling in the information gaps is rewarding.

There is a strong need for expertise and specialization on a local, regional, and provincial scale for all invertebrate groups. Those wishing to carve a specialist niche in the realm of conservation biology should consider becoming involved in invertebrate conservation.

MYSTERY OF AQUATIC BIODIVERSITY

1. Sea of miracles: industrial uses for ocean biodiversity

The seafloor is our planet's most biodiverse realm. It is in the sea that life on earth began over 3.5 billion years ago. It is in the sea

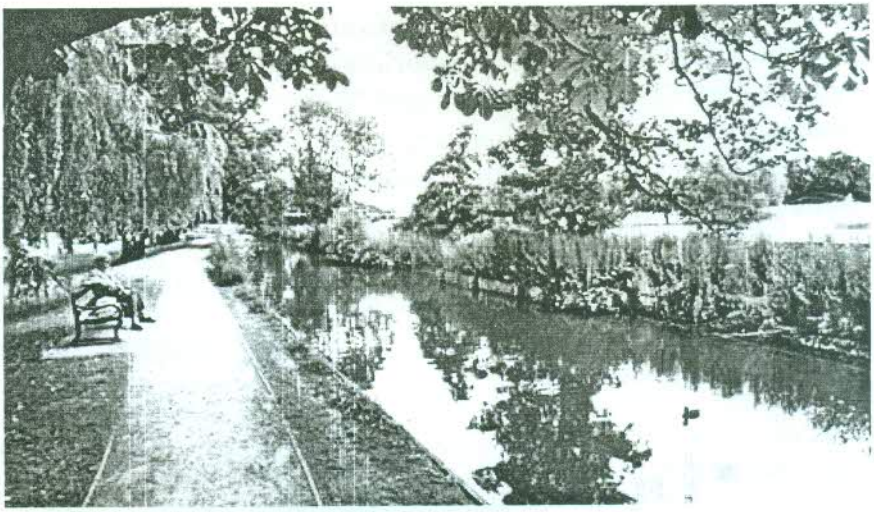
where 34 of the 36 known phyla of animals remain to this day, 15 of which are exclusive to the world's oceans. And it is in the sea where myriad opportunities await. The commercial potential of marine biodiversity is changing as technology evolves and we seek new services from our oceans beyond the current focus on food and energy supply and tourism. One new frontier lies in the novel biological systems and chemical pathways developed by marine creatures to survive extreme physical environments and ruthless biological competition in the ocean (Evans-Illudge 2013).

"Biodiscovery" is the search for these attributes so they can be developed as new products, including pharmaceuticals, agrichemicals, tools for environmental remediation, or more efficient and less polluting industrial processes. Biodiscovery is inherently sustainable. Only tiny amounts of natural material are needed for most screening programs, and once an attribute is ready for large-scale market supply, commercial realities require development of a reliable non-wild source, such as synthesis or aquaculture. And in the process, biodiscovery collections have contributed enormously to knowledge of biodiversity, and therefore the capacity to manage it for the future. Marine biodiversity and its extraordinary arsenal of metabolic machinery remains a relatively untapped source of raw materials. In an era of increased antibiotic drug resistance and new diseases needing novel therapeutics, this is good news.

2. **Health and wellbeing**

a. What impact do seas, lakes and rivers have on people's health?

New research has found that 'blue space' including sea, rivers, lakes and even urban water features can have a positive impact on wellbeing, writes Smedley (2013). The impact of water on health: new research suggests that 'blue space' can reduce stress and have a positive effect on wellbeing.



Photograph: David Levene for the Guardian

Most of us recognise the calming effect of a walk by the river or along a beach. Victorian doctors used to prescribe the "sea air" as a cure for an assortment of agues and ailments. But while the health benefits of green space are now well known, thanks to the pioneering research of Roger Ulrich and the Kaplans among others, little analysis has been made of "blue space" – the impact of the sea, rivers, lakes, and even urban water features on our health and wellbeing.

b. *Marine Biota and Psychological Well-Being*

Exposure to natural environments can have calming and stress-reducing effects on humans. Moreover, previous studies suggest that these benefits may be greater in areas with higher species richness (Sandifer *et al* 2015). The studies suggest that greater actual or perceived species richness is associated with greater psychological well-being (Dallimer *et al* 2012; Medical Research Council, 2011). In a study by Cracknell *et al* (2016) taking advantage of a "natural experiment" to examine people's behavioral, physiological, and psychological reactions to increases in levels of marine biota in a large aquarium exhibit

during three stages of restocking: Unstocked, Partially stocked, and Fully stocked. It was found that increased biota levels were associated with longer spontaneous viewing of the exhibit, greater reductions in heart rate, greater increases in self-reported mood, and higher interest. The report suggested that higher biota levels, even in managed settings, may be associated with important well-being and health benefits, particularly for individuals not able to access the natural analogues of managed environments. The work provided tentative support for previous, limited research that has suggested there are psychological and physiological benefits of watching aquaria. It extends earlier studies by exploring the potential influence of increasing biota levels on well-being measures recorded at several time points. The evidence that greater levels of stocking had positive effects on experience evaluations and mood extends findings from terrestrial studies that suggest dose–response relationships between biota levels and immediate psychological well-being. Finally, the findings further highlight that restorative effects can be derived from artificial, as well as "real" nature experiences. Opportunities for engaging with nature, even in "managed" settings, may be key in helping urban populations connect with natural environments. Furthermore, as marine ecosystems can be adversely affected by visitors, the ability to connect people to marine environments by proxy, for example, through aquariums, could be extremely important. Aquariums may therefore be important for delivering psychological well-being, enhancing perceptions of the value of natural ecosystems, and ultimately encouraging support for conservation efforts in the wild.

3. **Mermaids**

a. Mammy Water is a pidgin English name for a local water goddess worshipped by the Ibibio, Ijaw, and Igbo speaking peoples of southeastern Nigeria. The water goddess traditionally

gives wealth and children, compensates for hardships, and is sought in times of illness and need, especially by women. Her various cults are led, predominantly, by priestesses. There is this story of how *Mammy Water* frustrated the road construction and flood control work along Upper Siluko road in Benin City, Nigeria. However, when Oshiomhole came, after studying the situation with experts, it was agreed that, no matter how much is invested in road construction in the area, it will be a waste unless a solid erosion work was done, that will channel the flood from these area to the Ogba River. That was how government came up with the N30billion Benin Water Storm Project. Today, the impact is being felt in the area as those who abandoned their homes have returned.

b. Nigerian guitarist and music living legend, Sir Victor Uwaifo has confirmed that he actually saw and met with a mermaid popularly known as 'Mammy Water' among Africans, even though others still believe that their existence is a myth. He had an encounter with a mermaid at the beach in Lagos, an incident which inspired his popular global hit track.

My Vice Chancellor Sir, the mystery of the mermaid is yet to be unravelled but the closest explanation by science is that what people refer to as mammy water may just be the manatee. In Nigeria, the manatee inhabits large water bodies of the Sahel and is distributed throughout the country to the coastal region. The population is threatened by human pressure and is now limited to large water bodies of the Plateau and a more substantial population is found in the coastal and delta regions, in particular around the Cross River and Akwa-Ibom states where this animal is worshipped. Only the species *Trichechus senegalensis* is indigenous to Nigeria and is well distributed in West Africa along the estuaries of the Senegal, Niger and Congo rivers (Arimoro 2009).

c. Traditional natural resources management is shaped around local rules and regulations. These rules and regulations are most often enshrined in religious or cultural beliefs and superstitions and enforced by prohibitions. These have no legal backing, but the beliefs have been strong enough in the past to make people obey the regulations. In the context of natural resources management, they enhance biodiversity conservation and minimize the continuous use of natural resources eg. (1) The *"Obi"* pond popularly called *Obi* Lake located at Okorobi village in Ethiope East Local Government Area of Delta state (2) The source of River Ethiope at Umuaja, in Ukwani Local Government Area of Delta state is yet another example.

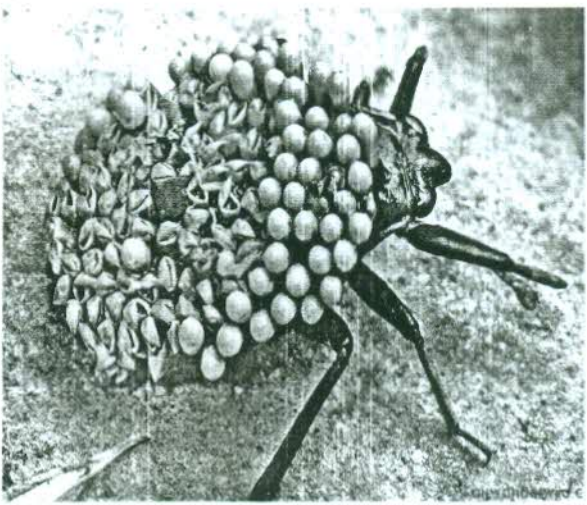
4. **Whitetail Deer Survival**

Whitetail deer are great escape artists, and that is another key to their successful strategy for survival. Their style of escape is a high speed sprint which puts obstacles between themselves and their pursuer. They can also play cagey tricks: they might hide and remain hidden until the predator is very near, and then make an explosive escape...they're gone down a well known escape route before the confused predator knows it. They will cross their own path, sometimes circling and crossing many times, to make their trail confusing. They will slink away on their bellies. They will walk in water to delete their trail, and will even hide by submerging themselves in the water, using their noses like snorkels. They are also known to run near other deer trying to shuck off the predator onto another unlucky animal. When they escape to a brook their odour can no longer be detected as it blends with that from the brook. What then can we learn from this spectacular animal? At least, we can learn how to deal, wisely and tactfully with the predatory realities that face us on a daily basis.

5. The Waterbug and the Necrotic Bite

These water bugs live in areas that they can have access to

freshwater, such as streams, lakes, and ponds. They are called Giant Water Bug due to their sizes and habitat. They only live near freshwater sources, which they need to reproduce. Moreover, their size varies from 2 cm to over 12 cm, which is around 4.75 inches. That is as big as a width of an average male's hand. Despite their looks, these water bugs feed off of a wide range of insects and animals. Insects in the Belostomatidae family employ toxic saliva capable of inducing extreme agony and even paralysis in vertebrates (Haddad *et al* 2010). Typically found in freshwater streams and still bodies of water, e.g., ponds, they are attracted to electric lights, which can cause them to draw towards humans. If they happen to bite a hapless human, their bite will provoke excruciating pain - it's been said that their bite is one of the most painful bites inflicted by an insect. Their necrotic bite is caused by the toxic effects of the salivary gland secretions from the proboscis in the head.



Source: Haddad *et al* (2010)

6. Leech Therapy

Since the time of ancient Egypt, leeches have been used in medicine to treat nervous system abnormalities, dental problems, skin diseases, and infections (Gileva and Mumcuoglu 2013). Today, they're mostly used in plastic surgery and other microsurgery. This is because leeches secrete peptides and

proteins that work to prevent blood clots. These secretions are also known as anticoagulants. This keeps blood flowing to wounds to help them heal. Currently, leech therapy is seeing a revival due to its simple an inexpensive means of preventing complications. Medicinal leeches have three jaws with tiny rows of teeth. They pierce a person's skin with their teeth and insert anticoagulants through their saliva. The leeches are then allowed to extract blood, for 20 to 45 minutes at a time, from the person undergoing treatment. This equates to a relatively small amount of blood, up to 15 milliliters per leech. There are several situations in which leech therapy may be used. People who may benefit include those who risk limb amputation due to the side effects of diabetes, those who have been diagnosed with heart disease, and those who are undergoing cosmetic surgery in which they risk the loss of some of their soft tissue. The therapy has also been recommended to treat blood clots and varicose veins. During a session, live leeches attach themselves to the target area and draw blood. They release the proteins and peptides that thin blood and prevent clotting. This improves circulation and prevents tissue death. The leeches leave behind small, Y-shaped wounds that usually heal without leaving a scar (Mumcuoglu 2014).

MY CONTRIBUTION

Vice-Chancellor Sir, my research and contribution to scientific publications began in 1996 after the completion of my Masters degree thesis titled: *'The improvement of the nutritional composition of the freshwater rotifer, Brachionus calyciflorus as live food for fish fry'.*

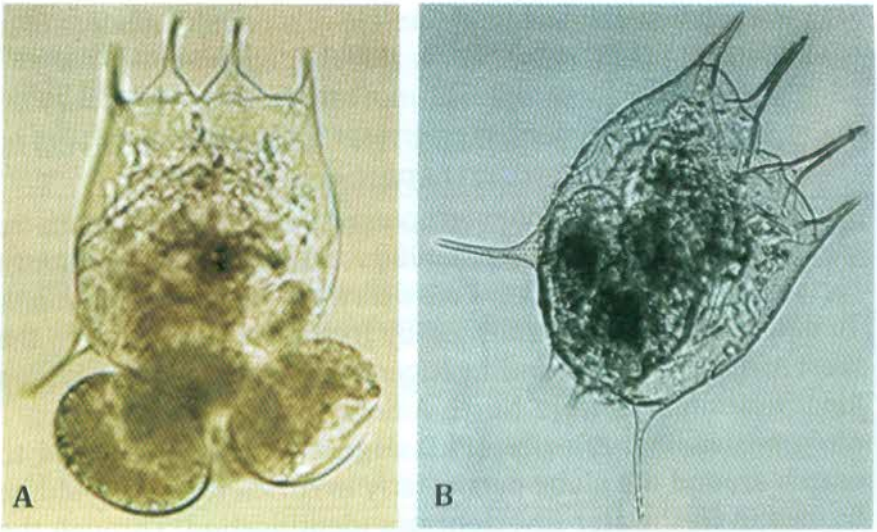
1. ROTIFER CULTURE

My then Supervisor, Prof. P. C. Ofojekwu had a nursery fish pond for the culture of the gold fish, Carassius auratus (an Aquarium fish). The problem he was experiencing as at that time was high

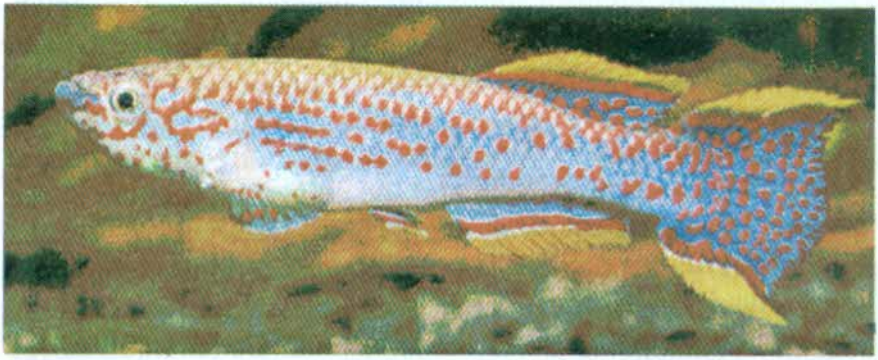
fry mortality with imported Artemia culture. Again, the high cost of Artemia was a great challenge. I went into the culture of the freshwater rotifer, B. calyciflorus with great success. My discovery was that the freshwater rotifer, B. calyciflorus is an ideal live food for the first few days culture of most fish larvae because of its numerous characteristics; small size, slow morbidity and easy catchability by the larvae (Arimoro and Ofojekwu, 2003; 2004). I was able to maintain high density of this rotifers in tank using bakers yeast and green algae. It is also important to enrich this rotifer for all round best performance in the larva. The culture of the freshwater rotifer, B. calyciflorus can be maintained continuously in a 'feed back' culture system (Arimoro 2005). Many scholars have corroborated the usefulness of rotifers for the raising of fish fry and how one can expect to raise a high percentage of the spawned fishes and end up with quality specimens from feeding rotifers. Rotifers can be used as a conditioning food to induce adult fish to spawn.

The findings of this investigation and related studies will lead to improvement in larval performance, increase yield and facilitate breeding of new fish species. This will ensure an overall satisfactory performance in hatchery operations (Arimoro 2006; Agbikimi *et al* 2017).

The rotifer, *Brachionus calyciflorus* from our investigation is ideal live food for the first few days of culture of the toothed carp, *Fundulopanchax gardneri*. Thereafter, other live foods such as mosquito larvae, *Moina,* Chironomid and Oligochaete worms can be used as food. In addition, knowledge gathered from our work will enable aquaculturists to propagate and conserve the population of the toothed carp as aquarium fishes, biological agents and as food for large predatory fishes (Arimoro *et al.* 2008a).



The freshwater Rotifer, *B. calyciflorus* with eggs (A), without eggs (B)
Source: Arimoro (2006)



Fundulopanchax gardneri JOS PLATEAU Photo by: A. Persson

It is worthy to note here that the successful mass culture of this freshwater rotifer, *Brachionus calyciflorus* and rearing success with catfish fry and minnow carp led to my collaboration with eminent scientists from Turkey (Prof. Telat Yanik and Dr. Nilgun) and visit of Dr. Gladys Bwanika (from Makerere University,

Uganda) to my laboratory in Nigeria on international scholarship.

2. TAXONOMIC STUDIES IN ALBANY MUSEUM GRAHAMSTOWN, SOUTH AFRICA

The identification of Ephemeroptera and indeed other macro invertebrates in Nigeria before 2008 was non-existence although certain genera and species were described by few taxonomists. To date most articles published by freshwater scientists in the West African region, including Nigeria, have depended largely on identification keys from North America and Britain, which are often misleading. After my PhD degree in 2007, I decided to search around the globe particularly in Africa where I could be trained in freshwater invertebrates identification. Through the assistance of a curator, Helen James from the Albany Museum in South Africa, I got NRF (National Research Foundation) support to do taxonomic identifications and training in Albany Museum, South Africa. The museum is perhaps the biggest in South Africa with over two million freshwater invertebrates collection.

With the help of several freshwater invertebrate guides most of them published around 2003 and the help of instructors at the museum I learnt the act of naming correctly these invertebrates. I found the Guides useful for the identification of Nigerian freshwater invertebrates to the generic level, but, outside the southern African region, it should be used with caution for identification to species level. For nymph identification, especially of the baetids, the dissection of mouthparts is a *sine qua non*. This can be accomplished with the aid of a dissecting microscope (at ×50 magnification), forceps with acute tips, and a thin dissecting needle, and it requires concentration and skill to perform. I found it very difficult and rather tedious when I was introduced to it by Dr. Helen James at the Albany Museum. However, with continuous practice, one learns to do more

accurate and decent dissections, especially when there is enough material to work with. It was while I was still at Albany museum that I got an invitation from the Editor of African Journal of Aquatic Sciences (AJAS) to write a review on one of the guide.

> *Book Review:* **Guides to the Freshwater Invertebrates of Southern Africa. Volume 7: Insecta I. Ephemeroptera, Odonata and Plecoptera IJ de Moor, JA Day and FC de Moor (editors)**
> *April 2003, Water Research Commission, Pretoria, South Africa*
> *Soft cover, 288 pages*
> *WRC Report No. TT 207/03; ISBN 978-1-77005-017-4; price R100 (South Africa), US$50 (international)*
> *Obtainable from the Water Research Commission, Private Bag X03, Gezina, Pretoria 0031, South Africa, or orders@wrc.org.za*

In addition to this and with the assistance of Helen James we produce a preliminary pictorial guide for the identification of freshwater invertebrates of Delta state, Nigeria. The materials I brought from sampling of some streams in Delta state were deposited in the museum and information is being updated into the data base and made available to freshwater researchers and water resources managers (available on SABIF).

Although, I have not been able to develop my full potentials in taxonomic studies because of time constraint, I have continued to keep abreast by attending workshops on taxonomy of aquatic invertebrates around the globe including the AFRESH workshop in South Africa and Kenya in 2016.

Aquatic Studies

In the course of my research work, I have undertaken biodiversity assessments, ecotoxicology and pollution studies in over 80 water bodies nation – wide and elsewhere. My colleagues and I have looked at the effects of certain organic pollutants such as abattoir effluent, rubber effluent, cassava discharge, urban

run-off, farm wastes and effluents from food processing industries and brewing industries, on several aquatic biota ranging from plankton to macroinvertebrates and fish. These pollutants are biodegradable and are easily oxidized by making use of the dissolved oxygen in water. As dissolved oxygen drops fish and other aquatic life are threatened or killed in the extreme case. Number of algae and bacteria is increased. Macrophytes are also adversely affected due to light reduction and solids rendering the bed of the river unstable for plants. I will review some of the works here under the subtitles; Macroinvertebrate as indicators, investigative research using aquatic biota chironomid deformity as bioindicators etc.

3. MACROINVERTEBRATES AS BIOINDICATORS

Freshwater bodies are increasingly being studied for their uniqueness, species diversity and the services they provide for society. However, freshwater pollution is becoming a matter of serious concern threatening environmental sustainability and further social–economic development in sub-Saharan Africa. Therefore, monitoring and assessing resident biota of a stream will provide both an integrative view of the effects of human influences and a rich variety of signals that can be used to diagnose the causes of degradation. Also, the need for evaluation and implementation of programmes of direct biological monitoring will be instrumental in 'restoring and maintaining' ecological integrity of the nation's waters. In Europe for example, it is a legal requirement for all jurisdiction within the Water Framework Directive (WFD). Macroinvertebrates, large enough to be seen with the naked eyes, form an integral part of the aquatic environment and are of ecological and economic importance as they maintain various levels of interaction between the community and the environment. My research over the years has been focused particularly in streams and rivers

using macroinvertebrates as bioindicators. Some of my works are reviewed here:

(a) The Impact of abattoir effluents (characterized by intestinal and stomach contents of slaughtered animals, ashes from roasted animals and blood stains) on water quality, distribution and abundance of Diptera were investigated in an urban stream, River Orogodo, Southern Nigeria, from July 2003 to June 2004. Water quality changes indicated significant differences ($p < 0.05$) in conductivity, dissolved oxygen, BOD_5, COD, total hardness, nitrate-nitrogen and phosphate-phosphorus between the three stations sampled. Higher values of these parameters were observed at the impacted station. The abundance and community structure of Diptera patterns, especially **Chironomidae, Culicidae and Syrphidae** families (all indicative of poor water quality) showed strong evidence of impact from the abattoir effluents. Analysis of faunal similarities showed that upstream station 1(unpolluted site) was significantly different from stations 2 and 3. The distinct taxa found in station 2 (the impacted station) suggest that the organic input from the abattoir favoured their abundance as most of them were opportunistic species (Arimoro *et al.* 2007).

(b) In another related development, we used aquatic insects as bioindicators of water quality and Ecological integrity of upper Warri River, in Niger Delta (Arimoro and Ikomi 2009). The structure, composition and diversity of the insects showed different physical and chemical variables had overiding influence on their distribution, diversity and composition as explored at three designated stations. A total of 57 taxa were recorded with station 2 accounting for the greatest Ephemeroptera–Plecoptera–Trichoptera (EPT) richness. Abundance of the aquatic insects was affected by the nature of the substrate, macrophytes and canopy cover at the various

stations examined. Based on the diversity and types of insects encountered in the study, the upper Warri River was reported as a fairly clean water body rich in EPT organisms. Pollution tolerant insect taxa such as chironomids and culicids larvae were only sporadically present.

(c) The published paper in (b) above attracted interest from some researchers in Imperial College, London. Professor Grahams Matthew specifically requested that his Cameroonian partners should make all effort possible to seek my expertise for remediation and best control measures for the control of black fly. Vice-Chancellor Sir, From 2009 to the present day, I have been actively involved in research and consultancy with the Yaounde Iniatiative Foundation - Cameroon where I am the Lead River Ecologist on a collaborative research to explore the influence of various insecticides used against the target organism (blackfly larvae, *Simulium*) on their abundance and distribution with the ultimate goal of using such an assemblage as a biomonitoring tool. This Project is sponsored by Imperial College Consultants Limited, UK, The World Health Organization (WHO) and the government of Cameroon. In June 2017, a meeting was organized to discuss basic questions about onchocerciasis control in Yaounde by the Ministry of Health and Economy and a review of the achievements already attained. I was opportune to chair the session on control of the nuisances caused by black fly and Onchocerciasis using hydrobiological evaluations. Efficient control method against disease causing insect vectors, first involved taking an inventory of all the different non target aquatic species (Plankton, invertebrates and fish) in the water body in order to minimize the effect of different chemical treatments on these non target species when insecticidal activity commences. Before this present investigation, the Cameroon Black Fly Suppression was based on field monitoring and laboratory identifications of black fly populations throughout

the catchment of the Sanaga River. The information gathered from the hydrobiological investigation is now used by trained biologists to schedule treatment operations in Sanaga River. Also, the results from ecotoxicological testing of different chemicals on target and non target species has enabled the calculations of appropriate concentrations of chemicals to be used for the control programme which will have little or no effect on the non target aquatic species.

(d) ***Point and non point sources / effluent on macroinvertebrates***

i. We investigated the impacts of co-occurring stressors (**organic wastes and various human activities**) on macroinvertebrate assemblages and environmental variables in a municipal stream, River Orogodo in southern Nigeria between the months of June 2004 and July 2005 (Arimoro and Ikomi 2008). Four sampling sites, each 25 m long were selected along 15 km stretch of the stream. There was a marked difference in the taxonomic composition of macroinvertebrates in the reference sites (I and IV) and those of the perturbed sites (II and III). A combined total of 78 benthic macroinvertebrate taxa were collected from the four sites of the river. The abundance and community structure patterns showed strong evidence of impact arising from the abattoir waste discharge such that the comparison of abundance values demonstrated high significance between the reference sites and the perturbed sites. Pearson correlation coefficient analysis indicated temporal trends in macroinvertebrate density and community composition. The high levels of BOD_5 values, total alkalinity, conductivity, nitrate and phosphates and low values in dissolved oxygen observed in Sites II & III was an indication of deterioration of the water quality as a result of various anthropogenic activities in these sites. Site III recorded rather high values in nutrients (Nitrates

and Phosphates) indicating significant input of organi discharges in this site. These factors produced spatial an temporal heterogeneity and exerted major influence on th benthic communities. Results obtained from this stud showed similarities in macroinvertebrates groups recorded i the perturbed sites II and III. The abundance of mayflie particularly, *Baetis* and *Siphlonurus*, Coleoptera (*Gyrinus Gerris lacustris*) and the near restriction of Trichopter (*Hydropsyche* and *Stenophylax*) to site I is an indication tha this site is relatively free from gross pollution. Th preponderance of Oligochaetes and diptera and deterioratio in water quality at sites II and III are attributed to the intensit of human activities at these sites.

ii. The impact of **sawmill wood wastes** on the distribution o benthic macroinvertebrates at the Sapele section of Beni River, Niger Delta, Nigeria, was investigated from March 200 to August 2005 (Arimoro and Osakwe 2006). A total of 43 individuals were collected by kick-sampling method representing 21 taxa of benthic macroinvertebrates. Thre stations, 1, 2, and 3, were selected from upstream of the site receiving wood wastes discharge, the impacted site and it down stream, respectively. Among the water quality variables conductivity, dissolved oxygen, biochemical oxygen demand (BOD_5), nitrate-nitrogen, phosphate phosphorus, transparency, and alkalinity were significantly different ($P<0.05$) among the stations. Orthogonal comparison by Duncan multiple range test showed that station 2 (the impacted site) was the cause of the difference. More sensitive species such as Ephemeroptera or Plecoptera were completely absent from station 2, the impacted site (Fig 2 and 3). Species abundance was similar in station 1 and 3, indicating that the wood wastes must have adversely affected the distribution of these macroinvertebrates, especially the

iii. Still on monitoring pollution, my colleagues and I investigated the effect of cassava effluents on macroinvertebrates along downstream reaches of the Orogodo River, the Niger Delta was carried out monthly from January to June 2006 (Arimoro *et al* 2008b). Three study stations were selected along the river course (upstream of the cassava impacted site, the cassava-impacted site, and downstream of the cassava impacted site). The study showed that cassava effluents caused a decrease in dissolved oxygen and pH and an increase in biochemical demand (BOD) and nitrates. Significant differences in these parameters were established among the stations sampled. Cassava effluents permitted the dominance of oligochaetes and dipterans at station II and this resulted in a decline and total elimination of other benthic macroinvertebrates, which are intolerant of the effects of effluents. It was evident from the study that water quaiity deteriorated as one moved downstream of the Orogodo River basin and this is mainly due to the indiscriminate disposal of effluents of untreated wastewater from cassava washing which is organic waste. Consequently, this has resulted in environmental degradation, which means that only non-sensitive species can survive while sensitive species are prone to extinction. Furthermore, non-sensitive species increased in population density due to the decline of competition with more sensitive species.

iv. The ecological impact of **rubber effluent** on macroinvertebrate communities of the Adofi River, Niger Delta area of Nigeria were evaluated for a 6 month-period as part of a study to understand pollution processes in the river that may lead to improved regulation and policy development (Arimoro 2009). Three sampling stations, each 25 m long were selected along 7 km stretch of the stream. Station 1, located upstream of the outfall from the rubber processing plant, station 2, immediately downstream of the effluent discharge point and station 3, 3 km downstream were sampled monthly. The rubber

effluent impacted negatively on the sediment and water chemistry by elevating the levels of some heavy metals (Ni, Pb, and Zn), chemical parameters as biochemical oxygen demand (BOD5), chemical oxygen demand (COD), conductivity and the amount of nutrients at the discharged site. The abundance and community structure showed variation between the effluent impacted site and the reference sites as most sensitive macroinvertebrate taxa were completely missing from the effluent impacted site.

v. **Canopy cover** is well known to influence the distribution of macroinvertebrates in temperate streams. Very little is known about how this factor influences stream communities in Afrotropical streams. Therefore, we evaluated the effects and possible interactions of environmental factors and canopy cover on macroinvertebrate community structure (abundance, richness, and diversity) were examined in four stations in Eriora River, southern Nigeria bimonthly from May to November 2010 (Arimoro *et al* 2012). We found out that canopy cover and environmental factors affected macroinvertebrates abundance, diversity, and richness and that the individual taxon had varying responses to these factors. These results help identify the mechanisms underlying the effects of canopy cover and other environmental factors on Afrotropical stream invertebrate communities.

vi. In another study (Arimoro *et al* 2015), we evaluated the impact of **anthropogenic influences** on the Ogba River using water chemistry and macroinvertebrate data sets obtained over a period of 6 months. Overall, the responses of macroinvertebrates to stress were reflected by the different assemblage structures recorded at the four study stations. Substrate and microhabitat obliteration and poor water quality appeared to be the factors responsible for the observed

assemblage structure in the Ogba River. CCA clearly separated the less impacted stations from the impacted ones. The CCA ordination also showed that macroinvertebrate fauna were significantly associated with environmental factors measured in Ogba River. Nitrate concentration, BOD_5 and electrical conductivity were higher at station 2 than at the other stations followed by station 3. The combination of variables might be used to identify and describe the multiple-scale stressor. Station 2 was an extreme outlier in our ordination analysis, with a very different macroinvertebrate assemblage including most of the tolerant dipteran groups such as *Cryptochironomus* spp., *Tanypus* and *Tabanus* spp. and the oligochaetes including *Nais, Dero, Stylaria, Dero* and *Pristina* species which were either not common or completely absent at the other stations. The dominance of naidid oligochaetes, chironomids and certain molluscs at stations 2 and 3 are indicative of deteriorating biotic and overall ecological health of the river. Several other studies have reported increases in abundance of these organisms in polluted water bodies in southern Nigeria (Arimoro *et al* 2008b; Arimoro and Ikomi 2008; Arimoro *et al* 2012). This study therefore provides information on the present status of the water quality of the Ogba River and serves as a baseline survey of macroinvertebrate fauna in the river. The outcome of this study can form the foundation for long-term assessment of the river and for the use of bioindicators for the management of the river system.

vii. The intensity of human-induced impacts on the distribution and diversity of macroinvertebrates and water quality of Gbako River, North Central, Nigeria, was evaluated monthly for 6 months using modified kick sampling techniques (Arimoro and Keke 2017). Four study stations were selected along the river course (upper reaches of less human impacts through mid-reaches with relative high human impacts to lower reaches of

less human impacts), designated as Stations 1, 2, 3, and 4. The low relative abundance of Ephemeroptera – Plecoptera – Tricoptera (EPT) taxa indicated that the environmental conditions were relatively stressed, along the whole stations. However, the abundance of mayflies (Ephemeroptera), Coleoptera *(Gyrinus, Dytiscus)*, and Anisoptera in all the sites studied is an indication that the sites are relatively free from gross pollution, especially at the upper reaches. Overall, relatively less human impacts in some of the study stations and the heterogeneous nature of the stations served as suitable habitat for a more diverse benthic fauna. The study revealed that macroinvertebrate communities responded to changes in disturbance as well as water quality along the river stations.

4. INVESTIGATIVE RESEARCH USING AQUATIC BIOTA

I have been involved in investigative research for more than 15 years now working with several Environmental firms, Federal Ministry of Environment, Niger Delta Biodiversity Project and a host of others. I shall try to provide a few examples of some of my findings and contributions here.

(a) Chevron was drilling a gas-exploration well at Funiwa, about six miles (9.6 kilometers) off Nigeria's delta coast, when it exploded in January 16, 2012 killing two workers. The fire that followed stopped on March 2 (After 46 days) after the flow of natural gas dried up. NOSDRA (the oil spill agency), reported that the accident was caused by equipment failure. Following this incidence a team of researchers including socioeconomic experts, Hydrobiologists, Engineers, Plant taxonomists and government regulators were contracted by Chevron Nig Plc to carry out a full scale investigation on the fire incidence and the extent of damage on the aquatic biota and effects on the livelihood of the adjoining communities. I was opportune to be the only Aquatic Ecologist on the team.

My findings showed the following: The fish assemblages in and around the area covering the brackish and marine waters communities in Bayelsa State including Fish town, Sangama, Koulama 1 & 2 and Izetu 1 & 2 are presented in Table 2. A total of 14 species of fish representing eight (8) families were collected (Table 2). The relatively low species richness may not be unconnected with the incidence of the rig fire disaster and perhaps the high rainfall at this time of the year that is associated with low fish abundance. The raging fire must have caused destruction of fishes and other sea foods. A greater number of the fish species were pelagics, which moved within the upper strata of the water column and are more likely to move away from environmental perturbation such as oil/gas pollution. The demersals occupy the lower stratum and could be more susceptible to habitat perturbation. There were a total of 2 species of inland origin and 12 species of marine origin in the entire study stretch.

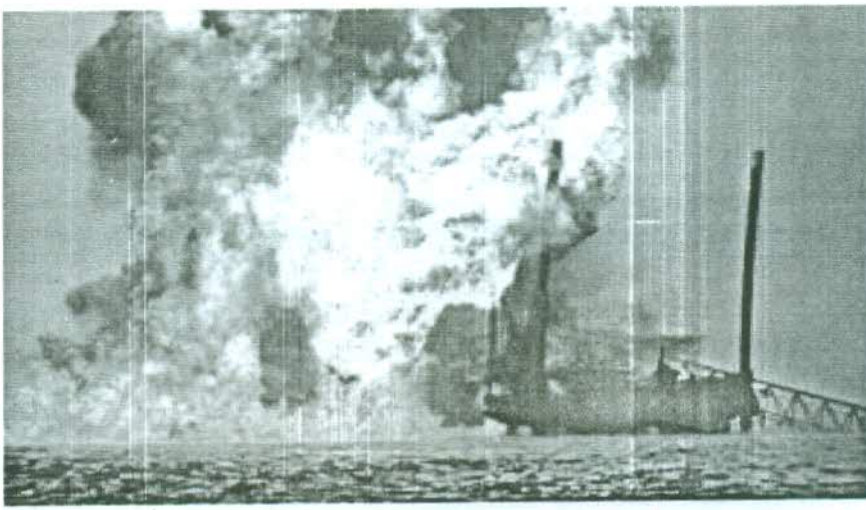
Adult fish have very sensitive sense organs so they taste the carbon and quickly leave the area of the discharge, unless they are trapped there in some way. It is very rare to have large fish kills due to gas explosion as was the case in this post impact assessment. In addition, more juvenile fishes were collected in this study in contrasts to oil spill effects that is known to eliminate more of the Juvenile fish as they are more vulnerable since they often live in shallow water near shore areas known as "nursery areas" until they become adult. The implication therefore of the impact is that the adult fish which were threatened by the pollution had reduced maturity rate and were forced into early reproduction thus ensuring the survival of their progeny. It means that the entire fish stock is capable of replenishing itself within a limited period of time (Arimoro *et al* 2014). There are at least five possible ways gas explosions can affect fish pollution: (1) eggs larvae can die in spawning or

Table 2: Fish Assemblage of the Study Area

Family	Taxa	Fish origin	
		Inland water (Rivers)	Marine Estuary
Cichlidae	*Chromidotilapia guentheri* (Sauvage, 1882)	+	
Eleotridae	*Eleotris vitatta* (Steindachner, 1870)		+
Mugilidae	*Liza falcipinnis* (Valenciennes, 1836)		+
	Mugil cephalus (Linnaeus, 1758)		+
	Liza grandisquamis (Valenciennes, 1836)		+
Clupeidae	*Ethmalosa fimbriata* (Bowdich, 1825)		+
	Pellonula afzellusi (Johnels, 1954)		+
	Ilisha africana (Bloch, 1795)		+
	Sardinella maderensis (Lowe, 1839)		+
	Chrysichthys nigrodigitatus (Lacepede, 1903)		+
Carangidae	*Caranx hippos* (Linnaeus, 1766)		+
Channidae	*Parachanna africana* (Gunther, 1861)	+	
Sciaenidae	*Pseudotolithus elongates*		
Polynemidae	*Polydactylus quadrifilis*		+
TOTAL		2	12

nursery areas due to anoxia or direct toxic effects (2) adult can die or fail to reach spawning grounds; (3) spawning behaviour may be changed; (4) local food species of the fish or larvae may be adversely affected or eliminated; and (5) sub-lethal effects may reduce fitness and affect the ability to endure environmental stress. As seen from this study, there was a drastic shift in feeding to herbivorous and carnivorous nutrition probably as a result of reduced plankton abundance and availability. Gas explosions of this magnitude not only threaten commercial and subsistence fishing by harming fish resources, but also by interfering with fishing operations and dramatically affecting catch rates. Studies have shown that gas explosions and fire have greatly reduced catches of fish around areas where they occur. These studies have demonstrated reduced catches over 20 miles away from the source. Gas explosion prevention and control-lessees must prepare contingency plans addressing prevention, detection, and clean up. Fishing is the major occupation of the people in the area and most of the communities are fishing communities. Because of the importance of fishing to the fishing communities, any environmental degradation will affect their means of

livelihood. Although not very devastating the gas explosion must have affected the fish distribution and composition in these areas but it is believed that since many juveniles fishes are found presently the fish stock will replenish within a short period of time but in the mean time any form of pollution should be avoided.



Source: http://businessnews.com.ng/2012/08/16/nosdra-recommends-3-billion-fine-against-chevron-for-oil-rig-fire/

We also reported the effects of industrial activities on zooplankton species composition in Koluama Area of Niger Delta in Nigeria following the fire incidence. The pollution affected the abundance and distribution of zooplankton in the area. The Cyclopoids copepods and cladocera each constituted 26% and 22% respectively. Rotifers comprised 17%; while Calanoid copepods constituted 12%. According to Abowei et al (2012) the zooplankton community groups were well distributed in the sampling stations except the Decapod crustacean *Mysis* sp. in station SW/SD 3 and SW/SD C1. This may be due to human and industrial activities in the study area going on at this station that

causes constant disturbance of the surface water column. There is the need to monitor human activities in the study area.

Environmental sensitivity of the rig fire disaster on the pelagic offshore ecosystem (phytoplankton, zooplankton and fish) indicated that these organisms, which spend their lifetime in the water column, are at high risk.

(b) Following the 'pristine' baseline survey of macrozoobenthic communities of soft bottom intertidal flats in Bodo Creek, spanning from May 2006 to April 2008 (Zabbey, 2011), the creek was hit by two large oil spills from August 2008 to February 2009. Zabbey and Uyi (2014) compared infauna macrobenthos community structure before and after the two major Bodo oil spills. However, pre-spill data on the relationships between environmental variables of interstitial water and the macroinfauna of Bodo Creek has not been published. In 2013, the Dutch Embassy in Nigeria, Abuja, assisted by a coalition of environmental civil society groups and non governmental organizations (NGOs), the National Coalition for gas flaring and oil spill in the Niger Delta (NACGOND), initiated cleanup mediation talks between the Bodo community and the Shell Petroleum Development Company (SPDC) (the mediation process hereafter referred to as the Bodo Mediation Initiative, BMI). The BMI has agreed a framework for the cleanup, remediation and restoration of Bodo Creek. These include cleanup targets and agreed applicable cleanup methods and timelines. In addition, UNEP (2011) recommended methods for the cleanup of oil-impacted environments in Ogoniland, and the Ogoni-wide cleanup was flag-off by the Federal government of Nigeria on the shores of Bodo Creek on June 2, 2016 (Vanguard 2016). Recently, Zabbey *et al* (2017) analysed prospect and potential challenges of remediating contaminated environments in the Niger Delta. They emphasized robust stakeholder

engagement, enactment of appropriate backing legislation, establishment of designated remediation fund and the need for baseline, especially before contamination as issues needing attention. To understand how a system is responding to restoration efforts, pre-impact (baseline) and post restoration monitoring data are critical. However, many restoration projects lack appropriate reference data, especially pre-disturbed and pre-restoration data for establishing meaningful performance benchmarks of the restoration initiatives. Moreover, such data dearth interventions may fail to develop and implement comprehensive restoration monitoring programmes. Owing to this, Dr. Zabby and I provided pre-impact baseline data to effectively monitor and evaluate the restoration of Bodo Creek (Zabbey and Arimoro 2017). The historical (pre-spill) information on the relationships between interstitial water physico-chemical gradients and macrozoobenthos community structure presented in our paper is hope to provide insights and template for monitoring and evaluating water quality responses during Bodo Creek 'restoration' chain. We present a rare case of available pre-spill data of how distribution and abundance of macrobenthic infauna were structured by some physical and chemical variables of interstitial water in Bodo Creek, lower eastern Niger Delta, Nigeria, before two major oil spills impacted the creek in 2008. Monthly composite samples of macrobenthos and interstitial water in four soft-bottom unvegetated intertidal flats were analysed for one year. Thirty six taxa, twenty-two families and four classes of macrozoobenthos were recorded. The bivalves *Lorepis aberrans, Macoma innominata, Senilia senilis,* and polychaetes *Nereis diversicolor, N. virens, N. pelagic* and *Clymenella torquata* were eurizonal in distribution and abundant, attaining sub-dominant and dominant status at the sites. Plans for cleanup, remediation and 'restoration' of Bodo Creek, have reached implementation stage as the Federal Government of Nigeria flagged off cleanup of Ogoniland on June

2, 2016. The usefulness of these data as potential template for monitoring and evaluation of water quality response to the proposed cleanup and restoration was highlighted in the study. Restoration of these triggers to life supporting gradients would largely influence recovery of the benthic fauna.

5. CHIRONOMID DEFORMITY AS AN INDICATOR OF ENVIRONMENTAL QUALITY

Freshwater chironomids are considered to be an ideal bioassay organisms since they spend most of their larval stages in surface sediments, their relatively sedentary forging behaviour ensures that their home ranges are restricted to localized areas, and have an ubiquitous distribution. Thus, the chironomid community structure is an index of environmental quality (Arimoro 2011).

The head capsule of chironomid larva is one of the most impacted structures in the body of the organism when the environment in which it lives is altered, and it is an indication of stress. Deformities of the head capsule in larval Chironomidae indicate sub-lethal effects of exposure to contaminants and are considered to be an early warning signal for environmental water quality deterioration. Several studies, especially in the temperate region, have examined the use of head capsules of different species of chironomid larvae in response to a variety of contaminants including increase in morphological deformities of antennae and other parts of chironomid larvae as a result of heavy metals elevation in surface water and sediments. Although Chironomidae larval deformities have been successfully used as a biomonitoring tool in other parts of the world, its potential as an indicator of pollution stress in Nigeria freshwater system is yet to be fully explored. From our investigation (Arimoro 2011; Arimoro *et al* 2015b; Odume *et al* 2012a; 2012b; 2014; 2016) The high incidences of head capsule and mouth parts deformities observed in Chironomids larvae could make them good

bioindicators for heavy metal and other anthropogenic pollution. Therefore, we recommend their inclusion in biomonitoring, especially in tropical Africa as it will add inferring power to assess ecosystem health and contaminated sediments.

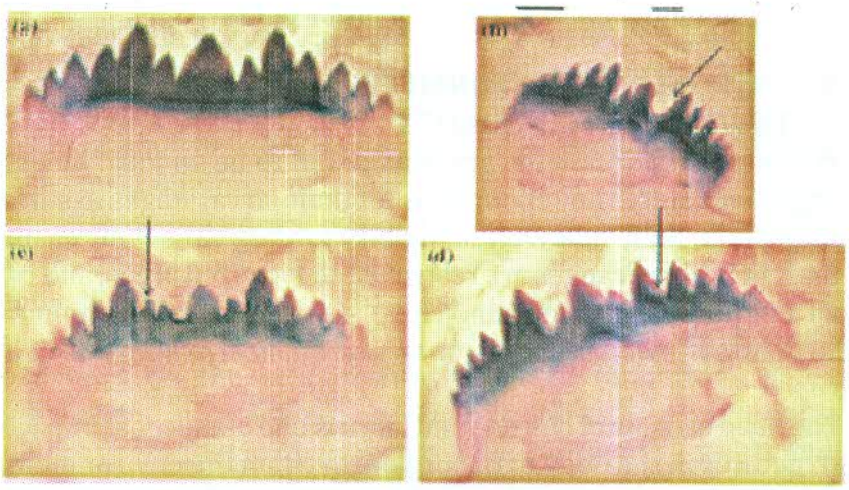


Figure 4. Chironomus mentum: (a) normal, (b) mentum with a missing lateral median tooth, (c) mentum with multiple deformities, a gap and extra tooth and (d) missing second lateral tooth.

Based on morphological deformities in the mentum of selected genera, we developed a new index, the extended toxic score index (ETSI), to assess the extent of deviation of ecological conditions at the impacted sites from that at the control site. The development of the index followed a five-step empirical approach (Odume *et al* 2016).

6. PLANKTON BIODIVERSITY AND USE AS INDICATORS

Zooplankters offer several advantages as indicators of environmental quality in both lakes and rivers: as a group, they have worldwide distribution and the species composition and community structure are sensitive to changes in environmental

conditions, nutrient enrichment and different levels of pollution (Arimoro and Oganah 2010; Anyanwu *et al* 2013). Zooplankton play an important ecological role in lakes and rivers, feeding on non-living organic matter, phytoplankton and bacteria, and in turn being eaten by secondary consumers such as fish. The physicochemical parameters of an aquatic ecosystem are very important in assessing the composition of any aquatic biota and also their sensitivity to pollution. Therefore, a major interest in zooplankton investigation is to understand environmental factors that influence their diversity. Certain knowledge of the responses of zooplankton to changes in water quality could therefore constitute an important tool to be used by water managers in Nigeria to continually and rapidly assess the health of the water bodies. From our investigation we report that the changing water quality status of the water bodies such as Orogodo River (Arimoro and Oganah 2010), Ogba River (Anyanwu *et al* 2013), Lower Kaduna River (Arimoro *et al* 2018) affected the zooplankton diversity and abundance and such measure could be used as a biomonitoring tool to determine the ecological health of the river.

7. EXPLORING COMMUNITIES IN A TROPICAL BIODIVERSITY HOTSPOT

Exploring and describing biodiversity and the mechanisms structuring it is fundamental to advancing ecology. This is particularly pertinent in understudied biogeographical regions, such as the Afrotropics, that are characterised by strong seasonal climatic shifts. We investigated the characteristics of stream biodiversity in the Niger Delta region of Nigeria, a tropical biodiversity hotspot, by examining patterns in 20 stream invertebrate communities across both the wet and dry seasons (Tonkin et al. 2016). For this, we took a multifaceted approach accounting for the three levels of biodiversity (a, b and c), including partitioning the nestedness and turnover components of b diversity, regional occupancy abundance patterns, niche

characteristics, and the environmental drivers of community structure. a diversity was low in these streams, with strong turnover between sites leading to high b diversity contributing to regional biodiversity, but there was little variation in communities between seasons. The proportion of sites occupied by taxa declined with increasing niche position, and decreasing niche breadth. Occupancy was predicted well by a combination of these two factors (niche position and breadth), but not mean local abundance, as the abundance-occupancy link was an upper-limit unimodal relationship. Onaverage, community structure was linked more strongly to environmental variables in the wet season. Our findings demonstrate the clear role of spatial, but not temporal, turnover in assemblages, which likely reflects the environmental heterogeneity of this region. This is further supported by the fact that regional occupancy was mostly related to niche characteristics, particularly niche position. We emphasised the importance of continued basic and applied ecological work in this important biogeographic region to enable better protection of its biodiversity.

Utilization of Nuisance Aquatic Resources for Wealth Creation

Water hyacinth, *Eichhornia crassipes* is a free floating aquatic that constitutes a nuisance to fishing and transportation activities in many river communities. Due to its high growth rate, the plant outpaces all efforts directed at containing it. Consequently, my research associates and I with the assistance of GEF-UNDP have designed a programme for utilizing it to produce crafts and furniture for the Niger Delta Biodiversity Project (NDBP). We held Sensitization workshop/exhibition for Eastern Obolo communities in Akwa Ibom state on the management and sustainable utilization of water hyacinth as a means of livelihood where I was the chief resource personnel We are also producing organic manure from this weed. Our major research effort in this

regard concerns efficient and cost effective means of harvesting and processing the plant. We have already made an assortment of crafts from the plant and are exploring ways of commercializing it for youth empowerment through job creation.

Mentoring and Manpower Development

My Vice Chancellor Sir, I want to state here that over the years of my career as a lecturer and researcher, I have contributed to the development of manpower through teaching and mentoring of students. We have produced manpower for different sectors of the economy including the education, manufacturing, regulatory, and petroleum sectors. I have supervised several undergraduate research projects and over 30 M.Sc/MTech. dissertations. I have also successfully supervised Four PhD students. One of my M.Sc student when I was in Rhodes University Grahamstown is now the Director of Unilever Centre for Environmental Water Quality (UCEWQ), Institute for Water Research Rhodes University, Grahamstown. I got the research grant/Fellowship for him to study at the institute. Outside this, I was the lead researcher on UNDP/GEF fund for Development of a School Curriculum Teaching Modules on Biodiversity for use in the Niger Delta area Schools and Institutions and study of mangroves and barrier islands in the Niger Delta. I was the Facilitator of USAID West Africa Water, Environment and Health Network (Federal University of Minna, Niger State, Nigeria) USAID sub award-University of Mississippi, USA value of $50,000.00. and the CARNEGIE RISE award (USA) for joint collaborative research in Biomonitoring of Chanchaga River, Niger State, Nigeria, TWAS-DFG award (The world academy of Science and German Research Foundation) collaboration visit to Senckenberg Research Institute and Natural History Museum, Frankfurt, Germany, IFS (International Foundation for Science), Sweden scholarship/grant for research in the development of bioassessment protocols for Nigerian streams. This awards and

grants has enabled me to build capacity in the area of biomonitoring for my students

Consultancy and professional services

As an Aquatic Ecologist, I have had the privilege in my career of interacting with the other professionals outside the education sector through consultancy especially in the Niger Delta Biodiversity Projects. This town and gown mix which span my career to-date has indeed been rewarding and most especially afforded me the opportunity of using tools that are not available in the university in exploring the freshwater and offshore marine environment. I have served as consultant to assess the environmental impact of several projects ranging from oil field development, crude oil spill fingerprint, road constructions, goldmine exploration, dam rehabilitation, Tank farm, Community Biodiversity Plan, gas flare down, Independent power project, free trade zone, fertilizer plant, Leisure resorts, refine crude oil production facility construction, etc.

CONCLUSION AND RECOMMENDATIONS

Aquatic biodiversity is extremely threatened. Findings from the comprehensive assessments undertaken by my colleagues and I to date show that aquatic biodiversity to be highly threatened, possibly more so than in other systems. This is largely a result of the high degree of connectivity within aquatic systems such that threats like pollution and invasive alien species spread more rapidly than in terrestrial ecosystems.

- *Public awareness of the threat to aquatic species needs to be raised as well as awareness to ecosystem services.* The value of aquatic species to peoples' livelihood need to be evaluated and relevant information made available to demonstrate these values as key part of future bioassessments.

- *Protected areas must be designed to protect aquatic species.* An aquatic bio-reserve is a defined space within a water body in

which fishing is banned or other restrictions are placed in an effort to protect plants, animals, and habitats, ultimately conserving biodiversity.

- *We need to support in-situ conservation actions.* Increased support of *in-situ* conservation initiatives capable of addressing immediate known problems is needed.

- *Environmental Impact Assessments (EIAs) need to take better account of impacts to aquatic species.* EIA guidelines and legislation should aim to highlight potential impacts to aquatic species. EIA specialists should be encouraged to consult the information being collated through the biodiversity assessments conducted by IUCN, its partners and others.

My Vice-Chancellor Sir, I must state here that this University urgently requires a museum of natural history where aquatic specimens will be preserved for posterity. The University can served as the centre for the north central region. Also, we urgently require a Biological garden.

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PROFILE OF THE INAUGURAL LECTURER

Professor Francis Ofurum Arimoro is the first son of Elder and Mrs James Ofiri Arimoro, born on the 20th of April 1970. He started his primary school education at Orogodo Primary School, Agbor, Delta State and left after second term in Primary 1 to St. Theresa's Primary School, Makurdi, Benue state where he completed his Primary Education. He was offered admission to the prestigious Mt. St. Gabriel's Secondary School Makurdi where he started and completed his Secondary School Education from 1982 to 1987. He gained admission to University of Jos from 1988 to 1992 where he graduated with a Second Class Upper degree in Zoology. During his undergraduate study, he was a University Scholar receiving several awards and prizes. For instance, he was the best student in academic excellence in the Faculty of Natural Sciences and best graduating student in academic excellence in Zoology. After his National Youth service in Benin City he gained admission to the University of Jos where he read M.Sc. Applied Hydrobiology and Fisheries with distinction grade in 1996.

Francis Arimoro was a Biology teacher for some years at Jos, Agbor and lastly in Comprehensive Secondary School, Igbodo, Delta state before gaining employment as an Assistant Lecturer in the Department of Zoology, Delta State University, Abraka. He started his PhD studies and research from 2002 to 2007 at the Delta State University, Abraka. He was the first student to be awarded a PhD degree in the Faculty of Science, Delta State University in 2007. He rose through the ranks and eventually was offered the position of an Associate Professor of Biological Sciences at the Federal University of Technology, Minna in 2012

and was promoted to Professor of Biological Sciences on 1st October, 2016.

He did a one year postdoctoral research in Water Resource Management at Rhodes University, Grahamstown, South Africa supported by a Carnegie Rise scholarship, USA from February 2009 to January 2010. During the period, he was involved in the development of a rapid bioassessment protocol for Nigerian rivers using multimetric and multivariate statistical approaches. This project was later sponsored by the International Foundation for Science (IFS) in Sweden till 2011. He was a visiting Research Scientist/Counterpart Lecturer to the Department of Aquatic Sciences and Fisheries, University of Namibia in August 2009 and a visiting scholar in the Department of River Ecology & Conservation, Senckenberg Research Institute and Natural History Museum, Gelnhausen, Germany from April to July 2014.

Over the years, he has been actively involved as an Aquatic Ecologist and Zoologist in Environmental Impact Assessment for some organizations including several oil and gas companies as well as seating as Panel Reviewer (Ecologist) for several EIA reviews organized by the Federal Ministry of Environment. He was involved as the lead consultant in UNDP/GEF fund for development of a School Curriculum Teaching Modules on Biodiversity for use in the Niger Delta area Schools and Institutions, survey of the status of mangroves and Barrier Island in Niger Delta, Akai Edoholdua Community Biodiversity Action Plan, developing a Community Biodiversity Action Plan at Kaiama (Oruwari Land Kolokuma/Opokuma LGA, Bayelsa State. He is currently the Lead River Ecologist in a collaborative research to investigate the aquatic invertebrates' assemblages in the Sanaga River, Cameroon with sponsorship from Imperial College Consultants Limited, UK and the World Health Organization (WHO).

Professor Arimoro has held several positions at both the Delta state University, Abraka and FUT Minna. He held the position of Registration Officer/Course Adviser, Coordinator, SIWES, Member, Pre-Degree Committee, Examination Officer, Postgraduate Coordinator, Chairman-Accreditation committee, Department of Biological Sciences, Federal University of Technology, Minna and the Head of Department of Animal Biology to date.

Francis Arimoro has lectured undergraduate and postgraduate courses, as well as professional courses and has great passion for teaching. This has entailed both the development of courses and course materials, as well as their coordination. As a mentor, he has supervised over 100 undergraduate research projects, more than 30 Master theses and four PhD theses. He has acted as External Examiner to over 40 postgraduate research projects in various Nigeria universities and outside the country and has attended many conferences, workshops and training within and outside Nigeria. He has to his credit over 120 scholarly publications in reputable journals, edited proceedings and chapters in edited books. He is currently on the Editorial Board of four Journals including African Journal of Aquatic Sciences, Journal of Aquatic Sciences and International Journal of Applied Biological Research (IJABR) and the Editor in Chief of Applied Science Research Journal. He is an active member of several associations and professional bodies within and outside the country. He is the current President of Freshwater Biological Association of Nigeria (FBAN), the Publicity Secretary of Zoological Society of Nigeria (ZSN), a fellow of African Scientific Institute (ASI,) etc. He is the Principal Investigator of a USAID/University of Mississippi sponsored programmes at the Federal University of Technology, Minna and has also won and managed successfully some research grants in recent times. Professor Arimoro has innate passion for wildlife and is happily married with children.