INAUGURAL LECTURE SERIES 23

LADOKE AKINTOLA
UNIVERSITY OF TECHNOLOGY
OGBOMOSO, NIGERIA

BRIDGING THE POVERTY GAP THROUGH THE AQUATIC ENVIRONMENT

PROF OLATUNDE OLUBANJO FAWOLE
B.Sc. (Lagos) M.Sc. (Ibadan) M.B.A. (Ife) Ph.D (Ife) MZSN, FCPA, FPMA
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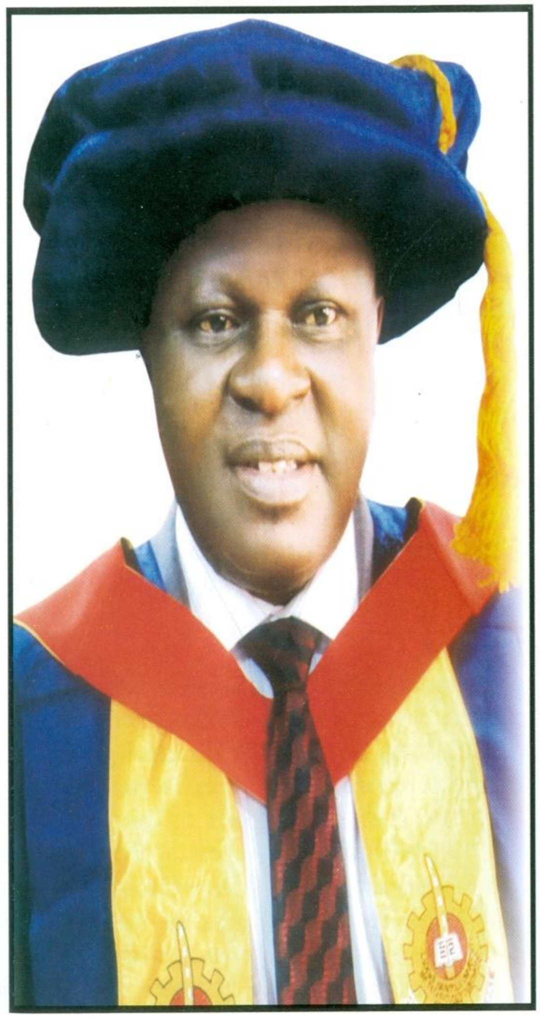

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BRIDGING THE POVERTY GAP THROUGH THE AQUATIC ENVIRONMENT

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The Registrar

The Bursar

The University Librarian

The Provost

All Deans

Distinguished Members of the University Senate

Other respected Colleagues here present

Other members of University Community

Students of this great University

Gentlemen of the Press

Distinguished Guests

Distinguished Ladies and Gentlemen

PREAMBLE

Today's inaugural Lecture is the second in the Department of Pure and Applied Biology and the first in the Environmental Biology unit of the Department. The Department is a foundation department in the Faculty of Pure and Applied Sciences. The Faculty prides itself as the mother of all other faculties in the University. It is also referred to as the Gateway Faculty as all first year courses are handled by the faculty. The Department is well acknowledged for its pioneering role in research, teaching and supervision at the postgraduate level, local and international networking, consultancy and collaboration and a visible star among institutions with outstanding community engagement in applied field research.

Introduction:

It is with the greatest pleasure and honour that I stand before you today to deliver my inaugural lecture on a topic that borders on ways of improving the quality of life of an average Nigerian through our God-given and Natural Resources. The question to be asked is this "Why bridging the poverty gap?" and not total eradication of poverty through the aquatic environment. The answer to this is "if total eradication through the aquatic environment is a tall dream, at best the gap can be reduced i.e. the poverty level can be reduced using the aquatic environment as the medium".

Several parameters can be used to classify aquatic environment. The Aquatic Environment consists of two major types. The saline/sea water constitutes 97% while only 3% of the Earth's water is fresh water. Most of the fresh water is in icecaps and glaciers (68.7%) and groundwater (30.1%), while all lakes, rivers and swamps combined only account for a small fraction (0.3%) of the Earth's total freshwater reserves (Figure 1).

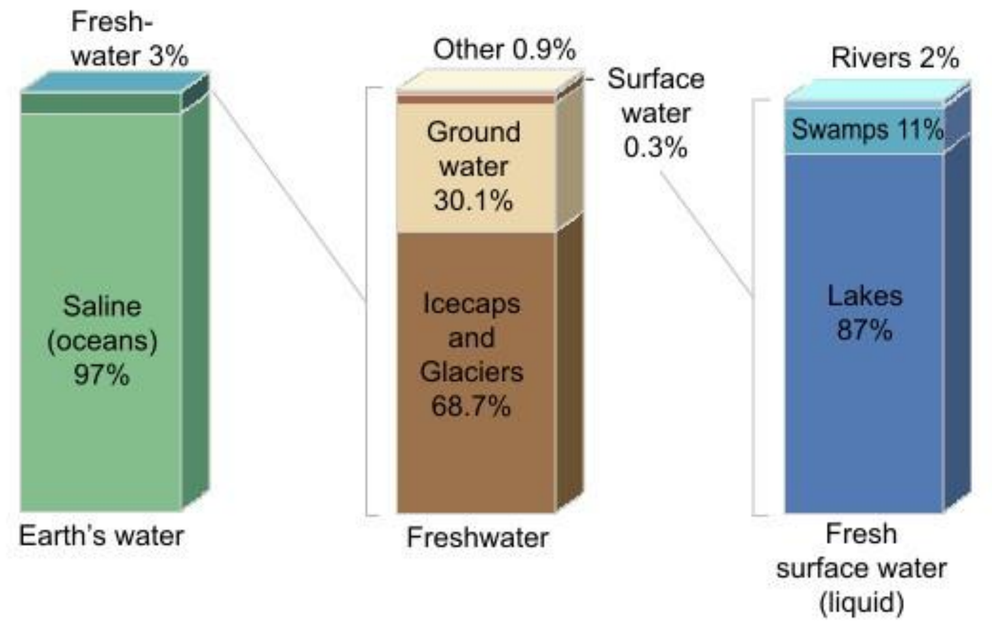


Figure 1: Distribution of Earth Water (USGS 1993)

Also, broadly, in terms of distribution of the resources in the aquatic environment, there are three major habitats and these are Freshwater habitat, Estuarine (Brackish) habitat and the Marine habitat. The Freshwater habitat is characterized by low salinity (**0.5%** or less) and they include streams, puddles, rivers, ponds and lakes. The Estuarine habitat is a halfway house between conditions in the sea and those in the freshwaters i.e. estuarine water is a mixture of saltwater from the sea and freshwater from the land. The salinity range is between **0.5% and 29%**. Examples are lagoons and mouths of rivers

The marine habitat consists of the great masses of saltwater on the earth surface with a salinity range of between 30 and 35**%.** However, it must be noted that the marine environment covers a little over 362 million.km^2 (71%) of the total 510 million km^2 of the total earth surface. The seas and oceans alone constitute approximately two-third of the total earth's surface. Others (terrestrial environment, fresh water e.t.c.) are 29% bringing out the importance of aquatic environment.

Aquatic ecosystem

An **aquatic ecosystem** is an ecosystem in a body of water. Communities of organisms that are dependent on each other and on their environment live in aquatic ecosystem and this includes marine, brackish and freshwater ecosystems (Alexander, 1991)

Marine

Marine ecosystems cover approximately 71% of the Earth's surface and contain approximately 97% of the planet's water. They generate 32% of the world's net primary production (Alexander, 1991). They are distinguished from fresh water ecosystems by the presence of dissolved compounds, especially salts. Approximately 85% of the dissolved materials in water are sodium and chlorine. Seawater has an average salinity of 35 parts per thousand (ppt) of water. However, actual salinity varies among different marine ecosystems (USEPA, 2006)

Marine ecosystem can be divided into many zones depending upon water depth and shoreline features (Figure 2). The oceanic zone is the vast open part of the ocean where animals such as whales, sharks, and tuna live. The benthic zone consists of substratum below water where many invertebrates live. The littoral zone is the area between high and low tides; in this figure it is termed the intertidal zone. Other near-shore (neritic) zones can include estuaries, salt marshes, coral reefs, lagoons and mangrove swamps. In the deep water, hydrothermal vents may occur where chemosynthetic sulfur bacteria form the base of the food web.

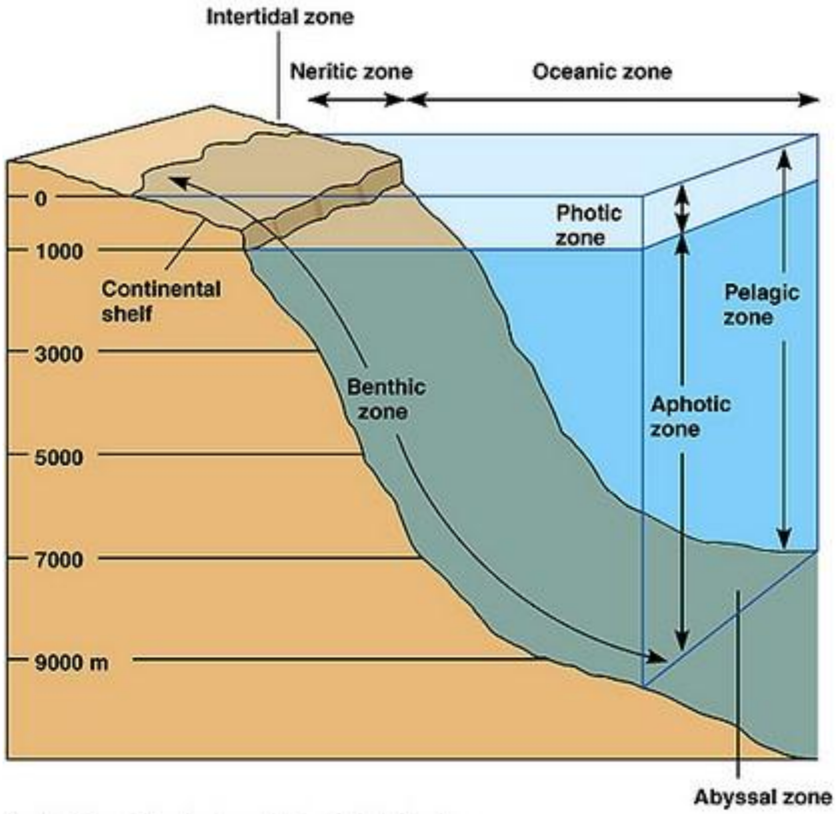


Figure 2: Zonation in marine environment

Classes of organisms found in marine ecosystems include brown algae, dinoflagellates, corals, cephalopods, echinoderms, and sharks. Fishes caught in marine ecosystems are the biggest source of the commercial foods obtained from wild populations (Alexander, 1991)

Environmental problems concerning marine ecosystems include unsustainable exploitation of marine resources (for example overfishing of certain species), marine pollution, climate change, and building on coastal areas (Alexander, 1991).

Brackish/Estuarine

An estuary is a partly enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea. Estuaries form a transition zone between river environments and maritime environments.

Example of this in Nigeria is Lagos Lagoon which is more than 50 km long and 3 to 13 km wide, separated from the Atlantic Ocean by a long sand spit 2 to 5 km wide, which has swampy margins on the lagoon side. Its surface area is approximately 6,354.7 km^2 (Okunsipe, 2008). The lagoon is fairly shallow and is not plied by ocean-going ships, but by smaller barges and boats. The lagoon receives the discharge of the Ogun River and the Osun River.

Nigeria’s mangrove (Figure 3A, B) is acclaimed the largest in Africa and third largest in the world behind Indonesia and Brazil. Much of this mangrove lies within the Niger Delta region. The Cross River estuary has its name from the Cross River, the largest river emptying into this estuary. The mangrove is relatively untouched, with exploitation as the only source of significant human impact. In the rest of the Niger Delta, oil exploration and exploitation processes, including gas flaring are additional disturbances of the mangrove ecosystem.

Figure 3A: Forest of *R. racemosa*, during low tide at Bayeku, Lagos State, Nigeria, typifying a mangrove swamp environment (Adekanmbi and Ogundipe, 2009).

Figure 3B Niger Detta Mangrove (Chen, 2013)

Freshwater

Freshwater ecosystems cover 0.80% of the Earth's surface and inhabit 0.009% of its total water. They generate nearly 3% of its net primary production (Alexander, 1991). Freshwater ecosystems contain 41% of the world's known fish species (Daily 1997).

There are three basic types of fresh water ecosystems:

- **Lentic**: slow moving water, including pools, ponds, and lakes
- **Lotic**: faster moving water, for example streams and rivers.
- **Wetlands:** areas where the solid is saturated or inundated for at least part of the time (Vaccari 2005).

Lentic

Lake ecosystems can be divided into zones. One common system divides lakes into three zones (Figure 4). The first, the littoral zone, is the shallow zone near the shore. This is where rooted wetland plants occur. The offshore is divided into two further zones, an open water zone and a deep water zone. In the open water zone (or photic zone), sunlight supports photosynthetic algae, and the species that feed upon them. In the deep water zone, sunlight is not available and the food web is based on detritus entering from the littoral and photic zones. The offshore areas may be called the pelagic zone, and the aphotic zone may be called the profundal zone. Inland from the littoral zone, one can also frequently identify a riparian zone which has plants still affected by the presence of the lake; this can include effects from windfalls, spring flooding, and winter ice damage. The production of the lake as a whole is the result of production from plants growing in the littoral zone, combined with production from plankton growing in the open water.

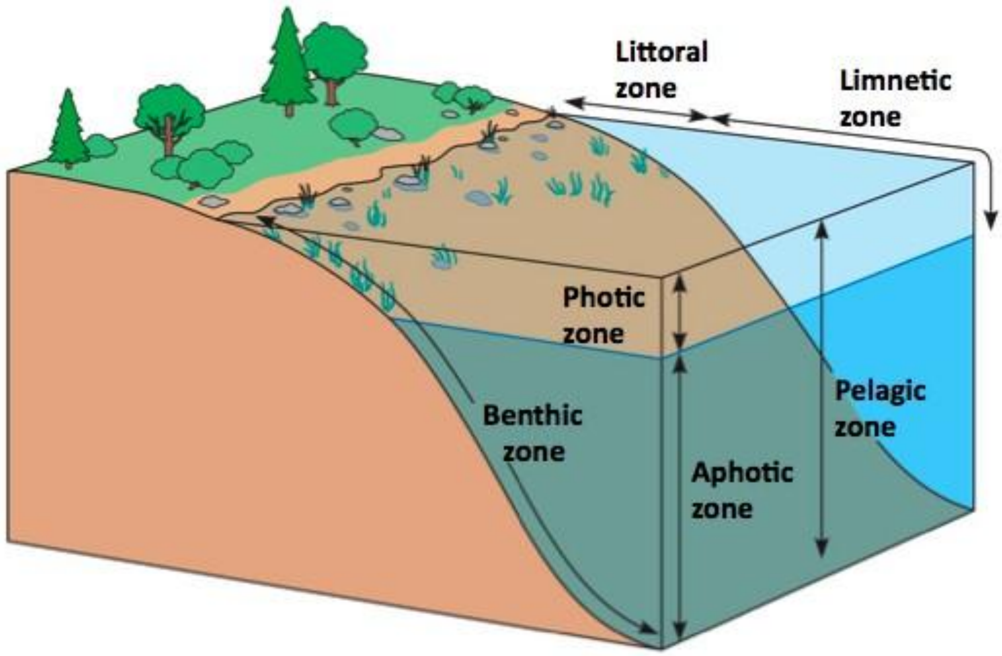


Figure 4: Zonation in Lake

Two important subclasses of lakes are ponds, which typically are small lakes that intergrade with wetlands, and water reservoirs. Over long periods of time, lakes, or bays within them, may gradually become enriched by nutrients and slowly fill in with organic sediments, a process called succession. When humans use the watershed, the volumes of sediment entering the lake can accelerate this process. The addition of sediments and nutrients to a lake is known as eutrophication (Alexander, 1991).

Ponds

Ponds are small pools with shallow water, marsh, and aquatic plants (Clegg, 1986). They can be further divided into four zones: vegetation zone, open water, bottom mud and surface film (Clegg, 1986). The size and depth of ponds often varies greatly with the time of year; many ponds are produced by spring flooding from rivers. Food webs are based both on free-floating algae and upon aquatic plants. There is usually a diverse array of aquatic life, with a few examples including algae, snails, fish, beetles, water bugs, frogs, turtles, others and muskrats. Top predators may include large fish, herons, or alligators. Some ponds dry up each year thereby killing resident fish that provide important refuge for amphibian breeding (Keddy, 2010). Ponds that dry up completely each year are often known as vernal pools. Some ponds are produced by animal activity, including alligator holes and beaver ponds, and these add important diversity to landscapes (Keddy, 2010).

Lotic

The major zones in river ecosystems are determined by the river bed's gradient or by the velocity of the current. Faster moving turbulent water typically contains greater concentrations of dissolved oxygen, which supports greater biodiversity than the slow moving water of pools. This distinction forms the basis for the division of rivers into upland and lowland rivers. The food base of streams within riparian forests is mostly derived from the trees, but wider streams and those that lack a canopy derive the majority of their food base from algae. Anadromous fishes are also important sources of nutrients. Environmental threats to rivers include loss of water, dams, chemical pollution and introduced species (Alexander, 1991). A dam produces negative effects that continue down the watershed. The most important negative effects are the reduction of the spring flooding, which damages wetlands, and the retention of sediment, which leads to loss of deltaic wetlands (Keddy, 2010).

Wetlands

A wetland is a place where the land is covered by water either salt; fresh or somewhere in between. In order words, wetland occur where water meet land (Figure 5A, B). Wetlands are land areas that are completely, partly or temporarily inundated, such as floodplains, swamps and

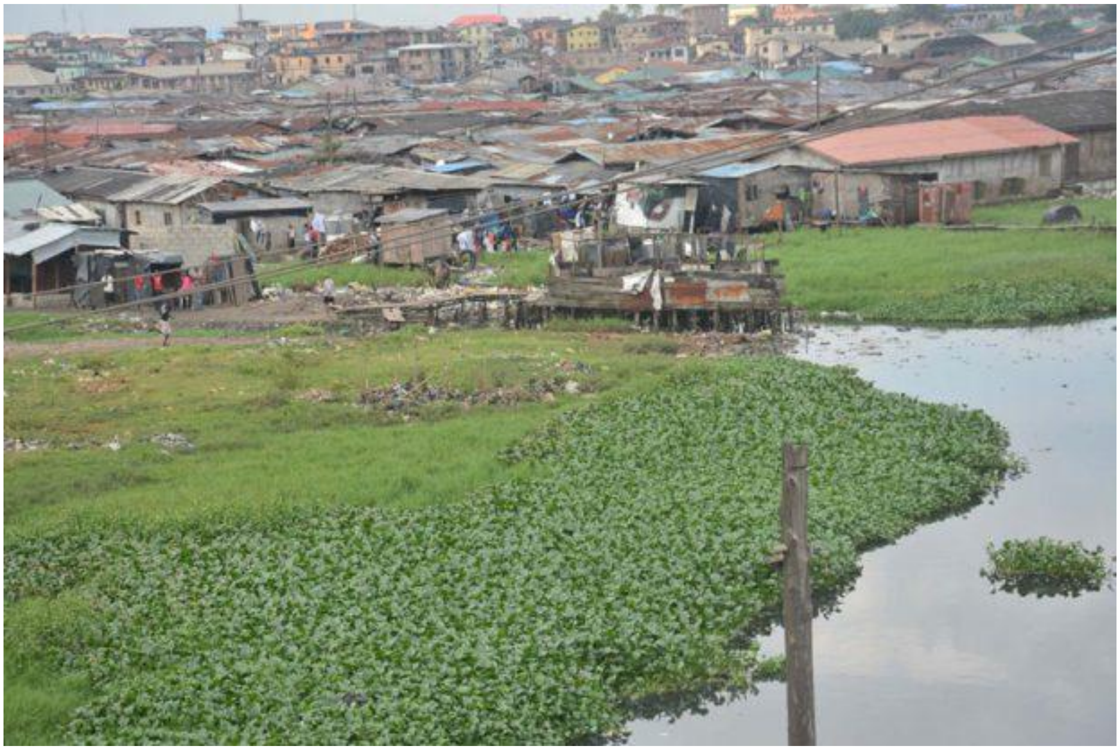


Figure 5A: Kiokio wetland area 36km North of Lagos (http://www.environewsnigeria.com/lagos-cost-urbanisation/)

Figure 5B: Wetland along Benue River South east of Yola, Adamawa State Source (Wikimedia Commons, 2006) https://commons.wikimedia.org/wiki/File:Benue_SE_Yola.jpg marshes, peat lands, lakes, mangroves, and river deltas. According to the Ramsar Convention of Wetlands, the inundation of a wetland is a maximum of six meters. Wetlands exist in every country and in every climatic zone, from the polar regions to the tropics. They are distributed around the world. Africa has 131 million hectare of wetlands which spread over most countries (Figure 6), varying in type from saline coastal lagoons in West Africa to fresh (Nigeria inclusive) and brackish water lakes in East Africa.

Wetlands are dominated by vascular plants that have adapted to saturated soil (Alexander, 1991). There are four main types of wetlands: swamp, marsh, fen and bog (both fens and bogs are types of mire). Wetlands are the most productive natural ecosystems in the world because of the proximity of water and soil. Hence they support large numbers of plant and animal species. Due to their productivity, wetlands are often converted into dry land with dykes and drains and used for agricultural purposes. The construction of dykes, and dams, has negative consequences for individual wetlands and entire watersheds (Keddy, 2010). Their closeness to lakes and rivers

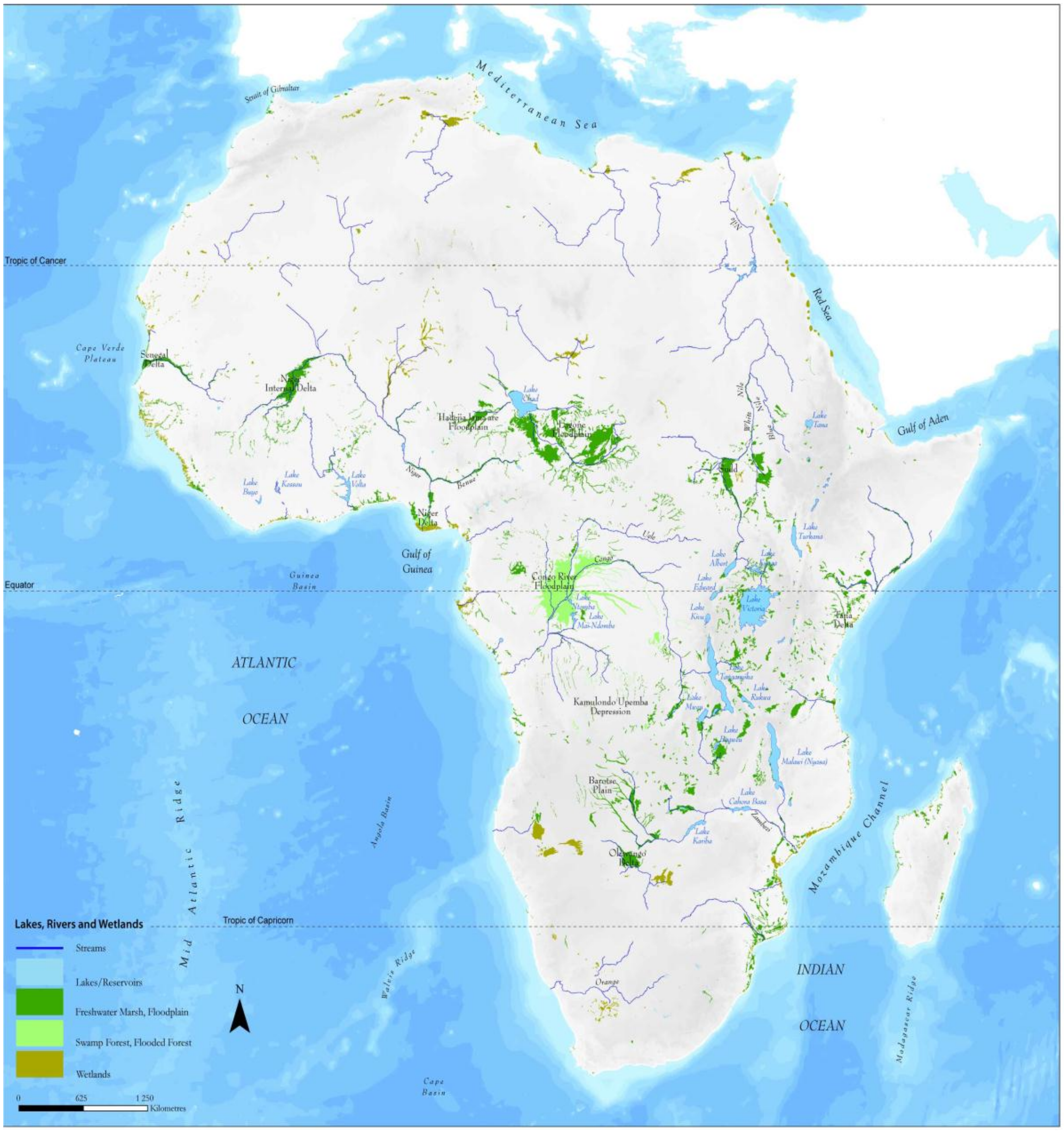


Figure 6: Locations of Wetlands across African countries

means that they are often developed for human settlement (Keddy, 2010). Once settlements are constructed and protected by dykes, the settlements then become vulnerable to land subsidence and ever increasing risk of flooding (Keddy, 2010). The Louisiana coast around New Orleans is a well-known example (Keddy *et al*. 2007); the Danube Delta in Europe is another (Gastecscu, 1993)

Wetlands can be part of the lentic system, as they are formed naturally along most lakes shores, the width of the wetland and littoral zone being dependent upon the slope of the shoreline and the amount of natural change in water levels, within and among years. Often dead trees accumulate in this zone, either from windfalls on the shore or logs transported to the site during floods. This woody debris provides important habitat for fish and nesting birds, as well as protecting shorelines from erosion.

<u>Functions of Aquatic Ecosystem</u>

Aquatic ecosystems perform many important environmental functions. For example, they (i) recycle nutrients, (ii) purify water, (iii) attenuate floods, (iv) recharge ground water and (v) provide habitats for wildlife (Loeb, 1994). Aquatic ecosystems are also used for (vi) human recreation, and are very important to the (vii) tourism industry, especially in coastal regions (Daily, 1997). A typical example is Lagos coastal area being used as tourist and recreation centre while Oluminrin water fall (Figure 7A,B) in Erin Ijesa and Ikogosi warm spring (Figure 8A, B) in Ekiti State are being used for tourism

A B

Figure 7(A,B) Oluminrin water fall in Erin Ijesa

A B

Figure 8A, B: Plate Ikogosi wam spring

The health of an aquatic ecosystem is degraded when the ecosystem's ability to absorb a stress has been exceeded. A stress on an aquatic ecosystem can be a result of physical, chemical or biological alterations of the environment. Physical alterations include changes in water temperature, water flow and light availability. Chemical alterations include changes in the loading rates of biostimulatory nutrients, oxygen consuming materials, and toxins. Biological alterations include over-harvesting of commercial species and the introduction of exotic species. Human populations can impose excessive stresses on aquatic ecosystems (Leob, 1994). There are many examples of excessive stresses with negative consequences. The environmental history of the Great Lakes of North America can be used to illustrate this problem, particularly how the trio of multiple stresses such as water pollution, over-harvesting and invasive species combine (Vallentyne, 1974) . The Norfolk Broadlands in England illustrate similar decline with pollution and invasive species (Moss, 1983). Lake Pontchartrain along the Gulf of Mexico illustrates the negative effects of different stresses including levee construction, logging of swamps, invasive species and salt water intrusion (Keddy *et al.*, 2007). Primary causes of wetland loss in Lagos Metropolis in Nigeria are human activities which include incessant sand filling and conversion of wetland environment to economic uses (construction) and perennial flooding that are common and regular occurrences in the metropolis (Ajibola *et al*., 2012).

Abiotic characteristics

In aquatic ecosystem, abiotic characteristic are non-living chemical and physical parts of the environment that affects living organisms and the functioning of the ecosystem. As part of the ecosystem, these factors do affect the living things in it but are not living themselves. The abiotic factors include light intensity, water flow, temperature, dissolved oxygen, acidity (pH), salinity and depth. Light intensity is an important factor in aquatic ecosystem.

An ecosystem consists of biotic communities that are structured by biological interactions and abiotic environmental factors. Some of the important abiotic environmental factors of aquatic ecosystems include substrate type water depth, nutrient levels, temperature, salinity, and flow (Leob, 1994; Keddy, 2010). It is often difficult to determine the relative importance of these factors without rather large experiments. There may be complicated feedback loops. For example, sediment may determine the presence of aquatic plants, but aquatic plants may also trap sediment, and add to the sediment through peat.

The amount of dissolved oxygen in a water body is frequently the key substance in determining the extent and kinds of organic life in the water body. Fish need dissolved oxygen to survive, although their tolerance to low oxygen varies among species; in extreme cases of low oxygen some fish even resort to air gulping (Graham, 1997). Plants often have to produce parenchyma, while the shape and size of leaves may also be altered (Sculthrope, 1967). Conversely, oxygen is fatal to many kinds of anaerobic bacteria (Manahan, 2005). Nutrient levels are important in controlling the abundance of many species of algae (Smith, 1982).

The relative abundance of nitrogen and phosphorus play a great role in determining which species of algae predominates (Smith, 1983). Algae are a very important source of food for aquatic life, but at the same time, if they become over-abundant, they can cause decline in fish when they decay (Vallentyne, 1974). Similarly, over-abundance of algae in coastal environments such as the Gulf of Mexico had been reported, upon decay, this cause a hypoxic region of water known as a dead zone (Turner and Rabelais, 2003).

The salinity of the water body is also a determining factor in the kinds of species found in the water body. Organisms in marine ecosystems tolerate salinity, while many freshwater organisms are intolerant of salt. The degree of salinity in an estuary or delta may be an important control factor on the type of wetland (fresh, intermediate, or brackish), and the associated animal species. Dams built upstream may reduce spring flood, and reduced sediment accumulation, and may therefore lead to saltwater intrusion in coastal wetlands (Keddy, 2010) .

Freshwater used for irrigation purposes often absorb levels of salt that are harmful to freshwater organisms (Manahan, 2005).

Biotic characteristics

The living things in an ecosystem are called the biotic characteristics. The living things include plants, animals, bacteria, fungi e.t.c. They are sorted into three groups which are producers i.e. autotrophs, heterotrophs and decomposers. The biotic characteristics are mainly determined by the organisms that are present in the environment. For example, wetland plants may produce dense canopies that cover large areas of sediment or snails / geese may graze the vegetation leaving large mud flats. Some aquatic environments have relatively low oxygen levels thus forcing adaptation of the organisms found there. For example, many wetland plants produce parenchyma to carry oxygen to roots. Other biotic characteristics are more subtle and difficult to measure, and this includes relative importance of competition, mutualism or predation (Keddy 2010).

There are a growing number of cases where predation by coastal herbivores including snails, geese and mammals appears to be a dominant biotic factor (Silliman *et al*., 2009).

Biotic organisms also fall into two categories viz:

Autotrophic organisms/ Primary producers

An autotroph or producer is an organism that produces complex organic compounds from simple substances present in its surrounding, generally using energy from sunlight or inorganic chemical reaction. Autotrophs are important because they are a food source for heterotrophs (consumers). Autotrophic organisms are producers that generate organic compounds from inorganic materials. Algae use solar energy to generate biomass from carbon dioxide and are possibly the most important autotrophic organisms in aquatic environments (Manahan, 2005). Of course, the more shallow the water, the greater the biomass contribution from rooted and floating vascular plants. These two sources combine to produce the extraordinary production of estuaries and wetlands, as this autotrophic biomass is converted into fish, birds, amphibians and other aquatic species.

Chemosynthetic bacteria are found in benthic marine ecosystems. These organisms are able to feed on hydrogen sulphide in water that comes from volcanic vents. Great concentrations of animals that feed on these bacteria are found around volcanic vents. For example, there are giant tube worms (*Riftia pachyptila)* 1.5 m in length and clams *(Calyptrogens magnifica*) 30 cm long (Chapman and Reiss, 1998).

<u>Heterotrophic organisms/ Secondary producers</u>

An heterotroph is an organism that cannot manufacture its own food and instead obtain its food and energy by taking in organic substances, usually plant and animal matter. All heterotrophs depend on autotrophs for their nutrition. Heterotrophic organisms consume autotrophic organisms and use the organic compounds in their bodies as energy sources and as raw materials to create their own biomass (Manahan, 2005) Euryhaline organisms are salt tolerant and can survive in marine ecosystems, while stenohaline or salt intolerant species and can only live in freshwater environments (USEPA, 2006). There are four main types of heterotrophic nutrition and these are holozoic, saprophytic, parasitic and symbiotic nutrition.

<u>RESOURCES IN THE AQUATIC ENVIROMENT</u>

There are several resources in the aquatic environment and these include living and non-living resources. The living resources are also called renewable resources i.e. they cannot be used up completely. The non-living resources are usually non-renewable and cannot regenerate themselves.

The living resources include.

(i) Fish – which is a highly quality food, is of great value in the diet because of high quality protein, a lot of vitamins and minerals. These fishes are eaten fresh, canned, frozen or smoked. Prominent families of fish that are of great commercial value include Cichlidae, Clupeidae, Clariidae, Bagridae e.t.c. However, there are thirty two families of fish in existence.

(ii) Crustaceans, crayfishes, molluscs, oysters, octopuses, whales, frogs, turtles and sea urchins. All these are used either for human consumption or the production of animal feeds. They are also used for aesthetic purposes, sport fishing etc. Apart from the above, drugs can also be obtained from the aquatic resources. The fishes belonging to the Family Tetraodontidae (puffer-fish) produce a poison which is known to have pain killing effect on human beings and the poison is extracted for making pain killing drugs. Also, some antibiotics are extracted from sponges which are said to be even stronger than Penicillin. The body fluid of molluscs (snails and oysters) can be processed into medicine to combat virus diseases. Oil (edible oil) can be extracted from fish and whales and these are very rich in vitamins especially vitamin D. Shells of aquatic molluscs can also be used in jewellery and home decoration.

(iii) Plants such as algae are also important resources in the water. Phytoplankton and sea weeds are being used for production and human consumption. Some sea phytoplanktons are used for the production of ice cream and jam. Aquatic Algae are also being used as cosmetics and synthetic chemicals while some aquatic plants are used as fuel and fertilizer. Also, some algae are used in the production of agar. Through fermentation, algae can also be used for the production of methane i.e. burning or cooking gas.

(iv) Seabirds especially when they occur in large number produce faeces that can be used as fertilizers because it contains high quality phosphate.

The non-living resources of the aquatic environment include petroleum products (oil and gas), coal and minerals such as diamond, gold, tin, sulphur, iron ore, sand, gravel, lime and common salt (NaCl). Water is also used for domestic and industrial purposes. Water can also be used as a source of energy through hydro-electric production and for recreational (sporting) purposes.

In view of these rich natural resources in water, the aquatic environment has also been proposed to become future abode for man hence we refer to the environment as future cities. The earth surface has a limited capacity and with steady increase in the population of human beings. It is envisaged that a possible avenue for man to accommodate the teeming population is water. In some parts of the world like U.S.A and Japan, floating cities are already being established.

The aquatic environment is therefore a major reservoir of man's major resources and man's hope for the future. There is the need to study the environment in order to manage it efficiently and effectively rather than destroy it. As at 2005, only a small fraction (17%) of this resources is being extracted (FAO, 2005). Also, it was estimated that fishing takes place only in 17.5% of the available water i.e. less than 20% of the available fishery resources is being currently utilized. If man can therefore rationally protect the aquatic resources in the water, the level of poverty in the country and Africa in general will be reduced and man's hope for a brighter future will be enhanced.

RESEARCH CONTRIBUTIONS

(i) Fisheries

Since 1985, my studies and research has been focused primarily on the biology of economically important fish species. Such aspects of the biology include fish nutritional quality, condition factor (State of health), fish growth, reproduction, population dynamics, water quality viz-a-viz fish production and toxicology in fish culture. Information obtained from these studies has contributed largely to the improvement in the utilization of the rich natural resources in the aquatic environment. It has also enhanced the subsequent exploitation of the various fish species in Nigerian inland water bodies.

Fawole (1985) made a quantitative assessment of the diet of *Tilapia mariae* occurring in a natural population of fish in Asejire reservoir, Ibadan. The weight of food in the entire gut on the average was 2.02% of the body weight. i.e. 0.71% in the stomach and 1.3% in the intestines. Fagade (1978, 1982) obtained 0.42% for *Tilapia guineensis* and 0.55% for *Sarotherdon galilaeus* respectively. The information provided in the study is of good practical value in fish farms where a sound knowledge of the quantity of food that should be given as supplementary food is of important economic consideration.

Arawomo and Fawole (1997) examined the food and feeding habits of *Sarotherodon galilaeus* in the Opa Reservoir which is located on the Obafemi Awolowo University Campus. The fish, *S. galilaeus* belongs to the family of fish called cichlidae and they are commercially exploited fishes for human consumption especially in African lakes. The study by Arawomo and Fawole (1997) revealed that *S. galilaeus* is an herbivorous feeder which fed on a wider variety of plant materials like blue-green algae in cellular, colonial as well as filamentous green algae. In addition, the fish species also fed on diatoms, zooplankton, detritus and mud. Also, the age and growth of the fish were determined from fish scale studies. The annular rings on the scales as shown by Arawomo and Fawole (1997), indicated that there were six age groups of the fish, thus *S. galilaeus* can attain the age of 5 in the reservoir. All these studies were embarked on with a view to utilize fully the rich natural resources and this thus enhances the subsequent exploitation of the fish species which has a very great potential.

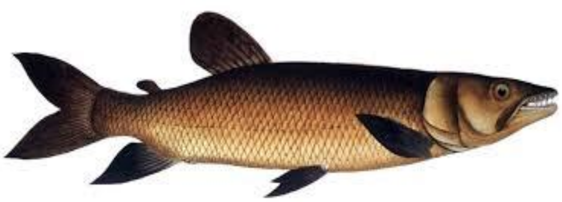
Fawole (1998) also examined the relative abundance and mode of distribution of fish species in Opa reservoir. Seven species of fish were caught by gill nets and cast nets and these were as shown in Figure 9

Sarotherodon galilaeus

Oreochromis niloticus

Tilapia zillii

Clarias lazera



Hepsetus odoe

Momyrus rume

Labeo coubie

Figure 9: Some of the commonly found fishes in Opa reservoir, Ife, Osun State

The study also showed that a wide range of sizes of the fish are available in the reservoir. From the results obtained, the commercial sizes can be effectively caught in the gill nets of stretched mesh sizes of 7.6 cm and10.2 cm. Most of the fish specimens were more concentrated at mid-depths than in other areas. This might be attributed to the abundance of their plankton food which was available in the photic zone of the reservoir. Specifically, *S. galilaeus* were found in both offshore and onshore areas of the reservoir i.e. the distance from the shoreline did not play any significant role in the distribution. The above study had contributed necessary information which led to the drawing up of the fisheries management programs for Opa reservoir.

Fawole and Arawomo (1998, 2000) provided information on the reproductive biology of *Sarotherodon galilaeus* in Opa reservoir. In the study, six stages of gonad development were observed. The stages are

State I	-	Immature, inactive
Stage II	-	Immature developing
Stage III	-	Maturing
Stage IV	-	Mature (Ripe)
Stage V	-	Ripe running
Stage VI	-	Spent

The Mature ovarian (Stages III & IV) were available all year round and this is an indication that the fish breeds throughout the year. In the study, both sexes of *S. galilaeus* are involved in mouth breeding activities; hence the fish species is a biparental mouth brooder (Figure 10). In the fish species, either the male or both the male and female will pick up and incubate the eggs in their mouths. During incubation, they move to more protected areas until the frys are ready to feed; averagely 10-12 days post fertilization. After release of the frys, they nature the frys and anytime the frys are threatened, they will return to the mouth of the parent. This behaviour last for several weeks.

Figure 10: Female *S. galilaeus* carrying eggs in its mouth

The mouth brooding habit and the ability to reproduce many times in a year might be responsible for relative success in the reservoir. Furthermore, this study established relationship between fecundity and standard length (using regression equation). The correlation coefficient (r) obtained was 0.806 (p=0.001; n-117) as shown in the scattered diagram in Figure 11

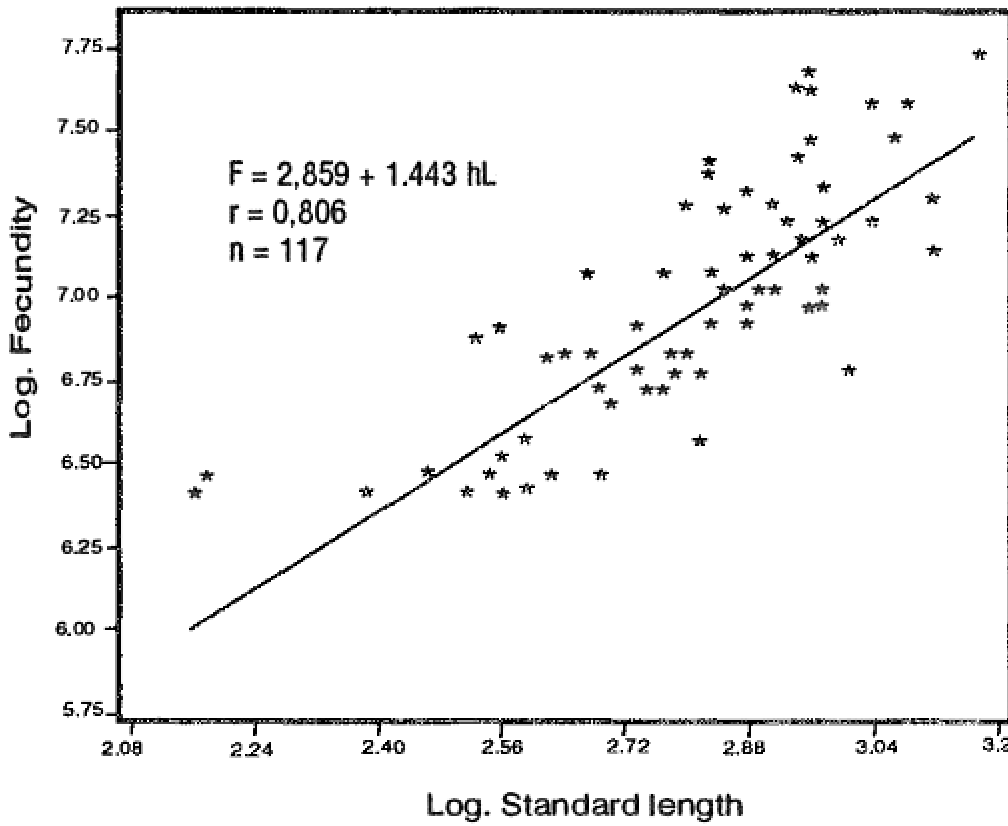


Figure 11: Log. Fecundity – Log. Standard length relationship in *S. galilaeus*

In Ogbomoso land, Oba reservoir was created in 1961 by the Oba River (Odo-Oba). The river took its source from Igbon-Ile and the reservoir is situated in the Northwest region of Ogbomoso (Figure 12). The reservoir is about 0.25 kilometres wide and 8 kilometres long. The Oba reservoir was primarily constructed to provide pipe-borne water to the Ogbomoso community. The establishment of a fishery is however of secondary importance.

Figure 12: Oba river

The fish fauna of the reservoir include *Clarias gariepinus. Sarotherodon galilaeus, Tilapia zillii, Oreochromis niloticus, Chana obscura, Lates niloticus, Malapterurus electricus, Hespsetus odoe, Hemichromis fasciatus, Mormyrus rume e.t.c* (Figure 13).

Clarias gariepinus

Sarotherodon galilaeus

Tilapia zillii

Oreochromis niloticus

Hemichromis fasciatus

Mormyrus rume

Figure 13: Some commonly found fishes in Oba reservoir, Ogbomoso.

Fawole and Adewoye (1998, 1999) studied some aspects of the biology of the fish species in the reservoir. These aspects included the length-weight relationship, condition factor and fecundity of *Tilapia zillii* and *Sarotherodon galilaeu.* Fawole and Adewoye (1998) obtained a statistically significant correlation between the length and weight of *T. zillii*. Also, the condition factor ranged from 0.45 to 3.00 while the fecundity ranged from 78 eggs to 3,791 eggs with a mean of 1,206 eggs. In the study, fish of the same length or weight had variable fecundities. This wide fluctuation in the fecundity was attributed to differential feeding success within the members of the populations.

Fawole and Adewoye (1998) in their study of *S. galilaeus* of Oba reservoir obtained a mean condition factor of 1.91. The egg diameters ranged from 0.8 mm to 3.2 mm with a mean of 1.81mm, while the fecundity ranged from 231 eggs to 3,122 eggs with a mean of 1,703 eggs. The result obtained in this study is lower than that observed in some other water bodies. Fecundity in *T. zillii* was reported to be up to 7,000 eggs by Fryer and Illes (1972) while Akintunde and Imevbore (1979) reported that *T. zillii* in Lake Kainji had a fecundity of 3,849. A relatively lower fecundity obtained in our study might be attributed to the degree of parental care in the fish species. As a rule fecundity of a fish is inversely related to the degree of parental care it exhibits (Nikolsky, 1963; Lagler *et al*., 1987).

Fawole (2000) also carried out field and laboratory investigations on the physico-chemical parameters of Oba Reservoir. The parameters studied under field investigation include pH, the temperature and turbidity measurements while the laboratory investigation include the conductivity, dissolved oxygen, carbon dioxide, fatal alkalinity, total dissolved solid, hardness as well as plankton studies (Table 1). The results showed that the physico-chemical parameters exhibited temporal variations and that the reservoir is moderately productive, and suitable for fish production.

Table 1: Limnological parameters of Oba Reservoir, Ogbomoso (January- December, 1998)

Months	**Temp. (°C)**	**Turbidity (cm)**	**Conductivity (Nmbos/cm)**	**DO (mg/L)**	**CO_2 Content**	**pH**	**Hardness (mg/L)**	**Total Alkalinity (mg/L)**	**TDS (mg/L)**
January	29.1	22	74	3.4	11.01	7.25	118.2	4.8	0.25
February	30.2	23	72	3.3	9.92	7.34	102.4	5.9	0.28
March	30.1	21	54	3.2	11.30	7.16	94.0	4.2	0.29
April	26.3	21	54	5.3	16.01	7.38	70.0	6.1	0.43
May	26.1	20	55	5.2	17.57	7.32	72.2	5.6	0.83
June	26.4	21	56	5.2	14.46	7.19	58.6	4.7	0.91
July	26.0	18	55	5.0	19.97	7.06	55.4	3.6	0.53
August	25.8	19	53	5.0	11.31	7.18	54.0	4.5	0.53
September	28.0	25	68	4.9	7.65	7.30	92.0	5.0	0.26
October	28.3	23	67	4.1	11.97	7.42	138.0	6.5	0.26
November	28.6	22	71	4.3	11.92	7.18	111.2	4.4	0.25
December	29.7	22	72	3.5	11.42	7.09	120.0	3.9	0.25
Mean	27.9±2.3	62.58±3.57	62.58±10.52	3.37±1.14	12.88±6.03	7.24±0.17	90.5±42.0	4.93±1.45	0.43±0.33

NB: the monthly values are means of three different values.

Fawole (1998) reviewed the problems and prospects of culturing Tilapia in Nigeria. In the study, the Tilapia species that are used for artificial culture were listed. In Africa, the most widely distributed tilapia used for culture is *Sarotherodon galilaeus* (Moses, 1983). Other species of Tilapia suitable for culture are *Sarotherodon niloticus, Sarotherodon macrochir, Tilapia zillii, T. rendali* and *T. mariae*. In Nigeria, Fawole (1998) recommended only three species (*S. galilaeus, S. niloticus* and *T. zillii*) due to following reasons:

(i) These species are generally hardy, i.e. both the eggs and the adult stages are capable of being reared under artificial but controlled conditions.

(ii) They have the ability to survive at low oxygen tensions.

(iii) They can survive on a wide range of artificial and natural foods.

(iv) They have the ability to feed very low in the food chain.

(v) They also have the capability to withstand a wide range of salinities.

(vi) They can reproduce in captivity or semi confinement.

(vii) They are capable of being manipulated generally for improved production.

However, inspite of the above qualities, Tilapias make a relatively small contribution to fisheries production in Nigeria because of their early sexual maturity which results in prolific rates of reproduction thus leading to stunted growth (Fawole, 1998).

Fawole (1999) studied the chemical composition of the diet and the absorptive capacity of the different sections in the gut of *Tilapia zillii* in Asejire Lake, Ibadan, Nigeria. In the study, the weight of food in the entire gut was 1.74%, of the body weight. The diet also contained 33.0%, 47.8%, 10.0% and 11.4% of crude protein, carbohydrates total facts and crude fibre, respectively. The mid-gut was found to be the major site of food absorption, while the hind-gut was responsible for water absorption. Similar observation in the absorptive capacity of the mid-guts of

Sarotherrodon galilaeus was reported for Kainji Lake by Akintunde in 1976. It was also reported that the fore-gut of *S. galilaeus* contained many more digestive enzymes than the mid and hind guts which is an indication that the fore gut was probably more concerned with digestion while the mid-gut was mainly for absorption (Akintunde, 1976).

Trichiurus lepturus (Figure 14) is a commercial fish species which is usually sold fresh or smoked in the markets of Lagos, Nigeria. Fawole (2001) described *Trichiurus lepturus* (silver fish) as a fish that possesses a band-like body tapering into a fine point without caudal fin. They are predominantly marine predatory fishes descending to moderate depths while a few of them are surface fishes living in the vicinity of the coast. Amadi (1980) reported that *Trichiurus lepturus* occurred primarily at the depths of between 50 m and 130 m and had a mean catch rate of 2 -8 kg per hour. Amadi (1979) observed that the fish is a carnivore and dietary piscivorous.

Figure 14: *Trichiurus lepturus*

Fawole (2001) studied some aspects of the growth and reproductive biology of *T. lepturus* of the Lagos Coast, Nigeria. In the study, the length-frequency distribution showed the species to be of the two age groups. The length-weight relationship of *T. lepturus* reflected the common general increase in weight with increasing length. The mean fecundity of 17,596 obtained in the study is an indication that the species is of high fecundity thus it may lack any form of parental case. As a rule, the fecundity of a fish is inversely related to the degree of parental care it exhibits (Lagler *et. al*.1962, Nikolsky, 1963). The gonadotropic index obtained showed that the fish species used 3.6% of its body weight for egg production.

In Nigeria, there is paucity of knowledge on the biology of Mormyrid species. Fawole (2007) examined the morphometry and diet of *Mormyrus rume (Elephant snout fishes)* in the Lekki, Lagoon, Nigeria. The fish (Figure 15) belong to the family Mormyridae and they are found in freshwater of tropical Africa. The major food items of the fish were found to be detritus and plant parts. Other food items are fish eggs, fish bones, crustacean larval parts and some diatoms. There was the presence of mud in all the stomachs containing food suggesting that *Mormyrus rume* are bottom dwellers thus corresponding with the findings of Omotosho (1993), who reported that *Mormyrus rume* fed on detritus algae and macrophytes in Ogun mini-dam, Ilorin, Nigeria. The long tubular snouts are used to burrow in searching for their food items (Holden and Reed, 1972). This specimen was encountered throughout the study period, this agreed with the findings of Scott (1974) that most of the species of the Family Mormyridae spawn more or less throughout the year. The gonadosomatic index showed that the fish species uses 7.89% of its body weight for egg production. The species was found to be highly fecund with an average of 3,371 eggs per female.

Figure 15*:* *Mormyrus rume*

Fawole *et al.* (2003, 2006) also did some studies on the meristic (Gill raker, dorsal fin ray, pectoral fin ray, Anal and caudal fin ray and number of vertebrae) and morphometric characteristics (head length, total length, pectoral fine length e.t.c.) of *Clarias gariepinus* and *Sarotherodan galilaeus* from two freshwater environment of Oba and Asa reservoirs of Ogbomoso and Ilorin in Oyo and Kwara States, respectively. The results showed that there were no significant differences for all the parameters used for the population of the two species from both reservoirs when compared (Tables 2 and 3). This is an indication that the populations of fishes from both reservoirs are genetically inseparable.

Table 2: Mean value of meristic characters obtained for *Clarias gariepinus* from two reservoirs

CHARACTERS	ASA	OBA
Left Gill Rakers	37.04	37.04
Right Gill Rakers	36.96	36.92
Dorsal Ray	60.84	59.64
Pectoral Ray	9.56	9.00
Pelvic Ray	6.64	6.60
Anal Ray	45.32	46.00
Caudal Ray	19.36	19.92
Number of Vertebrae	54.92	54.84

Table 3: Correlation coefficient r, slope (b) and intercept values for the morphometric characters of *Clarias gariepinus* from two reservoirs

	R		B		A	
CHARACTERS	ASA	OBA	ASA	OBA	ASA	OBA
Weight/standard length	0.814	0.854	25.43	24.33	-121.720	-101.500
Total length/Standard length	0.989	0.946	1.254	0.614	-2.569	14.680
Head length/Standard length	0.940	0.895	0.317	0.275	-1.970	-0.831
Trunk length/ standard length	0.984	0.894	0.695	0.223	1.510	13.210
Tail length/Standard length	0.790	0.748	0.250	0.240	-2.630	-2.040
Dorsal Fin Base length/Standard length	0.900	0.891	0.643	0.614	0.390	0.712
Anal Fin Base length/ Standard length	0.720	0.695	0.305	0.196	0.373	0.849
Pectoral Fin Length/ Standard length	0.906	0.825	0.155	0.041	-0.695	2.125
Pelvic Fin Length/ Standard length	0.892	0.879	0.125	0.109	-0.843	-0.485
Anal Fin Length/ Standard length	0.771	0.702	0.350	0.295	2.790	3.960
Body Width/ Standard length	0.951	0.931	0.205	0.186	-1.731	-1.210
Head Width/ Standard length	0.953	0.660	0.227	0.137	-1.570	0.800
Dorsal Fin Length/ Standard length	0.890	0.652	0.668	0.498	0.230	4.010

Fawole *et al.* (2007) studied the elemental and proximate composition of some freshwater species in Nigera. These fish species are *Oreochromis niloticus, Sarotherodon galilaeus, Clarias gariepinus* and *Heterotis niloticus.* The species contained appreciable concentration of sodium, potassium, phosphorus, magnesium, calcium and iron indicating that the fish species are good sources of minerals. The proximate composition values were highly pronounced most especially the crude protein.

Furthermore, Fawole *et al*. (2013) studied the nutritional qualities and concentration of trace metals (Pb, Fe, Cu, Zn, and Cd) in six fishes (*Hemichromis fasciatus, Siluranodon auritus*, *Sarotherodon galilaeus*, *Tilapia zillii*, *Chrysichthys nigrodigitatus,* and *Hepsetus odoe*) obtained from Oba reservoir, Ogbomoso (Figure 16),, The value ranges of 55.95 to 68.80, 16.91 to 26.18, 5.46 to 18.18, 0.51 to 9.05, 7.67 to 10.14 and 0.97 to 1.41% were obtained for moisture, protein, fat, carbohydrate, ash and fibre contents, respectively. Highest protein and fat contents were obtained from *H. odoe*. The studied trace metals were found at various concentrations in fishes especially lead and cadmium indicate contamination of the water body. High levels of essential metals; Fe, Cu and Zn, were found in the fishes. The results showed that the fishes evaluated are rich in essential nutrients.

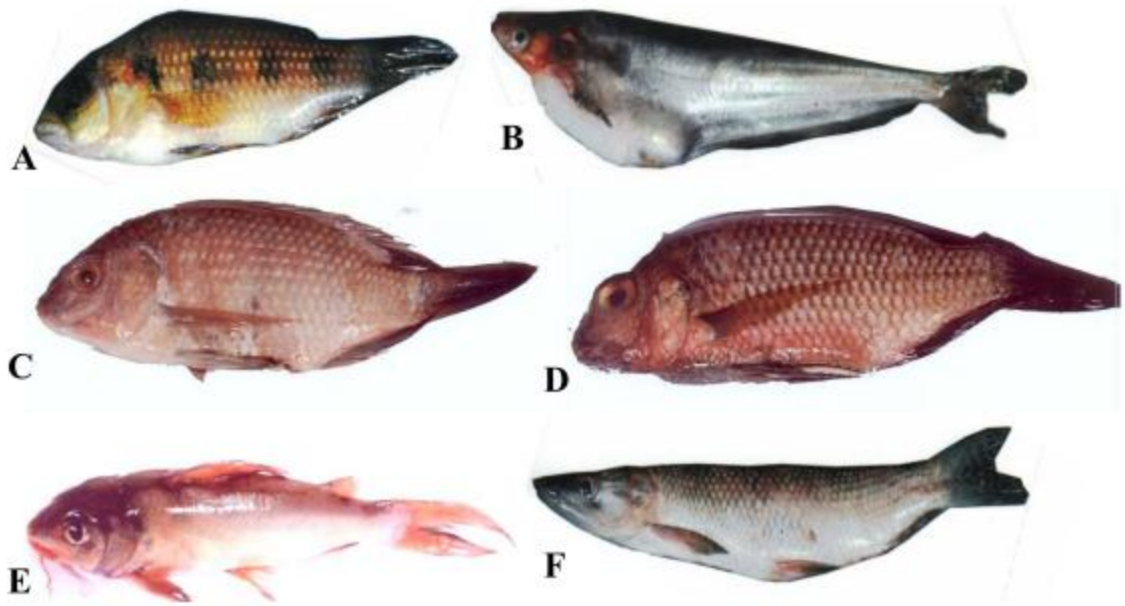


Figure 16. Some fresh water fishes of commercial importance obtained from Oba reservoir, Ogbomoso. A. *Hemichromis fasciatus*. B. *Siluranodon auritus*. C. *Sarotherodon galileaus.* D. *Tilapia zillii.* E. *Chrysichthys nigrodigitatus*. F. *Hepsetus odoe.*

Adedokun and Fawole (2012) investigated the population structure of *Hepsetus odoe* during the rising and falling water levels in Oba Reservoir, Ogbomoso. The study showed that *H. odoe* exhibits a wide distribution pattern while the majority of the fish were found in the grassy area (56.39%). The fish was also found to be primarily an ambush predator while it frequently uses dense beds or aquatic vegetation for cover.

Information on parasites of fish are important not only to improve yields in fish farming but also to prevent infection of man by parasites using fishes as intermediate hosts. Also, due to rapid development of aquaculture especially with advances in raising fishes in Freshwater, brackish and marine waters, there has been increasing demand for knowledge about the nature and control of fish diseases, Fawole and Akinsanya (2001) studied the level of parasite infestation of *S. galilaeus* inhabiting the Opa Reservoir in Ile-Ife Nigeria. The only parasite found to be infesting *S. galilaeus* was the plerocercoid larva of pseudophyllidean cestode (Figure 17) and the parasite was found in the intestinal walls of the fish species.

Figure 17: The plerocercoid larva of pseudophyllidean cestode found in the intestinal walls of S. galilaeus.

Akinsanya *et al* (2002) also found the metacercariae of *Clinostomum marginatum* (Figure 18) to be the only parasite infecting, the cichlid fish species of Eleiyele River, Ibadan. The parasites were found on the skin around the eyes, pharyngeal region along the vertebral axis, the area that join the gills and mouth. The cichlid species examined were *Sarotherodon melanotheron, S. galilaeus, Oreochromics niloticus, Tilapia zillii* and *Hemichromis fasciatus.*

Likewise Ajala and Fawole (2012) studied food and feeding habits and parasitic infestation of *Clarias gariepinus*, *Oreochromis niloticus*, and *Sarotherodon galilaeus*, in the Oba reservoir. As observed in the study, parasitic infestation was highly diversified and affected the body weight of fish species. On *Clarias gariepinus*, assemblage of helminth species was found on host scales

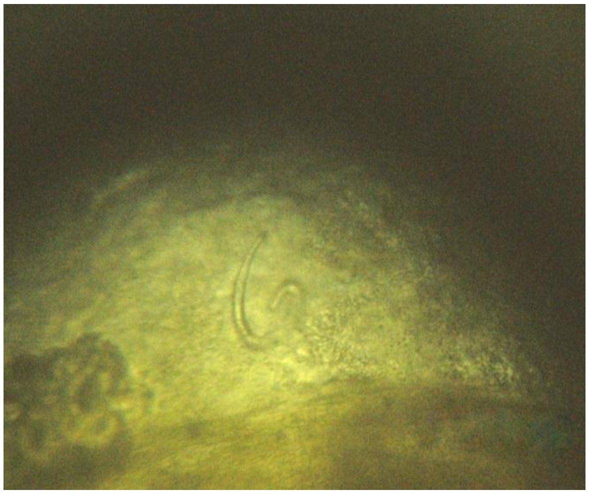
Figure 18: *Clinostomum* metacercariae after emerging from their fish host

while multiple infestation was observed in the stomach and intestine (Ajala and Fawole 2014a, b). Enteroparasitic Infestation was observed for *S. galilaeus* (Ajala and Fawole 2015a, b) and *Oreochromis niloticus* (Ajala and Fawole 2015c, 2016) obtained from Oba reservoir as shown abridged in Table 4 and Figures 19A-G.

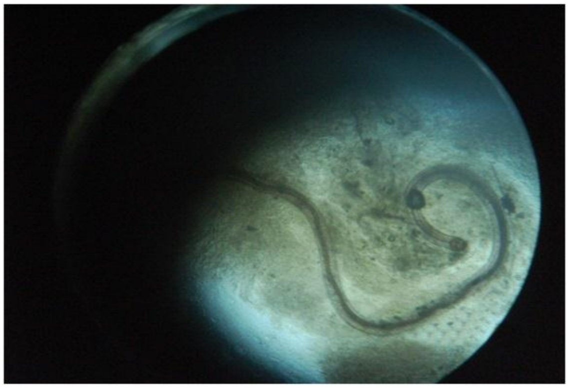
Table 4: Enteroparasites found in selected fishes in Oba reservoir

Parasite	***C. gariepinus***	***S. galilaeus***	***O. niloticus***
Procamallanus laevionchus	+	+	-
Neoechinorynchus rutile	+	+	+
Paracamallanus cyathopharynx	+	+	-
Monobothrium sp	+	-	-
Polyonchobothrium clariae	+	-	-
Anomotaenia sp	+	-	-
Clinostomum tilapiae	-	+	+

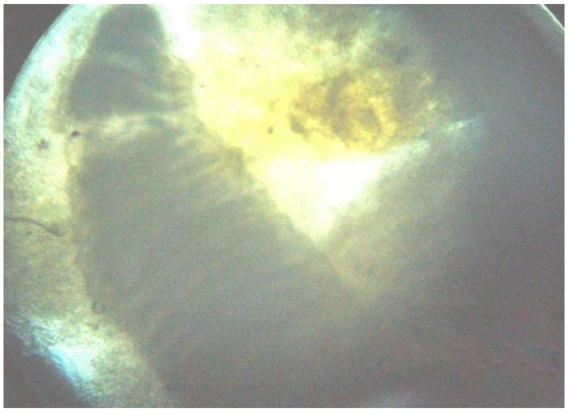
+ (present) ; - (absent)

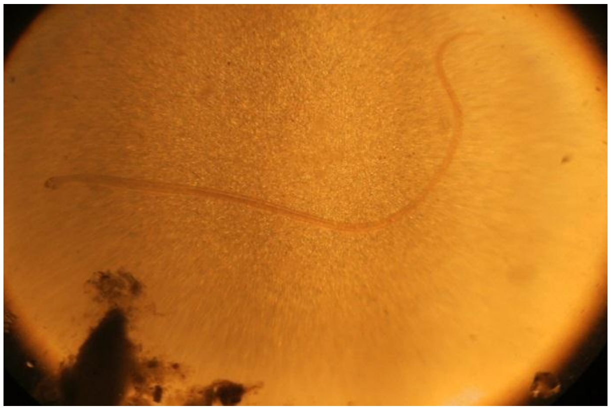


***A: Procamallanus laevionchus.* (x100).** **B: *Neoechinorynchus rutili* (x 400).**



***C: Paracamallanus cyathopharynx.* (x40)** **D: *Monobothrium sp.* (x 100).**





***E: Polyonchobothrium clariae.* (x 40).** **F: *Anomotaenia* sp.(x100).**

G: Clinostomum tilapiae.**(x 100).**

Figure 19 A-G: Different enteroparasites found in three selected fishes in Oba reservoir

Fryer and Iles (1972) reported that protozoan parasites with three major sub-divisions Microsporidia, Myxosporidia and Haemosporidia are commonly found in cichlid fishes. Other fish parasites that have been discovered include *Neascus* sp, *Clinostomum tilapiae* and *Acanthocephalan Anomotaenia (acestode)* (Aderounmu and Adeniyi, 1972). Hile (1934) reported that heavy infestation of fish by parasites result in slow growth.

Other works on parasitism although not directly on fishes include that of Arinola and Fawole (1995a and b) where the prevalence and intensity of two protozoans (*Entamoeba histolytica* and *Trichomonas vaginalis*) and four helminthes infection were described. The two studies concluded that parasitic infection is dependent on

(i) Occupation and age

(ii) Contamination of environment with human and animal faeces

(iii) Infected foods and dirty hands

(iv) Insufficient cooking or consumption of raw food.

(2.) Toxicology and fish culture

Considering the fact that fishes are being threatened by rising levels of man-made sources of pollution, myself and my research team turned our searchlight on the area of aquatic toxicology. This is with a view to solving some of the problems threatening the aquatic, environment. The geometric growth in human population coupled with industrialization and agricultural practices (including the use of pesticides) has worsened water and other forms of environmental pollution. Our water bodies have been exposed to different types of effluents (wastewaters). These effluent discharges into surface waters inflicting many adverse impacts on aquatic life. These adverse impacts as highlighted by Odiete (1999) are:

1. The dissolved oxygen content of the receiving water becomes reduced.
2. The self-purification processes in the water become overstretched.
3. Algae, phytoplankton and aquatic plants may blossom into excessive numbers and with sedimentation produce eutrophication.
4. Toxic chemicals in effluents and thermal discharges kill aquatic organisms.
5. Aquatic ecosystems and food chains become disrupted.
6. Aquatic organisms bioaccumulate toxic chemicals which become bioconcentrated or biomagnified in food chains.
7. Streams and other water bodies become coloured by some effluents that have obnoxious odours and shellfish and finfish may be tainted.
8. Pathogens constitute health hazards causing cholera, diarrhoea, dysentery, hepatitis, typhoid fever etc. in human.
9. The physico chemical water qualities of surface waters become generally lowered.
10. Radionuclides impact health risks as they are carcinogenic, mutagenic and teratogenic.

11. Suspended particulate matter may cause heave siltation.

Most of the industrial effluents discharged into water contains organic and inorganic pollutants in dissolved, suspended and insoluble forms. The toxic effect of industrial liquid waste is dependent largely on the inorganic substances content particularly heavy metals. These are always in varying degrees forming complex mixtures that have diverse multiple biological effects, most times leading to mortality of the aquatic life. Various workers have reported the effects of industrial effluent toxicity against aquatic life by means of a short-form bioassay. Adewoye and Fawole (2001) carried out an acute toxicity test of effluent from Soap and Detergent Industry using *Clarias gariepinus* fingerlings. The results obtained from the study provided information on the use of fish in the assessment of lethal concentrations of wastewater. The 96 hours LC_{50} value of 0.58 mg^{-c} recorded is an indication that at such concentrations the fitness of a natural population would be relatively impaired. Further evaluation was made on the effect of the effluent on haematological and biochemical profile of *C. gariepinus* (Ogundiran *et al*., 2007)

Adewoye and Fawole (2002) also assessed the lethal toxicity of cassava factory wastewaters on *C. gariepinus* fingerlings using a renewable static bioassay. At each exposure time in the toxicity test the fish showed signs of serious stress which led to sharp increase in mortality over relatively small increase in concentration. The result also showed that the waste water had higher levels of BOD, TSS, Cyanide and low dissolved oxygen. We also evaluated the impacts of cassava mill effluent on the nearby stream and wells in saw mill area, Ibadan as well as its toxic effects using two bioassays (*Allium cepa* and rat sperm morphology assays). The effluent was found to inhibit cell division in *Allium cepa* and also induced chromosomal aberrations (Chromosome fragments, Chromosome bridge, lagged chromosome and disturbed spindle). Rat sperm cell count, motility and morphology were also affected significantly. The bacterial isolates showed multiple-drug resistance to commonly used antibiotics which might have serious health implication (Fawole *et al*., 2014).

Fawole *et al.* (2008) studied the impact of abattoir waste on physicochemical parameters and microbial load of Alamuyo River in Ibadan, Nigeria and selected wells along its course. The results showed that the river contained toxic substances and high microbial load which have effects on the surrounding wells due to infiltration. Aquatic organisms include fishes in the river are also affected.

Good and quality water is basic necessity of life especially in rural areas where there are no alternative as such. Reports have shown that Oluwa river, Agbabu, Ondo State is polluted with seepage of bitumen. Ayandiran and Fawole (2014a,b) assessed the water quality of this river and found that some of the parameters measured were not in conformity with the acceptable limit. Furthermore, toxic effects of bitumen seepage on inhabitant fishes of Oluwa river was investigated. Histopathological, haematological, and biochemical parameters of in situ *Clarias gariepinus revealed* abnormalities (Ayandiran and Fawole, 2015**)**. Heavy metals and polycyclic aromatic hydrocarbon concentrations were also high in the fish samples. Bitumen seepage impact negatively on the physicochemical properties of the Oluwa river.

Impact of industrial effluents discharges on some physical, chemical and physiological parameters of Asa River, Ilorin, Nigeria was extensively studied. The research was carried out over the period of twenty four months (between April, 2011 and March, 2013). The data revealed that virtually all the physical and chemical parameters including heavy metal analyzed were significantly higher compared with the control water sample and reference standards *(*Ogundiran and Fawole, 2014a). Further evaluation on sediment and sampled fish species showed high concentration of heavy metals which was relatively higher than the permissible limits as recommended by World Health Organization and other standard references (Ogundiran and Fawole, 2014 b). The fish were with varied level of histopathological, haematological, and biochemical imbalances and the histopathological studies of the sectioned gills showed marked histological alterations. The observed pathological lesions of the gills include infiltration of secondary lamellae, inter-lamellae hyper plastic lesion, oedema among others (Ogundiran and Fawole 2014, b). Relative Abundance and Length-Weight Relationship of other *Clarias* species (*Clarias buthupogon* and *Heterobranchus longifilis*) in Asa river were also studied (Ogundiran and Fawole, 2014 c).

As a result of increase in the use of pesticides in the field of agriculture more pesticides are released which affect the non-target organisms. Records of field application of pesticides even in advanced countries has revealed that less than 0.1% of pesticides applied to crops reach target pest (Pimentel and Levitan, 1986). Most of it is washed into aquatic environment through run off. They are directly toxic to aquatic organisms and also deteriorate the quality of water by changing its physico-chemical nature thus reducing the amenity value of water. We have reported various effects of pesticides on non-target organisms in the laboratory. Yekeen and Fawole (2009) reported Toxic effects of endosulfan pesticide on sperm count, motility and morphology of *Rattus novegicus.* The study revealed that endosulphan (an organochlorine pesticides) have potential to reduce sperm cell motility and also capable of inducing various sperm cell morphological aberrations. The toxic effects of endosulfan on haematological and biochemical indices of *fish*, *Clarias garieppinus,* was equally evaluated where it was observed that the pesticide have significant reduction of haematological parameters which led to microcytic anaemia (Yekeen and Fawole, 2011).

Studies were also made on some of the commonly used synthetic pyrethroid pesticides in Nigeria (deltamethrin, cypermethrin and lambdacyhalothin). Acute toxicity of emulsifiable concentrates of deltamethrin on juvenile catfish, *Clarias gariepinus revealed that the pesticide induced stress and cause hyperactivity and loss of equilibrium (Yekeen and Fawole 2009).* Further evaluation of the deltamethrin pesticide showed its *a*lteration in haemotological and some selected biochemical indices of exposed *Claria gariepinus* (Fawole and Yekeen, 2014). In another study, lambdacyhalothrin (pyrethroid) was also found toxic and affect the haematology and selected biochemical parameters of African catfish *Clarias gariepinus (Yekeen et al., 2013). Lambdacyhalothin* ability to alter the haematology, biochemicals and reproductive indices of treated *Rattus novegicus* was demonstrated (Yekeen *et al*., 2016). The outcome of our toxicological experiment is assisting in ecotoxicological evaluation.

Our just concluded research (2018) on the Oba reservoir through one of my masters student (Okaseun; unpublished) revealed that human activities are important factors that affect the quality of the fresh water. Physicochemical parameters and benthic macroinvertebrates (as bioindicators) were used to determine the impact of human activities on the water quality of Oba river. TSS and turbidity with highest mean values of 104.01±20.31 and 49.94±8.78 in station 2 and DO, BOD, phosphate, nitrate and lead with respective highest mean values of 10.27±0.55, 4.55±0.48, 0.92±0.10, 17.65±3.79, 0.08±0.01 in station 3 deviated from recommended aquaculture standards (Figure 11, above). A total of 9 taxa comprising of 1407 individual species were recorded of which three (3) major phyla (Arthropoda, Annelida and Mollusca) were identified. The relatively abundant pollution tolerant species were *Chironomous sp*. (4.69%), *Tubifex sp.* (11.58%), *Bithynia sp.* (22.31%) in the river. The high values of BOD, low values of DO, the abundance of pollution tolerant macroinvertebrates (Arthropoda, Annelida, Mollusca) indicate that the river is under pollution stress.

Strategies for exploiting the living resources in the aquatic environment

Mr. Vice Chancellor, sir in order to exploit fully living resources in the aquatic environment thus bridging the poverty gap in Nigeria, both the aquatic resources and the environment itself must be fully protected. The following are suggested:

1. Limitations of fish sizes that can be landed. This is to be done through mesh-size regulation as it is done in developed countries of the world. Where patrols are carried out to check the mesh sizes. Bigger Mesh sizes of 7.62 cm that will protect fingerlings and juveniles should be encouraged. Other fishing gears should be banned.
2. Introduction of closed areas and closed seasons. Fisheries of notable lakes and water bodies may be closed down and fishing is prevented for a certain period of time to allow for possible recovery. This is usually during the peak spawning or reproductive period. Fishing is regulated in order to prevent fishing during spawning sessions or when the fish are congregated in much reduced water area during the dry season or when pre-spawning fish are vulnerable to certain fishing methods (Arawomo, 2008).
3. Limitations of total catch and total effort. The effectiveness of this method should be judged against the objectives of management which is to achieve the maximum sustainable yield.
4. Banning of obnoxious and illegal fishing practices. This is done by strict monitoring, control and surveillance of lakes most especially in the use of approved fishing nets and methods such as

   (i) Use of poisonous chemicals

(ii) Use of ichthyotoxic plants in water bodies so as to maximize catch

(iii) Use of dynamites, hand grenades and bombs which can lead to mass mortality of fishes.

(iv) Use of castnets and beach seines with small meshes so as to prevent the catching of juvenile fish.

(v) Use of electric fishing devices except under license.

5. Prevention of poaching by foreign vessels or poaching by unauthorized fishermen in rivers and lakes. Proper security check should be made available throughout the season to check the activities of unregistered fishermen so as to put an end to the use of toxicants.
6. Development and improvement on artisanal fisheries. This could be done by the registration of fishermen and carrying out a baseline survey of all the artisanal fishing communities in the country. After creating a baseline data in the communities, they could now be educated on a regular basis through seminars, workshops on the need for the sustainability of the fish resources in the aquatic environment.
7. Establishment of fish replenishing stations across the country. These stations will serve as centres for breeding and restocking of fish species of economic importance into water bodies across the nation. This will thus ensure that the stock of fish is available for exploitation by fishermen on a sustainable basis, and therefore also protect livelihood of artisanal fishing communities.
8. Establishment of pilot fishing towns across the different riverine zones of the country. Each fishing town should have a fisheries development unit (FDU) which will have the following components:

(i) Processing centre to reduce Post-harvest loss

(ii) Fish preservation facilities

(iii) Outboard engine repair workshop

(iv) Net loft (For mounting fish net during construction and repair)

(v) Market facilities

The effort of Lagos State Government in this regard is appreciated. It must be noted that Lagos State Government took the initiative by the establishment of pilot fishing towns in Epe and Badagry.

9. Capacity building through vocational schools and public trainings and workshops. This is with a view to building middle-level man-power for investors.
10. Enhance aquaculture programme through the provision of fingerlings of fast growing fish species such as *Clarias* spp, *Heterobranchus* spp, *Tilapia* spp etc.
11. Popularisation and encouragement of Homestead fish, farming in residential areas as well as community farm projects.

The effectiveness of all these methods must be judged against the objectives of management which is to obtain maximum sustainable yield. All the methods can be combined in order to have an impact on the citizenry of Nigeria.

It is also imperative to control the aquatic environment, the following are suggested.

1. Industries that generate wastewaters with high concentration of conventional pollutants (e.g oil and grease), toxic pollutants (e.g. heavy metals, volatile organic compounds) or other non-conventional pollutants such as ammonia must acquire specialized treatment systems for treating waste waters before discharge.
2. As it is the practice in developed world, our industries should be mandated/ encouraged to redesign their manufacturing processes to reduce or eliminate pollutants, through a process called pollution prevention.

3. Heated water generated by power plants or manufacturing plants should be controlled with cooling ponds, i.e. man-made bodies of water designed for cooling by evaporation, convection and radiation.
4. Finally, government agencies that are concerned with educating and enforcing environmental laws to be more alert. Also public enlightenment about dangers inherent in fouling our aquatic environment should be carried out at all levels of Government i.e. Local, State, and Federal levels. Qualified personnel and experts should be recruited into the various State and Federal Ministries of Environment. The staff should also be exposed to modern trends in the protection of the Aquatic Environment.

Conclusion

Mr. Vice Chancellor Sir, Can we really bridge the poverty gap using the Aquatic Environment? This question can be better answered by those responsible for governance in this country. As a scientist, I strong believe that the Aquatic Environment holds the future for the survival of the country. Many rivers, streams, natural and man-made lakes, ponds, lagoons and even the sea serve Nigeria. These water bodies constitute very valuable natural resources with a lot of them yet to be fully exploited.

All the resources in the aquatic environment including water itself should therefore be properly managed. This should be a concerted effort of all stakeholders. These stakeholders include residents, scientists, and various governments at all levels.

I thank you all for listening

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