FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

THE AFRICAN CATFISH CULTURE FOR THE 21ST CENTURY

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INAUGURAL LECTURE SERIES 22

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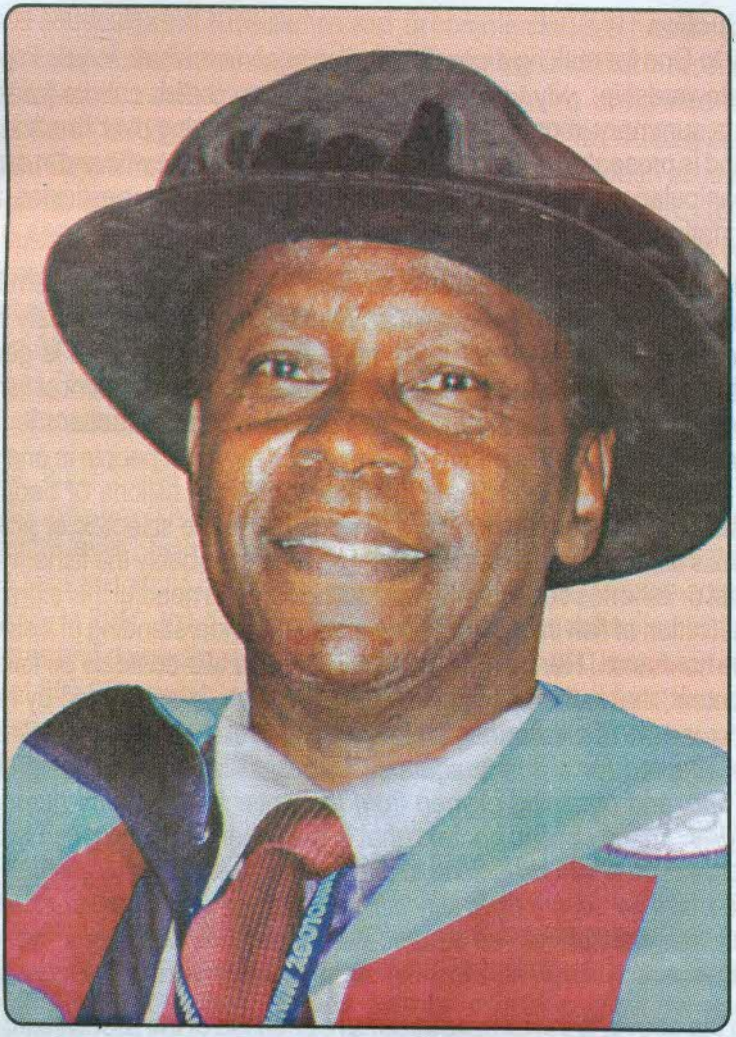

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1.0. Introduction

I give glory to God for making it possible for me to communicate to you in part my research stewardship. My Lecture title: The African catfish culture for the 21st Century is a summary in part of my research work spanning over two and a half decades and is presented in 4 parts - The African catfish in the wild and in captivity, its sex manipulation, response to a representative of the pesticides and a recommendation for a 21st century culture system.

Fish is perhaps the most valuable item in water as far as man is concerned. It is almost inevitable that where there is water there is fish. And it is probably the first thing man looks for in any water body apart from water itself. It is generally observed that when there is a crowd near any water body the element of fish is the main object. It is no wonder therefore, that one of man's occupations is fishing. But then what is **fish**? Fish is a word used everyday by most people in one way or the other to convey messages. It is interesting that the billions of people that consume fish world wide may not know what fish is. In the scientific or academic world, there is still the confusion as to what fish is. It is probably the fisherman, the fish biologist or fisheries scientist that can define fish. It is needful therefore to give a proper definition of fish in order to provide a better understanding of it as well as remove the confusion. Hence, Fish can be defined in two contexts as follows: In the first context, that is the biological context, true fish, is as defined by Norman and Greenwood (1975). According to Norman and Greenwood, *fish is defined as a vertebrate adapted for a purely aquatic life, propelling and balancing itself by means of fins, and obtaining oxygen from the water for breathing purposes by means of gills.* In the second context, that is the fisheries context; *fish is defined as a collective term which in addition to the first definition includes shellfish, curtle fish, starfish, sea horse, crayfish, jellyfish, mudskipper that is the sum total of the harvestable fish and fish related aquatic life.* From these definitions, the layman and any other person is now able to understand what fish is in the two contexts.

Related to the above, is the term **aquaculture** because of the association; and its being the subject of this lecture. The term aquaculture is almost as old as man as the Chinese have been in it well before 1000 BC (Nash, 2011), though it has improved and developed to such an extent that it has become an art. According to the Food and Agricultural Organization (FAO, 1998) aquaculture is defined as, *the farming of aquatic organisms including fish, mollusks, crustaceans, and aquatic plants. Farming organisms implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from*

predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated.

Traditional aquaculture at subsistence and or commercial level has for a long time been in existence in China, Japan, South East Asia and more recently Israel where fish protein ranks high in their diet hence having a significant Fishery Industry. Bard (1972) and Huet (1972) traced the art of Fish Culture in ponds to the ancient Egyptians and the Chinese. However, the first written account of fish culture ponds was by Fan Lai, a Chinese Fish Farmer in 475 B.C. (Chackroff, 1976). In Africa, Hecht and Britz (1990) and Hoffman *et. el.* (2000) have described it as a recent event, even though Nash (2010) reported that the earliest practice was started by the British colonial government in Kenya in 1924. Today, Fish Culture in Africa is practiced in central and Southern Africa, the Congo Basin, Cameroon, Ghana, Sudan, Egypt, Uganda, Ivory Coast, Nigeria and a host of other countries, but these are not as successful as in the far East and tropical Asia.

In Nigeria, aquaculture is generally practiced mainly at a subsistence level by individuals, very few private small-scale entrepreneurs and by Government at the experimental level. Fish alone contributes on the average 20 -25% per Capita animal in take and could be as high as 80% in coastal and riverine communities FAO (2000). In 2010, the demand for fish in Nigeria was estimated at 1.2 million metric tones and domestic production stood at only 600,000 metric tones leaving a deficit of 600,000 metric tones that was met by importation at the cost of ₦35 billion or as recently stated by the new Agriculture minister and reported by one of The Daily Newspapers at ₦75 billion for the same period.

The aim of aquaculture is principally to produce food fish for human consumption. It is also to enhance Culture-Based fishery by providing fingerlings for re-stocking open waters like natural and artificial lakes, reservoirs and running streams in order to prevent the extinction of commercially important species of fish especially when and where there is over exploitation. Fish Culture provides additional income to farmers and their families thereby alleviating poverty, particularly among the rural populace. At the national level, it can serve as a source of foreign exchange like in China.

It is noteworthy to state here that fish is one of the most traded commodities in the world today and the contribution of aquaculture to food security, human health, general well being and employment generation can not be over emphasized. Globally, the fisheries sub sector employs about 500 million and sustains the livelihood of more than 3 billion world-wide.

Recirculating aquaculture system represents a new and unique way to farm fish. Growing public demand for a healthy, tasty and affordable fish is stimulating the boom in this industry. The decline in wild fish populations as a result of overharvest and other factors including water pollution has promoted the culture of farmed fish that are grown in contaminant-free waters in indoor tank system.

1.1 .The origins and abundance of fish

Except for the Bible record of Gen.1:21, which states *that "So God created the great creatures of the sea and every living and moving thing with which the water teems, according to their kinds,"*(NIV), geological record has so far provided no evidence as to the origin of fishes either from fossils or living forms. Except that different groups appeared at different geological time periods (eras, periods and epochs) in their evolution. Broadly speaking, fishes (both fossil and living forms} belong to two large super classes: Agnatha (Jawless) and Gnathostomata (with jaws). For their distribution and abundance, fishes are the most numerous of the vertebrates. As at January, 2010 the estimated total of recently described species stands at 31,500 species making it the largest single vertebrate group on Earth. They have been able to keep pace with development of places of abode and now live almost wherever there is water, both on the surface and in the surface-connected subterranean waters. They occupy everything from Antarctic waters below freezing to hot springs of more than 40°c, and from soft freshwater to water saltier than the seas. They are present in sunlit mountain streams so torrential that neither man nor dog can wade or swim them, in waters so quiet, deep, and dark that they have never been inhabited by other vertebrates or thoroughly explored by man (Lagler *et.al.*, 1977).

1.2. Fish and Humanity

The relationship of fish to man has been that of prey-predator until recently when the art of ornamental fisheries came into being. Fish as food, medicine, ornament or weapon must have found favour with man at a very early stage. From the remains of Stone Age kitchen middens, archeologists have been able to identify the species that were most commonly eaten by early man (Nash, 2010). Fishing as an activity has engaged man from time immemorial. Fish was one of the earliest natural resources to be exploited by man (Norman and Greenwood, 1975). Since early times, fish was exploited by man for the reasons stated earlier using very simple gears with inestimable catches as stocks seemed inexhaustible then. This trend continued for centuries until a few decades ago when the signs began to indicate rapid decline in stocks. Man at this point realised that the

combined factors of uncontrolled use of high-tec facilities, obnoxious fishing practices, pollution and recently, Climate change and the high demand for food fish due to population increase, have occasioned the decline in feral stocks globally. To understand why fish has been close to man since time immemorial, the following secrets of fish to man will tell the story:

From the religious angle, among the ancient Christian relics, fish had always featured prominently and carried the symbol of Christianity. The man Jesus identified as the *'rock' on whom He will build His Church, and the gates of Hell shall not prevail against it*, Simon Peter was a fisherman and on his grave The Basilica in Rome stands. From the food dimension, fish generally presents the cheapest but most excellent source of protein. It is cheaper to obtain either by capture, culture or purchase. That's why it is generally referred to as the poor man's meat and explains why more people consume fish than any other animal protein source. It is the only animal protein in the world that offers all the essential amino acids, vitamins, minerals and oils required for a healthy body in man and other animals, and in children, improves their IQ. Its flesh is highly digestible, offering the most nutritious protein to the young and old. From the medical angle, fish oil, for example Cod liver oil is used in the treatment of Vitamin A deficiency, and certain ailments in Children and fatty acids, like the commonly called omega-3 in salmon, is used in the treatment of coronary heart disease and high cholesterol levels in adults respectively. In fact, the American Heart Association recommends a daily dose of 2 servings of fish per week and those with coronary heart disease 1 g. of Omega-3 and those with high Cholesterol 2-4g per day (AHA, 2007). It is the only source of protein in the world without consumption taboo culturally or religiously.

For the aforementioned reasons and more, the world's demand for fish and fish products has more than tripled over the last two decades. Today over 40% of the fish stocks are fully exploited (Nylor et al., 2000) and Capture fisheries can no longer meet the increasing fish demand in the world (FAO, 2007). The status of aquaculture globally has changed for the good of humanity. The global picture was captured in a World press conference on aquaculture at Shanghai World Expo, August, 24,2010 and the last World Aquaculture Conference in Natal Brazil, 6-10 June, 2011, when the organizers observed that "over the past decades, aquaculture has become the fastest growing food-producing sector in the world. It has evolved from a marginal industry in the 1970s to a very successful bio-industry meeting almost 50% of our global needs for aquatic protein. They went on to state further, that with the expanding world population and the stagnation of fisheries catches, aquaculture will continue to grow at a rate of 7% per year to meet market

demands in the decades to come". Mr. Vice Chancellor, as a member of both The World Aquaculture Society and The North American Aquaculture Society and having been in attendance at the last two conferences in New Orleans, USA and in Natal, Brazil in March and June, 2011 respectively, I can attest to that.

In order to meet up with this shortfall, most regions of the world are now engaging in aquaculture but in a more technologically advanced form, either marine-coastal carried out in cages or ponds, or freshwater fish culture in intensive systems. For Africa, one of its Pan African fish, the African catfish, *Clarias gariepinus*, (Burchell, 1822) (Plate 1) has received recognition as an aquaculture candidate for at least forty years but the culture system has remained traditional.

This lecture therefore is the story of how simple technological advances in the culture of this fish over the years, can give impetus to the efforts being made at increasing the production of the African catfish in Nigeria, Africa and indeed globally as a source of cheaper and affordable protein, through the adoption of the new advances in intensive production systems.

The African catfish is today comparable to all other world traditionally cultured species like, Carp, Salmon, Trout, Cod, Bream, Sturgeon, Tilapia, Shrimp, Oysters, Bivalves, Abalone, etc to name but a few that are farmed in commercial quantities. The reason why they occupy this exalted position is because of the research efforts that have been invested in them for decades. However, the singular distinguishing factor is that the African catfish though a new comer into the spectrum, may soon overtake them because of its global appeal.

2.0. The African catfish, *Clarias gariepinus* in the wild

As a prelude to domesticating the African catfish, the first step was to study the fish in the wild. These studies are reported in part in this lecture. And even after that, field and laboratory studies are still continuing on the fish, with respect to its breeding and genetics. The author is convinced that this fish has a global appeal with unlimited research opportunities.

Though the African catfish has been a subject of wild studies for some time, however, before the author embarked on his investigations a lot of gaps in a comprehensive understanding, especially in captivity, were still to be filled. This therefore gave impetus to a more intensive investigation on several aspects that would eventually recommend the fish for a more advanced form of intensive culture in recirculation aquaculture systems.

Plate.1. The African catfish. ***Clarias gariepinus (Burchell, 1822)***

Mr. Vice-Chancellor, as you are aware, in any scientific endeavour that has to do with taming and subsequent domestication of aquatic life or any wild stock for that matter, one of the prerequisites is to, first, understand the organism in the wild or *in situ* and then in captivity or *ex situ*, through simulation of the natural environment. Nations of the world that have been identified with particular fishes, for example the American catfish, Indian catfish, American Salmon, Spanish bream, Argentinean Anchovy, etc have all had to go the same way. The African catfish is currently going through the same process and is being reported.

2.1. Morphology, Habit and Taxonomy

The African catfish, *Clarias gariepinus* commonly called the African mudfish is a fish that is known to most Nigerians not only because it is found in all our freshwater bodies in and around almost all communities but because it is one of the most accessible and delicious and prepared as food in various forms varying from sun drying to pepper soup. To corroborate this assertion, I would like to cite the case of a Nigerian Professor of Food Science from one of our Universities who met me working in the Aquatic Biology Laboratory, Sonning, England on this fish, her first reaction was 'can you give me some of our experimental fish even the hormone treated fish to eat?' despite my repeated plea she insisted, I had to give her and she was very grateful for it. This is the extent of the love for this fish by Nigerians even though hormone treated and outside the homeland. That probably explains why in Nigeria almost every tribe has a name for it. For example, Nigeria's

major tribes have documented their own as follows: The Hausa people call it *'Tarwada or kusa da baki,'* the Ibos call it, *'okpo';* the Yorubas, call it, *'aro'; and* in Nupe, it is called,' Ezenghi'. The lower taxa description of the specie, *Clarias gariepinus* has been by (Moussa, 1957 Bolock and Koura, 1960; Dekimpe and Micha, 1974; Clay, 1979; Lamai, 1993; Hecht et al., 1996 and Tuegels, 986). *Clarias* belongs to the family Claridae; a group of catfish found in most fresh waters of Africa and Asia Minor (Mills, 1956).There are two genera in this family *Clarias* and *Heterobrancus.* The genus, *Clarias* has a wider distribution than *Heterobrancus.* Over 10 species of *Clarias* have been described as found in West Africa. Ezenwaji (1985) tried to simplify the classification of the fish into two major groups that is, "small" and "large" species for ease of identification by non-taxonomic field workers who might be interested in culture fisheries. He described the "large" species as large and fast growing and the "small" species as usually slow growing and stunted. The "large" mudfish species can be identified by their characteristic dark horizontal stripes, one on either side of the undersurface marks. *Clarias gariepinus* and *Clarias angullaris* are the only two African catfish species that belong to the "large" specie and are therefore of higher economic importance in Nigeria. Incidentally, these are the two species that are most common in natural waters (Bakare, 1968).

2.2. Geographical distribution of the African Catfish

The African catfish, *Clarias gariepinus,* as the name implies, is a pan African fish, as presently recognised, it has a natural range from southern Natal and the Orange River in Southern Africa and northwards through Central, West and North Africa, the Middle East and into eastern Europe, Hecht and Britz (1990). It is believed that it is the fresh water fish species with the widest latitudinal range in the world (70 °latitude) (Fig. 1).

The African catfish is eurytopic and inhabits a very wide range of inland waters, including streams, rivers, pans, swamps, underground sink holes, shallow and deep lakes as well as impoundments. Catfish thrive in shallow turbid lakes, as well as in deep clear lakes but are particularly successful in rivers. The environmental tolerances of African catfish are quite wide; Water temperature: 8 °c-40°c, breeding at 18°c; Water temperature for egg hatching: 17°c - 30°c optimal temperature for growth: 20°c - 30°c Salinity: 0 to 12 ppt, 0 to 2.5 ppt is optimal.

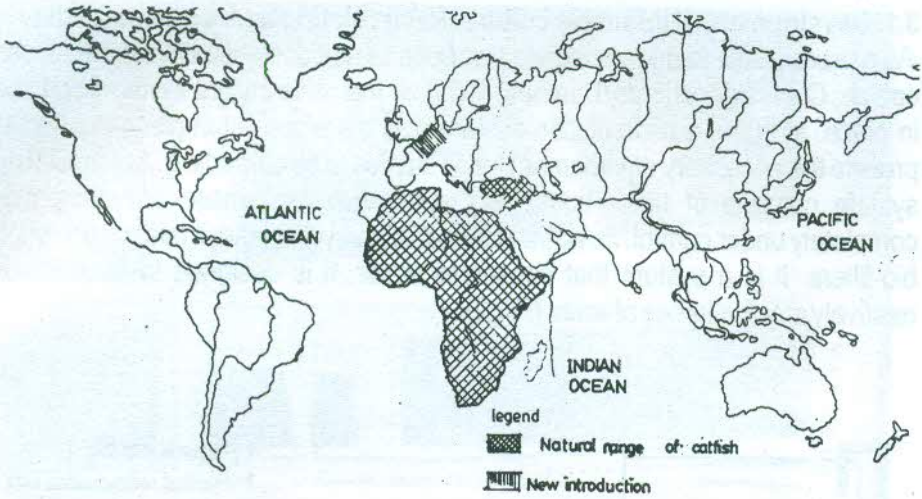

Fig.1. The Geographical Distribution of the African Catfish. Clarias

3.0. The African catfish, *Clarias gariepinus* (Burchell, 1822) in captivity

From wild studies, the African catfish was transferred into captivity under a simulated environment.

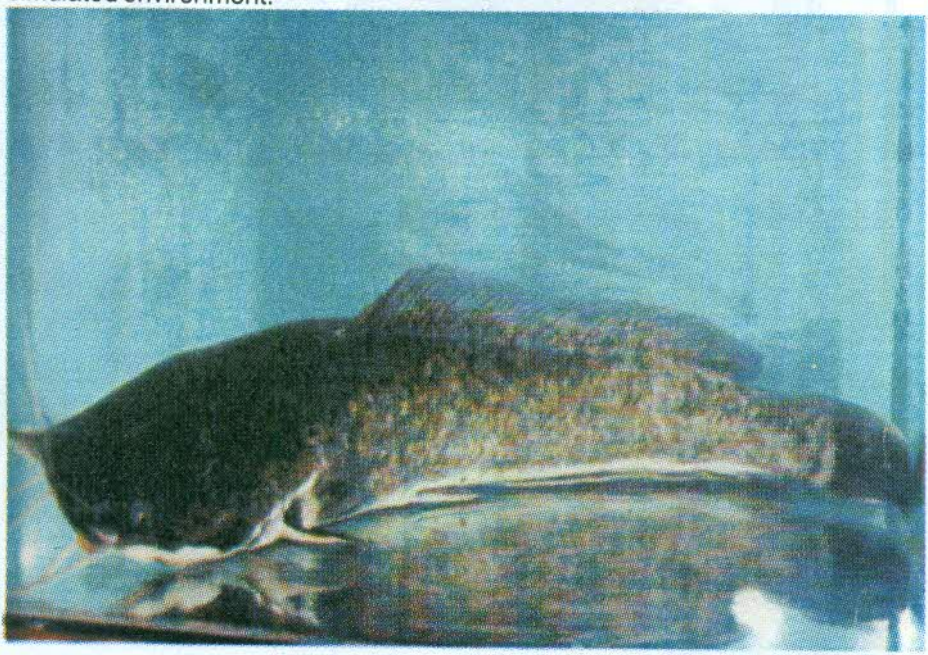

Plate.2. The African catfish. ***Clarias gariepinus (Burchell, 1822)*** in captivity

3.1. Development of intensive culture (Recirculating tank systems) facility

As a prerequisite to understanding and subsequent domestication of the African catfish, *Clarias gariepinus* (Burchell, 1822) an intensive culture system had to be in place. In 1989, a recirculation system was therefore put in place that would provide the necessary environment for all studies to be carried out. A recirculating system consists of tanks containing water with fish whose environment is completely under control. Its water is reused by recycling after it has gone through bio-filters. It is a system that conserves water. It is designed to raise fish in relatively small volumes of water (Fig.2).

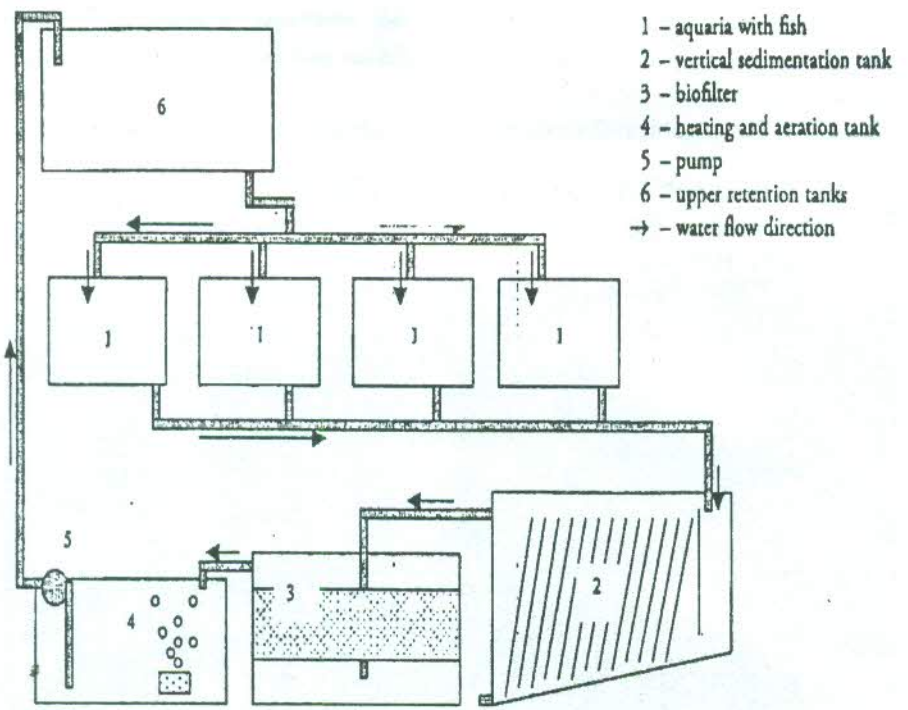

Fig. 2. Experimental water recirculation system design

Plate 3. Experimental water recirculation system in operation

3.2. Reproduction in captivity

The development of a reliable method of production of *C. gariepinus* fingerlings was the priority of aquaculture research in Africa. As such one of the first studies to be conducted on this fish while in captivity was reproductive activity. In the hatchery, observations commenced with gonads (Plate 4 & 5). Gonad maturation was observed to be identical with the stages observed earlier in the field. However, in captivity, sexual maturity is attained at 6-9 months. Since breeding is hormonally controlled, the study of hormonal control of reproduction in fish is critical. The first of such studies was conducted in Argentina by Houssay (1930) on the catfish, *Cnestrodon decemaculatus* using pituitary glands taken from *Prochilodus platensis* injected intra-peritoneally. Since then the technique has been applied in many countries by different fish biologists. Generally the induction – maturation techniques in fish fall into two categories. The first category involves the induction of maturation and spawning in fish which would not otherwise reproduce in captivity; the second involves the manipulation of spawning time in fish which reproduce in captivity.

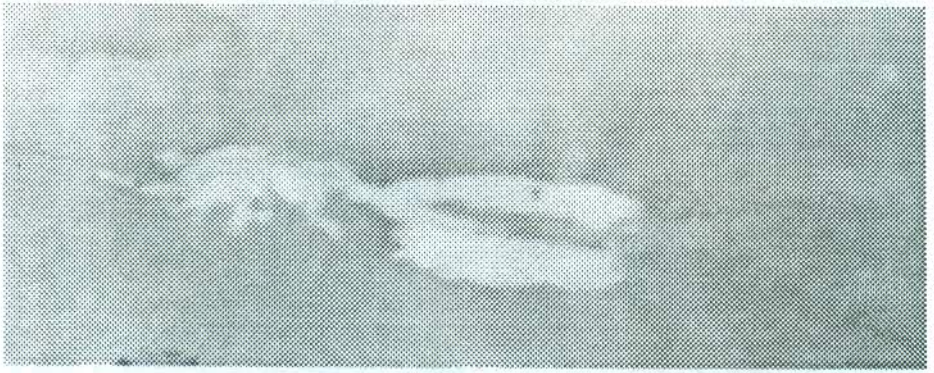

Plate 4. Ripe Male testis

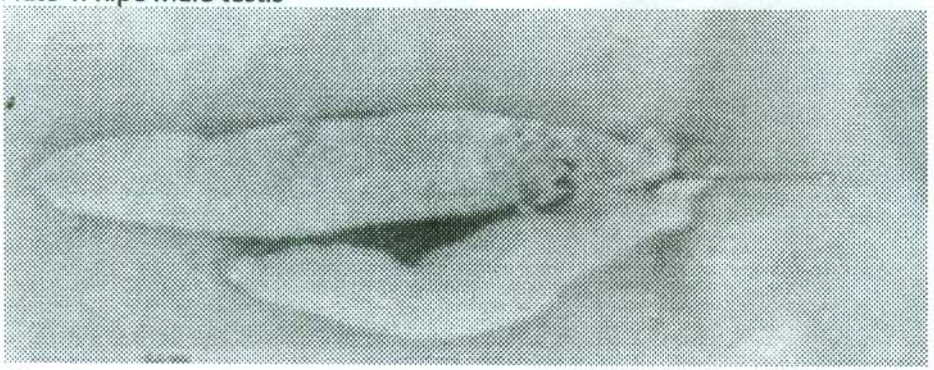

Plate 5. Ripe Female gonads

The basic principle of induced breeding in captivity hinges on the manipulation of the activities of the hypothalamic-pituitary-ovarian axis (Donaldson, 1973). The sequence of natural hormonal mechanisms creates chances for intervention at several levels to produce desired results (Fig.3). As can be seen in the figure, the natural sequence which is hormonally controlled clearly indicates the possibility of external intervention at any stage or time. The most common method has been the injection of a hypophysis into the female fish when it is ready to spawn. In the figure, there are five intervention points as indicated. Each of these intervention points is very critical to an effective outcome which again is a function of the inducing agent as shown.

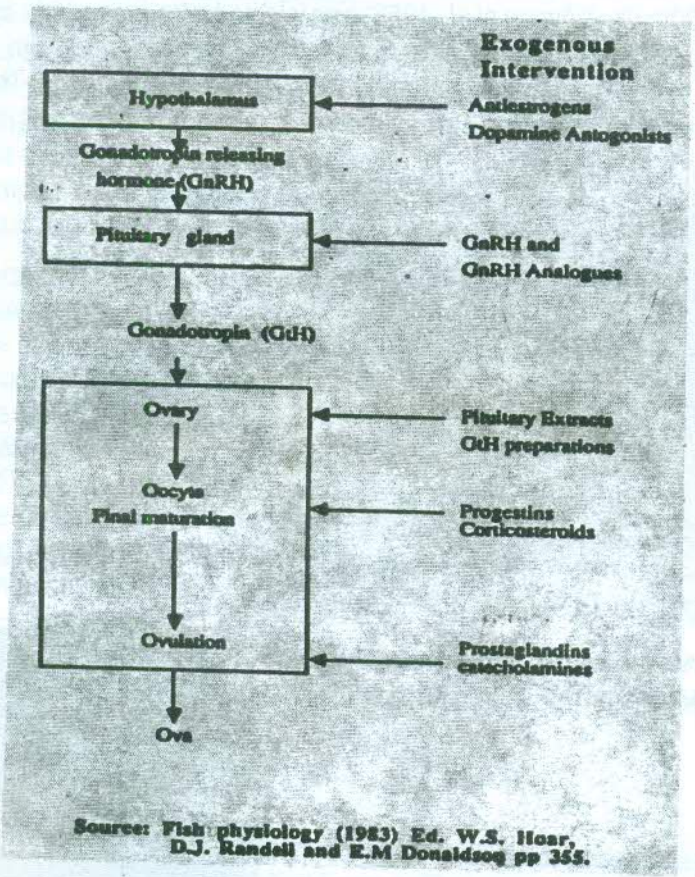

Fig.3. Levels of external intervention in the Hypothalamic-Pituitary-Ovarian axis which is used to induce maturation and ovulation in teleosts

3.3. The Procedure for reproduction in Captivity

The procedure for spawning *C. gariepinus* has been described by Hecht (1982), Polling *et al.* (1987) and Viveen *et al.* (1986). At the ABRU hatchery in Sonning, England the procedure I developed during the course of this work is outlined below. The methods I used during my work vary slightly from published procedures in the hormone dose, latency period, expression of milt over eggs, fertilization and incubation set-up. My methods varied because they were simple, convenient and successful. They were developed and perfected over time.

Forty-eight hours before the intended spawning time, the following gonads stimulation (induction) was carried out. A priming dose of hCG (Sigma Ltd) at a dose of 4000iu/kg (Viveen *et al.*, 1986) was injected intra-muscularly. Eggs and or milt were extruded from the previously induced females, and from the males' removed testes were macerated and held over the stripped eggs. The milt was then squeezed out, allowing it to run freely onto the eggs.

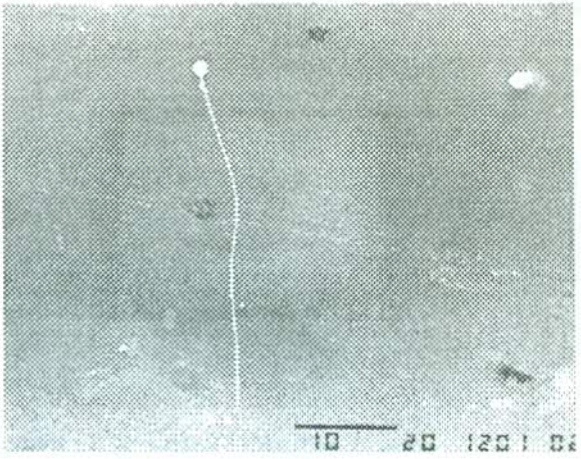

Plate 6. African catfish, *Clarias gariepinus*
Male sperm

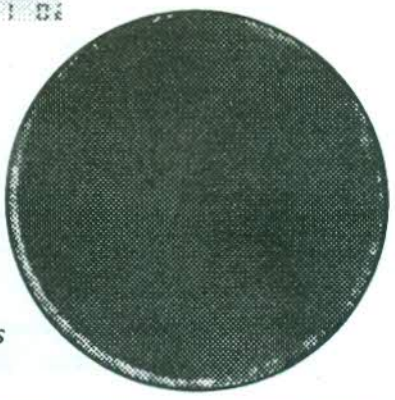

Plate 7. African catfish, *Clarias gariepinus*
female Egg

Fertilization and Incubation are the two final stages and are carried out together. Fertilization was effected when the eggs had the milt expressed on them and when the milt was activated by the addition of water.

During the process, the following observations were made which became crucial to understanding the reasons for failure or success in the hatching rate of this fish.

3.4. Factors that were found to increase incubation, fertilization and hatching success included:

I. Use of priming and resolving doses, this enhances egg maturity and release.
ii. Strict adherence to latency period.
iii. Non-use of cream milk to remove stickiness.
iv. The use of tray instead of jars, this allows eggs to spread in a monolayer and remain still, hence, reducing mechanical damage which is common with jars.
v. Use of optimum temperature for incubation. During this work, I found in a comparative observation, that best hatching rates were achieved at 26°C.
vi. Incubation of eggs should be carried out in total darkness.

3.5. Factors that were found to decrease incubation, fertilization and hatching success included:

i. Use of jars for incubation. This causes mechanical damage to eggs as a result of stirring.
The system gets easily blocked resulting in egg/larvae mortality.
ii. Attempts to fertilize eggs that are not completely ripe. Unripe eggs die and influence water quality.
iii. Use of fresh milk to remove stickiness. This stimulates bacterial and fungal growth and reduces water quality.
iv. Non-primining of spawners results in the release of in mature eggs or non-thinning of milt.
v. Exposing fertilized eggs to bright light.
vi. Non-adherence to both latency period (Viveen *et al.*, 1986) and water temperature.
vii. Poor water quality.

3.6. Early life stages

The early life stages of, *C. gariepinus* are on Plates 8- 13 and is based on eggs and larvae held at 27±2°C in a recirculation system. The early life stages were then compared with those of Bruton (1979). My observations agreed with previous descriptions attesting to the fact that this fish can be bred effectively in a recirculating system.

Plate 8. Blastophore (1hr)

Plate 9. Head and notochord (15hr

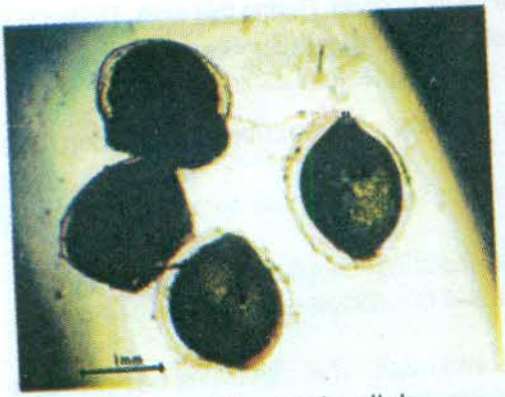

Plate 10. Gastrulation with cellular outgrowth (8hr)

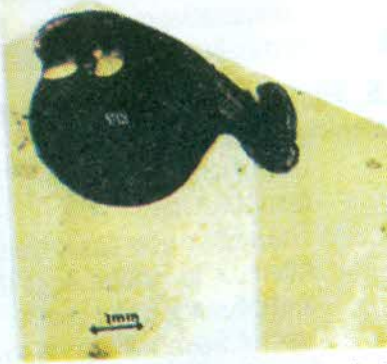

Plate 11. Hatched Yolk-sac (24

Plate 12. Mouth parts (48hr)

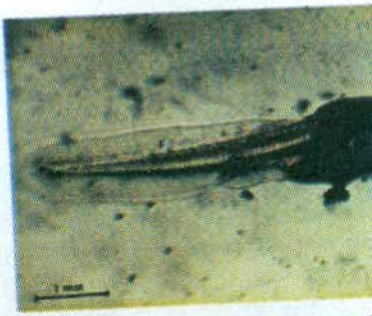

Plate 13. Free living fry (10 d

Larval feeding commences immediately after yolk absorption. An optimal dry food was tested against natural live food by Uys and Hecht (1985; Lamai, 1989). Degani *et al.* (1988) examined the effect of low protein diet on the growth of *C. gariepinus* maintained at different temperatures. The weaning time in *C. gariepinus* larvae was investigated by Verreth and Van Tongeren (1989). The importance of live diet in rearing fish fry can not be over emphasized (Bruton, 1979b). The survival rates of fish larvae, especially *C. gariepinus* both in feral and cultured stocks have been attributed to live diet in the form of natural or cultured *Daphnia*, *Artemia* or *Orachionus* (Bruton, 1979b; Verreth & Van Tongeren, 1989). However, the availability and composition of live food if taken from the wild, is subject to seasonal variation. Its collection from the field is usually cumbersome. There is also the risk of transferring diseases. If cultured in the laboratory, live food is rather expensive and subject to carefully controlled culture conditions. On the other hand, artificial diets are quality controlled; supplies are regular, can be transported to all places and are sterilized.

In the course of breeding *C. gariepinus*, the need for fry survival and growth became crucial to building a stock within a reasonable time just like in other experimental stations or farms. This was prompted by the problems of low hatchability and survival of *C. gariepinus* fry immediately after yolk-sac absorption.

Although artificial diets are accepted by most fish they lead to low growth rates and to high mortality when fed exclusively between hatching and 'metamorphosis' of the fish. The reasons for these difficulties are not fully understood. However, one of the twin most critical factors observed to be responsible for high mortality rate in this fish's early life stages is the type of feed fed to them at this stage of development. Several studies were conducted to overcome this, one of which is reported here.

Three different diets and particulate sizes were administered to 5-day-old post yolk-sacs of *Clarias gariepinus* reared in glass aquaria for a period of ten days (240 hours).

The effects of the different diets and the particulate sizes on their utilization hence, survival and growth of the 5-day-old *Clarias* fry were determined. Results (Table 1) indicated a significant difference ($P<0.05$) between diets in terms of survival and growth. The difference was found to be as a result of food particle size and their utilization by the fry. *It was therefore concluded that the particulate size and wholesomeness of the diets had a profound effect on the survival and growth of the fry of this fish. This explains why locally formulated diets perform poorly.*

Table: 1

The result of the experiment on the effects of different diets and their particulate sizes on their utilization, survival and growth of 5-day-old *C. gariepinus* larvae. Replicate data were not different, hence the combination of data *highly significantly different from ground pellets and trout started (p-0.001) according to Chi square test and t test.

	Artemia Nauplii Pellets	Ground Trout	Trout Starter
Initial number	40	40	40
Init. Mean wt. (mg)	1.491	1.491	1.491
SD	±0.2	±0.2	±0.2
Init. Mean 1cn. (mm)	6.043	6.043	0.043
SD	±0.58	±0.58	±0.58
Final mean wt. (mg)	86.064*	12.300	7.444
SD	±24.46	±4.76	±1.5
%. Survival	62.25	27.5	22.5

Table 1 shows that mortalities were significantly higher ($p<0.001$) in larvae fed trout starter and ground pellets than in Artemia fed larvae. In addition, those larvae fed on live diet grew significantly better than those fed on dry diet ($p<0.001$). This agrees with the suggestion of Uys and Hecht (1985) and Verreth and Van Tongren (1989) who suggested that when larvae have passed their weaning time, they do better on dry formulated diet than on live diet. These larvae had not yet reached their weaning time of 10 days (Verreth and Van Tongren, 1989), before the commencement of feeding trails.

It was therefore concluded that live diet consisting of freshly hatched Artemia nauplii offers the best utilised diet for both survival and growth in 5-day-old Clarias gariepinus larvae. Therefore it is advisable for fish farmers in order not to experience high mortalities and become discouraged to use live feed as first choice diet before weaning.

4.0. Hand stripping of Male African catfish, Clarias gariepinus

A breakthrough at solving one of the twin problems of the African Catfish farming, that is male sacrifice at each breeding exercise, was recorded. From the experience of breeding and culture techniques developed in studying this fish in

captivity it became clear that one of the major constraints of rapidly building a stock of *C. gariepinus* was the inability to strip the males. The traditional method of obtaining milt has been to sacrifice the male, remove its testes and macerate on eggs as described earlier.

The first step was to understand the underlying factor responsible for this problem and so an investigation of the gonads anatomy being the source of milt was carried out which eventually revealed one of the main factors as a highly onvoluted vas deferens (Plate 2) which constrains free flow of milt as in other species like Carp through mere application of thumb pressure which only muscular contraction within the fish does. Hence a way or method had to be developed to solve this problem. The absence of natural cues, crowding, artificial rearing methods, etc. all contribute to suppress natural spawning in captivity (Bruton, 1979; Huisman and Richter, 1987b).

To attempt this two trials were carried out, one to determine the possibility and the second to confirm the outcome and establish its reproducibility. The results, Mr. Vice Chancellor were a stunning success and became the first reported attempt in the fisheries and Aquaculture world. The protocol of this first successful attempt is reported here and the inducement processes in Tables 3 and 4.

During the first attempt, thirteen male and two female spawners were selected while in the second experiment, thirty-two male and two female spawners were selected from a group of *Clarias* spawned and reared in captivity. Twenty-four hours before priming (for the first and second experiments respectively), the fish were further regrouped into 4 groups of three for the first and four groups of four for the second experiment for treatment with the hormones, and 4 groups of four for the controls (without hormones) in the second experiment only, the females and the thirteenth male in experiment I remaining as they were. In both experiments, the male fish were primed (see Table 2) using 500iu (i.e. 0.5ml) hCG (Sigma Co. Ltd) dissolved in distilled water. This was injected intramuscularly at two different times of the day. The first two groups of fish (treatment A in duplicate) were primed at 0800h, while the second two groups (treatment B in duplicate) were primed at 2000h. The controls were all primed with 0.5 ml distilled water (the vehicle in which hCG was dissolved) at their respective times. The next day, at 0800h, the resolving dose of one gland, each an equivalent of 3mg of cPS (Inter-fish, Germany) suspended in 1.5ml of 0.9% saline, was injected intramuscularly to all fish treated earlier with hCG, irrespective of weight. The controls were all given 1.5ml of 0.9% saline as their own resolving dose. The females were then given

their only induction of the same dose of cPS. Table 2 gives a summary of the gonadal stimulation procedure.

Eight hours after the resolving dose was administered to all the fish, they were moved from their tanks according to their groups, beginning with A1, and anaesthetized Males were stripped by the application of strokes. When performing the stripping, an assistant held a 20ml analytical grade plastic cup, under the genital papilla to catch the milt that was coming in steady squirts in some cases or flowing gently in a few cases. Strokes were applied and continued until milt no longer flowed from the fish. The milt so collected was then stored in a refrigerator until all the males were stripped. The two females were then stripped of eggs the stripped fish were then left in freshwater to recover from the effect of the anesthesia. The thirteenth male in the first experiment was sacrificed and the testes squeezed to measure milt volume. This milt was then kept in the refrigerator at 4°C to assess durational viability.

When all the fish including the females were stripped, the milt from each fish that gave milt had the volume recorded in ml or µl. However, It was not enough to shout *eureka* at obtaining milt from a hatchery reared fish that never reproduces in captivity. There was the need to test whether the milt produced from this exercise was viable, whether it would fertilise eggs and whether the embryos would hatch. Hence, some tests were carried out for verification as follows:

Determination of sperm motility and density: The motility of milt determination was carried out 30-45 minutes after stripping by inspection of a drop of milt taken from each remaining sample and examined under the light microscope at a magnification of x400. (Plate 6) shows what a single sperm of *C. gariepinus* looks like as seen under the electron microscope. The presence or absence of motility of spermatozoa was expressed as present (1) or absent (0). The density was rated 1, 2 and 3 (i.e. low, medium and high).

Determination of fertilizability/hatchability: The eggs obtained from the females were weighed out in aliquots of one gram and placed in petri-dishes. Each petri dish then received two drops of milt from a different male, followed by distilled water to both activate the milt and to cover the eggs. The eggs and milt were then swirled gently (Hecht, 1982) and left for a few minutes at room temperature for fertilization to occur. In the first experiment, eggs were incubated and after 24 hours were examined and hatchability determined. In the second experiment, after 15h, the eggs were examined under a binocular microscope and fertilized eggs were counted to determine percent fertilizability.

Table: 2

Gonadal stimulation procedure for male handstripping experiments in June 1991 and 1992. n = number of fish. T1 = time of priming injection of 500iu hCG in 0.5ml water (controls 0.5 ml water only), T2 = time of resolving injection of 3mg cPS in 1.5ml saline (controls 1.5ml saline only), T3 = time of stripping.

Treatment	n	T1	delay	T2	delay	T3
June 1991						
A1 + A2	3+3	0800	24h	0800	8h	1600
B1 + B2	3+3	2000	12h	0800	8h	1600
Females	2	-	-	0800	8h	1600
June 1992						
Treatment	**n**	**T1**	**delay**	**T2**	**delay**	**T3**
A1 + A2	4+4	0800	24h	0800	8h	1600
Cont. A1+2	4+4	0800	24h	0800	8h	1600
B1 + B2	4+4	2000	12h	0800	8h	1600
Cont. B1+2	4+4	2000	12h	0800	8h	1600
Females	2	-	-	0800	8h	1600

Table: 3

Hand stripping of male C. gariepinus carried out on the 7th of June, 1991. The results show the volume of milt produced in ml per fish (v), in the two treatment groups A & B (Table 3), and the sperm motility (M), sperm density (D) and % hatchability of eggs fertilized with the milt (H)

		V	M	D	H
A1	1	0.05	1	2	30
	2	0.05	1	2	45
	3	-	0	-	-
A2	1	0.1	1	1	30
	2	0.05	1	2	26.7
	3	0.1	1	3	70.92
B1	1	-	-	-	-
B2	1	0.05	1	2	37
	2	-	0	-	-
	3	0.2	1	3	42
	Squeezed	1.5ml	1	3	not tested.

Table: 4

The hand stripping of male C. gariepinus carried out on the 8th of June, 1992. The result shows the quantity of milt produced in ml per fish (V) in the two treatments A and B (Table 4), and sperm motility (M), sperm density (D), and % fertilizability (F) of eggs fertilized with the milt. No milt was produced by the control fish. * = blood produced.

		V	M	D	F
A1	1	0.13	1	1	23.39
	2	0.00	0	0	-
	3	1.05	1	3	38.65
	4	0.20	1	1	27.55
A2	1	0.95	1	2	20.80
	2	0.1	1	1	-
	3	0.0	1	1	11.60
	4	*	1	1	-
B1	1	0.28	1	1	30.34
	2	0.05	1	1	25.40
	3	0.03	1	1	-
	4	0.29	1	1	7.94
B2	1	1.95	1	3	19.78
	2	0.23*	1	1	9.76
	3	0.00	0	0	-
	4	0.02*	1	1	-

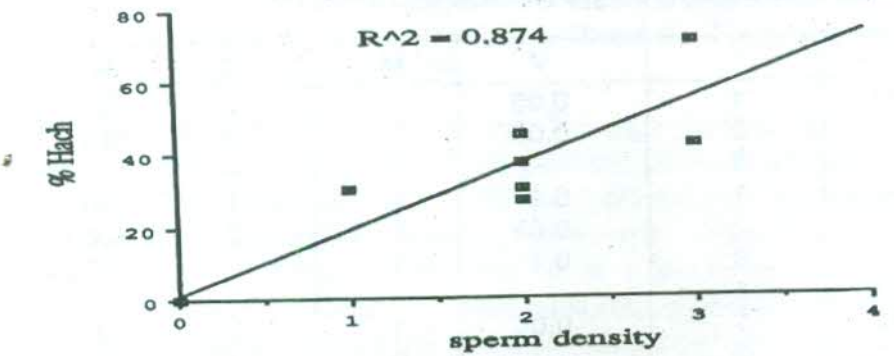

Fig. 4. The relationship between sperm density and % hatch of handstripped male *C. gariepinus*.

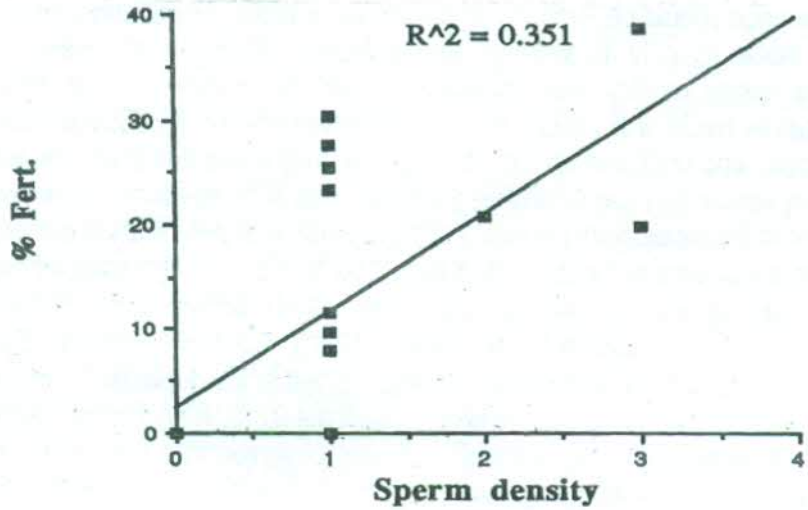

Fig.5. The relationship between sperm density and egg fertilizability of handstripped male *C. gariepinus.*

The results of the hand stripping exercise are shown in Tables 3 and 4. In the first experiment, eight out of 12 gave milt, and in the second experiment, 12 fish out of 16 gave milt. The results demonstrate the need and effectiveness of the hormones used, though not all fish responded and milt volumes were very variable. There were no apparent differences between treatments A and B, indicating that the delay between the priming and resolving injection is not critical.

On the whole, more milt was produced in the second experiment than in the first as mean values of 0.054ml and 0.33ml were produced in the first and second experiments respectively. The mean fertilizability % of the milt in experiment 2 was generally low in all cases, perhaps due to the fact that there was a long delay before the milt was added to the eggs. In contrast, the first trial showed higher mean % hatchability than the mean % fertilizability in the second experiment. This was attributed to the number of experimental fish. That is, while the first trial had only 15 fish (13 males and two females), the second had 34 (32 males and two females). This means it took longer to carry out the process of fertilization. Hogendoorn (1979) reported that unfertilized eggs of *Clarias lazera* develop 'normally' until the 8 or 16 cell stage. This might occur in *C. gariepinus*, which is synonymous to *C. lazera* (Bruton, 1979) and suggests that any delay would adversely affect fertilizability of the eggs. Hecht *et al.* (1982) recommended that *C.*

gariepinus eggs should be fertilized as quickly as possible. The sperm are also active or motile for only 30 seconds after activation (Polling *et al.*, 1984). *C. gariepinus* sperm motility was observed to last for a short time at room temperature by Hecht *et al.* (1982); they also observed a % motility decrease with time of diluted and undiluted sperm. For example, they found that at 45 minutes undiluted sperm motility was 40% while the diluted was 30%. However, I observed that the sperm squeezed from the testes of the control made in the first experiment and stored at 4°C remained viable after 8 days. Low fertilizability from stripped milt was observed by Polling and his colleagues (1984) among some of their treatments, and they observed an overall 53.1% hatching success. The fertilizability in my second experiment showed highest in the duplicate A1 which had a mean value of 29.86% and the least in duplicate B2 (9.84%). On the effects of weight on fertilizability or hatchability, it was observed that there was no relationship as the correlations calculated for the first and second experiments were 0.062 and 0.183 respectively.

Motility seemed to be higher where more milt was obtained though this was not statistically significant. There was a strong relationship between sperm motility and the % hatching in the first trial (fig. 4. & 5). A negative relationship was observed between weight and density. There was a positive relationship between the mean volume of milt produced and % hatching in the first experiment corresponding to the motility as stated above. The milt production and hatching success do suggest that the method of hand stripping can provide an alternative to the traditional method of maceration of testes. The fact that up to 1.95 ml (B2, 1) was obtained in one individual compares well with 1.5ml of milt obtained by squeezing in one individual in the control of the first trial. This quantity can fertilize 10,000 eggs or more, indeed, Hecht (1982) estimated that semen obtained from a 2kg male (5-6ml) was sufficient to fertilize eggs from 3 females (i.e. 200,000 eggs).

Based on these observations, it was concluded that it is possible to hand strip hatchery reared C. gariepinus and that hand stripping the male is by far more useful than the maceration method, because it economises on males. It also has the advantage of allowing continuing genetic investigations as the presence of a live parent can allow for back crosses since the male parent has not been lost through sacrifice.

5.0. Sex reversal in the African catfish, *Clarias gariepinus*

One of the requirements for profitable aquaculture is the production of table–size

fish within the shortest possible time. One way to do this is to examine among culturable fish, which of the sexes grows faster and to develop a mechanism to produce same sex fish. Hence, one of the studies to be conducted on this fish in captivity was the determination of sex reversibility having established the most profitable sex. This was to be the first time that such could be conducted on this fish; it was to determine whether like Trout, Tilapia, etc. its sex can be reversed. Generally, as stated earlier, the compelling reason for sex reversal in genetics and breeding is to take advantage in aquaculture of a desirable character in one sex for commercial purposes or the elimination of one sex. For instance in 1979, British scientists were trying to control the sex of trout because male trout produce poor quality flesh, grow slowly, have a poor appearance and cannot survive in seawater, hence they are of lower economic and commercial value than female trout. The African catfish on the other hand has a bigger male that grows faster and is of higher market value than the female. In fish, the underlying factors behind either maleness or femaleness could be attributed to sex-hormone differences. When embryos are produced, they are sexually undifferentiated and sex-labile until, in the course of development and the subsequent production of sex hormones, sex differentiation becomes apparent. The effects of sex hormones are seen in the production of both primary and secondary characters. In *C. gariepinus,* newly hatched larvae are sexually determined at between 28 – 42 days after hatching (van den Hurk *et al.*, 1989). In some other species sex differentiation takes a longer time, for example in members of the Cichlidae it takes about four months.

Investigations into natural populations have shown that a great number of fish species change sex as a natural part of their life histories and evidence suggests that social and other exogenous factors may be responsible (Naish and Ribbink, 1990). In cultured fish species, sex-reversal is only possible artificially, through the administration of natural or synthetic steroids. These can be administered orally, by injection, implantation or immersion.

While investigations of wild populations on this aspect might be to establish the causes of such a phenomenon, in cultured species the aim might be different. And while wild stocks may find sex-reversal beneficial for survival, sex-reversal in cultured species is for scientific, economic or commercial purposes. Scientific interest in sex reversal experiments is due to interest in sex determining mechanisms, including genetics, and the possible advantages in aquaculture of one sex or the other, or advantages due to elimination of breeding (e.g. Tilapias). The reasons mentioned seem to justify this work. Early experiments on sex-

reversal started in the 1930s by Padoa in Rainbow trout *Onchorynchus mykiss* using the follicular hormone to produce ova in gonads that had previously been testes and Houssay (1930) in reptiles. Since then sex reversal attempts have varied not only in species of fish used but also in the inducing agent, dose level and combinations. Steroids have been widely used in sex-reversal experiments; however, one hormone, namely 17-α-methyltestosterone (17-α-MT), stands out as the earliest and most consistently used either singly or in combination with others for sex-reversal to male. This is because it is readily available, effective and easy to administer. Thus 17-α-Mt was chosen for the work reported here, the aim of which was to produce sex-reversed male in *C. gariepinus*. In *C. gariepinus*, males grow faster and bigger and hence are of higher market value than females (Hogendoorn, 1983; Viveen *et al*., 1986). The fry produced from spawning in May 1990, March 1991 and August 1991, where they had been bred and maintained as described above, were removed respectively for the first two experiments at approximately six days post hatching and for the third at ten days post hatching.

Hormone treated fresh feed was prepared before treatments commenced. 17-α-MT dissolved in 96% ethanol was mixed with ground trout pellets at a level of 40mgKg^{-1} of food for the first two experiments, using the methods described by Scott *et al*. (1989). At approximately three months of age a sample of the fish (10) was removed to determine their sex. The presence of a urogenital papilla indicated that the fish was male while the absence means that the fish was female. To confirm the accuracy of this external method, the aceto-carmine stain technique, describe by Guerrero & Shelton (1974) was then applied on the same sample of fish. Generally, the results of the three sex-reversal experiments, which are summarized in Tables 6, 7 and 8 under the three different experiments, showed that all doses administered, whether orally or in water, produced feminization (paradoxical feminization). Mortalities were significantly higher ($p<0.001$) in both treatments and controls when ground trout pellets were used as feed, than when live diet was given. Deformities were observed among fish treated at 40mg kg^{-1} food, however, none occurred among fish treated at 4mg kg^{-1} food or 200µg 1^{-1} of water.

Feminization and sterility: Histological examination of the gonads at 3-5 months old revealed 100% female fish in all the treated groups irrespective of duration. Control groups, had 1:1 sex ratios (Table 6). Dissection of feminized fish showed a reduction in gonadal material. Gonad sizes were reduced in varying proportions to 1/10 or 1/20 of the normal size in about 3 of the treated fish of that stage of development (3-5 months). Internal observations did confirm sterility (lack of

gonads) in one feminized fish, and this was systematically investigated.

Survival: No dose-dependent mortality was observed in the treated group which is in agreement with observations on rainbow trout by Solar *et al.* (1984). The computation of % survival of treated and controls are given in Table 6. An analysis of variance showed no significant difference in the % mortality between the controls and the treated. However, high mortalities were probably due to the dry diet (*Clarias* fry are known to suffer severe mortalities when fed dry diet). All the survivors of the treatment grew normally except for a sterile one that grew bigger than the rest, about 1.5 times the size of a normal fish.

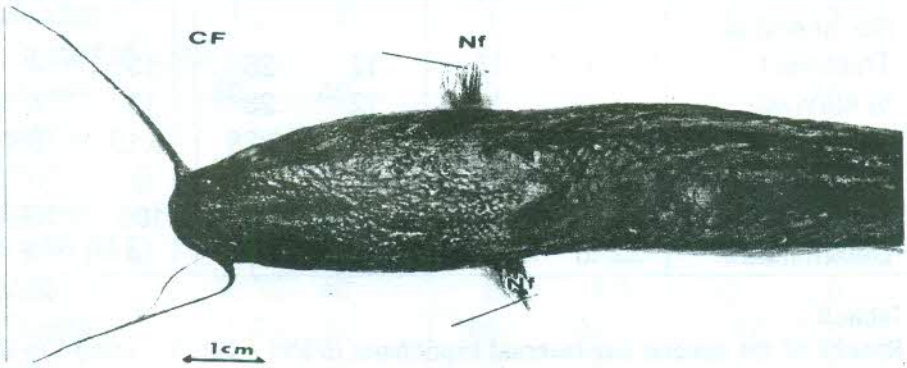

Plate 14 Normal fins of C.gariepinus

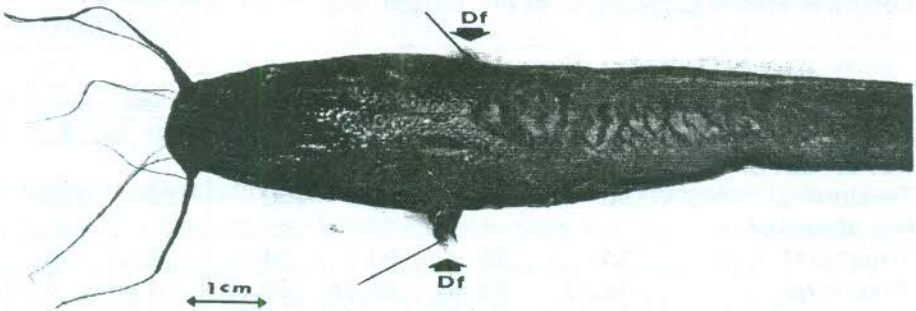

Plate 15 Deformed fins of C.gariepinus

TF	=	treated fish
CF	=	control fish
Df	=	deformed pectoral fins
Nf	=	normal pectoral fins.

Table: 5

Results of the first sex-reversal experiment (10/5/90 – 31/5/90) using 17α-MT administered orally at a dose level of 40mg kg^{-1} food for a period of 10 (MT-1) or 20 (MT-2) days. # present, numbers not recorded.

	Experimental Groups					
	Control		MT – 1		MT -2	
	1	2	1	2	1	2
No. at start of Treatment	100	100	100	100	100	100
No. at end of Treatment	11	18	12	28	13	4
% survival	11	18	12	28	13	4
Sex ratio (M:F)	6:5	9:9	0:12	0:28	0:13	0:4
% Male	55	50	0	0	0	0
% female	45	50	100	100	100	100
Deformities	0	0	#	#	#	#

Table: 6

Results of the second sex-reversal experiment (8/3/91 – 28/3/91) using 17α-MT administered orally in feed at a dose level of 40mg Kg^{-1} food for a period of 10 (MT1) and 20 (MT2) days. Asterisks indicate significant difference of male ratio in controls to male ratio in MT-1 and MT-2, and also number of deformities in MT-1 compared to MT-2 according to the Chi-squared test *(P<0.001).***

	Experimental Group					
	Control		MT - 1		MT - 2	
Replicated	1	2	1	2	1	2
No. at start of Treatment	150	150	150	150	150	150
No. at end of Treatment	53	25	91	54	7	11
% survival	35.33	16.66	60.66	33.33	4.66	7.53
Sex ratio (M:F)	26:27**	23:2**	3:88	4:50	0:7	0:11
% Male	49.06	92	3.29	7.41	0	0
% Female	50.94	8	96.71	92.59	100	100
No. sterile females	0	0	21	26	6	5
% Sterile Female	-	-	24.18	52.00	85.71	45.4
No. of deformities	0	0	5**	9**	3	5
% deformities	0	0	5.49	16.67	42.9	45.5
Experiment III						

Table: 7

The results of the third sex-reversal experiment (18-28/8/91) using 17a-MT administered both orally in food, and in water, at a dose level of 4mg kg^{-1} food and 200µg 1^{-1} water for a period of 10 days. Asterisks indicate significant difference in survival number of MT-water treatment when compared to that of MT-food, according to Chi-squared test.

	Experimental Group					
	Control		MT - Water		MT - Food	
Replication	1	2	1	2	1	2
No. at start of Treatment	40	40	40	40	40	40
No. at end of Treatment	33	25	21**	23**	13	9
% survival	87.5	62.5	52.5	57.5	32.5	22.5
Sex ratio (M:F)	12:21	10:15	0:21	1:22	0:13	0:9
% Male	36.36	40	0	4.3	0	0
% Female	63.64	60	100	95.7	100	100
No. of def.	0	0	0	0	0	0

From the evidence above and elsewhere (Solar *et al.*, 1984; van der Hurk *et al.*, 1989), it is possible to find paradoxical feminization in sex-reversal experiments which could be explained in the light of dosage level. The concept of paradoxical feminization, is that in starting with the objective to produce masculinity, one ends up with feminization which is interpreted as being a 'pharmacological' effect (van den Hurk *et al.*, 1989), that is the conversion of excess androgen to estrogen.

It is, however, possible to induce sex-reversal to male in *C. gariepinus* by treating the gonadally undifferentiated fry with sex hormones. Results, however, seem to vary with different species and the steroid used (Ridha *et al.*, 1991). The two methods of administration of hormone did not seem to have any effect on the overall results obtained as both had the same effect, administration of the hormone in the water and the use of live diet, however, improved survival.

Deformities are a rare occurrence in sex-reversal experiments and suggest that the dose was too high and that this particular fish is much more sensitive to the hormone than the Tilapias are. The deformities were observed to be confined externally to the pectoral fins (Plate 15) and internally to the ovaries. Gonad

deformity was also observed by Johnstone *et al.* (1979) and occurred in all male populations of rainbow trout resulting from the dietary administration of 17-α-MT at a concentration of 3 mg kg^{-1} food to juvenile fish during a 40-day period following 'swim up'. Deformities were mainly limited to the reproductive system and prevented normal expression of milt although spermatozoa from the testes were viable. The observation of deformities being restricted to particular organs (pectoral fins and ovaries) could suggest the possibility of some physiological relationship between the development of these particular organs and the activity of its metabolic product in this fish.

The dose levels used in the three experiments gave almost identical results suggesting that all levels were above the threshold of producing masculinization in *C. gariepinus*, van den Hurk *et al.* (1989) induced some masculinization in *C. gariepinus* at a dose level of 30µg 1^{-1} of 17a-MT. This seems to indicate that there is a critical period in this fish, before or after which it changes its response to this androgen. The duration of exposure in this work did not seem to produce any marked effect in terms of enhancing or decreasing sex-reversal, the only males in any treatment groups were in 10-day treatments.

The medium of administration of the hormone in the third experiment seems to suggest that sex-reversal in *Clarias* does not depend on the medium but rather on the correct dosage and duration of exposure.

The results of this work did not suggest any effects of age on sex-reversal. There was a slight age difference between the fry used in experiments I and II and that of experiment III, however, results were all the same. Van den Hurk *et al.* (1989) used 28 day post hatching and still got some masculinization with 17a-MT, suggesting a reduction in the sensitivity to this hormone with increasing age.

The use of live diet in this work did not appear to affect the results obtained. However, live diet did affect the survival rate which is in line with the observation made. A comparison of the survival rates in the last experiment showed a significantly higher ($p<0.001$) survival rate in the third experiment where live diet was given than in the MT-food. Survival of *C. gariepinus* fry is known to depend on use of live diet- *Artemia nauplii* (Uys & Hecht, 1985 & Viveen *et. el.*, 1986). Survival rate is important in sex reversal experiments for statistical analysis and convincing inference. The fact that, live diet does not interfere with the hormone effect, but increases the survival rate in this fish, suggests the need for live diets in similar experiments with this fish.

The outcome of these attempts at sex reversal in Clarias gariepinus suggests that this fish has a uniqueness of its own, as other fish species that have been treated with the same hormone, same exposure medium and same dosage, produced a higher percentage of maleness. It was therefore concluded that the procedure can be effectively used to produce more females than males.

6.0. The African catfish response to aquatic pollutant (pesticide)

Any fish lives in an environment whether wild or in captivity, that is sometimes contaminated in one way or the other by direct or indirect human activities. These pollutants pose a serious threat to their well-being and existence. In trying to understand pesticide mobility in aquatic living forms and especially fish, I was interested to know what happens to the African catfish when exposed to pollution (pesticides) because in Africa there is a heavy application to crops, etc. of pesticides. The studies under captivity afforded an opportunity to test this fish using one of the world's once celebrated insecticide, dieldrin. This used to be one of the most toxic organchlorines and one with the longest biodegradable half-life used extensively from the 1960s until its ban in 1986. It has a half life of 25 years. Its notorious attributes informed its choice for use on this fish. As a pan African fish and with the Africans penchant for excessive and uncontrolled insecticide use, it was not out of place to choose it. This study was to involve all the life stages of the African catfish from egg to adult and also other parameters that indicate immediate effects. This is because sometimes water supply to a recirculation system may not be properly screened before being supplied to the system and accidental spills can lead to disaster. There was therefore a need to understand the effect it would have on this fish at all life stages.

These pesticides still have important applications in some tropical countries (Crick, 1990) and the possibility exists of organochlorines accumulating in fish that may subsequently be used for human consumption. The catfish is cultured in many parts of Africa, and the toxicity and bioaccumulation of dieldrin in this species has therefore been studied as an aid to impact assessment of application in areas where aquaculture may be practiced.

It was Holden, (1973) and Moriarty (1985) that were able to determine the route of uptake in fish which mainly starts from the gills and ends in the liver. As a lipophilic compound, dieldrin normally shows a high bioconcentration factor (Walker; 1987). Koeman *et al* (1971), studied the dieldrin residue levels in different Nigerian indigenous freshwater species following wild test sprays and found that levels of dieldrin varied both between species and between tissues.

In this work, the African catfish (*Clarias gariepinus*) and Nile tilapia (*Oreochromis niloticus*) were both exposed to this pollutant for all life stages and all responded negatively, some resulting in mortality. Worthy of note is the ability of this fish to accumulate dieldrin in the liver six times the concentration in other tissues Figure 7. *This is important for a fish of such high value to Nigerians. The way and manner this fish has to be cultured as an omnivore must be in an environment free of contaminants, the one being recommended today.*

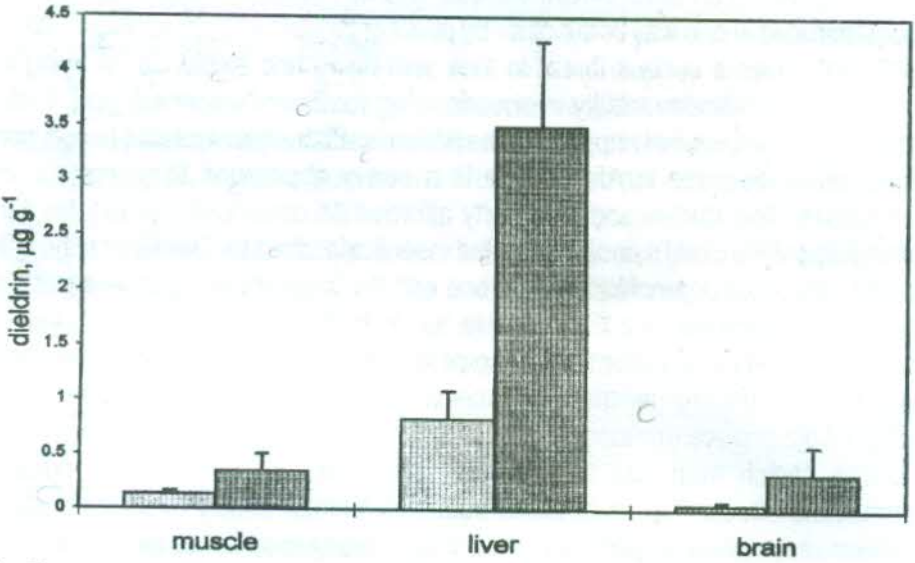

Fig.7.

Dieldrin extracted from tissue samples of fish exposed to 2.4µliter-^{1} (light stipple) 4.0µg liter-^{1} (heavy stipple) dieldrin for 30 days. No dieldrin was found in control tissues. Error bars indicate standard deviation.

Mr. Vice Chancellor, having been privileged to pioneer some studies into Nigeria's number one aquaculture fish for over 25 years in captivity from egg to adult stage, its reproduction, nutrition, growth and survival, sex reversal, toxicology, etc and having applied recent technological advances in relation to its aquaculture potentials in intensive aquaculture systems either on small or large scale, I have come to the conclusion that it has the requisite attributes for adoption into recirculation aquaculture system which is the only culture system for the 21 Century anywhere, any day by anybody in this country as explained below.

7.0. Aquaculture qualities of the African catfish

On a comparative basis, this fish has more aquaculture potential than the

celebrated and over cultivated Tilapias. For example the introduction of Tilapia culture in 1946 and 1949 in Central Africa received an overwhelming support from both governments and local farmers of Africa. Hence, the rise in aquaculture activities in African between 1959/1960, when about 300,000 ponds became operational in 20 African countries (Meschkat, 1967). However, the same Tilapias were later to be responsible for the decline in aquaculture in Africa (Huet, 1972). This was as a result of widespread discouragement among African local fish farmers, who were harvesting small size Tilapias from over-populated ponds caused by poor stocking methods, coupled with its high reproductive rate.

In terms of total production in Africa, however Hecht et al. (1996), states that the principal Clariid species which make up the bulk of the production are *Clarias fuscus*, *Clarias macrocephalus*, *Clarias batrachus* and *Clarias gariepinus*. It was stressed that total world production of Clariid catfish for 1993 has been estimated at approximately 90,013 tons. Aquaculture in Africa is predominantly rural, and orientated principally to the immediate needs of the farmers and their families (Hecht 1996). In many instances the fish are consumed directly (e.g as much as 50% of the harvested in Kenya, Ivory Coast and Rwanda). Consequently the production figures are not always reported or recorded as stressed. More recent information according to FAO Fisheries statistics of 1993 and 1994 was obtained from the scientific literature, aquaculture and agriculture magazines and in unpublished research reports of research stations on the continent and through personal contacts of some of the compilers of this section. Using this information and assuming a considerable measure of under- reporting and non- recording. 30% out of the total production of Clariid species (mainly *Clarias gariepinus)* for 1993 in Africa was estimated to be around 90,003 tons (Hecht 1996).

FAO (1992) reported that *Clarias gariepinus* has been translocated to several countries from Africa and is now farmed either in its pure form or as a hybrid in The Republic of Korea, Peoples Republic of China, Taiwan, Philippines, Vietnam, Cambodia, Hong Kong, Guam, Laos, Thailand, Malaysia, Indonesia, India, Brazil, Poland, Hungary, Belgium and The Netherlands.

One of the reasons why the African catfish is preferred to others is seen in the production level compared to the commonly cultivated Tilapia spp nationally. The production of this fish rose from a mere 1,906 tonnes in 1999 to 37,600 tonnes in 2007 while its counterpart, the Tilapia, rose from 1,589 tonnes to 9,272 tonnes within the same period (FAO, 2010). This is a clear indication of a meteoric rise in production due to consumption preference for the African Catfish. This is equally an indication that the African catfish is likely going to be Nigeria's fish for the next

millennium. Apart from the factors of production and consumption demand, other favourable factors like improvement in production methods and expanding market for the fish and its products might have been responsible.

8.0. The challenges of African catfish culture in the 21st Century

As stated earlier, this fish is currently cultivated at subsistence and to some extent commercial basis all over the world including 12 African countries, the most important of which in terms of tonnage produced are Nigeria, South Africa, Zambia and Ghana. It is only reasonable to challenge Nigerian fish farmers on the culture of this fish in recirculation systems.

The scientific and technological foundation for the culture of this fish is sound and has been developed over time in Europe and Africa. Most of the important parameters, inclusive of spawning, incubation, larval feeding and rearing, reproduction and feed formulation, have received enough attention for a successful intensive culture in recirculation systems.

One of the problems facing us as a nation today, in spite of being one of Africa's leading catfish producers, is that the level of operation is still very low(Lamai,2000). In 2009, Nigeria's total harvest from aquaculture stood at only 620,000 metric tones consisting mainly of catfish. This is a far cry from our consumption rate of over 2.66million metric tones per annum. Catfish production has contributed significantly to our economy as fish farming has contributed nearly $1billion to the national economy and our domestic fish food production for many years. This is simply because it has proved to be successful in most aquaculture systems locally. Generally, the main challenges of extensive and intensive catfish culture in Nigeria are a good understanding of the catfish and input which consists of skilled labour, capital, seed, feed, culture system, pond size, dependence on others, main beneficiaries, etc. In recommending the recirculation system for African catfish culture the following challenges are presented:

8.1. Stocking Density in Recirculating systems

A research to determine the optimum stocking rate of *Clarias gariepinus*, which will bring maximum yield, growth and corresponding effects on the water quality parameters for example, dissolved oxygen, ammonia level, temperature etc and survival rate of the fish was conducted in 1996 (Obadiah and Lamai, 1996) and established a stocking density of 80 per 40 litres of water. However, any increase in stocking density beyond that resulted in decrease in both survival and growth. Huisman (1976 b) observed that *Clarias gariepinus* proved to be a very suitable species for higher density culture, having a higher growth rate, whilst maintaining

very efficient feed utilization. It uses up to 80% of the dietary metabolizable energy for growth which compares favorably with values of non air breathing fishes like rainbow trout and common carp fed with the same diet.

Even though results like in this experiment give hope for RAS production, there are a few surmountable challenges that face the operation of RAS for *Clarias gariepinus* in Nigeria and indeed the world over, these include among others the following:

8.2. Capital

The greatest challenge to productive large scale intensive aquaculture generally is capital, especially for rural farmers. Recirculating aquaculture system continues to be expensive because it is mechanically sophisticated and biologically complex. Hence, government financial assistance, in form of start-up funding may be critical in the early stages. The argument in support of this is that aquaculture in Nigeria is still at an infancy stage and until it reaches a stage when it is competitive, there will still be need for government support. The private sector that is supposed to drive this very important economic sector has not shown enough courage, will and commitment. This aspect has scared many a potential farmer, however, realistically it is not as expensive as it is thought to be, and it all depends on scale. The average set-up may only cost between ₦50,000 and ₦400,000.00 for a small and medium/large unit.

8.3. System operation

To provide a suitable environment for intensive fish production, recirculating systems must maintain uniform flow rates (water and air or oxygen), fixed water levels and uninterrupted operation. According to Michael *et al.* (1999), the main cause of flow reduction is the constriction of pipes and air diffusers by the growth of fungi, bacteria and algae, which proliferate in response to high levels of nutrients and organic matter. This can cause increases or decreases in tank water levels and reduce biofilter efficiency. To overcome this problem the use of oversize pipe diameters and configuring system components to shorten piping distances as well as regular cleaning of the pipes and air passages are necessary to remove blockages.

As a requirement for continuous operation, an automatic backup power source should be in place as it takes only a brief power failure to cause a catastrophic fish loss. For example, if a power failure occurred in a system maintained at 29°C at saturated oxygen concentration containing 200g fish at a stocking density of 50g

fish per litre of water, it will take only 16 minutes for the oxygen concentration to drop to 3ppt. The same system containing 500g of fish at a stocking density of 200g per litre will drop to this level in 6 minutes. These scenarios should give the prospective manager a sobering feeling for how important backup power is. Biological filters can fail as a result of senescence, chemical treatment, or anoxia. It takes a while for a bacteria colony to grow, age and die. They are susceptible to water quality changes, like low DO, low alkalinity, low or high $_{P}H$, high CO_2, chemical treatment. They are sensitive to rapid changes. This can be easily and effectively handled by engaging skilled labour.

8.4. Particulates and their removal

The removal of particulates is one of the most difficult problems in recirculating systems. They come from uneaten feed and from undigested wastes. It has been estimated that no less than 60% of what is given as feed ends up as wastes. The best solution is quick and efficient removal. This helps to reduce biological demand as well as improve the biofilter efficiency and lower oxygen demand on the system. One of the reasons why some recirculating systems give a lot of odour is because of poor handling of wastes.

8.5. Water quality management

The one other challenge in running an efficient recirculating system is good water quality management. Good water quality must be maintained for maximum fish growth and optimum effectiveness of bacteria in the biofilter. The essential parameters include temperature, carbon dioxide, dissolved oxygen, pH, ammonia, nitrite and solids. They all must be maintained within tolerable limits.

8.6. Production management

Another challenge associated with intensive recirculating catfish production is appropriate stocking. Fish to be stocked whether fry or fingerlings should be from a reputable producer or farmer, who is quite versatile in fish breeding and handling. Fish must be checked for diseases and parasites. The other important aspect is feeding. Knowing how feed is to be given without overfeeding is a problem in any type of fish production (Michael *et al.*, 1999). Over feeding can lead to generation of wastes, degradation of water quality and overloading of biofilter. In managing production, one challenge faced by managers is stress management. Fish can be stressed by changes in temperature and water quality, handling, nutritional deficiencies and by exposure to diseases and parasites. To reduce stress the factors listed and others above must be properly managed.

Unexpected sounds and sudden flashes of light often trigger escape responses leading to injuries.

9.0. Conclusion and Recommendations

Traditional aquaculture has been with us for a very long time. It has no doubt contributed and is still contributing to alleviating poverty, reducing hunger and meeting the protein need of nations. However, people would benefit more from shifting away to an intensive system. Ttraditional land based aquaculture system with all its problems that range from extensive water requirement to exposure to all the vagaries of weather and poaching may not be the answer to our future fish production needs.

Recirculating aquaculture system is best suited for this fish. All studies conducted by the author and others on the fish in captivity have revealed quite a lot on the totality of its reproduction, growth, survival and tolerance to adverse conditions in a recirculating aquaculture environment.

Based on this understanding, Nigeria's food fish self-sufficiency drive can be achieved through production in intensive recirculating aquaculture system (Fig.2). A careful observation of the facts of these series of study of the life cycle which started first from the wild for about two decades, I have no doubts whatsoever in my mind that it stands out as the most suitable for this culture system considering the several advantages that it has.

I need to state here as I did earlier that fish is one of the most traded commodities in the world as it runs in multibillion dollars and the contribution of aquaculture to food security, human health, general well being and employment generation can not be over emphasized. Globally, the fisheries sub sector employs about 500million and sustains the livelihood of more than 3 billion world-wide. Recirculating aquaculture system represents a new and unique way to farm fish. Growing public demand for a healthy, tasty and affordable fish is stimulating the boom in this industry. The decline in wild fish populations as a result of overharvest and water pollution has promoted the culture of farmed fish that are grown in contaminant-free waters in indoor tank system. Hence, the following recommendations are made for Nigeria and indeed, our people:

1. There is the need to further advance the technological benefits of the intensive culture of this emerging National aquaculture fish, to boost its production level to

enhance fish self-sufficiency. Currently my four PhD students working on some of these new technologies are likely going to contribute significantly towards that.

2. The new technology of Recirculating aquaculture system has developed to the point that it should be adopted as one of the means of fish production for food security, poverty alleviation and economic growth, as it can be carried out within a house hold. Currently Fisheries as a whole contributes about 4 % of Nigeria's National Gross Domestic Product (GDP) this can be enhanced through it.

3. Climate change has offered another challenge for the nation and indeed globally, to examine some of our traditional ways of fish culture that would meet up with the challenges of acute water shortages, increased temperature and therefore unfavourable weather conditions for extensive aquaculture.

4. In view of the increasing demand for protein intake nationally, the need to develop fish production system in populated centres at all levels is of paramount importance.

5. Recirculation systems offer a better culture system for Nigeria for the 21st Century as it has the requisite attributes for closing the gap between dwindling catches from our waters, both fresh and marine; and present healthy fish on the table, thus:

i) It is currently one of the fastest growing sectors of Agriculture in the United States of America, Europe and China.

ii) This is probably the only aquaculture system that is environment friendly.

iii) Recirculation systems conserve water and allow producers to control all the environmental factors that might affect the fish. The aquaculturalist has complete control over temperature, dissolved oxygen, salinity, predators and introduction or transfer of diseases.

iv) Recirculation systems can be built just about anywhere including urban settings where they can use existing structures and be placed close to markets thereby reducing transportation costs.

v) It can be used to grow a wide range of fish species as well as integrated with vegetables production as in Aquaponics.

vi) Recirculation systems are probably the only intensive aquaculture systems

that check the major problem of sibling cannibalism in *Clarias gariepinus* and the human problem of poaching.

vii) In addition to all these, much research has been dedicated to improving on this technology especially with the issue of sludge management.

viii) The attention of the world is turning to finding ways of food production that would conserve water resource, reduce habitat loss, reduce degredation of the aquatic and benthic environment, remove genetic interactions with wild populations, marine mammals and turtles, eliminate displacement of coastal fishing and farming communities, reduce social exclusion, social unrest and conflicts, eliminate conflicts with tourism, recreational fish and commercial fishing and remove environmental contaminants and food safety concerns.

ix) Aqua- vegeculture system consumes 1% of water that is required in pond culture to produce equivalent yields. Such low-water use symbiotic systems are applicable to the needs of semi-arid regions.

The foregoing is a call for a shift away from our traditional culture system to a better 21st Century system that will secure the future of aquaculture. This will also mean an inclusion in the Fisheries curriculum of Nigerian Universities to give effect to a more technological advantageous production system since that is one of the benefits of research any where in the world.

Nigeria given its enormous human resources, large consumer market could be at the threshold of fish food self- sufficiency in the shortest possible time with the adoption and adaptation of the 21st Century fish production system in Recirculation Aquaculture System for the African catfish, ***Clarias gariepinus*** and indeed other species.

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Mr. Vice-Chancellor, my being able to stand before you today to deliver this inaugural lecture, is a sum total of God's divine construction through many hands and ideas of men, women and events in time and space as you heard read out to you. That is, God's accomplishment through the contributions of innumerable people in different places at different times, some present and some not; and some living and some long gone to the great beyond. It is unfortunate that time and space will not allow me to mention all by name and their individual or collective contributions, however they are equally acknowledged. God who knows them better will reward them abundantly.

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His Excellency is the one Governor in this country, who has impacted positively on the affairs of the Federal University of Technology, Minna. He will always be remembered as the first Governor to strengthen the presentation of inaugural lectures in this great University of which I am today a part.

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Mr. Vice Chancellor, I would like to end this lecture by quoting my favourite Scripture verse:

"But we have this treasure in earthen vessels, that the Excellency of the power may be of God, and not of us". **I Corinthians 4:7 (AKJV)**

Thank you for your kind attention. God bless.

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