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Review of Aquaculture Production and Management in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. *All authors read and approved the final manuscript.*

Review Article

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ABSTRACT

Fish is an important source of food, income, employment, and recreation for people around the world and it is a very important source of animal protein for both man and livestock in developed and developing countries. In Nigeria, the current demand for fish is about four times the level of local production. Humans consume approximately 80 percent of the catch as food. The remaining 20 percent goes into the manufacturing of products such as fish oil, fertilizers, and animal food. Fisheries and aquaculture are integral parts of agriculture which were found to have the capacity to increase the country's GDP (Gross Domestic Product) and can solve the unemployment problem for our teeming youths if adequately managed. Therefore, this paper reviewed the status of Aquaculture in Nigeria, its problems and development prospects, different fish species that can adequately thrive in Nigerian pond and its preparation, and finally showed some first-rate management practices that can boost aquaculture production in Nigeria.

Keywords: Aquaculture; development; management; production; stocking.

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1. INTRODUCTION

The demand for fish in Nigeria mostly outstrips the local production. Nigeria is the largest fish consumer in Africa and among the largest fish consumers in the world with over 1.5 millions tons of fish consumed annually. Yet, Nigeria imports over 900,000 metric tons of fish while its domestic catch is estimated at 450,000metric tons/year [1]. [2] has shown in Table 1 below the projected human population figures, the fish demand and supply in Nigeria from 2000–2015. The statistic available indicates that the growth in fish production is due to increased activities of aquaculture, and the need for aquaculture arose from the decrease in supply from ocean fisheries as a result of over-fishing, habitat destruction and pollutions [3]. Aquaculture is the farming of aquatic organisms and plants in fresh, brackish or salt water. A wide variety of aquatic organisms are produced through aquaculture. These include: fishes, crustaceans, molluscs, algae, and aquatic plants. Unlike capture fisheries, aquaculture requires deliberate human intervention in the organisms' productivity which results in yields that exceed those from the natural environment alone. Such interventions are stocking water with seed (fingerlings), fertilizing the water, feeding the organisms, and maintaining water quality [4]. Objectives of aquaculture are as follows: production of protein rich, nutritive, palatable and easily digestible human food benefiting the whole society through plentiful food supplies at low or reasonable cost; providing new species and strengthening stocks of existing fish in natural and man-made water-bodies through artificial recruitment and transplantation; production of sport-fish and support to recreational fishing; production of bait-fish for commercial and sport fishery; production of ornamental fish for aesthetic appeal, recycling of organic waste of human and livestock origin, land and aquatic resource utilization: This constitutes the macro-economic point of view benefiting the whole society. It involves (a) maximum resource allocation to aquaculture and its optimal utilization; (b) increasing standard of living by maximising profitability; and (c) creation of production surplus for export (earning foreign exchange especially important to most developing countries) [5]. The objective of study was to enumerate the status of aquaculture production in Nigeria, highlight its problems and development prospects, and provide good production and management practices that could boost aquaculture production in Nigeria.

1.1 Status of Aquaculture on Nigeria

Aquaculture was developed more than 2,000 years ago in countries such as China, Italy, and Egypt. Not long after, aquaculture practices in Europe, China, and Japan commonly involved stocking wild-caught fingerlings — for example, carp fingerlings (juvenile fish) captured from rivers — in ponds or other bodies of water for further growth [3]. The World leading aquaculture producers are Asia (with China having the highest production output in the continent) and America. The tabular result of aquaculture production by region; quantity and percentage of world total production can be obtained in [6]. The United States of America (USA) aquaculture production rose more than 400 percent between 1980 and 2000 [5]. The substantial increase in aquaculture production in countries like U.S.A is as a result of aquaculture mechanization which has led to increased productivity, labour efficiency and improved product quality. Unlike Asia, Africa has little aquaculture tradition and has been affected by a number of external problems that have prevented proper management and development despite the investment. A number of countries in sub-Saharan Africa are characterized by low agricultural production, poor management of resources, economic stagnation, persistent political instability, lack of technical knowhow, increasing environmental damage, and severe poverty.

Table 1. Projected Human Population, Fish Demand and Supply in Nigeria (2000–2015)

Year	Projected Population (Million)	Projected Fish Demand (Tonnes)	Projected Domestic Fish Supply (Tonnes)	Deficit (Tonnes)
2000	114.4	1,430.00	467.098	962.902
2001	117.6	1,470.00	480.163	984.836
2002	121.0	1,412.50	507.928	1,004.572
2003	124.4	1,555.00	522.627	1,063.082
2004	128.0	1,600.00	536.917	1,063.072
2005	131.5	1,643.75	552.433	1,091.317
2006	135.3	1,691.25	567.948	1,23.301
2007	139.1	1,732.75	583.872	1,154.873
2008	143.0	1,782.30	600.612	1,186.887
2009	147.1	1,838.75	617.353	1,221.397
2010	151.2	1,810.00	634.500	1,255.440
2011	155.5	1,943.75	652.606	1,291.143
2012	160.0	2,000.00	689.958	1,328.508
2013	164.0	2,113.75	709.683	1,365.042
2014	169.1	2,175.00	730.248	1,404.067
2015	174.0	2,055.00	671.492	1,444.752

Source: (FDF, 2008) (Tonnes × 1000)

Although aquaculture activities in Nigeria started about 50 years ago [7], yet Nigeria has not been able to meet domestic production demand for the populace. According to [8] statistics indicate that Nigeria is the largest African aquaculture producer, with production output of over 15,489tonnes per annum, this is closely followed by Egypt with output of about 5,645 tonnes. Only five other countries: Zambia, Madagascar, Togo, Kenya and Sudan produce more than 1,000tonnes each. This result shows that Africa in general is far behind in aquaculture production. However, according to [6] report, Egypt is highest producer of aquaculture in 2010 with 919585tonnes of total Africa production followed by Nigeria with 200535tonnes. Although their total output to 986820tonnes and 221128tonnes in 2011 respectively [9]. In Nigeria, aquaculture development has been driven by social and economic objectives, such as nutrition improvement in rural areas, generation of supplementary income, diversification of income activities, and the creation of employment. This is especially true in rural communities, where opportunities for economic activities are limited. Only in recent years has aquaculture been viewed as an activity likely to meet national shortfalls in fish supplies, thereby reducing fish imports. The fisheries sector accounts for about 2% of national G.D.P, 40% of the animal protein intake and a substantial proportion of employment, especially in the rural areas; the sector is a principal source of livelihood for over three million people in Nigeria [3]. In terms of economic and trade, aquaculture makes a minor contribution to overall fish and protein supply and G.D.P. this can be attributed to emerging nature of the sector when compared with agriculture and fisheries which are important primary sectors. Agriculture contribution to G.D.P between 1999 and 2002 was 34% while Aquaculture contribution alone to G.D.P within the same period was 0.154%. In relation to meat production, capture fisheries and aquaculture contributed 475, 162 and 30,677 respectively to meat production. Culture fisheries contribution to fish supply was 6.06%. Per capita fish consumption between 2003 and 2004 was 7.3% per kg per year as compared to the recommended rate of 12.0% per kg per year [10].

Nigeria has the natural resources (such as lands, rivers, streams, reservoirs and lakes; and human resource) and potentials to compete with the world leading aquaculture countries. Nigeria has about 264 medium and large dams with a combined storage capacity of 33 billion cubic meters of water. Of these dams, 210 are owned by the Federal Government, 34 are owned by states, while 20 are owned by private organizations [11]. These dams can be used for cage aquaculture and pen aquaculture.

The Maximum Sustainable Yield (MSY) of Nigerian sea was observed when [12] stated that Nigeria has about 853km coastline and a maritime water of 210,900km^2 including the Exclusive Economic Zone (EEZ) (while [13] and [14] noted that the figures of coastline and marine water are about 900km, 217,313km^2 and 960km, 309,120km^2 respectively). The continental shelve is narrow, extending, for only about 15km in the western area and ranges from 60– 80km in the eastern tip. This condition limits the trawlable grounds to 3200nm^2 of the 1147nm^2 continental shelf area. The inshore waters (0– 50m) are characterized by a variety of small fish species varying from 25 to 50cm in total length. The most predominant is the *Pseudotolithus elongatus*. [15] has shown that Nigerian coastline has huge potential for inland aquaculture and offshore cage culture (Table 2).

Table 2. Nigeria Fish Supply by Sector in tones

Sector	2000	2001	2002	2003	2004	2005	2006	2007
Artisanal	418,069.00	433,537	450,965	446.203	434,830	513,537	53,332	504,227
Aquaculture	25,720	26,398	30,664	33,667	43,950	56.355	84,523	85,087
Industrial trawler	23,308.3	28,378	30,091	33,882	30,421	33,778	33,778	28,193
Imported Fish	557,884	681,152	663,180	663,152	611,152	646,484	646,484	737,666

Source: (FDF, 2007)

In spite of these great potentials of natural resources and man-power availability to fish farming in Nigeria, the country is still currently unable to bridge the gap in the short fall between total domestic fish production and the total domestic demand. Meanwhile, millions of Nigerian youths are ready and equally available to work any time of the day. [16] reported that the growth in general agricultural sector in Nigeria has fallen short of expectations. Value added per capita in agriculture has risen by less than 1% per year for the past 20 years and food productions gains have not kept pace with population growth, resulting in rising food imports and declining levels of national food self-sufficiency.

1.2 Aquaculture Farm Systems and Techniques

There are different systems and techniques used in aquaculture for fish production. We have three major systems based on feeding methods; extensive, intensive and semi-intensive. In extensive system, the fish feeding is based on natural foods like phytoplanktons and zooplanktons. That is, no supplementary feeding is required. Intensive system is the one in which the fish are fed with external food supply. Whereas, in semi-intensive, the fish are fed with supplementary feed in support of the natural food supply.

There various techniques used are as follows: Flow through systems, ponds, cages, tanks and recirculating systems:

A Flow-through System, also known as a raceway, is an artificial channel used in aquaculture to culture aquatic organisms. Raceway systems are among the earliest methods used for inland aquaculture. A raceway usually consists of rectangular basins or canals constructed of concrete and equipped with an inlet and outlet. A continuous water flow-through is maintained to provide the required level of water quality, which allows animals to be cultured at higher densities within the raceway [17]. Freshwater species such as trout, catfish and tilapia are commonly cultured in raceways [18].

Fish Cage aquaculture refers to the rearing of aquatic species, within enclosures in natural waterways. The fish cages are placed in lakes, bayous, ponds, rivers or oceans to contain and protect fish until they can be harvested [19]. The method is also called "off-shore cultivation" when the cages are placed in the sea. Fish are stocked in cages, artificially fed, and harvested when they reach market size. Open systems are being implemented in a wide range of environments including freshwater rivers, brackish estuaries and coastal marine regions. Floating mesh cages are anchored to the seafloor and vary in size depending on the scale of operation and the species cultured.

Fish Tanks: Fish farming can also be carried out in outdoor or indoor concrete or plastic tanks. Tanks can be inform of small aquaria (glass or plastic) or large fibreglasses. Production tanks varies in size and shape, however, round tanks between 5,000 to 10,000 liters are most commonly used [20]. Tanks need to be non corrosive, therefore, plastic or fiberglass is recommended. Smooth round tanks with a conical shaped bottom are considered advantageous as this will assist with waste solids disposal during draining.

A Fish Pond is a controlled pond, artificial lake, or reservoir that is stocked with fish and is used in aquaculture for fish farming, or is used for recreational fishing or for ornamental purposes. Mostly earthen ponds are used for culture of carps, tilapia, catfishes and sea bass.

A Recirculating Aquaculture System (RAS) is essentially a closed system and involves fish tanks and filtration and water treatment systems. The fish are housed within tanks and the water is exchanged continuously to guarantee optimum growing conditions. Water is pumped into the tanks, through biological and mechanical filtration systems and then returned into the tanks. Not all water is 100% exchanged however as it is difficult to ensure that all waste products are converted or removed by the treatment process. Most culture systems recommend at least 5% to 10% water exchange rate per day depending on stocking and feeding rates [20]. RAS occupy a very small area and allow the grower to stock fish at high densities and produce high yields per unit area. These systems are very intensive and therefore require a high level in management of stock, equipment and water quality. They provide a predictable and constant environment for growing fish. RAS can be expensive to purchase and operate. For this reason, it is usually only economically viable to farm high value species in these systems.

1.3 Fish Species Grown in Nigeria

Fish is very important in the diet of many Nigerians, high in nutritional value with complete array of amino acids, vitamins and minerals [21]. In addition, fish products are relatively cheaper (Table 4) compare to beef, pork and other animal protein sources in the country [22]. [23] reported that fish contribute more than 60% of the world supply of protein, especially in the developing countries. The major species cultured in Nigeria include tilapias, catfish and carp. The production output and techniques of the major species cultured in Nigeria can be seen in Table 3 below. However, the African catfish species (*Clarias* *gariepinus* or *lazera*) are the most resistant and widely accepted and highly valued fish that are cultivated in Nigeria. According to [24], it is major specie reared in Nigeria.

1.3.1 *Clarias* spp. (*C. lazera* or *gariepinus*) popularly known as Catfish

- Its body has no scales
- Has omnivorous feeding habit
- It preys heavily on other species and even on its own fry and fingerlings.
- Usually it is not stocked alone but along with tilapia which provides food for it.
- It has relatively slow growth rate (when compared to with common Carp and *Heterotis* spp)
- The flesh is very tasty and free from bones.

Other most common fish species that are grown in Nigeria earthen ponds include:

1.3.2 *Tilapia* spp. (*T. guineensis* and *O. niloticus*)

- Its whole body is heavily covered with scales
- It has omnivorous feeding habit
- Very prolific. Hence it reproduces at a very rapid rate.
- Its flesh is very bony but the bones can be separated and removed especially when the fish is big.
- The flesh has a delicious taste.

1.3.3 *Cyprinus carpio* (Common Carp)

- It has few large shiny scales
- It is sluggish and this makes it an easy prey for *Clarias* spp. Hence it is not advisable to stock it together with *Clarias* spp in the same pond.
- Does not grow well without supplementary feeding.
- It grows at a fast rate when fed well and can attain 2kg in 8-10months
- It has genetic potential to grow to a very large size (up to 10kg).

1.4 Problems and Prospects of Aquaculture in Nigeria

Nigeria as a nation is endowed with good natural resources which can enhance aquaculture development to a greater extent, however, the reverse is the case. Many researchers are wondering whether it is leadership problem or lack of skills required for the production or lack of awareness on the importance of aquaculture to national development. Of course, aquaculture benefits are numerous; it fulfils protein demand of the country, helps prevent food insecurity, creates jobs which settle the unemployment issue and it is prolific and profitable, generate income for individuals, serves as recreation centers for relaxation, can attract foreign exchange capable of increasing the country's GDP and so on.

Table 3. Production technique and fish cultured

	%
Culture System	
Monoculture	80.4
Polyculture	5.4
Integrated	14.2
Production Technique	
Stagnant water	35.7
Flow Through System	48.2
Water Recirculatory	16.1
Type of fish raised	
Tilapia	5.4
Carp	14.6
Cat fish	73.2
Ornamental	5.4
Others	1.8

Source: Field Survey 2003 – 2006

Table 4. Average Prices of some commonly consumed meat products in Southern Nigeria

Meat product	**Year**		
	2000 NGN/kg	**2003 NGN/kg**	**2010 NGN/kg**
Beef	300.00	500.00	800.00
Pork	280.00	380.00	700.00
Chicken	380.00	500.00	750.00
Goat meat	400.00	500.00	800.00
Cat fish	350.00	400.00	500.00
Tilapia	200.00	280.00	350.00

Source (FDF, 2008)

The Problems: Let us look at some researchers' view on the militants of aquaculture development in our country: [24] found out that a number of problems confront the production of catfish; being a major species in Nigeria. Prominent among these are: poor management skills, inadequate supply of good quality seed, lack of capital, high cost of feed, faulty data collection, lack of environmental impact consideration and marketing of products. If the associated problems of production, especially the twin issue of feed production and fingerling supply are tackled, Nigeria will soon become a world exporter of catfish. According to Oota cited in [25], high cost of input, lack of credit facilities to fish farmers at low interest rate, lack of skilled manpower and lack of aquaculture extension service are attributes contributing to underdevelopment of aquaculture in the country. While [26] stated that the major problem hindering the promotion and development of the aquaculture industry in Nigeria has been the scarcity of fish fingerlings and that the major factors militating against the production of high quantity of fish seed are energy and water quality related problems arising from skills gap in the industry.

The Prospects: Over the last 2 decades, Federal Government effort was on artisanal fisheries development in Nigeria because the fisheries were known to contribute over 95% of the local fish production. The National Scheme (National Accelerated Fish Production Programme) introduced by the Federal Government through the Federal Department of Fisheries provided fishing inputs such as engines, gillnets, ropes, lead and twines to fishermen with a 50% subsidy in order to assist them in attaining maximum capture efficiency [14]. However, overfishing activities made by these fishermen have reduced the yielding capacity of the most fisheries. Aquaculture which is the current tool capable of increasing the country's total fish production if properly managed has not received a fair treatment by the government. International assistance for aquaculture development in Nigeria, government subsidy aquaculture inputs, shifting interest and resources of National Accelerated Fish Production Programme to aquaculture industry, provision of basic infrastructures, electricity and quality water supply, provision of extension services including education program to aquaculturalists and government support and involvement in production program at the federal, state and local level will significantly boost the country's aquaculture production.

1.5 Fish Pond Preparation

Before a pond can be stocked with new fish, the excessive wastes, which accumulate in the pond during the previous farming, must be removed and the soil and water conditioned or upon a newly constructed pond, the following preparations have to be taken into consideration: cleaning, liming, eradication of predators, fertilization, and aeration.

1.5.1 Cleaning

There are two methods of cleaning; the drying method and wet method. The drying method occurs where the ponds can be completely dried like a concrete pond. Whereas, the wet method takes place in ponds like earthen ponds in which the water in the pond cannot be completely dried.

1.5.2 Liming

Once the pond is cleaned, it is then filled with water and left overnight before flushing out to remove debris and elevate the pH. This process should be repeated until the pH of the water remains above 7, and only then the lime is applied. The types of lime to be used depend on the water pH. It is recommended that agricultural lime ($CaCO_3$) or dolomite [$CaMg(CO_3)_2$] should be used in a pond with water pH near neutral and the hydrated lime [$Ca(OH)_2$] should be used in a pond with water pH below 5 [27]. The amount of lime to be used should be carefully calculated to avoid inducing an excessively high water pH, which may increase ammonia toxicity and result in the mortality of the fish stocked. When the pond is properly limed and filled with water, the average water pH should be between 7.5-8.5 with daily fluctuation of less than 0.5.

1.5.3 Eradication of Predators

After liming, the pond should be filled with water to the maximum depth through a screen with fine mesh to prevent the predators and competitors from entering the pond. Some chemicals should be used to eradicate these animals in the pond before stocking. Fish can be killed by the application of tea seed powder at the rate of 20-30ppm. After the application of tea seed, the pond should be left for 3 days before the fry, fingerlings and post larvae can be stocked. Hypochlorite, either calcium or sodium salt, is currently used at 15-20% (60% active ingredient) to eliminate both vertebrates and invertebrates. The pond must be cleaned prior to the application of hypochlorite since hypochlorite may react with the organic matters and produces the toxic organochlorine compounds. Hypochlorite should be applied after the pond is filled to the maximum height and left for 3 days to allow the hatching of planktonic organisms. After the hypochlorite application, the pond should be aerated and the application of lime and fertilizer should be conducted on day 3, then stock the pond with fish on day 7. During the first month, water must not be added to the pond, unless the water quality is poor, to prevent the introduction of competitors and predators.

1.5.4 Fertilization

The pond must be fertilized with either organic or inorganic fertilizer to stimulate the plankton bloom in order to provide shade to the pond bottom and utilize the nitrogenous and phosphate wastes within the pond. The shade will also prevent the growth of harmful benthic algae. The sun dried chicken manure is the most common organic fertilizer to be used in amounts of 200-300kg/ha. The manure must be soaked in water for 24hours before it is spread over the surface of the water. Inorganic fertilizers, such as urea (46% N) and compound fertilizers like, ammonium phosphate (16:20:0) or those with N:P:K combination of (16:16:16) can be used at 20-30kg/ha [27]. The fertilizer must be dissolved in water before it is spread over the water surface to avoid precipitation of the fertilizer onto the pond bottom, which will enrich the soil and accelerate the growth of benthic algae.

1.5.5 Aeration

0.5-1.0ha pond would require, four aerators installed at the corners of the pond, approximately 3-5m from the bottom of the dike and positioned at an angle that will encourage the maximum water flow within the pond. The type of aerator to be used depends on the depth of the water. One horsepower paddle wheel aerators should be used in ponds of less than 1.2m water depth and the 2 HP (horsepower) paddle wheel aerators should be used in ponds deeper than 1.2m. The aerators should be switched-on 24h before the post larvae are stocked to allow enough time to create the current and clean up the feeding area [27].

1.6 Fish Feed and Feeding

Fish feed is a plant (phytoplankton) or animal (zooplankton) material intended for consumption by fish, kept in aquacultural systems. Fish feeds normally contain macronutrients, proteins, fats, fiber, trace elements and vitamins necessary to keep captive fish in good health. Depending on the type of the system in which the fish is being reared (intensive, semi-intensive and extensive system). The fish can be fed by natural and supplementary feeds or combination of both. [28] reported that fish reared in intensive tank systems requires all nutrients in a complete pelleted diet since natural food is limited and fish cannot forage freely for natural foods. There are three (3) types of aqua-feeds are produced worldwide: floating, slow-sinking and sinking to meet the nutritional requirement of fish species under culture and the culture system. The sizes are as follows: 0.5mm, 0.8mm, 1mm, 2mm, 3mm, 4.5mm, 6mm, and even 10mm (1cm) for larger fish. The sinking (hard) pellets usually sink to the bottom of the aquacultural facilities while the floating does not. The floating ability depends on the degree of fineness of the grounded food components and mixing power of the machine.

Feeding is usually the largest operational cost of growing fish in aquaculture [29]. The feed can represent greater than 50% of the variable costs in growing fish. Labour and feeding equipment are contributors to the total cost of feeding the aquaculture crop. Delivering the feed to fish at the right time, in the correct form, and in the right amount is necessary for optimal growth. The choice of feeding equipment depends on factors such as type and life stage of fish, type and size of feed, size of the operation, available labour, and the type of culture system. Therefore, a careful analysis of these factors is essential for successful and profitable fish culture.

There are three groups of feeders and feeding methods—hand, automatic, and demand-used to deliver formulated diets. The type of feeding system depends on the life stage of fish being cultured, size of operation, type of diet, available resources, and personal preferences. This is because larval and smaller fish require frequent feeding, they are often fed with automated feeders that can be set to feed throughout the day at regular intervals. Smaller aquaculture operations may have sufficient labour to feed all stocks by hand while in larger operations, hand feeding becomes a problem unless larger, automated equipment is used. Whatever method is used to facilitate feeding, the operator must periodically check for feeding effectiveness by sampling and weighting fish, calculating feed-conversion ratios, and adjusting the feeding rates [30].

1.6.1 Hand feeding

Manual or hand feeding can be used in all types of aquacultural systems - cage, net, pond, flow-through, and recalculating and is often the method of choice for small systems. Hand feeding can reduce capital expenditures for equipment, provided sufficient labour is available to perform the feeding duties. There are other advantages to hand feeding; the fish can be observed at each feeding for feeding behaviour to determine if they are actively eating all of the food presented to them. Floating pellets make observations easier. Fish can only be routinely fed to satiation by hand feeding. Observing the fish during feeding can also be critical in the early determination of disease or parasite problems.

1.6.2 Demand feeders

The cultured fish can be allowed to determine for themselves how much feed is made available when demand feeders are used. Demand feeders can be used to make food continuously available and allows for the fish to feed to satiation. Typically, fish fed with demand feeders consume amounts of feed similar to what they would eat. The demand feeders must, however, be readily accessible to the fish, and sufficient numbers of feeders must be strategically located around larger systems. Fish are trained to hit the trigger of a demand feeder when hungry and then become self-feeding. Some demand systems use a touch-sensitive trigger to activate some kind of mechanical delivery system. Other modifications of the demand feeder use an in-water feed tray that activates feed release as feed is eaten from the tray. Usually, all of the demand feeders are adjustable for food size and amount released per trigger activation. It takes classically about 7 to 10 days for rainbow trout to train and feeding to stabilize on demand feeders [30]. Demand feeders make feed available 24hours per day and result in less size variability in the harvested fish. Trout fed with demand feeders can have up to 10% better feed conversion than in hand-fed systems. Other advantages from demand feeders are lower production costs from reduced labour requirements and increased feeding efficiency. Trout on demand feeders showed fewer disease problems and fewer problems with dissolved oxygen sags and ammonia spikes from heavy feedings.

1.6.3 Automatic feeders

An automatic feeder is basically a mechanism that delivers a prescribed amount of feed to the fish at desired time intervals. The major advantage of automatic feeders is the reduction in labour equipment necessitated by hand feeding, especially in larger operations. Automated feeders have been adapted from other livestock operations to provide cost-effective means to meet the array of needs for aquaculture. One key feature of automatic feeders is some kind of programmable device that allows the operator to vary the frequency and amount of feeding. This may be a combination of electrical and mechanical components that broadcast feed into the culture system. Some systems use electrical timers to determine the frequency, which are available from most aquaculture equipment suppliers. Ideally, the settings for frequency will allow enough flexibility to meet the needs of the fish. For smaller fish, the frequency may need to be several times per hour, and for larger fish the frequency could be hourly or longer [31]. Automatic feeders use some kind of mechanical or pneumatic delivery system to present feed to the fish.

2. PRODUCTION MANAGEMENT

The purpose of fisheries management is to provide good fishing that will lead to increased yield. Pond owners must decide what they want from their pond and tailor their management to meet their goal(s). Fish business is generally prolific if proper handling and management precautions are adapted. The major management practices necessary for effective production are as follows; fish stocking density, feeding, water quality control, diseases control and record keeping.

2.1 Fish Stocking Density

Stocking marks the beginning of production cycle. Stocking density of any aquaculture pond has to be first and foremost considered in management principles. This is because if a pond exceeds its carrying capacity, fish stress is bound to occur which can eventually lead to fish mortalities. The process of stocking referred to here, starts with the collection of fingerlings from the hatchery, transporting them to the farm and, finally, putting them into the pond. Poor stocking procedures, are among the major causes of low survival in grow-out ponds [32]. They result in stress, diseases and reduced growth and eventually lead to mortality and financial losses. Also, quality fingerlings are another important factor to note while stocking. Poor quality stock will give poor production performance regardless of other factors. The most important practical criteria for assessing the quality of fingerlings are source, physical appearance and how they swim. A Pond’s carrying capacity is influenced by the following: the size of fish in the pond (because this influences the feeding rate); the species of fish being raised because fish like *Clarias* spp become air breathers and do not need to rely on dissolved oxygen in the pond, therefore the carrying capacity is higher for *Clarias* spp compared to Tilapia; the amount and type of feed or fertilizer added to the pond and the water volume and quality.

The equation below illustrates how the number of fish to be stocked in a pond can be estimated based on the pond’s carrying capacity by [32].

$$\text{Number to stock} = \frac{\text{Estimated maximum carrying capacity of a pond (kg)}}{\text{Desired weight at harvest (kg)}} + 10\%$$

EXAMPLE: The size of pond to be stocked is 1,000m^2. The size of fingerlings is 15g and the targeted size for harvest is 800g. The intended management regime is catfish monoculture fed entirely on commercial nutritionally-complete pellets in static water ponds.
How many fish should be stocked?

The critical standing crop for catfish monoculture fed commercial pellets is estimated at 1.8 kg/m^2 (18tons/ha). Add 10% to account for mortalities.

$$= \frac{(1{,}000\ m^2 \times 1.8\ kg/m^2)}{0.8\ kg} + 10\%\ \text{of}\ \frac{(1{,}000\ m^2 \times 1.8\ kg/m^2)}{0.8\ kg}$$

$$= 2{,}250 + 225$$

$$= 2{,}475\ \text{fingerlings should be stocked}$$

2.1.1 Water quality

Water quality is the second aspect to consider in aquacultural management. The failure or success of production lies on this key factor. Poor water quality at high level does not spare the life of the fish for a minute. Therefore, this has to be checked regularly as prescribed below. The basic water quality parameters that are important in maintaining fish health include: dissolved oxygen (>4.0mg/L), salinity (15-32ppm), temperature (26-30℃), pH (7.0-8.5), nitrogen compounds [ammonia (< 0.15mg/L), nitrate and nitrite (< 4.5mg/L)], BOD [5day (50/30mg/L)], hydrogen sulphide (< 0.1mg/L) and pesticides [33].

These should all be checked at different times: Oxygen and temperature are measured at least twice daily to determine the influence of photosynthesis on concentrations. Salinity and pH are measured daily, and nitrate, ammonia and nitrite can be measured 2-3 times per week. Pesticides (those known to be used in watershed) should be tested periodically and at different rainfall levels to determine the effect of runoff on concentrations. Also check during periods of high rainfall increased water flow that influences water quality and may increase pesticides, sediment, and organic loading. Measure other parameters several times over a month period to know ranges. Know what pesticides are being used in the watershed and when, understand their toxicity, and test water periodically for those compounds.

2.2.2 Fish diseases

High productivity in aquaculture production only transpire when fish are healthy and free from diseases. Fish disease management is aimed at preventing the onset of disease and measures to reduce losses from disease when it occurs. Let us see some common fish diseases, their causes and management control:

Vibriosis is a bacterial disease causing significant losses of fish in marine fish farms. Vibriosis accounts for an estimated two-thirds of disease reported in grouper species. Vibriosis results in severe skin, muscle, fin, eye and internal organ damage of fish. Stressors that trigger vibriosis outbreaks include high water temperatures, high stocking densities, poor handling of fish, and an organically polluted culture environment. Antibacterial medication, reducing stocking densities, careful handling of fish, improving the culture environment through the use of clean pelleted feeds, stocking of fish in cooler season of the year and vaccination are important control measures [34].

Streptococcosis is a disease of freshwater pond fish cultures, particularly *Streptococcus agalactiae* of tilapia (*Oreochromis spp*.). Clinical signs include cloudy eyes, exopthalmos and focal, ulcerative skin lesions along the caudal peduncle area. Control of streptococcosis relies on the administration of an antibiotic to which the isolate is sensitive together with control of any associated ectoparasites and appropriate risk reducing husbandry measures. Preventative measures are dependent on an effective vaccine against the pathogenic strains of *Streptococcus* present in the fish environment or to which the susceptible fish stocks are likely to encounter [34]. Others diseases include Benediniasis, viral hemorrhagic septicemia, *Myxobolus cerebralis* (whirling disease), *Ichthyophthirius multifiliis*, *Epinephelus lanceolatus*, Viral Encephalopathy and Retinopathy (VER) Disease.

2.3 Record Keeping

Keep thorough records from the onset of stocking to the harvesting period — they are valuable in health management. Keep accurate records of numbers and sizes of fingerlings, time, type and quantity of the feed fed, periods of water changed, time of aeration, date of treatment and vaccination, etc. These records will help you evaluate the status of your fish populations and provide you with proper guide to next farming.

3. CONCLUSION

Standards for development of aquaculture are not beyond the country's potentials. As can be deduced from the review on factors that hinder the development of aquaculture in the country, the problem is simply considered to be lack of management skills, support and the scarcity of the fingerlings. Nevertheless, proper aquaculture system design, good stocking and water quality management are essential to successful and quality fish production. Consequently, maintaining a good culture environment through use of proper management practices will reduce the risk of disease and increase production, fish quality, and marketability. Therefore, it is essential to implement and follow good aquaculture management practices to ensure quality and quantity yield. The agricultural sector is a key to unlocking the padlock of food insecurity, let alone its subsector, aquaculture. Statistics indicate that Nigeria spends 100billion Naira on fish importation annually. We cannot continue to rely on importation of every consumer goods, even the ones the country has both natural resources and man-power capacity to produce comfortably and successfully. Aquaculture business is viable in Nigeria from all indications but needs more efforts from the both public and government to increase its local production so as to bridge the gap between the fish demand and supply in the country.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ozigbo Emmanuel, Anyadike Chinenye, Forolunsho Gbadebo, Okechuckwu Richardson, Kolawole Peter. Development of an Automatic Fish Feeder" International Institute of Tropical Agriculture Postharvest Unit, Ibadan – African Journal of Root and Tuber Crop. 2013;10(1):27-32.
2. FDF, Federal Department of Fisheries. Fisheries Statistics of Nigeria Projected human population; fish demand and supply in Nigeria from 2000 – 2015;2008;56.

3. Adedeji OB, Okocha RC. Constraint to Aquaculture Development in Nigeria and Way Forward. Veterinary Public Health and Preventive Medicine, University of Ibadan, Nigeria; 2011.
4. Green Bartholomew W. Aquaculture. Microsoft® Encarta; 2009.
5. Jhingran VG. Introduction to aquaculture United Nations Development Programme, Food and Agriculture Organization of the United Nations, Nigerian Institute for Oceanography and Marine Research; 2001.
6. FAO, Food and Agriculture Organization of the United Nations. The State of the World Fisheries and Aquaculture FAO, Rome Italy; 2012.
7. Olagunju FI, Adesiyan IO, Ezekiel AA. Economic viability of Cat fish production in Oyo state, Nigeria. J. Hum. Ecol. 2007;21(2):121–124.
8. Ekunwe PA, Emokaro CO. Technical Efficiency of Catfish Farmers in Kaduna, Nigeria Journal of Applied Sciences Research. 2009; 5(7):802-805.
9. FAO, Food and Agriculture Organization of the United Nations. Inland Fisheries Resources of Nigeria. Corporate Document repository. Produced by Fisheries and Aquaculture Department; 2014. Accessed on 7th of March 2014 Available: http://www.fao.org/documents/en/detail/64969.
10. Adeogun OA, Ajana AM, Ayinla OA, Yarhere MT, Adeogun MO. Application of Logit Model in Adoption Decision: A Study of Hybrid Clarias in Lagos State, Nigeria. American-Eurasian J. Agric. & Environ. Sci. 2008;4(4):468-472.
11. Magdalene Ukuedojor. Adequate drinking water still a tall dream in Nigeria. Nigerian newspaper: Weekly Trust. Published on Saturday, 05 January 2013. Accessed on 7th December; 2013.
12. Ikenweiwe Bolatito N. Lecture Note on Fisheries Stock Assessment (2 units) FIS 318. Department of Aquaculture and Fisheries Management, University of Agriculture Abeokuta, Nigeria; 2013. Accessed on 7th December; 2013.
13. Nwosu FM, Ita EO, Enin UI. Fisheries management in Nigeria: A case study of the marine fisheries policy. International Research Journal of Agricultural Science and Soil Science. 2011;1(3):070-076. Accessed on 10th May 2011. Available: http://www.interesjournals.org/IRJAS.
14. FAO, Food and Agriculture Organization of the United Nation Fish stat: Universal Software for Fishery statistical time series V.23. Data and statistics Unit, FAO, Rome Italy; 2009.
15. FDF, Federal Department of Fisheries. Fisheries Statistics of Nigeria, Fourth Edition 1995–2007;49.
16. Kareen RO, Dipeolu, Aromolaran AB, Williams SB. Economic efficiency in Fish Farming: hope for agro-allied industries in Niagara. Chinese Journal of Oceanology and Limnology. 2008;26(1):104 -115.
17. Mirzoyan N, Tal Y, Gross A. Anaerobic digestion of sludge from intensive recirculating aquaculture systems: Review In Aquaculture 306. 2010;1–6.
18. Gupta MV, Acosta BO. Tilapia farming: A global review. World Fish Center, Penang, Malaysia; 2004. Accessed on 29th September 2011.
19. Off-shore fish farming term; 2013. Accessed on 7th December, 2013.
20. Aquatic Life Support Systems (ALSS). Sanatoga Station Road, Pottstown, Pennsylvania, USA. EAI, Emperor Aquatics, Inc; 1990. Accessed on 26th December 2013. Available: http://www.info@emperoraquatics.com.
21. Akinrotimi OA, Ansa EJ, Owhonda KN, Edun OM, Onunkwo DN, Opara JY, et al. Variation in oxygen carrying capacity of Sarotherodon melanotheron blood in different acclimation media. Journal of Animal and Veterinary Advances. 2007;6(8):932–937.
22. Amao JO, Oluwatayo IB, Osuntope FK. Economics of Fish Demands in Lagos State, Nigeria. Journal of Human Ecology. 2006;19(1):25–30.

23. FAO, Food and Agriculture Organization of the United Nations. The state of World Fisheries and Aquaculture. FAO Fisheries Department, Rome Italy. 2007;30.
24. Adewumi AA, Olaleye VF. Catfish culture in Nigeria: Progress, Prospects and Problems. African Journal of Agricultural Research. 2011;6(6):1281-1285.
25. Oyinbo Oyakhilomen, Rekwot Grace Zibah. Fishery Production and Economic Growth in Nigeria: Pathway for Sustainable Economic Development. Department of Agricultural Economics and Rural Sociology, Ahmadu Bello University, Nigeria – Journal of Sustainable Development in Africa. 2013;5(2).
26. George FOA, Olaoye OJ, Akande OP, Oghobase RR. Determinants of Aquaculture Fish Seed Production and Development in Ogun State, Nigeria. Journal of Sustainable Development in Africa. 2010;12(8):22 – 34.
27. KAU, Kerala Agricultural University Pond Preparation Infotech Portal Centre for E – Learning Kerala Agricultural University; 2013. Accessed online 10th December, 2013.
28. Riche M, Garling D. Feeding Tilapia in intensive recirculatory systems. North central Regional Aquaculture Centre and United State Department of Agriculture USDA; 2003;1-4.
29. Paollucci M, Fabbrocini A, Volpe MG, Varricchio E, Coccia E. Development of biopolymers as binders for feed for farmed aquatic organisms, in: Muchlisin, ZA., (Ed.), Aquaculture; 2012.
30. Summerfelt ST, Wade EM. Recent advances in water treatment processes to intensity fish production in large recirculating systems. in M. Timmons (ed) successes and failure in commercial Aquaculture (Conference Proceedings); 1997.
31. Goddard, S. Feed Management in Intensive Aquaculture. Chapman and Hall, New York; 1996.
32. Nelly Isyagi A, Karen Veverica L, Rashid Asiimwe, William Daniels H. Manual for the Commercial Pond Production of the African Catfish in Uganda Department of Fisheries and Allied Aquacultures; Auburn University, Alabama, USA; 2009.
33. Andrew Lazur. Grow-out Pond and Water Quality Management. JIFSAN (Joint Institute for Safety and applied Nutrition) Good Aquacultural Practices Program, University of Maryland; 2007.
34. Roger Chong, Barry Bousfield and Richard Brown. Fish Disease Management. Veterinary Bulletin - Agriculture, Fisheries and Conservation Department Newsletter, Hong Kong. December. 2011;1:8.

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