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# Possible Aquaculture Development in Nigeria: Evidence for Commercial Prospects

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**Abstract:** The cultivation of desirable aquatic organisms is becoming increasingly important as one of the fastest-growing agro-industrial activities in the world. Nigeria, over the years, practised traditional methods of aquaculture in tidal pools and floodplains of inland waters. Recently, the coastal region has been the focus of aquaculture development with introduction of cage culture system. Nigeria is one of the top aquaculture producers in Africa with numerous opportunities for large-scale production, and 80% of production is from small-scale farmers who involve in brackish and freshwater cultivation, except mariculture which has several setbacks. Nigeria is yet to show feasible interest in non-fed aquaculture (macroalgae) which is among the world's most efficient mass producer of proteins and other products. Constraints to production in the industry have been identified, while the prospects can be achieved by expanding aquaculture zones, enhancing management practices of production systems and improving product quality with the resultant creation of jobs, regular income and investment, etc.. This paper explores the status of aquaculture in Nigeria, and the components and the systems of commercial aquaculture were elucidated.

**Key words:** Aquaculture, commercial fish farming, macroalgae, mariculture, industry.

## 1. Introduction

Aquaculture productions have increased in the last decade. Presently, world food fish production of aquaculture has expanded by almost 12 times, at an average annual rate of 8.8% [1-3]. Over 300 aquatic species are farmed worldwide for production in a variety of facilities of varying input intensities and technological sophistication, using fresh, brackish and marine water [4]. The most prominent species includes finfish, crustaceans and mollusks, which are commercially cultured with a relevant production in some country. Global production of farmed food fish was 32.4 million metric tonnes in 2000 up by 7.5% to 55.7 million metric tonnes in 2009 and 60 million

metric tonnes in 2010 with a total value of US \$119 billion [3]. Aquaculture remains one of the fastest-growing agro-industrial activities in the last four decades and is projected to outpace population growth. In the next decade, total output from both capture and aquaculture is envisaged to exceed that of other livestock produce [2, 3]. Asia is the highest aquaculture producer with about 90%; the largest quantities are from China, while Africa and Latin America produce less than 5% [3, 4]. Currently, the African continent accounts for less than 1% of the annual total global aquaculture production [3, 5], and the vast majority of Africa's aquaculture is in fresh water. There are many setbacks for the development of aquaculture to meet the global food security and economic growth, as well as to reduce the pressure on wild harvested fisheries stock.

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Fish is currently the cheapest source of animal protein consumed by the average Nigerian and it accounted for about 50% of total protein intake [6]. Fish supply in Nigeria is mainly from the capture sector, especially the coastal and inland artisanal fisheries. The sector contributes about 85% of total domestic production [5, 7]. Nigeria imports over 700,000 metric tonnes of fish per annum, and annual deficit of about 0.5 million metric tonnes still exist (Table 1). Aquaculture has recently been recognized as an alternative means of increasing domestic fish production. It is estimated to have the potential of overtaking capture fisheries in future. Aquaculture in Nigeria is receiving a wide participation as a result of the progressive development in most parts of the

country. The total current aquaculture production has leaped from 50,000 metric tonnes in 2005 to 85,000 metric tonnes [7], and demand is expected to continue to grow with anticipated population growth. As at 2004, there are over 2,600 fish farms and 215 feeds mills in the country with most of them located in the southern part of Nigeria, and fish feeds account for about 60% of the input cost production in intensive system in Nigeria [6, 8]. Aquaculture activities is concentrated in the coastal areas, but may at the long term be constrained due to competition by many industrial and domestic users [9]. This paper intends to elucidate the Nigeria's aquaculture potentials with a view to providing intervention recommendations on prospects for aquaculture development.

**Table 1 Projected population and fish demand/supply in 2000-2025.**

Year	Population (million)	Fish demand (million tonnes)	Fish supply in domestic production (million tonnes)	Short fall (million tonnes)
2000	114.40	0.87	0.53	0.34
2001	117.60	0.89	0.57	0.32
2002	121.00	0.92	0.61	0.31
2003	124.40	0.95	0.65	0.30
2004	127.90	0.97	0.69	0.28
2005	131.50	1.00	0.73	0.27
2006	135.20	1.03	0.77	0.26
2007	139.10	1.06	0.81	0.25
2008	143.00	1.09	0.85	0.24
2009	147.10	1.12	0.89	0.23
2010	151.20	1.15	0.93	0.22
2011	155.50	1.18	0.96	0.21
2012	159.90	1.22	1.00	0.22
2013	164.40	1.25	1.04	0.21
2014	169.10	1.29	1.08	0.21
2015	173.90	1.32	1.12	0.20
2016	178.80	1.36	1.16	0.20
2017	183.30	1.39	1.20	0.19
2018	189.00	1.44	1.24	0.20
2019	194.40	1.48	1.28	0.20
2020	199.90	1.52	1.32	0.20
2021	205.60	1.56	1.36	0.20
2022	211.40	1.61	1.40	0.21
2023	217.40	1.65	1.44	0.21
2024	223.50	1.70	1.48	0.22
2025	229.80	1.75	1.52	0.23

Source: FAO 2000 [10].

## 2. The Systems of Commercial Aquaculture in Nigeria

### 2.1 Freshwater Aquaculture

In freshwater fish culture, water salinity based on dissolved salts in parts per thousand (ppt) is < 0.5 ppt. Some cultivable fish species cultured in Nigeria, which are capable of thriving well in the fresh water environment, include: *Clarias gariepinus*, *Clarias lazera*, *Heterobranchus bidorsalis*, *Heteroclarias*, *Tilapia* sp., *Tilapia mariae*, *Oreochromis niloticus*, *Oreochromis mossambicus*, *Sarotherodon galilaeus*, *Sarotherodon melanotheron*, *Tilapia zilli*, *Tilapia guineensis*, *Hereterotis niloticus*, *Chrysiichthys nigrodigitatus* and *Cyprinus carpio*, etc.. However, there has been three major freshwater fish genus farmed in Nigeria, namely, *Clarias*, *Tilapia* and *Heterotis* [11]. Apart from the earthen ponds, tank cultivation is characterized by high yield, with its efficiency dependent on aeration, water quality and flow rate, etc. [11-13]. Tanks are usually made from treated wood, concrete or PVC plastic and fibreglass, with capacities ranging from a few hundred litres to several thousand cubic metres [11]. Even though this cultivation technique is a capital intensive venture, the input is usually relatively quickly recovered if the system is well managed [14]. The Nigeria freshwater aquaculture technology is developing, still undergoing research and has gained steady recognition, due to the increasing demand for cheap source of protein and livelihood that has seen the need for sustainable production [15].

### 2.2 Brackish-Water Aquaculture

Naturally, brackish water environment is characterised with the salinity of the water fluctuating widely from negligible to 30 ppt or 30‰, depending on the phase or phases of the tide and volume of fresh water discharged through the river into the sea. These phenomenons make it more turbid with influx of nutrients and fertile to accommodate good numbers of

acclimatized fresh and brackish water fish species, either for breeding or feeding. Brackish water contains 0.5-30 g of salt per litre or more often expressed as 0.5-30 ppt. Brackish water fish farming is a system of aquaculture that focuses on the production of quality fin and shell fish that are found in the creeks, lagoons and estuaries through rational rearing. The region is naturally endowed with a long coast line bordering the Atlantic Ocean and an extensive network of inland river systems [15]. Research estimated that there are about 729,000 ha of saline mangrove swamp suitable for development of commercial fish farming [16]. The significant aquatic flora around this complex estuarine/lagoon system in Nigeria is characterized by stilt-rooted trees with dense undergrowth of shrubs, and by raffia palms (*Raphia sudanica*) and oil palms (*Elaeis guineensis*). The dominant plant species in the swampy areas of the lagoon include *Rhizophora racemosa* and *Avicennia nitida*. The principle of brackish water fish farming mainly lies in allowing the tidal water to enter into the pond and flood it to the optimal depth as may be required by the cultured fish, and also allowing the outflow of the water during low-tide to a minimum tolerable depth [17]. Many fin and shell fish species are abundant in brackish water area, which can be cultured with the minimal capital input in most of the coastal communities. According to Deekae et al. [18], most of the shell fish production is yet to be developed in commercial scales, as obtained in other fish producing countries in Asian, like Japan, China, Indonesia, Thailand and Philippines among others. Hence, there is the need to focus more on these areas, in order to enhance food security and employment opportunities for people living in the region.

### 2.3 Marine-Water Aquaculture

In marine-water aquaculture, the water chemistry requirement for salinity based on dissolved salts is 0.30-50 ppt. Fish farming in this zone will have some major constraints because of the choppy conditions and heavy rainfall which occur in the coastal belt. The

teeming population of engineers of various disciplines, fisheries researchers (biologists and ecologists), seasoned aquaculturists, technologists, technicians and thousands of kilometres of low lying coastline containing billion cubic metres of marine water are mariculture great potentials [15]. The continental shelf is narrow, extending for only about 15 km in the western area and ranges from 60 km to 80 km in the eastern province. The culture of marine fish species can be a possibility in Nigeria, if all the available potentials can be harnessed. The five major constraints of mariculture in Nigeria are domiciled in the characteristic nature of the coastal area (Fig. 1) and can be summaries as follows:

(1) Nigeria coastal areas, like other developed coastal towns in the world, are densely populated with heavy commercial and industrial activities, which results in pollution;

(2) Inshore and offshore oil exploration usually lead to oil spill with a resultant effect on water chemistry and fish kill;

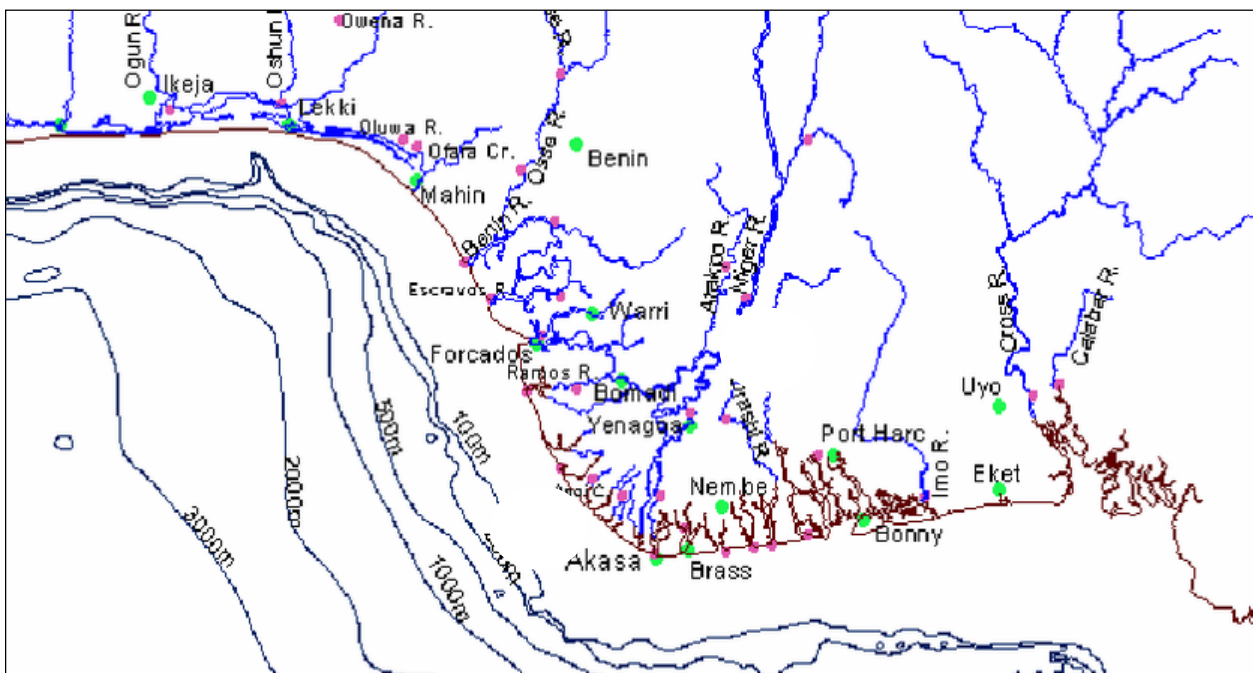
(3) The Nigeria coastal water from Lagos to Calabar region is very shallow, while coastal

mariculture (earthen) will require about 200 m depth above;

(4) Under-develop technology for sustainable aquaculture production in land base industrial mariculture;

(5) Lack of political-will on the part of government to have preferred crude oil to mariculture in the coastal area due to the dependent nature of the Nigeria mono-economy.

One of the major steps in the bid to establish this technology should involve carrying out more biological and ecological studies and review of literature to ascertain life cycle of culturable marine fish species in Nigerian marine waters. It is important to use package propagation procedures, care of larvae, fry, fingerlings and post juveniles to table size, while viable and genetically diverse brood stocks would be sustained in banks. Best method of live seed transport per fish species, as well as appropriate feed must be formulated for each stage of the fish species, that is, for larvae, fry, fingerling and adults. Several other constraints have prolonged the development of the mariculture industry in Nigeria, and these can be



**Fig. 1** The Nigeria coastal area.

summarized as: weak economies, poor aquaculture development policies, inappropriate technologies, weak extension services, weak impact of research institutions, inadequate information management systems, limited coordination between research and production sectors, scanty reliable production statistics, the high value/cost of coastal land and the associated competition for this land from other coastal industries [19].

### 3. Cultivable Fish Species in Nigeria

Of the over 210 species of fishes in Nigeria water bodies, little fraction of them are receiving cultivation attention from fish farmers. The production of freshwater fish culture is widely accepted and encouraged (contributing between 0.65-1.2 million tonnes of fish annually from inland fresh water alone), followed by brackish water aquaculture, while mariculture is clearly not popular (Table 2) [11]. Some conventional culturable fish species in Nigeria includes: *Clarias gariepinus*, *Clarias lazera*, *Heterobranchus* sp., *Heteroclarias*, *Tilapia*, *Oreochromis niloticus*, *Sarotherodon galilaeus*, *Sarotherodon melonoplura*, *Tilapia zillii*, *Tilapia guineansis*, *Chrysichthys nigrodigitatus*, *Cyprinus Carpio*, etc.. They are proven to be of higher consumer preference due to their high premium and food productivity, as they have been cultured widely in the tropics for food and ornamental purposes [11-13]. The unconventional cultured ones with low preference probably due to lack of promotion or identification are: *H. niloticus*, *G. niloticus*, *L. niloticus*, etc., as the following:

(1) *H. niloticus*: rapid growth, breeds in captivity, availability of wild fingerlings and brood stocks, mean standard length (SL) of 100 cm, mean total weight (TW) of 10.2 kg, mean fecundity rate (FR) of 4,000-6,000 eggs, good for polyculture and cage culture system as well sport fishing;

(2) *L. niloticus*: rapid growth, high premium, breeds in captivity, grows up to 200 cm (maximum length),

200 kg (TW), 3,000,000-15,000,000 eggs (FR), good for polyculture and cage culture system;

(3) *G. niloticus*: rapid growth, high premium, tasteful, seasonal availability of wild growers, grows up to 193 cm (SL), 200 kg (TW), 6,000-9,000 eggs (FR), good for polyculture;

(4) *P. obscura*: rapid growth, tasteful, medicinal properties, seasonal availability of wild growers, grows up to 54.0 cm (maximum length), 1.0 kg (TW) in 4-5 months, 126-1,580 oocytes (FR), good for polyculture and cage culture system;

(5) *L. coubie*: tasteful, seasonal availability of wild growers, grows up to 22.2 cm (SL), 619 g (TW) 10,411-24,143 eggs (FR), good for polyculture and cage culture system [11-14, 20-23].

### 4. Seaweed/Macroalgae and Its Potentials in Nigeria

Macroalgae is currently the most significant aquatic plant that has contributed to the development of fisheries and the aquaculture industry [24]. Nigeria is endowed with about 79 species of seaweed, and the coastlines are characterized by sandy beaches and extensive mangroves, deltas, estuaries and lagoons with correspondingly low algal diversity [25]. Recent researches by Amosu et al. [16], Fakoya et al. [26] and Abowei and Tawari [27] have shown the potential of macroalgae resources for exploitation, culture and utilization for Nigeria, but as yet, no targeted commercial harvesting and cultivation has commenced. The cultivation methods of varies depend on the macroalgae species, which includes open water cultivation, land-based or semi-closed cultivation, pond cultivation, tank culture and raceways, spray cultivation systems. However, the on-land integrated culture units flow through integrated multi-trophic aquaculture (IMTA), and paddle-wheel raceways (Fig. 2) are now widely viewed as the preferred method of cultivating the main species of macroalgae [16].

Macroalgae have been called the medical food of the 21st century [28]. According to the World Health

**Table 2 Summary of data on aquaculture species of finfish and shellfish in Nigeria (modified after Refs. [11, 17, 20-23]).**

Species	Popularity with consumers	Availability of seeds for stocking	Known feeding habits	Salinity tolerance (ppt)	Remarks
<i>T. rendalli</i> <i>T. nilotica</i> <i>T. galilaea</i> <i>T. zillii</i> <i>O. niloticus</i> <i>S. melanotheron</i> <i>O. mossambicus</i>	Average	Year round and adequate	Algae, phytoplankton, detritus, various supplementary feeds	0-26 or more depending on species	Hardy and good as standby species in absence of more popular species for stocking; Disadvantage is uncontrolled breeding.
<i>C. nigrodigitatus</i>	Very good	Year round but inadequate	Bivalves as supplementary feed; groundnut cake and palm kernel cake as essential food	0-26	Hardy, but supplementary feed absolutely necessary; Has grown well with tilapias and mullets.
<i>L. falcipinnis</i> <i>M. bananensis</i> <i>L. grandisquamis</i> <i>L. dumerilii</i> <i>M. monodii</i> <i>M. curema</i>	Good	Year round and adequate	Detritus, phytoplankton, algae, supplementary feeds	0-35	Has given good results in brackish water; Experiments in fresh water under way.
<i>C. lazera</i> <i>C. gariepinus</i>	Very good	Year round but inadequate	Omnivorous, supplementary feeds	0-25	Can be stocked very densely if supplementary feed is given; Now cultured with tilapias.
<i>H. niloticus</i> <i>Parachanna</i> sp.	Low	Seasonal and inadequate	Phytoplankton and zooplankton	Freshwater only	Small sizes favoured; Larger sizes said to be of lower taste.
<i>E. fimbriata</i> (Bonga)	Good	Seasonal	Phytoplankton	0-35	Comes into ponds with the tide; Appears to be sensitive to oxygen deficiency; Does not keep long once out of water.
<i>P. durarum</i>	Very good	Seasonal	Detritus of both plant and animal origin	0.5-35	Comes into ponds with the tide; Delicate and limbs easily damaged; Has grown to about 20 g in ponds.
<i>Macrobrachium</i> spp.	Very good	Seasonal	Detritus of both animal and plant origin	Fresh to about 10	Caught in abundance in certain areas of the country.
<i>L. niloticus</i>	Very good	Scarce	Predatory	Fresh water only	Good predator species for tilapias, but preys on carps also; Fast growth.
<i>H. fasciatus</i>	Low	Adequate	Predatory	0-26	Good predator species for tilapias; Does not grow beyond about 20 cm; When grown with large carps, feeds on tilapia fry and fingerlings only.
<i>L. apodus</i> <i>L. agennes</i>	Good	Inadequate	Predatory	1-32	Good predator species for tilapias in brackish-water ponds.
<i>G. niloticus</i>	Good	Inadequate	Predatory	Fresh water only	Good predator for tilapias. Fast growth.
<i>E. lacerta</i>	Low	Inadequate	Predatory	1-26	Comes into ponds with the tide; Delicate and sensitive to oxygen deficiency; Does not keep long out of water.
<i>C. gasar</i>	Good	Almost throughout the year	Phytoplankton	2-32	Spat settles better on hard timber than old oyster shells or asbestos; Better settlement in the shade than in open areas; Settlement more abundant in depths about 30-100 cm from water surface; Available all along the coastline in the brackish-water areas; Can grow to about 8 g (wet meat) in one year under natural conditions.

(Table 2 continued)

Species	Popularity with consumers	Availability of seeds for stocking	Known feeding habits	Salinity tolerance (ppt)	Remarks
<i>H. bidorsalis</i>	Good	Seasonal	Omnivorous	Fresh water	Responds well to fertilizer and supplementary feeding.
<i>D. engycephalus</i>	Good	Seasonal	Herbivorous	Fresh water	Some ponds are noted for excess grass and weeds; These species are suspected to keep weeds under control.
<i>D. brevipinis</i> <i>D. rostratus</i>	Good	Seasonal	Herbivorous	Fresh water	-
<i>M. electricus</i>	Good	Seasonal	Predator	Fresh water	Good predator species for excess tilapias in ponds.
<i>M. atlanticus</i> <i>P. jubelini</i>	Good	Seasonal	Predator	5-30	Comes into pond with tide; Good predator species for excess tilapias in brackish-water ponds.



**Fig. 2** Flow-through, paddle-wheel raceways for growing macroalgae.

Source: Dr. Deborah Vivienne Robertson-Andersson.

Organization (WHO), macroalgae are among the healthiest foods on the planet, as they contain vitamins, over 90 minerals and many antioxidants [1]. Most of this production is for human consumption either directly or indirectly, also these have been used commercially as feedstock for phycocolloid production, as well as the production of plant-growth stimulants used in the agricultural sector [29-31]. It has been used in the manufacture of pharmaceuticals and cosmetic creams [32]. This important marine resource has recently been emphasized due to the increasing demand for them as medicinal products, like anthelmintic, antibiotics, antifungal and antiviral, antitumour and antioxidant products, blocking and lowering of HIV/AIDS transmission and treatment of

cancer patients [26, 33-38]. Seaweed can remove excess nutrients and major metallic pollutants from industrial and agricultural effluent, thus reducing coastal eutrophication [39, 40]. Research findings have further proven that biotransformation of seaweed to liquefied petroleum gas (LPG) is viable and economically feasible as clean fuel [41, 42]. Seaweed also has the potential to be a successful fin and shellfish feed, particularly if the diets including macroalgae grown with enriched nutrient are good substitutes for protein in formulated commercial feeds [35, 43, 44]. Additional benefits from seaweed farming activities include bioremediation, ocean de-acidification, and capturing of atmospheric and dissolved CO<sub>2</sub> during growth to assist in climate change mitigation.

## 5. External/Internal Pressure on Aquaculture

Natural, biological and economic hazards have increased in intensity and frequency in this decade. The African region has reeled from natural hazards that have included flooding, drought and the global financial crisis. Nigeria has the classical case of the destruction of fisheries and severe impacts on present and future aquaculture development by a factor external to the sector—the fate of the coastal water. Red and green tides and eutrophication have occasionally affected coastal aquaculture in Nigeria. The immediate effect of these natural and biological disasters on aquaculture is destruction of physical facilities, natural resources and damage to stock or reduction in value of harvests and loss of capital investments (Table 3). They have not led to the abandonment of farms, but have setback in growth. Nigeria government, like most African government, usually fails to give compensation for damage to crops and infrastructure from catastrophic events [45]. But market-based insurance has not been a significant instrument of risk mitigation and coping in most of Africa.

### 5.1 The Ecosystem Approach to Aquaculture (EAA) and Risk/Impacts Management

The ecosystem approach to aquaculture is a strategic approach to development and management of the sector aiming to integrate aquaculture within the wider ecosystem such that it promotes sustainability of interlinked social-ecological systems. An enabling environment is crucial to adopt the EAA. There is a need for an enabling framework for an ecosystem sustainable development approach facilitating different sectors and institutions to talk amongst each other and to promote coordinated actions (e.g., legislation, management measures, etc.).

This could be attained with the application of the EAA management. Incorporating EEA and risk/impacts management strategies into policy and

development programmes; improving the capacities of institutions at the national, local and community levels for EEA application and risk/impacts management; and integrating the efforts of government, farmer groups, business and industry would increase collective resilience and likely provide ideas to find opportunities in the risks. These would give the aquaculture sector a much better ability to face external pressures [46].

### 5.2 The Implications of Climate Change

It represents best practice that should be pursued irrespective of climate change. Integrating disaster management into the fisheries sector, and vice versa, will be important, given the high vulnerability of the sector to extreme events. The suggested actions for way forward and mitigation are as follows: (1) ensure that the fisheries sector is clearly incorporated into mainstream climate change strategies and vice versa; (2) ensure that the opportunities and threats presented by climate change are understood and supported as part of adaptation measures for the sector; (3) identify and support high-risk coastal belt and locations; (4) build supportive economic and trade policies; (5) pursue appropriate technologies; (6) pursue mitigation actions in a manner that supports the sector more broadly [47].

## 6. Evidence for Commercial Prospects

Aquaculture production must increase to meet at least 50% of the global fisheries demand by the year 2030. The natural resources (aquatic and human resource) and potentials are endowed to Nigeria to propel aquaculture development and compete with Asian countries, like Japan. About 264 dams, with a cumulative capacity of 33 billion m<sup>3</sup> of water can be utilized for cage-culture [13, 48]. According to Federal Department of Fisheries (FDF) [7], Nigerian coastline has huge potential for inland aquaculture and offshore cage culture. The maximum sustainable yield (MSY) of Nigerian marine water was observed by



**Table 3 Possible environmental/culture impacts of aquaculture.**

Culture system		Environmental impact	System impact
<b>Extensive</b>			
1	Seaweed culture	May occupy formerly pristine reefs; rough weather losses.	Weakening pond materials and evaporation/dehydration; market competition; conflicts/failures, social disruption.
2	Coastal bivalve culture (mussels, oysters, clams, cockles)	Public health risks and consumer resistance (microbial diseases, red tides, industrial pollution); rough weather losses; seed shortages.	Shell cracks and low production, market competition especially for export produce; failures, social disruption.
3	Coastal fishponds (mulletts, milkfish, shrimps, tilapias)	Destruction of ecosystems, especially mangroves; increasingly non-competitive with more intensive systems; non-sustainable with high population growth.	Poor quality of producte; conflicts/failures, social disruption.
4	Pen and cage culture in eutrophic waters and/or rich benthos (carps, catfish, milkfish tilapias)	Exclusion of traditional fishermen; navigational hazards.	Poor quality of producte; conflicts, social disruption; management difficulties; wood consumption.
<b>Semi-intensive</b>			
1	Fresh and brackish water pond (shrimps and prawns, carps, catfish, milkfish, mullets, tilapias)	Fresh water: health risks to farm workers from waterborne diseases; Brackish water: salinization/acidification of soils/aquifers.	Both: market competition, especially for export produce; feed and fertilizer availability/prices; conflicts/failures, social disruption; poor quality of product and low yield.
2	Integrated agriculture-aquaculture (rice-fish; live stock/poultry-fish; vegetables-fish and all combinations of these)	As freshwater above, plus possible consumer resistance to excreta-fed produce; competition from other users of inputs, such as livestock excreta and cereal brans; toxic substances in livestock feeds (eg., heavy metals) may accumulate in pond sediments and fish; pesticides may accumulate in fish.	Poor quality of production and low yield.
3	Sewage-fish culture (waste treatment ponds; latrine wastes and septage used as pond inputs; fish cages in wastewater channels)	Possible health risks to farm workers, fish processors and consumers.	Low palatability/poor quality of produce and low yield, consumer resistance to produce.
4	Cage and pen culture, especially in eutrophic waters or on rich benthos (carps, catfish, milkfish, tilapias)	As extensive cage and pen systems above.	Occasional breakage of cage/pen materials; consumer resistance to produce.
<b>Intensive</b>			
1	Freshwater, brackish water and marine ponds (shrimps; fish, especially carnivores—catfish, snakeheads, groupers, sea bass, etc.)	Effluents/drainage high in biological oxygen demand (BOD) and suspended solids; market competition, especially for export product.	Occasional breakage of cage/pen materials and facility faults; conflicts/failures, social disruption.
2	Freshwater, brackish water and marine cage and pen culture (finfish, especially carnivores—groupers, sea bass, etc., but also some omnivores, such as common carp)	Accumulation of anoxic sediments below cages due to fecal and waste feed build-up; market competition, especially for export produce.	Occasional breakage of cage/pen materials and facility faults, conflicts/failures, social disruption; consumption of wood and other materials.
3	Other—raceways, silos, tanks, etc.	Effluents/drainage high in BOD and suspended solids.	Occasional breakage of cage/pen materials; many location-specific problems, facility faults.

Source: Modified from Pullin [45].

Ikenweiwe [49], who stated that Nigeria has about 853 km coastline and a maritime water of 210,900 km<sup>2</sup> including the exclusive economic zone (EEZ). Nwosu et al. [50] and FAO [51] noted that the figures of

coastline and marine water are about 900 km, 217,313 km<sup>2</sup> and 960 km, 309,120 km<sup>2</sup>, respectively. These together are evidence for commercial prospects for sustainable fish farming business in Nigeria.

Commercial aquaculture increases the availability of food fish, especially in the coastal areas. It produces food fish for farm households who consume their own fish, and for domestic buyers who consume purchased fish as well [11]. Commercial aquaculture may also earn foreign exchange from exports that can be used to pay food import bills [7, 11]. Aquaculture is also a sector for the poor who have few alternatives and no resources. In Nigeria, aquaculture does not typically attract the wealthy who perceive aquaculture risks as high and financing difficult. The wealthy prefer offshore fishing and trading [7, 11]. Aquaculture therefore is attractive to policy-makers, because it absorbs the poor. Nigerian women play a predominant role as hired workers in semi-intensive operations. For all species, about 80% of workers involved in aquaculture processing are women. On the one hand, traditional farming would include carp/catfish and tilapia culture in most coastal waters, and most aquaculture operations are small-scale [7, 11, 49, 51].

## 7. Conclusions

Aquaculture business is viable in Nigeria from all indications, but more effort is required from both the public and government to increase its local production and bridge the gap between the fish demand and supply in the country. Besides, the commonly cultured fresh water catfish in Nigeria, several marine shell and fin fish species can also be cultured in Nigeria, with the need for aquaculture to rise in terms of technological innovation and adaptation so as to meet changing and challenging requirements.

## 8. Recommendation

The Nigeria mariculture industry can be developed through innovative technology transfer between the aquaculture industries and research institutes/higher institution. This should reflect growth in terms of facilities, utilities and equipments that enable commercial production of aquatic organisms,

throughout their life cycles and in captivity. This increased production may be feasible from scientific and technology advancement through a sustainable aquaculture system.

In rearing cultured fishes in the natural aquatic environment (mariculture), caution is needed because transfer of diseases is usually rife in densely populated stocks of fishes, and in addition, pollution of the ecosystem can result from feed remnant and alter water quality.

Also, the Nigeria macroalgae aquaculture industry can provide raw materials for other sectors of the economy, as well as the potential for bioremediation of both the atmospheric and aquatic environment.

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