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Review

Sustaining the blue bounty: Fish food and nutrition security in Nigeria's evolving blue economy

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Abstract: Fish is a key component of Nigeria's protein supply, making up about 40% of the nation's protein intake and considerably aiding in the achievement of the second Sustainable Development Goal of feeding the expanding population. Despite its importance, Nigeria's fish production and supply cannot keep up with demand. While total fish output has increased from 1,073,059 tonnes in 2014 to 1,169,000 tonnes in 2018 and is expected to reach 1,275,000 tonnes by 2030, there is a great supply gap. Fish production not only affects food security but also the national economy and employment. Notwithstanding, the fisheries sub-sector suffers several difficulties, such as poor management, a deficient fisheries policy, overfishing, diminishing catch, and a lack of technical know-how among fish growers and fishermen. Thus, exploring untapped aquaculture potential and managing small-scale fisheries effectively are necessary to close the gap between the demand for and supply of fish. The fish output situation can be improved by enforcing fisheries policy and regulations, increasing investments in ethical fisheries and aquaculture, and providing sufficient training for fish farmers and fisherfolk. To reduce waste associated with the limited number of fish now produced, post-harvest losses must

also be addressed. By solving these issues and putting in place the necessary actions, Nigeria can increase its fish production, strengthen its food security, and accomplish the sustainable development goals in its evolving blue economy.

Keywords: small-scale fisheries; aquaculture; SDGs; sustainability, post-harvest management

1. Introduction

The second Sustainable Development Goal (SDG) emphasizes the significance of access to food and food security. Its purpose is to eradicate hunger and provide food to all people and vulnerable populations by the year 2030. However, one of the most obvious aspects of poverty, particularly in Africa, continues to be food insecurity. If drastic steps are not taken now, there is a risk that the SDGs generally may not come to fruition because most African countries are lagging in actualizing some of the goals. According to estimates from the FAO, one in every four individuals in Sub-Saharan Africa is undernourished [1,2], while the prevalence of iron deficiency in women and vitamin A deficiency in young infants are both highest in this region [3–5].

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [6]. As a result, four dimensions of food security such as physical availability, economic and physical access, utilization, and stability of these three dimensions can be identified. Therefore, for the objective of ensuring the security of food, these four dimensions must be fulfilled concurrently.

The phrase "food and nutrition security" is often used to describe the availability and proper intake of high-micronutrient foods, as well as the method of preparing these foods, absorbed by the body, and subsequently used in the body's physiological process [6,7]. As of the year 2006, there were 9.1 million undernourished Nigerians and this number increased to over 14 million by 2016. Between 2016 and 2018, the number climbed further by 25.6 million, or 281.32% [8,9]. Even though the nation's population's undernourishment rate was cut in half from 19.3% in 1990 to 8.5% in 2010, it remained at 8.5% up till 2012, with more severe situations observed in the North-Eastern regions of Nigeria. There are regional variances in food security as well as variations based on rural/urban and cultural factors [10].

Nigeria's measures to solve its food insecurity are predominantly supply-driven, and several local and national initiatives and policies are aimed at increasing agricultural output (e.g., National Policy on Food and Nutrition in early 2001; Zero Hunger by 2030, 2016 National Plan of Action on Food and Nutrition, FAO emergency programs, Global Food Security Strategy, and etc.). With fertility identified as a major determinant of food security, this offers a chance to apply demand-side solutions to the issue of food deficit in the nation [10]. However, a more practical approach to solving this problem entails taking drastic measures to upgrade the level of food production given the fact that the country is blessed with abundant resources for high-level agricultural production. Unfortunately, these resources are not adequately harnessed. With a contribution of 2.09%, the fisheries sector is essential to the nation's agricultural economy. Poor rural and urban households consume a substantial amount of high-quality protein and micronutrients thanks to products from livestock and fisheries [11].

Despite the potential of the country to produce more than its needs due to its abundant natural resources, there is a gap in the supply and demand for fish and fish products. Thankfully, a new ministry of marine and blue economy was recently created by the federal government of Nigeria, and

it is believed that fisheries and aquaculture would be given better attention unlike what was obtainable before the creation of this new ministry. We, therefore, aim, in this review, to identify the various means by which fish production could be stepped up to balance the needs of the ever-growing population in a bid to attain goal number 2 of the SDGs. Our objectives are, 1) to evaluate the country's food security status with a focus on the production and consumption dynamics of fish, 2) to assess potential avenues and activities that can help improve fish production, and 3) to emphasize the importance of fisheries and aquaculture in the country's emerging blue economy.

2. The Nigerian economy and its food security status

2.1. The economy

Nigeria is a country in West Africa with a lower middle-class income. Its southern boundary is the Atlantic Ocean. With a land surface area of 923,768 km^2, of which 42,000 km^2 are flat rocks, Nigeria has about 14 million hectares of inland water bodies that are utilized for fishing by artisanal fishermen [12]. The country is heavily dependent on its coastal fisheries for the security of its food, and nutrition, ranking third globally [13]. The country is made up of 36 states, which are divided into six geopolitical zones: The North-East, North-West, North-Central, South-East, South-West, and South-South [14].

According to a 2022 estimation, Nigeria now has a population of about 220 million people, but with a reproductive rate of 5.38 births per woman, the Nigerian population is predicted to rise by up to 90% to about 394 million people [15]. With an annual population growth rate of 3.2%, Nigeria is expected to have 440 million people by the year 2050, making it the third-most populous country in the world after China and India [16]. The urban growth rate in Nigeria (4.1%) accounts for one of the highest in the world and it is mostly due to the paucity of resources in the rural areas [17].

The country is rich in natural resources, having sizable oil deposits and the continent's greatest stocks of natural gas. Nigeria is the largest oil exporter in Africa with an economy that relies largely on oil, constituting about 95% of export revenues, 25% of GDP, and over 90% of government revenue. Nigeria is poised to be among the world's major economies, but poverty levels have remained high due to rising inequality and regional differences. Over 40% of the Nigerian population (approximately 83 million people) are living below the poverty income level of NGN 137,430 (USD 381.75) [17,18].

2.2. Food and nutrition security

The second SDG has emphasized the significance of access to food and food security as it seeks to end hunger and secure food security within the next few years - (the year 2030). The FAO states that "food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritional food that fits their dietary needs and food choices, for an active and healthy life."

According to the World Bank, the threshold for absolute poverty is $2.15 per person per day [19]. More so, in Nigeria's Multidimensional Poverty Index (MPI) for 2022, 63% of Nigeria's population, or over 133 million people, are estimated to be living in multidimensional poverty. With 65% of the poor residing in the North and the remaining 35% in the South, this indicator emphasizes widespread deprivation [20]. Notably, the percentage of people living in poverty varies greatly across states, from 27% in Ondo to an alarming 91% in Sokoto. With 72% of rural residents living in multidimensional

poverty as opposed to 42% of urban residents, rural areas are disproportionately affected. Children are especially at risk because 67.5% of them experience multifaceted poverty, which is concentrated in rural areas, especially in the North-East and North-West. The necessity for focused initiatives to address the complex aspects of poverty in Nigeria is highlighted by this in-depth analysis [20].

The country relies on imported goods to supplement domestic production, while the shortfall in local supply has significantly contributed to people's inadequate access to food and nourishment. Among the major contributions to the food deficit in Nigeria are pastoral conflicts and terrorist attacks, especially in the northern areas [21]. These activities over time have caused a great distortion in the livelihoods of its people, including agricultural activities.

In Nigeria, about 42.9%, 7.9%, and 3.6% of children are reported to be stunted, underweight, and wasted in farm households [22]. Nigeria is ranked 103 out of 119 countries in the Global Hunger Index, which calls the issue there "serious." Shocks in food prices frequently cause household food and nutrition security to be disrupted [23]. Food consumption is often reduced by households in response to increases in food prices, especially for relatively expensive foods high in micronutrients and high-quality protein, such as those derived from animals, vegetables, and fruits [24]. Unfortunately, even brief food shortages and poor dietary choices can have long-lasting effects on a child's nutrition.

Fish farming and fish production can help the nation increase its food security and decrease its reliance on imports. In addition to stabilizing food costs, this would also open job prospects in the fishing sector. Small-scale fish production enterprises might be very helpful for vulnerable and marginalized communities. Small-scale fishers can be given training, technical assistance, and access to resources through these projects, enabling them to raise fish for local consumption and economic production. According to Olaifa et al. [25], increasing overall fish production by 1% will result in a simultaneous rise in food security of 655.88%, while increasing the number of fishermen by 1% will result in a rise in food security of 28.01%. They further suggest the design and implementation of an aquaculture transformation plan to boost domestic fish output to close the supply-demand gap and, in the long run, enhance food production.

3. The value of fish and fisheries

3.1. Importance of fish

Fish is a source of protein and other beneficial nutrients that facilitate wound healing, prevent inflammation, modulate gut microbiota, and help the body fight against bacterial infections, coronary heart diseases, liver problems, and Parkinson’s disease among other benefits (Figure 1). They are also micronutrient-dense and may be crucial in the fight against diseases caused by micronutrient deficiencies that are common in developing nations [26]. The numerous micro-nutrients found in fish are crucial for resolving a range of health concerns globally and provide the most significant benefit [27]. Fish can help to attain improved maternal health, reduced risk of coronary heart disease, improved immune system function, favorable pregnancy outcomes, increased early childhood cognitive physical development, and relief from conditions like anemia, childhood blindness rickets, and stunted growth that are caused by micronutrient deficiencies. In addition to beneficial elements such as zinc, iron, calcium, phosphorus, and iodine, vitamins A, D, and B are found in fish. Notably, the exact nutritional spectra of fish differ depending on habitat, species, methods of preparation, and processing [28,29].

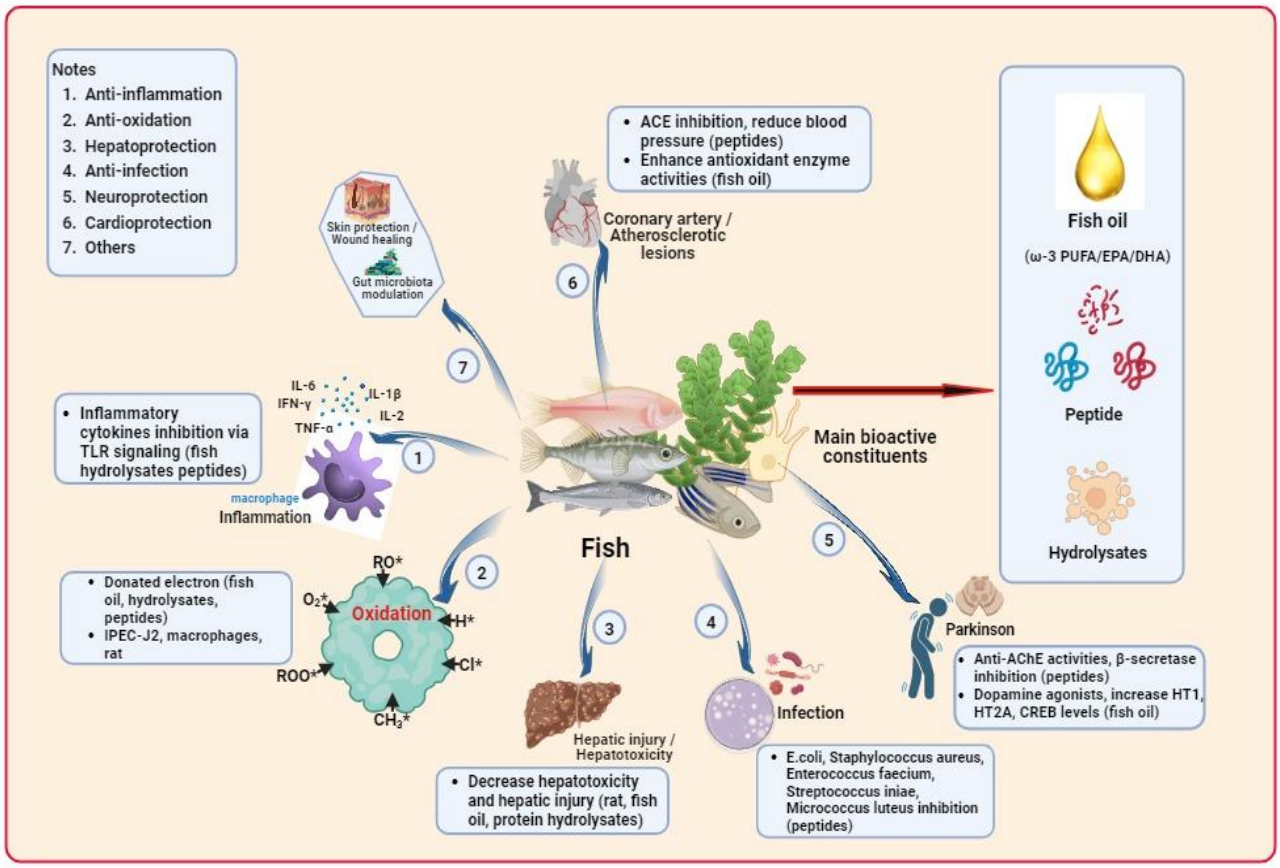

Figure 1. Health benefits of eating fish and their accompanying bioactive components. Adapted from Chen et al. [31].

Fish supplies beneficial and essential polyunsaturated fatty acids, which are necessary for the functioning of the heart, and brain. Fish or fish oil consumption has been linked to several advantages for a healthy heart, including a decreased risk of sudden death [5]. Omega-3 fatty acids from seafood sources are found in modest concentrations in the diets of 1.4 million people worldwide. In addition to a 12% reduction in overall mortality, eating fish is linked to a 36% reduction in heart attacks and heart disease [29–31].

Due to their higher need for minerals and protein-rich foods compared to adults, the consumption of fish is quintessential for children and women. Malnutrition is responsible for almost half of the deaths in children ages 5 and below under the age of four and leads to 45% of deaths of children under five in countries with poor income [30,32].

3.2. Fisheries' contribution to Nigeria's food and nutrition security

In Nigeria, marine, coastal (brackish), and freshwater bodies are the major water bodies with three major drainage systems, including the Niger Basin, the Chad Basin, and the West Coastal Basin [33]. The Niger system which also includes the Benue River is the largest system with the Niger-Benue complex having a catchment area that covers about 575,500 km sq. [33].

Fish is widely consumed in Nigeria and is becoming more popular; 72% of Nigerians ate fish in

2015, up from 59% in 2010, while the South saw a 5-year increase from 71% to 90%, and the North remained at about 50% [34]. Many Nigerian families experience either chronic or temporary food and nutrition insecurity [23,35]. This is caused by factors such as household income, region, and seasonality. These factors have their impacts on the accessibility and availability of fish and fishery products.

Fish consumption is put at 13.3kg/person/year and is greatly influenced by socio-economic status, fish consumption rates increase in households as income increases. According to research, 74% of Nigerians with high incomes consumed seafood at least twice per week, but just 64% of middle-class and 40% of low-class Nigerians consumed food at the same rate [36]. This may be attributed to the fact that most of the Nigerian population considers fish or seafood generally as a luxury food and an indication of wealth, hence not providing enough to end hunger.

Aside from socio-economic status, another important factor that influences fish consumption is the traditional beliefs, community, and individual views on certain fish species. Some tribes have certain taboos against women and children eating certain food types [37]. Interestingly, the restrictions to eating fish in mid-western Nigeria for example are quite minimal compared to other food types like snails, eggs, meat, oils, etc. Therefore, fish can be a good replacement for the forbidden foods especially those of protein sources because in the absence of an alternative, children, especially those under the age of five, are likely to experience malnutrition when these taboos are observed [38].

Nigeria generates about 1 million tonnes of fish annually, with about 70% attributed to capture fisheries and roughly 30% to aquaculture [39]. Fish consumption in Nigerian households is projected to be 13.3 kg per person per year, which is much less than the global average of 20.3 kg per person per year [39]. One of the major reasons for this is because of the high supply-demand gap, thus, the role of aquaculture in enhancing Nigeria's food and nutrition security status cannot be overemphasized. To increase the shelf-life of fish harvested in Nigeria, several processing and preservation techniques are used, the most popular of which is smoking. Other techniques include canning, chilling, and sun-drying [40]. Smoking is believed to increase the flavor significantly, and as a result, the commercial value of the product [41]. In addition, almost all species available in Nigeria can be preserved by smoking. These fish processing techniques are mostly done by women and the technique and business scale largely depend on the availability of processing materials and funds, size, quality, and quantity of fish produced [42].

3.3. Socioeconomic benefits

Fisheries in Africa have a major economic and social impact in addition to being an excellent source of enormous nutrients that are necessary for human health and nutrition. Through its contributions to the creation of jobs, generation of revenue, and earning of hard currency for various nations, the industry serves as a crucial social safety net [43]. About 12.3 million people are employed in the Sub-Saharan Africa (SSA) fisheries sector, of which half are fishermen, 42.4% are processors, and 7.5% work in fish farms. More so, the majority (40.4%) of fishers and fish processors work in inland fisheries, followed by marine artisanal (32.9%), marine industrial (19.2%), and aquaculture (7.5%) [44]. According to Muringai et al. [45], around 10 million people rely on fisheries as their primary livelihood, while 90 million engage in fishing as an alternative strategy.

In Nigeria, fish from both the capture and culture fisheries sectors make up 40% of the country's animal protein intake, while aquaculture and fisheries account for 3-4% of the country's annual GDP [17]. Since most of the domestic fish production in Nigeria is produced by the artisanal fisheries

sector, which employs about 10 million people, the artisanal fishery is the greatest employer of labour in the country's fishing industry [46]. The participation of women in value chains of the fishing industry is characterized by low capital and technological input. According to Nwosu et al. [47], women frequently comprise a significant segment of the labor force, particularly in the realm of small-scale fishing. Adewumi [48] estimated that approximately 47% of individuals who rely on capture fisheries are women. Women's participation in aquaculture, one of the primary output areas with the highest growth, is rising proportionately.

Through their involvement in agricultural production, processing, and marketing, women make a considerable contribution to national economies; yet, more than 60% of the world's impoverished are female, and females have fewer opportunities than men to accumulate wealth [49,50]. The provision of gender-friendly chances that would be devoid of inequality and assure a purposeful level playing field for women is one of these issues that has to be addressed. Extending the gender roles of women in Nigeria's small-scale fisheries and aquaculture beyond what is called the "gender-segregated division of labour" in the fishing industry would afford women more options to overcome poverty as a result [1,49–51].

3.4. Fish supply, production, and consumption

The fish supply in Nigeria is relatively high, estimated at around 24 per person/day, surpassing other animal source foods like meats, eggs, and milk [52]. Fish consumption as a percentage of all animal-source food consumption grew from 36% to 42% between 1980 and 2013 [17,53]. Also, the annual fish supply grew by 87% during that time, from 0.984 million to 1.84 million tonnes. Despite the increase in population from 73 million to 172 million from 1980 to 2013, the quantity of fish consumed per person stayed almost the same. The average expenditure and consumption in the northern part of the country are much lower than in the south, although fish is cheaper in the northern states than it is in the southern states. Even though the North is the major agricultural-producing region in Nigeria, this is of major concern because the North has greater rates of hunger than the South [17,54].

Modern fish farming in Nigeria may be traced back to the period of World War II when a fisheries organization was established in Lagos. In 1950, the institution was combined with the Department of Commerce and Industries and given a new name, the Federal Fisheries Services. A 160-hectare industrial-scale fish farm dedicated to carp cultivation was created in 1951. The practice of fish farming became more concentrated and efficient in the mid-1960s, via a partnership with the Food and Agriculture Organization. Between 1960 and 1970, there was a tenfold rise in the amount of fish production, which resulted in a higher number of Nigerians engaging in fish farming [55].

The native culture fish species prevalent in Nigeria include tilapia, catfish, and African bonytongue. On the other hand, introduced species include grass carp, common carp, Indian carp, silver carp, channel catfish, and largemouth bass. The major fish species responsible for approximately 90% of output include African catfish, torpedo-shaped catfishes, carp fishes, tilapia, Aba, and Nile perch [55,56]. The tilapia species commonly farmed include *Oreochromis niloticus*, *O. mossambicus, O. aureus, Sarotherodon galilaeus, S. melanotheron*, and *Coptodon rendalli* [57–59]. The catfish species consisted of two types: The African catfish, scientifically known as *Clarias gariepinus*, and the sharptooth catfish, scientifically known as *Heterobranchus longifilis*. The catfish species "Heteroclarias", which is a hybrid of two other catfish species, was also cultivated. *Heterotis niloticus*, known as the African bonytongue, is a promising species for pond aquaculture. The cultivation of *Lates niloticus* and *Chrysichthys* spp. was also documented [55,57]. Despite their modest quantity, these

species were effectively cultivated, either alone (monoculture) or in combination (polyculture) [57].

The marine artisanal fisheries resources consist of various fish species, such as croakers, bonga, shad, catfish, sardines, soles, shiny-nose, and *Polydactylus* spp. Additionally, the fisheries also include fish from the Sphyraenidae, Lutjanidae, Elopidae, Serranidae, and Carangidae families. Small-scale fishermen also catch sharks, sailfish, swordfish, as well as penaeid, palaemonid, and carid shrimps [60]. Nigeria's industrial coastal fishing operations include the use of trawlers to catch demersal finfish, shellfish, and penaeid shrimps. Nigeria is home to around 104 marine fish species, which are classified into 50 different families. The species composition is mostly comprised of croakers (*Pseudotolithus* spp.), grunts (*Brachydeuterus* spp.), different soles (*Cynoglossus* spp.), catfish (*Arius* spp.), and shrimps (*Penaeus* spp.) [60].

Nigeria, alongside Uganda, and South Africa stands as the leading producer of wild fish in Sub-Saharan Africa. Aside from its contribution to capture fisheries in the region, Nigeria also stands tall with Ghana and Uganda in the production of farmed fish in the region [61,62]. Conversely, overfishing, the employment of harmful fishing techniques, and climate change have all contributed to the stagnation of capture fisheries in recent years. As a result, fish farming now accounts for the increase observed in the region's fish production. The field of aquaculture is known for providing food more quickly than farm animal meat production and landings from capture fisheries [45].

More recently, it is quite unfortunate that only Africa experienced a decline in aquaculture production as opposed to other regions of the world because of the decrease recorded by Nigeria and Egypt. Moreover, other African countries leaped by 14.5% between 2019 and 2020, Nigeria experienced the worst decline since 2016 in the year 2020 at a 9.6% decrease [63]. For fish to truly contribute meaningfully to the security of food and nutrition, this negative trend must be reversed. Fortunately, the huge potential for aquaculture expansion in Nigeria’s inland waters has been established and assessed [63]. Therefore, Nigeria has a huge opportunity to drastically increase its fish production if these potentials are duly harnessed. However, other parameters such as potential impacts on the environment and necessary measures for sustainability must be adequately addressed.

Nigeria produced 1.17 million metric tonnes of fish overall in 2018, up from 1.04 million metric tonnes in 2016 mostly because of artisanal fishing [17]. Contrarily catches from commercial fishing and marine trawling have decreased recently, perhaps because of overfishing. According to Agbo [64], the volume of imported fish into the country is estimated at 1.9 million metric tonnes per annum. Trawling for penaeid shrimp, shellfish, and demersal finfish is the main industrial coastal fishing activity in Nigeria. The fish species are mostly croakers (*Pseudotolithus spp.*), grunts (*Brachydeuterus spp.*), different soles, catfish (*Arius* spp.), and shrimp (*Penaeus* spp.). Nonetheless, the major target species and families are:

i. Ariidae (Catfish): *Arius gigas*, *A. parki, A. latiscutatus, A. heudeloti*.
ii. Cynoglossidae (Tongue sole): *Cynoglossus browni, C. canariensis, C. senegalensis, C. mondi.*
iii. Carangidae (Jack fish): *Caranx lugubris*, *C. hippos, C. latus, C. crysos*.
iv. Lutjanidae (Red snappers): *Lutjanus fulgens, L. goreensis, L. dentatus and L. agennes.*
v. Haemulidae (Grunters): *Pomadasys incisus, P. suillus, P. jubelini, P. peroteti.*
vi. Polynemidae (Threadfins or Shrinynose): *Galeoides decadactylus*, *Polydactylus quadrifilis*.
vii. Sciaenidae (Croakers): *Pseudotolithus elongatus, P. senegensis, P. typus*, *P. brachynathus*, *Brachydeuterus auratus,* (*Vomer setapinnis*).
viii. Serranidae (Groupers): *Epinephelus aeneus*.
ix. Sparidae: *Dentex canariaensis*, *D. congoensis*, *D. angolensis*

x. Sphyraenidae (Barracudas): *Sphyraena afra*, *S. barracuda*, *S. guachancho*.

The fishing grounds in Lagos West and the soft mud substrate of the Niger Delta, which extends eastward to Cross River, are home to most of the commercial penaeid shrimps that are harvested in Nigeria's coastal waters. The following shrimp species, in order of prominence, are exploited in Nigeria's inshore shrimp fishery:

i. White prawn (*Penaeus notialis*)
ii. Brown or Guinea shrimp (*Parapenaeopsis atlantica*)
iii. Rose or red deep-water shrimp (*Parapenaus longirostris*)
iv. Tiger or striped shrimp (*Penaeus krathurus and Penaeus monodon*)
v. Estuarine prawn (*Nematopalaemon hastatus*)

Based on the data from the United Nations Conference on Trade and Development, approximately 265 ships totaling 6,485,000 deadweight tonnage (dwt) that belonged to Nigerian owners were listed in the foreign registry in 2020 [65]. Among the nations that control these registrations are Singapore, Panama, Marshall Island, Liberia, and others. In the same year, the African fleet numbered 7433 ships, whereas the Nigerian fleet, according to flag registration, comprised 726 ships with 4,526,000 dwt [65].

Over 70% of Nigeria's local fish supply is caught by artisanal small-scale fishers in coastal regions, Niger Delta lakes, inland rivers, creeks, and lagoons. Between 2014 and 2018, the average annual trade imbalance in Nigeria was USD 970 million, and is an importer of fishery products, while fishing is an important source of income [66]. About 10 million Nigerians work in the fishing industry, which contributes significantly to the country's GDP [67]. According to the FAO website, 653,000 persons reported working in inland fisheries in 2016, with women making up an estimated 21% of the workers [17]. Over two times (1,477,651 people) of the FAO figure was reported to be employed in the fishing industry in Nigeria, contributing 1.09% and 0.97% of the country's GDP in 2020 and Q3 of 2021, respectively [68].

More so, a decrease was reported in aquaculture productivity between 2016 and 2018 (Table 1). The price of feed is one big challenge. An imported and domestically made 15 kg bag of catfish feed cost NGN 6,000 before 2014 [69]. Similar products now cost between NGN 13,000 and NGN 15,000 for locally produced feed and between NGN 20,000 and NGN 30,000 for imported feed. It has been reported that a significant number of cooperative medium- and small-scale fish farmers who had previously used high-quality and/or imported feeds switched to local feeds, which most likely caused a reduction in aquaculture productivity and output.

The proportion of imported fish in Nigeria's overall fish consumption increased by more than fourfold between 1970 and 2000, reaching a peak of 39% in 2017 [53]. This is in contrast with a 13% import share of all food in 2017 [25]. Pelagic fish from exporting nations, including Japan, Holland, Denmark, Norway, and China include herring, hake, horse mackerel, mackerel, blue whiting, stockfish heads, and stockfish (dried cod). Nigeria's Ministry of Agriculture indicated in October 2013 that the country would ban fish imports for four years and increase the import duty from 10% to 50%, with a possible cap of 100%, starting on January, 2014. As a possible impact of this ban, there was an overall increase in the production of fish in the country from 2014 to 2018, with about a 39% increase in the coastal and brackish water fish production in 2016 (Table 1). Production from artisanal fishing (coastal, brackish, and inland) and aquaculture showed an increase, while the production from industrial fishing also increased moderately. Unfortunately, the country has continued to see an increase in its imports of fish over the years. The quantity of fish imported has increased despite limits and if the government does not make a serious effort to improve local fish output, fish imports may continually

serve to match local supply to demand, thereby depleting considerable sums of foreign currency. Nigeria's imports of aquatic goods increased from USD 188 million in 2000 to USD 896 million in 2021, making it the second highest of the continent's top 10 aquaculture nations [70]. Miscellaneous pelagic fish account for around half of the imported aquatic products, with cod, haddocks, hakes, herrings, sardines, anchovies, and unidentifiable marine species coming in second and third.

Table 1. Nigeria's fish production (FP) and fish supply (FS) from 2014 to 2018 in MT. TP = Total production, TS = Total supply.

Year	2014			2016			2018		
Sector	FP	%TP	%TS	FP	%TP	%TS	FP	%TP	%TS
Coastal and brackish water (artisanal)	435,384	38.8	22.9	684,359	51.9	32.2	474,328	40.6	22.5
Inland water (artisanal)	324,444	28.9	17.1	327,320	24.8	15.4	392,188	33.5	18.6
Aquaculture	313,231	27.9	16.5	306,767	23.3	14.4	291,323	24.9	13.8
Industrial fishing	49,952	4.4	2.6	NA	NA	NA	11,639	1.0	0.6
Total production	1,123,011	100.0		1,318,446	100.0		1,169,487	100.0	
Imports	776,552		40.9	806,000		37.9	940,099		44.6
Total supply	1,899,563		100.0	2,124,446		100.0	2,109,586		100.0

Adapted from Subasinghe et al. [17].

The percentage of total fish production contributed by industrial fish landings declined to 0.6% in 2018 from 4.4% in 2014. This could be a result of under-reporting of the landings. Figure 2 shows that the consumption of the product is generally higher in the southern regions, both rural and urban, compared to the northern regions. The prices of the products in the southern regions are also higher compared to those in the northern regions. Fish is being exported from Nigeria, especially in the processed form, however, data is lacking regarding the quantity exported. Most reports only estimate the economic value of fish exports from Nigeria. There is a likelihood that the exported fish are usually calculated as part of the country's consumption. Furthermore, unlike most of the leading aquaculture countries in Africa, Nigeria's income from the export of aquatic goods is mostly derived from shellfish. This figure has increased from USD 12 million in 2000 to USD 49 million in 2021 [70].

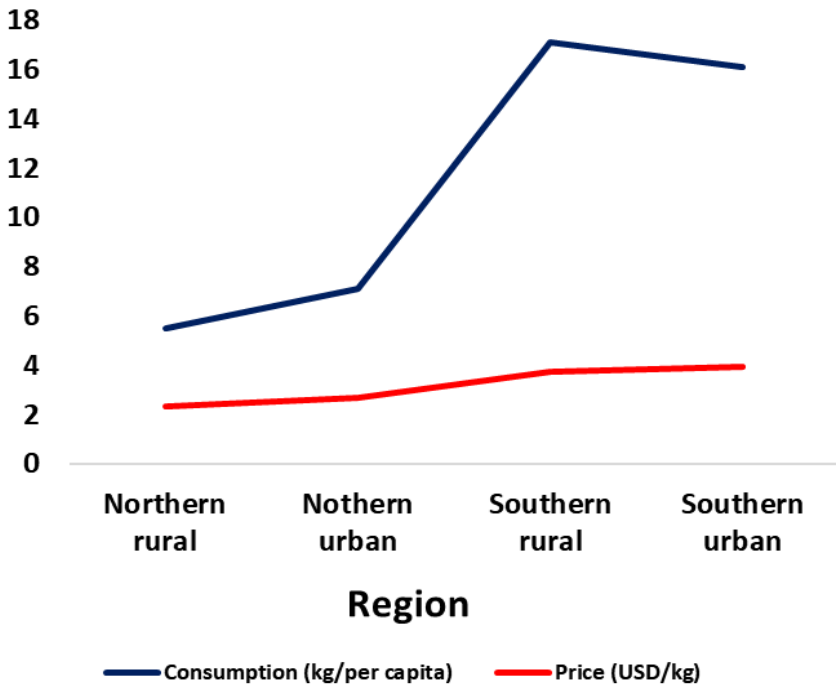

Figure 2. Per capita fish consumption and price of fish in different regions of Nigeria. Adapted from Subasinghe et al. [17].

4. Increasing the fish production in Nigeria

4.1. Contribution and prospect of small-scale fisheries

Small-scale fisheries are responsible for most fish caught in Nigeria. In 2017, these fisheries harvested 941,000 metric tonnes of fish and other aquatic products, compared to 13,000 metric tonnes from large-scale fisheries. Small-scale fishers play a vital role in providing most of Nigeria's fish supply, particularly from wild fish catches. However, there is limited information available on the specific species-level catch. Inland fisheries contribute approximately 40% of the total fisheries catch in Nigeria, significantly impacting food security by providing nutrient-rich food directly to local diets. Unfortunately, the potential and contribution of small-scale fisheries are often overlooked in food production policies, with freshwater fisheries receiving inadequate attention [52].

Due to proximity to the ocean, lagoons, and estuaries, southern states produce more fish than the northern states, reflecting the consumption pattern, where children in the South consume fish more frequently compared to those in the North. In states like Zamfara and Borno with relatively high fish production, children consume very little fish, suggesting targeted programs to increase fish consumption among children could improve childhood nutrition and health. Fish commonly consumed in the Nigerian diet are rich in bioavailable nutrients, offering an opportunity to address hidden hunger by increasing fish servings among vulnerable populations.

Nigeria has a vast coastline of over 850 km and an extensive network of rivers and lakes, making it a potentially rich source of fish and seafood [71]. However, the country has not yet fully harnessed its fisheries potential, particularly in small-scale fisheries. Apart from the vast coastline, Nigeria boasts

of abundant inland water bodies in the form of numerous rivers, lakes, and other inland water bodies that provide significant potential for small-scale fisheries. These water bodies support a variety of fish species, many of which are highly sought after for their nutritional and economic value. The diverse range of fish species includes both marine and freshwater, that can be harvested sustainably. This provides opportunities for small-scale fishers to target different species based on market demand and seasonal availability. More so, with a growing population and increasing demand for protein-rich foods, the demand for fish is expected to increase in Nigeria. This provides an opportunity for small-scale fishers to increase their productivity and contribute to meeting the growing fish demand.

Small-scale fisheries can support millions of people's livelihoods in Nigeria, particularly in rural and coastal areas, and contribute to poverty reduction and economic development. In addition, SSF can significantly contribute to enhancing nutrition in Nigeria, particularly in communities where diets are often poor and lacking in essential nutrients.

4.2. The potential of aquaculture

According to forecasts from the WorldFish Foresight Model, Nigeria's fish supply-demand gap will increase over the next decades. Future increases in fish supplies must come from aquaculture, artisanal fisheries, and imports, as it has been projected that marine capture fisheries will stay constant [17]. The aquaculture production data from major fish-producing regions in Africa including Nigeria is presented in Table 2. Of the total aquatic animal production in Africa, Nigeria took a share of about 16% in the year 2010 and about 12% in the year 2020 [72].

Table 2. Aquaculture production data from selected African regions for the years 2010 and 2020.

Regions and selected countries	2010			2020		
	Animals	Algae	All species	Animals	Algae	All species
Egypt (% in Africa)	919.6 (71.5)	-	919.6 (64.56)	1591.9 (70.74)	-	1591.9 (67.62)
Nothern Africa (% in Africa)	10.1 (0.78)	-	0.1 (0.71)	40.1 (1.78)	0.3 (0.27)	40.4 (1.72)
Nigeria (% in Africa)	200.5 (15.59)	-	200.5 (14.08)	261.7 (11.63)	-	261.7 (11.12)
Sub-Saharan Africa (% in Africa)	155.9 (12.12)	138.3 (100)	294.2 (20.66)	356.5 (15.84)	103.8 (99.73)	460.3 (19.55)
Africa (% in the world)	1286.1 (2.23)	138.3 (0.69)	1424.4 (1.83)	2250.2 (2.57)	104.1 (0.30)	2354.3 (1.92)

Note: all measurements are in thousand tonnes, live weight. Source: FAO [63].

4.2.1. Fresh/brackish water aquaculture

Nigerian aquaculture focuses on freshwater fish, with 64% of 2015's production coming from catfish species [73]. There are several prospects for large-scale production in Nigeria, which is the top producer in Sub-Saharan Africa (SSA). Small-scale farmers engaged in brackish and freshwater

agriculture account for 80% of Nigeria's production [71]. Nigeria has about 12,500,000 ha of inland waters, which include rivers, streams, artificial, and natural lakes. In addition, there is expected to be 1,000,000 ha of permanent freshwater wetlands. These waterways are suitable for aquaculture. Ponds can also be constructed in land-locked areas such as Sokoto, Kaduna, Jos, and Oyo, which together account for over 79,000,000 acres [74].

One system of fresh/brackish water aquaculture in Nigeria that holds great potential is the cage culture system, which has recently focused on the culture of tilapia. As shown in Figure 3, tilapia cage culture in Nigeria is more concentrated in the inland locations in the country where farmers have access to the abundant freshwater supply, compared to the coastal areas and other arid areas with low freshwater supply. Access to a freshwater environment with good water quality favors the survival, reproduction, and growth of Tilapia, which are known to be an important freshwater fish species. In addition to this, inland artisanal, and culture fish production in Nigeria are highly dependent on the hydrological pattern.

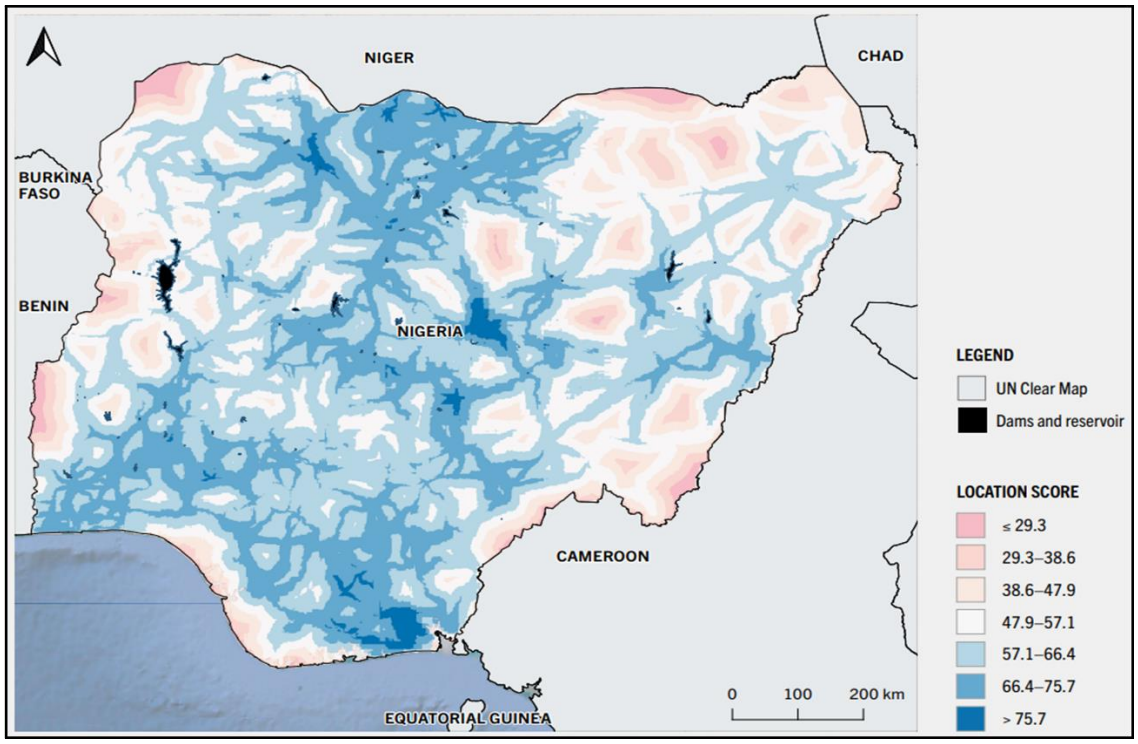

Figure 3. Favorable locations for tilapia intensive cage farming in large waterbodies of Nigeria. The score is the result of a normalized weighted sum of the values for the location factor (criteria) gridding with values between 0 and 100. 100 = the ideal location for large-scale tilapia cage farming. Pink = inappropriate sites, blue = appropriate sites. Source: FAO [63].

In Nigeria, non-intensive aquaculture systems are such that rely on natural food sources like ponds or small bodies of water, integrated systems like waste products from crops and animals, or additional feeding sources like locally or on-farm generated feed. As shown in Figure 4, this system is practiced across Nigeria with more locations found in the North-Central up to South-West, and South-South Nigeria, respectively. In this system, several households within these regions in Nigeria own and manage small ponds, tanks, and embarkments for subsistence and sometimes commercial fish production.

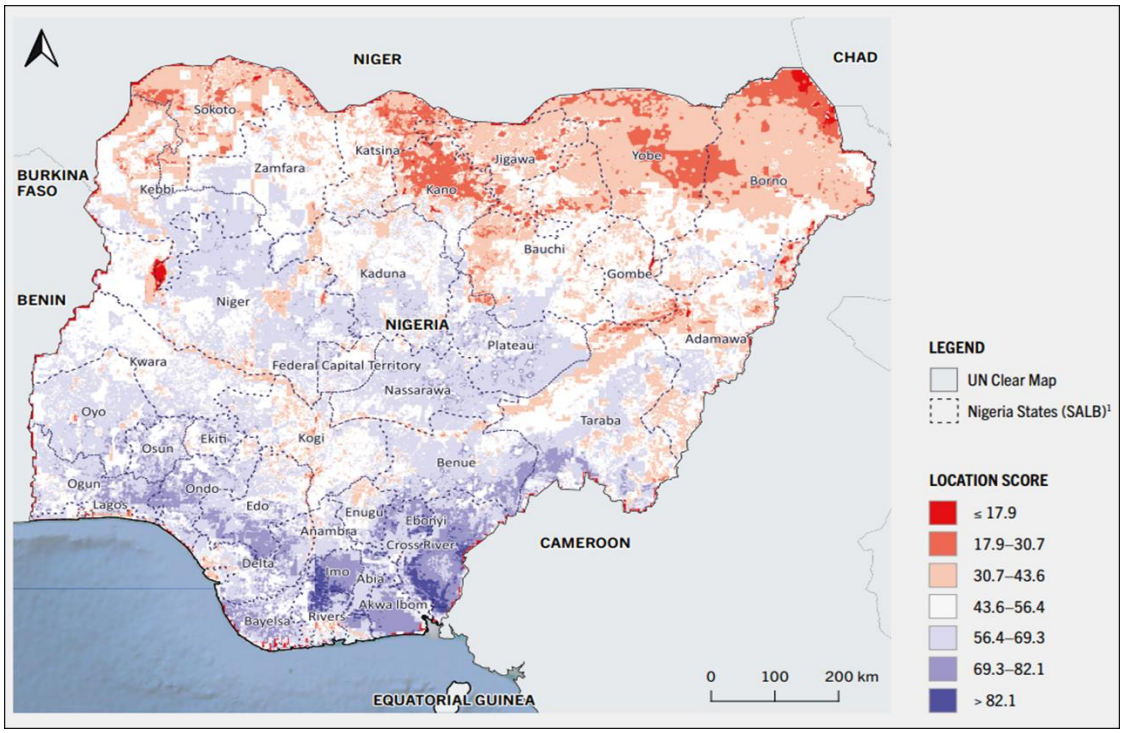

Figure 4. Favorable locations for open non-intensive farming systems in small waterbodies of Nigeria. NB: The score is the result of a normalized weighted average of the values for the location factor gridding with values between 0 and 100. 100 = ideal location for open, non-intensive farming systems. Red = Unsuitable locations, purple = suitable locations. Source: FAO [63].

In Africa, aquaculture is expanding quickly and gaining more significance, and in Sub-Saharan Africa at a rate of roughly 11% each year. The projection for aquaculture production by 2030 in Africa and three countries (Nigeria, Egypt, and South Africa) is shown in Table 3. More so, fisheries production is projected to increase by 1.72 million tonnes by 2030 out of which 22.6% of the increase is expected to come from aquaculture production. Of the fisheries production increase, a significant contribution of 16.3% is expected from Egypt (over 319,000 tonnes from aquaculture), followed by Nigeria (15.8% with over 56,000 tonnes from aquaculture production).

Table 3. Projected aquaculture and fisheries production in Africa, Nigeria, and selected countries to 2030.

Region/country	2020	2030	Growth of 2030 vs. 2020	2020	2030	Growth of 2030 vs. 2020
	1000 tonnes (live weight equivalent)		%	1000 tonnes (live weight equivalent)		%
Africa	12,044	13,763	14.3	2250	2759	22.6
Egypt	2011	2339	16.3	1592	1911	20.0
Nigeria	1045	1208	15.8	262	318	21.4
South Africa	602	522	−13.3	6	12	90.5

Source: FAO [63].

4.2.2. Coastal and offshore aquaculture

Despite challenges that have been discussed extensively by Anetekhai et al. [74], the potential for aquaculture to flourish in the coastal and offshore oceanic waters is huge because it can successfully provide over 15 million metric tonnes of fin fish yearly from the world's oceans. Furthermore, up to 1% of the ocean's surface would not be required for aquaculture to produce the same amount of seafood as is currently produced globally through wild-caught fishing [75]. To achieve increased fish production in Africa, particularly Nigeria, which is a coastal country, there is the need to harness the vast coastal, brackish, and offshore areas to produce fish and other aquatic products, albeit sustainably. Nigeria has a wealth of resources that enable it to compete with the top aquaculture-producing countries in the world.

Apart from its over 260 medium and large dams, with a combined capacity of more than 30 billion cubic meters of water for cage and pen aquaculture, the country has an expansive 210,900 km^2 maritime water area, including the Exclusive Economic Zone, and more than 850 km of shoreline [75,76]. The 1147 nm^2 continental shelf area contains 3200 nm^2 of trawl-able grounds despite the continental shelf's relatively small range of 15 km in the west to 60–80 km in the east [47]. A wide variety of tiny fish species, with total lengths ranging from 25 to 50 cm, are found in inshore waters (0–50 m) [77]. Among the 78 families of fish that have been demonstrated to be suitable for marine farming in Nigeria are the *Arius* spp., *Pseudotolithus* spp., *Cynoglossus* spp., *Lutjanus* spp., *Sardinella* spp., and *Pomadasys* spp. Additionally, numerous reports of shellfish with potential for culture have been made [55,74].

High energy offshore aquaculture conditions necessitate more robust construction of structures than inshore counterparts. The maintenance of facilities and cost reduction should be given top priority in the development of new offshore aquaculture technologies [75]. Although it is used in certain affluent nations, automation of offshore facilities needs significant time and resource commitment. Offshore aquaculture in Nigeria is faced with several significant challenges, such as coastal pollution from intensive commercial and industrial activity, oil exploration that results in spills that affect water chemistry and fish mortality, shallow coastal waters, inadequately developed sustainable aquaculture technology, and a lack of government support because the economy relied mainly on crude oil.

The effects of offshore aquaculture on benthic communities and the possibility of disease transmission between farmed and wild fish are two environmental issues. The environmental risks associated with fish treatment chemicals depend on the techniques employed for culture and how they affect water quality [78]. Even with these difficulties, offshore aquaculture has the potential to be biologically advantageous due to factors including improved water exchange, increased dissolved oxygen levels, decreased ammonia levels, and balanced temperature combinations. These elements help create an environment that is healthier for fish growth, producing fish with firmer flesh and less fat than inshore fish [79].

The aquaculture sector has fewer negative effects on the environment than the terrestrial meat-producing sector [80]. Compared to other terrestrial animal production systems, aquatic animal production systems have a reduced carbon footprint per kilogram of output [34]. Additionally, nitrogen and phosphorus emissions from aquaculture systems are far lower than those from beef and pork production systems [81]. Moreover, in terms of CO_2-equivalents per kg of protein, oyster aquaculture has less than 0.5% of the green house gas (GHG)-cost of beef, small ruminants, pork, and chicken, suggesting that shellfish aquaculture could offer a low-GHG alternative for future animal protein supply when compared to land-based sources [82]. Therefore, it is important to intensify the production

of aquatic food including fish which has been mostly produced worldwide. This would contribute to the mitigation of climate change due to the reduction of greenhouse gas emissions.

4.3. Data for fisheries sustainability and food security

Data collection is crucial for determining how the different components of the fishing industry are governed [13]. Data collected on the characteristics of the fishery are important indicators of how changes to a fishery could lead to its downfall or upscale. When these data are recovered, they assist in identifying the many relationships that occur within the sector and in predicting how specific actions may affect the interactions' long-term outcomes. Data collected are used to estimate the performance of a fishery, and its catch sustainability over a long period. Different algorithmic and assessment methods such as the holistic and analytical methods are used to determine the maximum sustainable yield, economic carrying capacity, yield per recruit, total effort, and other measures. These measures are set in place to prevent catastrophes and allee effects. This data could also be used to determine the overall long-term health of fish stocks and their impact on the economy. Unfortunately, Nigeria's fisheries are one of the numerous fisheries of the world with a paucity of not only basic fisheries data but comprehensive data streams required for formal stock assessments [83].

For years, relevant Nigerian institutions have collected some of the necessary fisheries and aquaculture data. Unfortunately, such data is hardly comprehensive and not up-to-date. The lack of easy access to this data makes the situation worse. Apart from improving the quality and quantity of data, all collected fisheries data need to be made public regularly (at least annually). The rigorous collection and analysis of biological data form the basis for ideas for scientifically supported management of fish populations and native species protection. The evaluation of important fish populations, the efficiency of regulations, knowledge of fisher preferences, observation of environmental changes, and public views of fisheries and aquatic ecosystems are all areas that require focus in Nigeria.

It is quintessential to borrow a leaf from some countries that are making good efforts in data collection and dissemination. For example, Malaysia publishes “Annual Fisheries Statistics” with up-to-date information about the different fisheries sectors. Necessary and up-to-date information bothering around the aquaculture sector should be collected about species cultured both native and exotic, disease outbreaks, feeding regimes, sources of fish seed, culture systems adopted, and stakeholder demographics. Malaysia publishes information such as the aquaculture profile which is a summary of cultured species including fresh, brackish, and marine species. In addition, the production by species and value of the aquaculture sector by waterbody type, ornamental fish production, aquatic plant production, and production of fish fries and hatchlings from government and private hatcheries. More so, for the capture fisheries, landings by species, number of fishermen and licensed fishing vessels, marine fish landings, and landings by fishing gear types among other information. Information about the landings of fish from inland waters is also made available. This is published as annual fisheries statistics which contains the valuation of the fisheries sector, marine capture fisheries profile (deep sea and coastal), aquaculture profile (freshwater and marine), and inland capture fisheries profiles.

The most vital investments in data collection and management by governing bodies should be in strengthening the tools used to collate data such as hiring more local and international experts, improving locations of landing sites and seaports, formulating local teaching organizations, incorporating good international policies, and purchasing new technological tools that improve data collection and management. Moreover, investments would also be needed in the educational sectors

to involve youth and locals in how data collection is needed to sustain aquatic resources. Advancement of SDG 14- Life Below Water will need to be incremented in educational institutions to develop a more knowledgeable approach towards sustaining the environment. Increased investments in fisheries data collection will aid in food security, reduced fish mortality, regulated fishing operations, improved gear selectivity, improved boat profitability, and sustainable stock densities.

4.4. Post-harvest management of fish and contribution to food and nutrition security

All levels of the value chain in the fisheries experience food loss and waste (FLW), which increases food insecurity and lowers the wages of value chain participants. Fish spoils quickly once it is dead, starting from the time of harvest. To prevent spoiling and extend shelf life, fish must be properly chilled, handled under sanitary circumstances, or processed by drying, salting, or smoking [84]. The projected global loss and waste rate for fish landings is 39% [2]. Despite estimates of higher fish output in the nation based on unreported border trade and some small-scale fisheries, it is predicted that post-harvest losses make up around one-third of the overall catch. significantly lowering the number of fish available for human consumption [85]. Approximately 30% of fish and other aquatic foods harvested by small-scale fisheries are lost through damage, waste, and discards, especially during seasonal fishing peaks. Addressing waste and loss can enhance fish supplies, quality, and economic returns to fishers and those involved in fish supply chains. By focusing on these aspects, Nigeria can improve food security, nutrition, and livelihoods in the fisheries sector [52].

The post-harvest losses in Nigeria have been shown to vary from 30% to 50%, with most of the losses occurring in the artisanal fishing sector [86–88]. The losses occur across the fish distribution value chain and pose a significant threat to the artisanal fishing industry in the nation [89]. The FAO's Code of Conduct for Responsible Fisheries (CCRF), in Article 11.1, acknowledges the issue of fish loss and emphasizes the importance of reducing post-harvest fish losses to address the shortage in fish supply [89]. As a result of the lack of detailed and updated assessment of post-harvest losses, there is a chance that they will be larger than estimated. This has aggravated the situation of fish availability thus widening the existing food security gap. Minimizing fish post-harvest losses will go a long way toward addressing the nation's food insecurity issue.

Increasing the value of aquaculture enterprises by reducing post-harvest losses of fish from farm gate to consumption is an economically practical technique for fostering sustainable economic growth. This is not to rule out the necessity of long-term productivity and fish production growth to practically increase fish consumption to tackle malnutrition in Nigeria. By reducing post-harvest loss, efforts to increase production will also increase employment and decrease waste [90]. Post-harvest-related losses occur because of difficulties with fish product handling, preservation, marketing, distribution, and evacuation [6,91]. Losses are especially increased during the peak fishing season when there is a large yield and when fishing settlements are inaccessible due to weak road networks [92]. According to Béné et al. [93], as is mostly the case in Nigeria, market systems in several Sub-Saharan African nations lack organization, basic infrastructure, and electrification facilities. Moreover, in the northern part of Nigeria, there are more rural settlements without roads or market facilities. Women handle most of the trade and processing of fish at the municipal, state, and federal levels. However, they lack the necessary capacity for most of their fish handling operations to adhere to technical and hygienic requirements at the national and international levels [91]. Minimizing stress in post-harvest management measures enhances the physical quality, nutritional value, and shelf-life of fisheries

products [94]. Improper treatment of fish may result in bodily harm, while implementing appropriate handling methods can minimize spoilage, hence addressing concerns related to food and nutrition security [95]. Enhancing post-harvest techniques may effectively prolong the freshness of harvests, minimize waste, preserve nutritional value, and fulfill the requirements for food quality and safety. However, if these interventions are not fully implemented, food waste and issues of food and nutritional insecurity will persist [96,97].

Along the entire fisheries value chain, access to finance is a crucial demand [72]. Women traders and processors demand finance and investment for items like working capital, equipment, and certification requirements. Most fishing communities in Africa blatantly lack efficient insurance, credit, and savings options for fishermen. Since small-scale fisheries are generally thought to be too risky to be included in most banks' credit loan schemes, only a small number of financial institutions provide some credit without security for "small" loans [85,98]. In Nigeria, one financial organization that provides agricultural loan schemes is the National Agricultural Bank, formerly the Nigerian Agricultural Cooperative and Rural Development Bank [NACRDB] [99]. However, fishermen often do not use them for their own needs. Modern cooperatives were originally introduced to the fisheries sector with the introduction of NAFPP in the 1970s, and they soon spread throughout the sector. These organizations, referred to as "esusu," "osusu," "adashi," and "club," replaced the conventional savings and credit clubs [85]. Banks and microfinance organizations should directly finance fish processing firms, with repayment choices that are modified to coincide with the busiest production months and training in the management of finances and businesses to boost viability and loan repayment capability. Village banks and Village Savings and Loan Association (VSLA) programs are more advantageous SSF sector models that are favorable for women's beneficiaries [84].

4.5. Enhancing food safety through certification

Inadequate post-harvest handling practices and lack of proper certification mechanisms have led to substantial losses in fish production and compromised food safety. According to Akintola et al. [6], if the only goal is to raise fish output without also addressing the problem of lowering post-harvest losses (PHL) in the fish supply chain, it will be difficult to achieve or sustain fish food security and nutrition. Food safety is a critical concern for consumers and regulatory authorities alike. Contaminated or mishandled fish products can lead to foodborne illnesses, posing severe health risks to consumers [100]. Inadequate food safety measures also hinder Nigeria's potential to export fish products to international markets, limiting income opportunities for fisherfolk and processors. Implementing food safety certification can instill confidence in consumers, enhance market access, and promote international trade by ensuring that fish products meet stringent quality standards.

Tran et al. [101] noted that strict regulations, consisting of voluntary standards overseen by third-party certifying agencies that are operated for profit, have been implemented in the global North due to consumer and regulatory concerns about the environmental sustainability and safety of seafood in developed countries. While such requirements might operate as obstacles for small-scale aquaculture farmers to enter export markets, in developing countries like Nigeria, they have prompted advances in post-harvest handling methods and production practices [90]. In 2009, the Nigerian Federal Department of Fisheries and Aquaculture began certifying and standardizing fisheries and aquaculture products [102]. Operational rules and standards for the nation's certification of aquaculture goods were produced because of this procedure. The African Organization for Standardization developed eco-

labeling standards for African aquaculture intending to standardize fish farm operations to lower potential health risks to people, and increase benefits, consumer confidence, and traceability in the production, processing, and marketing of aquaculture products [90].

Dechert [75] noted that fish producers in eight Nigerian states were identified through household surveys and key informant interviews as being willing to participate in aquaculture certification if it were to be established. Over 70% said they would be willing to take part in a certification program if it were to be introduced. From the standpoint of a producer, higher prices and greater demand for fish are the two most significant anticipated advantages of aquaculture certification. Consumer testing in Lagos state fish markets revealed positive and large surcharges for certified catfish. Fish with a certification was worth between 12.5% and 29 % more to consumers than fish without one. Moreover, it was confirmed that when compared to uncertified fish, consumers in Lagos were willing to spend between 3.1% and 18.8% more for fish that had received safety certification. Additionally, customers paid considerable premiums for high-value, larger-sized certified live and smoked catfish but not for smaller-sized certified live and smoked catfish, However, the major apparent barriers to certification are thought to be high charges, lack of trust in the certifying agencies, and failure to achieve the standards [103].

4.6. Fish health for food and nutrition security

Diseases present serious obstacles to the production of livestock and aquatic life, resulting in financial losses and reducing total productivity. Due to the high stocking densities, intense feeding in small water spaces, and shared water sources between ponds and fish farms, illnesses are spread particularly easily in aquaculture [104].

In Nigeria, there has been little research on aquaculture diseases and how they affect fish farming, which makes it difficult to identify current cases and draw lessons from the past. According to Selzer [105], parasites are responsible for losses of 20% in hatcheries and a reduction of 1–10% in the growth of cultured fish with annual losses in aquaculture and fisheries estimated to reach close to USD 10 billion. Fish are among the most parasitized vertebrates, and parasitic illnesses are common in fish worldwide, particularly in tropical areas. Public health issues could arise from some parasites' potential zoonotic transmission. Although many aquaculturists employ several means to manage the health of their fish using antibiotics and some herbal ingredients, there is little or no documented information as to how these operate and their effectiveness.

5. Petroleum subsidy removal and its possible consequences

In Nigeria, the term "petroleum subsidy" refers to a government initiative that offers financial support to maintain artificially low domestic fuel prices. Nigeria has historically been a significant oil producer, and the government implemented the subsidy to reduce the impact of rising international oil prices on its inhabitants. Discussions about the subsidy's viability and usefulness have grown more heated in recent years. The eventual decision to end the subsidy was the result of increasing pressure on the government to change its subsidy policy. The recent withdrawal of the petroleum subsidy represents a substantial shift in economic policy with ramifications for many different industries. The fisheries sector of the country is particularly vulnerable to the probable effects of the recent subsidy removal which could impact the nation's fish production and by extension, food security.

The current situation could have a substantial impact on the food and nutrition security of the

nation. Small-scale and artisanal fishermen may find it difficult to maintain their businesses due to rising fuel prices, which will result in less fishing activity and fewer catches. This might then lead to less fish being available in nearby markets, which would limit needy populations' access to cheap, protein-rich food. Additionally, higher operational costs for fishermen and dealers because of rising fuel prices could result in higher fish prices. As a result, customers could have trouble affording fish, which would influence the nutrition and dietary variety of populations that depend largely on fish as a key source of protein. Policymakers could consider actions including providing subsidies or support to fishermen, enhancing the fuel efficiency of fishing vessels, and supporting sustainable fishing practices to assure ongoing fish supply and affordability to lessen these potential effects.

The price of products made from farmed fish may change because of rising petroleum prices for aquaculture growers. Fishmeal is a key component of fish feed, a crucial input in aquaculture, and its supply can be altered by a lack of inputs obtained from petroleum. Aeration and fish feed transportation prices could increase further, pushing increasing production costs and possibly reducing the quantity of farmed fish produced and available. By encouraging the development of economical, alternative fish feed choices, promoting energy-efficient aquaculture technologies, and offering farmers financial incentives to help offset rising production costs, policymakers could address these issues to retain an aquaculture industry that contributes to the country's population's security of food and nutrition.

6. Harnessing opportunities in the blue economy to enhance food and nutrition security

The revolution, conceptualization, and emergence of the blue economy in various fora signify its importance as an alternative economic tool for global sustainable development depending on the oceans [106]. The philosophy and concept of the Blue Economy were first introduced in 1994 by Professor Gunter Pauli during his reflection on future business models in preparation for COP3 in Japan [107]. During the East Asia Seas Congress of 2012, the Blue Economy was defined as "a sustainable ocean-based economic model dependent on marine ecosystems and resources, through employing environmentally sound and innovative infrastructure, technologies and practices" [108]. According to UNECA [106], a blue economy is defined as a green economy in a blue world that adopts a novel strategy for the economic utilization of resources from oceans, lakes, rivers, and other water bodies. Blue economy as a broad term comprises various economic sectors, policies, and regulations for the sustainable utilization of oceanic resources for economic growth, job creation, livelihood improvement, and food and nutrition security while preserving the ocean's health. Traditionally, some of the major economic activities in the oceans were fishing activities, shipping, shipbuilding, coastal tourism and leisure, desalination of seawater, and offshore oil and gas exploration. There is a paradigm shift in economic activities with the emergence of new industries and sectors such as biotechnology, aquaculture, deep sea mining and exploration, offshore renewable energy, and blue carbon sequestration [109].

African countries including Nigeria have massive untapped opportunities and prospects in the blue economy sector. Nigeria has a mixed economy with the maritime industry as a major sector due to the enormous ongoing oil and gas exploration activities. Of the estimated 47,000 km of coastline in Africa, Nigeria has a coastline of about 853km with an exclusive economic zone of 200 nautical miles in the Gulf of Guinea [109]. According to [110], the Nigerian coastline has a maritime area of 290 km^2 or almost one-third of the land mass area of 924 km^2. Globally, Nigeria is one the countries with the largest wetlands in the world with its coastal and marine ecosystems covering 70,000 km^2, which are rich in fish diversity, aquatic birds, aquatic plants, forests, and other diverse aquatic fauna and flora [109]. As

a maritime nation, the role of the blue economy in national development and food and nutrition security cannot be over-emphasized. The blue economy in Nigeria encompasses several sectors like fishing, wastewater treatment, tourism, electricity production, and transportation. It has the potential to surpass the global economy [111]. Nigeria has the potential to harness the resources of the blue economy in sectors such as pharmaceuticals, maritime transport, capture and culture fisheries, coastal tourism, waste management, and hydro-electricity [111]. However, the country must consider elements such as security, financing, and environmental protection to fully capitalize on these opportunities [112]. The interaction between and among these various blue-economy sectors requires further inquiry to ensure sustainable utilization of these resources in a manner that ensures maximum benefits and minimum negative impacts.

Despite the benefits and contribution to food security, intensive marine aquaculture in earthen ponds releases a substantial quantity of dissolved nutrients, suspended particles, and organic matter into the environment for every metric ton of fish cultivated [113]. Implementing nitrogen removal methods in aquaculture may enhance water quality and mitigate environmental consequences, while also offering a cost-effective and eco-friendly feed source for promoting sustainable aquaculture [114]. The practice of sustainable wetland agriculture in Nigeria's Cross River basin encounters obstacles such as climate change, inadequate human resources, and a deficiency of enabling infrastructure [115]. The failure to consider the environmental consequences of small-scale catfish aquaculture techniques in Nigeria results in water contamination and deterioration of the environment [116]. Implementing sustainable fish farming practices and conducting thorough environmental monitoring may effectively mitigate the potential environmental hazards associated with intense marine aquaculture [117].

Presently, opportunities in Nigeria’s blue economy have gone beyond the traditional shipping, fishing, oil, and gas to encompass different activities targeted at harnessing ocean resources for economic benefits including offshore aquaculture, offshore power, renewable energy, and support networks. Marine ecosystems have a crucial role in mitigating climate change, generating energy, providing food, supplying natural resources, and facilitating water transportation [118]. Human activities such as fishing and the exploitation of resources from the ocean have resulted in overfishing and pollution, which have had adverse effects on both the economy and the environment [112]. The United Nations acknowledges the need for sustainable development and proposes a methodical approach for the benefit of future generations. Sustainable development entails the restriction of renewable resource use, the augmentation of technology and non-renewable resource output, and the limitation of waste deposits and industrial waste. Practitioners and specialists have a significant disparity in their understanding of ocean resources and ecology. Accurate comprehension is essential for effectively managing the dynamics of marine ecosystems. The postulations about the blue economy and marine ecosystem's potential for economic diversification lack precise information on quantities, timing, and seasonal variations. The use of computer and mathematical modelling techniques could be employed to estimate and comprehend the operation of marine ecosystems [112].

6.1. Aquaculture and fisheries in the blue economy

Several calls had been made by fisheries/marine experts in Nigeria including Prof. Shehu Akintola on the Federal Government of Nigeria to establish the Ministry of Fisheries, Aquaculture, and Marine Resources as an independent Ministry, rather than remaining as a Department under the Ministry of Agriculture [119]. This will enable Nigeria to tap into the enormous economic potential and benefits of the coastal areas, freshwater areas, mangroves, and creeks, thereby boosting the

country's GDP and generating employment. In response to these calls, President Bola Ahmed Tinubu recently created the Ministry of Marine and Blue Economy, headed by Adegboyega Oyetola as the pioneer minister. The newly established ministry will position Nigeria in the trajectory to key into the sustainable use of ocean resources for economic growth, employment generation, and improved livelihoods while preserving the health of the ocean ecosystem.

Expectations of fisheries and aquaculture in the new ministry of marine and blue economy are high. According to the Minister of Marine and Blue Economy, the blue economy is estimated to yield up to N7 trillion annually with fisheries contributing up to 20% if sustainably managed [33]. In 2021, the national GDP contribution of the fisheries sector was 1.16 %, and 0.47 % in 2022 with a general contribution of aquatic food systems to the GDP increasing from 0.5 % in 2013 to 4.5 % in 2021 [33]. Currently, over 1.48 million Nigerians are engaged in the fisheries sector which signals that Nigeria's blue economy is crucial for economic development especially as maritime trade and fisheries contribute 1.6 % and 3% to 5% to the GDP [33]. Based on data provided by the Nigerian Maritime Administration and Safety Agency (NIMASA), the Africa Blue Economy Alliance (ABEA) has projected the unutilized blue economy potential value of Nigeria at $296bn [120].

The acknowledgment of fisheries and aquaculture might serve as motivation for an effort to manage these resources sustainably. Overfishing and environmentally irresponsible practices are endangering the fish populations in Nigeria's waterways. A special classification could lead to improved laws, enforcement, and the promotion of sustainable practices, ensuring the long-term viability of certain industries. More so, preserving fisheries and aquaculture also contributes to the preservation of marine biodiversity. Through sustainable practices, marine ecosystems and species diversity can be preserved, hence reducing bycatch and habitat destruction. Promoting investment in technology and innovative activities can foster improvement in aquaculture practices, fishing methods, and value-added processing to boost output and competitiveness in global markets.

Until recently, aquaculture and fisheries have been under the Ministry of Agriculture and Rural Development. However, Anetekhai et al. [62] initially suggested the creation of a separate ministry for aquaculture and fisheries. This would have made it easier for that ministry to adequately focus on fisheries and aquaculture development in the country. With the new Ministry of Marine and Blue Economy in Nigeria, a challenge of where aquaculture and fisheries would eventually belong arises because of the cross-cutting nature of the sector.

In the short term, placing aquaculture and fisheries under the new Ministry of Marine and Blue Economy while it synergizes with the Ministry of Agriculture and Food Security may be a strategic imperative due to the following reasons:

1. Unique Nature of Fisheries: Although both are focused on the production of food, fisheries are distinct from traditional agriculture in significant ways. While agriculture primarily concerns terrestrial food production, fisheries also involve the management of aquatic resources, including both inland waters and marine environments. The multifaceted nature of fisheries demands specialized knowledge and tailored policies to harness the full potential of aquatic ecosystems.
2. Embracing Marine Aquaculture: Nigeria's untapped marine aquaculture potential offers a significant opportunity for economic growth and food security. A commitment to the growth of this industry would be demonstrated by placing aquaculture and fisheries under the Ministry of Marine and Blue Economy. This would allow for a holistic strategy that incorporates both freshwater and marine resources.
3. Focused Attention for Sustainable Fisheries: To guarantee the long-term availability of resources,

sustainable management of fisheries is essential. A ministry focused on the marine and blue economy overseeing fisheries would permit a stronger emphasis on sustainable practices, conservation initiatives, and responsible resource management. Additionally, it would make it easier to enforce fisheries laws more strictly to prevent overfishing and illicit activity.

4. Leveraging Economic Potential: With the potential to support millions of Nigerians' lives and greatly increase the GDP of the country, fishing has enormous economic potential. Recognizing the economic significance of the fisheries industry and opening opportunities for investment, research, and innovation that would ultimately spur economic growth.

Conclusions

Despite the country's potential to bolster its food production, particularly in the realm of fish production through small-scale fisheries and aquaculture, obstacles persist. The recent complete removal of fuel subsidies may exacerbate the issue of food and nutrition insecurity, posing further hurdles to overcome. Nevertheless, it is vital to recognize the potential of increasing food production in Nigeria, specifically in aquaculture and artisanal fisheries. Stepping up efforts to enhance aquaculture and small-scale fisheries can have a substantial impact on bridging the food supply-demand gap. By focusing on improvements in these sectors, Nigeria can harness its resources and expertise to move closer to food and nutrition security. As we approach the SDGs' target year, policymakers, researchers, and stakeholders must collaborate and devise innovative strategies that prioritize sustainable food production. Emphasizing the development of aquaculture and artisanal fisheries, while considering potential challenges posed by the fuel subsidy removal, will be key to laying the foundation for a more secure and nourished future for Nigeria. By prioritizing and investing in these critical sectors in the emerging blue economy, Nigeria can pave the way toward a brighter and more resilient food and nutrition-secure nation through aquaculture and fisheries.

Use of AI tools declaration

AI used in this article was limited to paraphrasing and grammar checks.

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Conflict of interest

The authors declare the absence of any conflicts of interest related to this manuscript.

Author contributions

AOS conceptualized the research and wrote parts of the manuscript. VOE and AEO contributed to the comprehensive literature review and drafting of the manuscript. VOE handled some reviewer comments. IOE assisted in defining the outline of the write up. KAF provided critical insights and

wrote part of the manuscript. AEO contributed to the comprehensive literature review and drafting of the manuscript. FOD and RAA wrote part of the draft manuscript. MNAA supervised the review project, proofread and provided guidance throughout the process.

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