SPECIES DIVERSIFICATION, A POSITIVE TREND TOWARD NIGERIA'S AQUACULTURE SUSTAINABILITY: A REVIEW.

IBIDAPO-OBE ELIZABETH & YUSUFF KHADIJAH O*.
Agricultural Technology Department, The Federal Polytechnic, Ilaro, Nigeria
*Corresponding author: khadijah.yusuff@federalpolyilaro.edu.ng

ABSTRACT
With its large population of approximately 150 million people, Nigeria has a significant fish demand, estimated at 2.66 million metric tons in 2012. However, local fish production only meets a portion of this demand, producing 1.32 million metric tons annually, of which 0.62 million metric tons come from aquaculture. Though critical for food security and economic diversification, this sector is currently underdeveloped, producing only 200,000 metric tons against a potential of 2.5–4.0 million metric tons. Aquaculture development is essential to meet Nigeria's fish demand and promote economic growth. Nigeria's aquaculture output has increased significantly, with tilapia and catfish being the predominant species. However, further growth and diversification are needed to close the supply-demand gap. Introducing exotic species like Rohu, Pangasius, climbing perch, and common carp presents a viable solution to enhance productivity. These species exhibit favourable traits such as fast growth, high nutritional value, adaptability to diverse environments, and efficient feed conversion. The integration of these species into Nigeria's aquaculture sector could substantially improve fish production, support food security, and provide economic opportunities. This review highlights the current state of aquaculture in Nigeria, the challenges faced, and the potential benefits of diversifying fish species. By leveraging existing infrastructure and addressing key challenges, Nigeria can enhance its aquaculture sector, reduce its fish import dependency, and improve the livelihoods of its citizens.

Keywords: Diversification, species, sustainability, productivity

1.0 INTRODUCTION

FISH FARMING IN NIGERIA

With an estimated 150 million people, Nigeria is the most populous black nation in the world. The anticipated fish demand of its population as of the end of 2012 was 2.66 million tons of fish (Adewumi, 2015). The amount of fish supplied throughout the specified time frame was 1.32 million tons, this amount included 0.62 million tonnes from aquaculture and 0.7 million tonnes from imports. Fish makes for around 40% of Nigerians' annual protein intake, with annual fish consumption ranging from 11.2 to 13.3 kg/person (WorldFish, 2018). Nigeria consumes less protein per person than the average for Sub-Saharan Africa. Significantly, fish is less expensive than other animal protein sources (Sheeska & Murkin, 2002). Fish production has increased to one million metric tons annually. 805,210 metric tons come from fisheries, while 275,645 metric tons come from aquaculture (WorldFish, 2018). The world's fastest-growing food production industry, according to Ayinla (2012), is aquaculture. As a result of wild fisheries reaching their biological limits and the growing demand for cultured fish worldwide, he said, aquaculture production has quadrupled globally over the past 20 years and is expected to treble over the next 15 years. Fish supplies are just 1.32 million metric tonnes annually, compared to Nigeria's 2.66 million metric tons of demand as of 2012. 0.7 million metric tonnes of this total are imported, and 0.62 million metric tonnes are the result of local production.

Nigeria has made significant strides in the development of fish farming and aquaculture over several decades (1950–1992). The second phase of the National Development Plan placed a strong emphasis on removing the main obstacles to the rapid development of aquaculture (Ezenwa, 1994). During the early stages of Nigeria's aquaculture growth, extension programs offered by the government demonstration fish farms at Itu and Opobo in the 1960s and 1970s increased technology adoption and awareness (Ajenifuja, 1998). The ensuing zeal led to a notable individual involvement in fish farming in Nigeria's Niger Delta region (Inyang, 2001). Fish farming has been shown to have the ability to significantly reduce poverty, unemployment, and protein deficiency, however, despite these claims, the region's output has been declining. According to Aina, Kaniki and Ojiambo (1995), information is essential to maintaining and enhancing any country's aquaculture output.

The demand for fish has consistently outpaced the availability over time. The annual national fish demand, estimated in 2005 at 1.5 million metric tons, is significantly greater than the domestic supply, which stands at 0.55 million tons (Dada, 2003). The average annual domestic fish supply, including fish from far-off waters, has never been able to meet demand. Imports have always been used to make up the shortfall. Fish imports made up 27.2% of the total fish supplied in 1990. This has increased to 57.1 % by 2022. Forecasts indicate that the deficit will keep rising. The severity of the mismatch between supply and demand, according to the 2005 report by the Presidential Committee on Fisheries and Aquaculture Development, if the Nigerian EEZ fisheries potential is fully utilized for tuna and deep sea demersal and pelagic resources, it is possible to significantly increase the sector's current contribution to domestic fish production from 27,000 MT to well over 200,000 MT (Raji, 2007). The yearly yield potential of aquaculture is estimated to be 2.5 million metric tons, but according to Musa, Oguntade and Atahiru (2005), the subsector's average contribution to domestic production is 25.2%.

STATE OF AQUACULTURE IN NIGERIA

Aquaculture has grown to be a significant industry in Nigeria for the provision of food, revenue, and jobs. Nigeria is well-positioned to become one of Africa's leading aquaculture-producing nations thanks to its extensive coastline, copious water resources, and pleasant climate. Nigeria has not been exempted from the global trend of rising demand for fish and seafood in recent years. In addition to being important providers of protein and other critical nutrients, fish and seafood also contribute significantly to economic

growth and food security. Unfortunately, overfishing, habitat degradation, and falling fish stocks are just a few of the issues facing Nigeria's capture fishery industry, which has historically provided the majority of the country's fish supply. The production of fish through aquaculture has become more popular as a substitute source of fish due to this. Over the past ten years, Nigeria's aquaculture output has increased at an average yearly rate of 10%, according to the Food and Agriculture Organization of the United Nations (Food and Agriculture Organisation [FAO], 2021). Nigeria ranked among the top producers of farmed fish in Africa in 2019 with an estimated 136,000 tons of fish generated from aquaculture. Tilapia and catfish, the two most widely cultivated species in Nigeria, account for the majority of the country's aquaculture production. Alongside Nile perch (*Heterotis niloticus*) which is among the other species that are farmed in Nigeria, as indicated in the figure below.

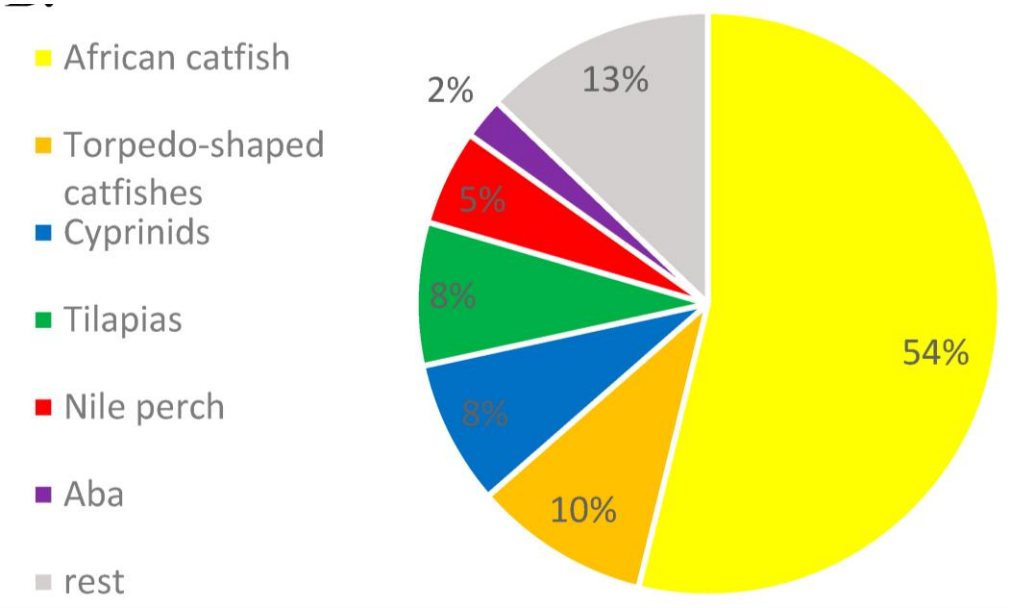


Figure 1: Contribution of the six most relevant species to the total production.
Source: Diversity of the Aquaculture Sector (Fish Statistics, 2006)

The Nigerian government, researchers, and foreign organisations have all contributed to the expansion of the aquaculture industry by giving farmers access to infrastructure, training, and support. Nevertheless, a number of issues still need to be resolved in spite of the aquaculture industry's expansion and promise in Nigeria. These consist of low infrastructure, a shortage of skilled workers, a lack of funding, and restricted market access. The industry has also suffered from the economic recession, which has resulted in high cost of feed, lower demand, lower revenue, and supply chain interruptions. The government and development partners must support and finance the industry, encourage the growth of value chains and market connections, and help the sector overcome these obstacles. The production of aquaculture in Nigeria is still behind. With production just over 1,000 tons, Zambia, Madagascar, Togo, Kenya and Sudan lag behind. This shows how far behind the rest of the African continent is in terms of aquaculture.

DEMAND AND SUPPLY OF FISH IN NIGERIA

According to FAO (2021), an individual Nigerian consumes an estimated 13 kg of fish yearly on average; however, the ECOWAS Commission's Directorate of Agriculture and Rural Development (2020) published a lower estimate of 8.33 kg. Over 74.09% of Nigeria's total domestic fish production was produced by artisanal small-scale fishers, primarily from coastal, inshore, Niger Delta creeks, lagoons, inland rivers and lakes. In contrast, aquaculture and industrial fisheries contributed only 24.91% and 1%, respectively, of the total fish produced in 2018 (Subasinghe *et al.*, 2021), This suggests that the seafood sector in Nigeria is underdeveloped and underutilized. The main capture is the tiny migratory Bonga (*Ethmalosa fimbriata*) (FAO, 2021). Although there has been some initial effort in creating an industrial fisheries sector, the infrastructure and fleet are ageing. The National Bureau of Statistics (2017) report on fish production in Nigeria states that out of the 5.79 million tonnes of fish produced between 2010 and 2015, Nigeria produced barely 204,403 metric tons of fish and shrimp industrially. Compared to the fish produced by aquaculture and artisanal fishing, industrial fishing made up only 4% of the total. The aquaculture subsector's overall fish production began to decrease in 2015. The production from capture fisheries began to decline after 2017, while the production from aquaculture was 316,727 metric tons in 2015, 289,543 metric tons in 2021, and 325,550 tons in 2020 (FAO, 2021; DARD-ECOWAS Commission, 2020). The data indicates a significant discrepancy between the increase in fish production and the population growth observed between 2015 and 2019. The decrease in the aquaculture subsector's fish production is extremely concerning because the nation needs more fish from this subsector to supplement its wild fish harvest to be able to meet its needs.

Nigeria's per capita fish intake has fluctuated and began to decline in 2011, despite the global trend of increasing fish eating since 1984. The world's per capita consumption of fish and fishery products was 18.9 kg in 2011; in contrast, Nigeria's per capita consumption was 15.2 kg. However, by 2018, Nigeria's per capita consumption had dropped to 13 kg (FAO, 2020, WorldFish, 2018).

POTENTIAL EXOTIC SPECIES FOR AQUACULTURE DIVERSIFICATION IN NIGERIA

The demand-supply gap for fish is expected to be closed and consumer demand for aquatic food is unlikely to be met in the next ten years by tilapia and catfish farms alone. This makes it essential to investigate and introduce potential exotic and/or native species diversification in Nigerian aquaculture.

The days of importing fish will come to an end if we can accept that these breeds make suitable replacements for the varieties that are often imported. With a 95–98% survival rate, market acceptance, low production costs, and the ability to be cultivated in both monoculture and polyculture systems, some of these potential fish may be cultivated and might flourish in Nigeria.

Our ability to fulfil future supply and demand will depend on our ability to leverage these breeds, as catfish alone will not suffice. These varieties offer a lot of potential to support fish farmers and provide the nation with food security, investment opportunities, and exports to boost Nigeria's economy.

This review looks at some foreign fish species that can be domesticated in Nigeria to determine which ones are suitable for Nigeria's Aquaculture sector. The review focuses on freshwater fish species, while there is still much to learn about the farming potential of fish species that can be farmed in brackish and marine environments.

ROHU (*LABEO ROHITA*)

Rohu is a huge fish with a noticeable arched head that is silver in colour and resembles a typical cyprinid. Although they average about 1.2 m (1.6 ft), adults can weigh up to 45 kg (99 lb) and reach a maximum length of 2 m. The species is an omnivore with distinct dietary preferences depending on the stage of life. In the early phases of its life cycle, it mostly consumes zooplankton; but, as it grows, it consumes an increasing amount of phytoplankton. Eventually, as an adult or adolescent, it becomes a herbivorous column feeder, consuming mostly phytoplankton and submerged vegetation. Its adapted gill rakers, which resemble fine hairs, indicate that it feeds by filtering the water. One of the best fish species for aquaculture is rohu. Rohu holds great potential for development and flexibility, which could revolutionize fish farming in Nigeria. Furthermore, our productive spawning method guarantees a steady and dependable supply of Rohu juveniles, making them more accessible to fish growers throughout the nation. With the right nutrition, this freshwater bony fish can grow to weigh 1 kg in just three months, with a documented 80% survival rate. It has good seedling output for induced spawning; supports monoculture and polyculture systems, and it's a freshwater fish native to South Asia. Rohu is highly promising for aquaculture because of its robust growth qualities and capacity to adapt to a variety of environmental circumstances. The following are some of the main factors that make Rohu an outstanding option for aquaculture in Nigeria:

Quick Growth: Rohu is a widely sought-after species for commercial aquaculture operations due to its well-known rapid growth as it exhibits a low feed conversion ratio. When grown in ideal conditions, rohu can reach marketable size in a comparatively short amount of time, giving farmers prompt returns on their investment.

High nutritional value: Rohu has a high nutritional value and is a good source of protein, vital amino acids, and omega-3 fatty acids. Due to its flavour and texture, which appeal to consumers' tastes both in Nigeria and abroad, its meat is highly valued. Fish from rohu has a high omega-3 fat content and less saturated fat, which helps prevent heart disease. It also aids in lessening osteoarthritis and rheumatoid arthritis symptoms. For those experiencing age-related macular degeneration, rohu fish is useful.

PANGASIUS HYPOTHALAMUS

Pangasius is one of the very few exotic species that can be diversified in Nigeria, one of the freshwater species in aquaculture with the quickest growth rates worldwide is the pangasius catfish (Jeyakumari, George, Ninan, Joshy, Parvathy, Zynudheen & Lalitha, 2016). Nowadays, pangasius is transported to more than 100 countries worldwide in the form of skinless and boneless fillets, portions, steaks, and other products with added value (Thi, Noseda, Samapundo, Nguyen, Broekaert, Rasschaert & Devlieghere, 2013). In terms of trade and output, the industry has grown in just six months. Pangasius can quickly reach a body weight of 1.2 to 1.3 kg. However, depending on marketability, harvesting often occurs after 8 months (Gurung, Shrestha & Karki, 2016). Due to its firm cooked texture, white, soft flesh, lack of fishy smell, high nutritional content, and superior sensory qualities, pangasius has become more and more popular among consumers (Rao, Murthy & Prasad, 2013). Since pangasius has a mild flavour, white flesh colour, firm cooked texture, low-fat content (Orban, Nevigato, Di Lena, Masci, Casini, Gambelli & Caproni, 2008), easily digestible protein (Thammapat, Raviyan & Siriamornpun, 2010), and nutritional qualities that are good for human health (Usydus, Szlinder-Richert, Adamczyk & Szatkowska, 2011), there is a lot of room to grow consumption by creating different value-added products from them. Fish-based products are in high demand, particularly value-added and ready-to-eat "convenience" items because of recent social and cultural shifts (Rathod, Pagarkar, Pujari, Gokhale & Joshi, 2012). Significant quantities of head, bone, scrap meat, and skin by-products are produced by the filleting industry (Thuy, Lindberg & Ogle, 2010). These by-products can be processed correctly to provide a variety of high-value products with strong economic efficiency. More than 30% of a fish's weight is made up of its skin and bones, making fish processing waste a good possible source of gelatin. Additionally, waste can be decreased by using garbage as a source for prospective products with additional value (Atma, 2017).

CLIMBING PERCH (*ANABAS TESTUDINEUS)*

The euryhaline climbing perch, scientifically known as *A. testudineus*, is a freshwater fish species belonging to the family Anabantidae. This fish species is native to Asia, and are often harvested commercially for food. The fish is well-known for its remarkable ability to survive out of water for extended periods, earning it the name 'climbing perch'. Typically, climbing perches grow to about 25 centimetres (10 inches) in length. They have a laterally compressed body that aids in their movement through narrow spaces. Their colouration ranges from olive to brownish-green on the back, with lighter, often yellowish or whitish, underbellies. Some may have faint dark stripes along their sides.

They possess strong and spiny dorsal and anal fins which can be used for defence and mobility. The pectoral fins are rounded and facilitate movement in water and on land. Their head is covered with large, bony scales that give it a turtle-like appearance, which is likely the origin of their name 'testudineus'. They thrive in a variety of freshwater habitats, such as rivers, lakes, swamps, and even stagnant waters. The species is distributed across South and Southeast Asia, including countries like India, Bangladesh, Myanmar, Thailand, Malaysia, Indonesia, and the Philippines. The climbing perch is a remarkable example of an aquacultural species, with a catchy potential due to its unique survival strategies which include;

Presence of Labyrinth Organ: One of their most distinctive features is the labyrinth organ, which allows them to breathe atmospheric oxygen. This adaptation enables them to survive in oxygen-poor waters and even out of water for extended periods. Their capacity to endure prolonged periods out of the water has increased its marketability

Amphibious Behavior: They are known for their ability to "climb" out of water and move across land. Using their gill covers and pectoral fins, they can wriggle and propel themselves over moist surfaces. This ability helps them escape predators, find new habitats, or survive when their water bodies dry up.

Diet and Feeding: Climbing perches are omnivorous, with a varied diet that includes small invertebrates, crustaceans, plant matter, and detritus. Their diet flexibility is another reason for their survival in diverse environments. It is fed with a floating pelleted feed having 30-35% protein or chopped fish. The fish being primarily an insectivore, fixing a hanging light just above the tank/pond/cage is a really good way to attract insects, which provide an additional source of food (Department of Fisheries, 2022).

Resilience: Their resilience to harsh conditions and adaptability make them a species of interest for studies on environmental stress and adaptation.

In many regions, they are considered a valuable food source and are caught for local consumption. They are also sometimes sold in the aquarium trade due to their unique characteristics. It is commonly consumed as food and believed by the Thais that this species of fish helps ward off disease, the reason why it is called *pla mo* (translated as *"physician fish"*) (Ahmad, Hadiaty, de Alwis Goonatilake, Fernando & Kotagama, 2019). This might be so because the fish contains a high amount of iron and copper which are essential for hemoglobin synthesis (Kumar & Mohanty, 2023). It also contains all the essential amino acids

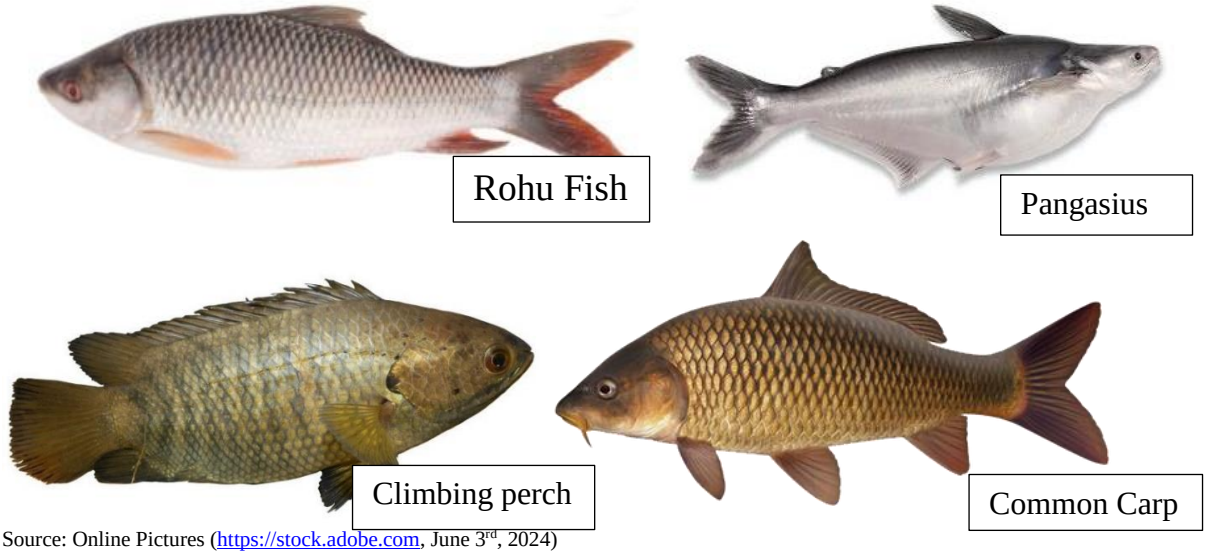
COMMON CARP (*CYPRINUS CARPIO*)

Presently, carp is one among the four most cultured species in the world and account for 8% of total fish produced in 2016 by aquaculture (FAO, 2017). The potential culture of this species is yet to be fully optimized in Nigeria. The wide adoption of common carp (*Cyprinus carpio*) for aquaculture in Nigeria presents a significant opportunity due to several factors, including the species' biological characteristics, adaptability, and economic benefits. Common carp is highly adaptable to a wide range of environmental conditions, including varying temperatures and water quality, making it suitable for Nigeria's diverse aquatic environments (FAO, 2020). The species has a fast growth rate and can reproduce easily in captivity, which is beneficial for maintaining sustainable fish populations and continuous production (Beveridge & Phillips, 1993). Carp farming can be a lucrative business for small-scale farmers, contributing to poverty alleviation and improving livelihoods (FAO, 2020). Common carp is a popular fish for consumption due to its taste and nutritional value. It has high protein, fat, minerals and vitamin contents. The protein content is between 15.9-18.5%. There is a significant market for it in both local and regional contexts (Gabriel, Akinrotimi, Bekibele, Onunkwo, & Anyanwu, 2007).

Nigeria has established aquaculture practices, particularly with species like tilapia and catfish. The infrastructure and knowledge from these practices can be adapted for common carp farming (Fagbenro & Adebayo, 2005). Common carp can be easily cultured in ponds, which are commonly used in Nigeria. Techniques such as polyculture, where carp are farmed alongside other species, can enhance productivity and resource use efficiency (Oladosu, Ayinla, & Ajana, 1990). Common carp can be integrated into existing farming systems, such as rice-fish culture, enhancing resource use and providing multiple outputs from the same area of land (Gabriel et al., 2007). Carp are efficient converters of feed into biomass, and they can utilize a variety of feed sources, including agricultural by-products, which can reduce feed costs and improve sustainability (FAO, 2020).

The major challenge to carp production is scarcity of seed supply. Establishing reliable hatcheries to provide high-quality carp fingerlings is crucial. Investment in hatchery infrastructure and training for hatchery management is needed (Fagbenro & Adebayo, 2005), while at the same time implementing effective biosecurity measures with regular monitoring that can mitigate disease risks, ensuring healthy fish populations (Beveridge & Phillips, 1993). Developing efficient market channels and improving processing and storage facilities can help farmers get better prices and reduce post-harvest losses (FAO, 2020).

Although, *C. carpio* is already under culture in Nigeria, its wide adoption is still far beyond that of catfish and tilapia. Common carp farming can be economically viable and beneficial for smallholder farmers, with the potential for scaling up to meet larger market demands (Gabriel et al., 2007). The adoption of common carp for aquaculture in Nigeria holds considerable promise due to the species' adaptability, economic benefits, and compatibility with existing farming practices. By addressing challenges such as seed supply and disease management and leveraging existing aquaculture infrastructure, Nigeria can significantly enhance its aquaculture sector and improve food security and rural livelihoods.



Source: Online Pictures (https://stock.adobe.com, June 3rd, 2024)

CONCLUSION

Diversification of fish species in Nigeria aquaculture sector will help enhance productivity, sustainability and profitability. Nigerian farmers can make use of a range of farming settings and methods by cultivating a diversity of species. Diversifying the different fish species cultivated in Nigeria might improve fish output, food security, and livelihoods in the nation—despite the tough, time-consuming, and costly nature of domesticating a species for aquaculture. Funding research institutes and universities to conduct the necessary studies for the development of the culture technologies for certain species should be the government's responsibility in order to promote the sector's growth.

High cost of fish feed is one of the major reasons for encouraging fish species diversification, some of the fish species review in this article require lesser crude protein to attain maturity compared to the indigenous fish species (e.g. catfish) thereby reducing the farmer's total cost of production which will in turn increase productivity of this sector. To fully optimize the blue economy the nation is working towards, there is a need to fund research on diversifying different fish species (indigenous and local). Diversification of fish species will boost aquaculture, encourage foreign exchange, boost local reliance and consumption, and foster value chain addition like filleting, deboning etc. Therefore, for successful domestication of the aforementioned species, there should be intensive research on their breeding, growth and processing method (cold blasting).

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