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Sustainable Nile Perch Aquaculture: Challenges and Innovations

Yi Lu, Rudi Mai
Tropical Marine Fisheries Research Center, Hainan Institute of Tropical Agricultural Resources, Sanya, 572025, Hainan, China
Corresponding author: rudi.mai@hitar.org

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Abstract Raising Nile perch is very profitable and beneficial to the environment, but it is not easy to achieve globally. This study discusses the current situation of raising Nile perch, including how it is raised, how much is raised, and how it is sold locally and internationally. We have researched new solutions, such as using better technology, improving fish species, and making more environmentally friendly feed. We have also proposed ways to protect the environment, such as combining different farming methods. Examples from Lake Victoria, Egypt, and East Africa demonstrate that these methods are indeed feasible. This study aims to help people better raise Nile perch, which can not only produce more fish but also protect the environment and society.

Keywords: Nile perch farming; Sustainability; Technological progress; Integrated aquaculture system; Environmentally friendly feed

1 Introduction

The cultivation of Nile perch (*Lates niloticus*) is now important in the global fish farming industry. This fish originally lived in the Nile River and Lake Victoria because of its large size, delicious meat, and popularity. Local people loved it and it was also sold abroad. Nowadays, the fish farming industry provides more than half of the world's fish (Nie and Hallerman, 2021). The fish farming industry is developing rapidly, and fish like Nile perch are crucial in meeting people's demand for fish. In East Africa and other regions, people have started using new methods to raise fish, such as circular aquaculture systems (RAS), which can raise more fish while causing less damage to the environment (Clough et al., 2020).

Raising Nile perch is important for both the economy and the environment. In terms of economy, it has brought jobs and income to residents near Lake Victoria and other fish farming areas. This industry not only helps local economic development, but also provides people with a stable source of protein (Mkuna et al., 2020). However, raising this type of fish can also bring environmental problems, such as potentially polluting water quality, causing excessive nutrients in the water, and possibly bringing foreign fish species to new places (Boyd et al., 2020; Chandan and Roy, 2023). The best way to solve these problems is to adopt more environmentally friendly farming methods, such as combining different farming methods and improving feed management. This is the only way to ensure long-term and stable cultivation of Nile perch.

This study aims to address two main issues in raising Nile perch: how to raise them better and how to reduce their impact on the environment. We will first take a look at how people raise this fish now, and then introduce some new farming methods. These new methods include using better technology and combining different farming methods. Our goal is to find a way to raise more fish to earn money while also protecting the environment. This can satisfy people's need to eat fish without damaging nature.

2 Current Status of Nile Perch Aquaculture

2.1 Distribution and production trends in major farming regions

The Nile perch is mainly raised in areas with abundant freshwater resources, such as some parts of Africa and Asia. Taking Egypt as an example, local fish farming is an important source of protein. Egypt mainly raises Nile tilapia, followed by carp and mullet (Henriksson et al., 2017). More and more people are paying attention to

environmentally friendly fish farming methods now. For example, the IEIDEAS project is researching how to improve fish species and aquaculture management, which can both increase yields and reduce environmental damage. Bangladesh also has a developed fish farming industry that utilizes natural water bodies and various aquaculture techniques, but Nile perch is not the main aquaculture species in the area.

2.2 Traditional practices and their limitations

The traditional methods of fish farming mostly use earthen ponds and natural water bodies, but there are many problems with this approach. Poor water quality control, easy illness of fish, and excessive waste of feed can all affect yield and damage the environment. Taking Bangladesh as an example, there are many difficulties in using ponds to raise fish locally. There are not enough fish fry, the fish often get sick, and weather changes make it more difficult to raise fish. However, there is a good local method called Baor aquaculture technology, which is particularly suitable for raising fish in Niujiaohu (locally known as Baor). The beauty of this method is to install screens at the inlet and outlet of the lake, which can control the water flow and prevent fish from escaping. The sieve traps the fish in the aquaculture area and allows water to flow and exchange, maintaining sufficient water quality and oxygen (Figure 1) (Chandan and Roy, 2023). This method is simple, practical, and cost-effective, especially suitable for rural areas. However, there is still a problem with traditional fish farming, which requires a lot of fishmeal and fish oil as feed. Nowadays, it is becoming increasingly difficult to obtain these raw materials, which raises concerns about whether fish farming can continue in this way in the future (Nie and Hallerman, 2021).

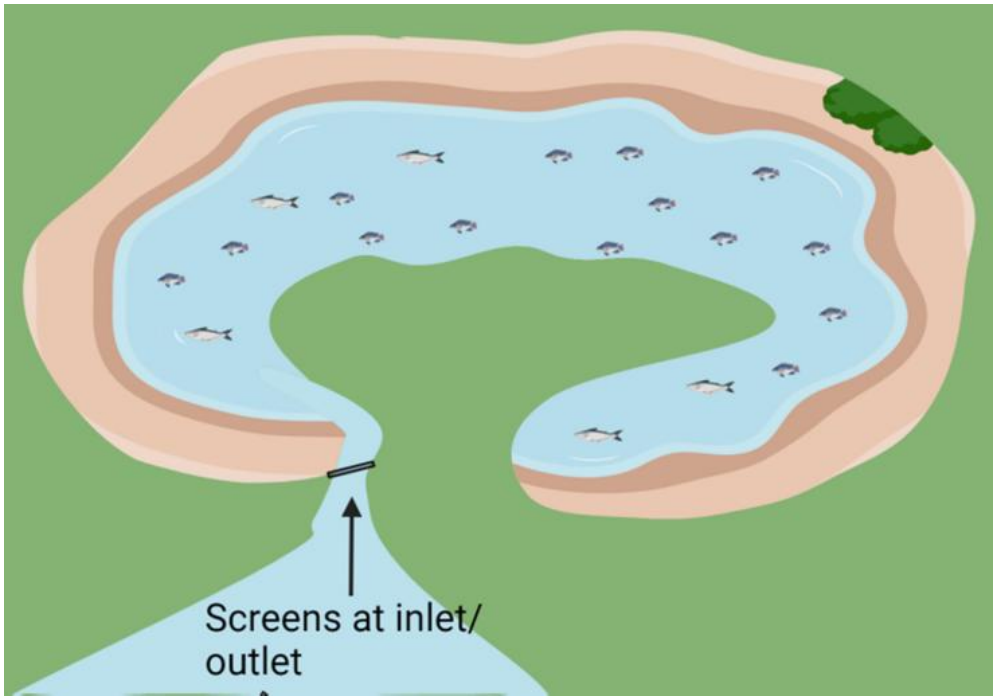

Figure 1 Common baor farming technique in Bangladesh by using screens at inlet/outlet (Adopted from Chandan and Roy, 2023)

2.3 Role of Nile Perch in local and global markets

Nile perch is important both locally and globally. In the local area, this fish not only provides nutrition for people, but also creates many job opportunities, helping to solve food problems and increase income (Boyd et al., 2020; Nie and Hallerman, 2021). The demand for this fish is increasing worldwide because it is rich in protein, and now people prefer to eat seafood. However, the rapid development of fish farming has also brought environmental problems, such as polluting water quality, causing excessive nutrients in the water, and possibly bringing foreign fish species to new places. In order to solve these problems, people began to try new methods of fish farming. For example, combining different farming methods or using plant-based feed instead of fishmeal and fish oil. These new methods can make fish farming more environmentally friendly.

3 Challenges in Sustainable Nile Perch Aquaculture

3.1 Environmental challenges

3.1.1 Habitat degradation and resource competition

Raising Nile perch faces two major environmental challenges: habitat destruction and resource competition. Firstly, aquaculture activities often alter the original living environment of fish, and this destruction often results in long-term effects. For example, the practice of transforming natural water bodies to expand aquaculture farms not only reduces biodiversity in the water bodies, but also alters the functionality of the entire ecosystem (Shepon et al., 2021). Secondly, the large-scale demand for water and land resources in the aquaculture industry (farms require continuous supply of clean water sources and appropriate land areas) will compete fiercely with other uses such as agricultural irrigation, urban water supply, and wildlife habitat protection (Boyd et al., 2020). This resource competition is manifested in the fact that farmers need irrigation water to grow crops, urban residents rely on stable water supply for their daily lives, and wildlife conservation also requires sufficient living space. The superposition of these multiple demands exacerbates environmental pressure, which may ultimately exceed the carrying capacity of the local ecosystem.

3.1.2 Water quality management and eutrophication

Water quality management is a major issue when raising Nile perch. Poor water quality can lead to excessive nutrients in the water, which is called eutrophication. Too much nutrition can cause algae to grow wildly and exhaust the oxygen in the water. This is not good for the fish and the surrounding water environment. Research has found that if the oxygen, ammonia, and pH levels in the water are not properly controlled, the aquaculture system will encounter problems and damage the environment (Wambua et al., 2020). To solve these problems, some good methods can be used, such as biological flocculation systems and recirculating aquaculture systems (RAS) (Khanjani et al., 2021).

3.2 Biological challenges

3.2.1 Disease outbreaks and pathogen control

Disease outbreaks and pathogen control are major biological challenges in Nile perch aquaculture. Pathogens such as bacteria, viruses, and parasites can cause significant mortality and economic losses. For example, bacterial pathogens like Streptococcus agalactiae and Francisella noatunensis have been identified as major threats to tilapia farming, and similar pathogens could affect Nile perch (Delphino et al., 2019). Effective biosecurity measures and regular health monitoring are crucial to prevent and control disease outbreaks.

3.2.2 Genetic bottlenecks and inbreeding risks

Genetic bottlenecks and inbreeding risks pose significant challenges to the sustainability of Nile perch aquaculture. Limited genetic diversity can lead to inbreeding, which reduces the overall fitness and adaptability of farmed populations. This can make them more susceptible to diseases and environmental changes. Genetic improvements and the use of diverse breeding stocks are essential to mitigate these risks. For instance, the introduction of improved strains, such as the Abbassa strain in Egyptian aquaculture, has shown promise in enhancing productivity and reducing environmental impacts (Henriksson et al., 2017).

3.3 Socioeconomic challenges

It is not easy to make money by raising Nile perch, which brings many difficulties to farmers. The main problem is that there is not enough money, and many farmers cannot afford environmentally friendly breeding equipment and feed. In addition, selling fish is also very difficult, requiring compliance with many regulations and competition with other meats. To solve these problems, the government needs to help formulate policies that enable farmers to use cheap and good technologies, and also teach them how to raise fish more environmentally friendly. This is the only way to protect the environment and make money for farmers (Chandan and Roy, 2023; Ibrahim et al., 2023).

4 Innovations in Nile Perch Aquaculture

4.1 Technological advancements

Raising Nile perch requires many new technologies, which make fish farming more environmentally friendly and

efficient. There are two commonly used methods nowadays: one is biological flocculation technology (BFT), and the other is recirculating aquaculture system (RAS). BFT technology is particularly excellent, it can effectively utilize water and feed to make fish grow faster. Research has found that Nile tilapia raised with BFT gain more weight and have higher feed utilization efficiency than those raised with RAS (Hisano et al., 2019). This indicates that BFT can indeed improve fish farming efficiency. In addition, scientists also use stable isotope analysis to study the effectiveness of feed, which can more accurately formulate feed and avoid waste (Narimbi et al., 2018). These new technologies make fish farming more scientific and cost-effective.

4.2 Genetic improvement strategies

Improving the species of Nile perch is crucial for sustainable development. Breeding good varieties is a good way to make fish grow faster, get sick less, and eat better feed. For example, there is an improved fish called Abbassa strain (G9) raised in Egypt, which grows better and has less impact on the environment (Henriksson et al., 2017). Kenya is also doing similar work, selecting better fish species so that farmers can raise good fish fry (Abwao et al., 2021). Scientists say that maintaining genetic diversity in fish is important so that fish populations do not engage in inbreeding and can adapt to environmental changes.

4.3 Sustainable feed development

To raise Nile perch, it is necessary to find more environmentally friendly and cheaper feed. There are several good ways now: one is to use fermented pig manure as feed. Research has found that tilapia fed in this way grow well and are a good source of protein (Tongmee et al., 2021). The second is to add black soldier fly larvae powder to the feed, which can save a lot of feed money and provide sufficient nutrition (Basiita et al., 2018). The third is protein feed made from factory waste, which fish love to eat (Alves et al., 2019). These new feeds can both protect the environment and help farmers save money.

5 Environmental Sustainability in Nile Perch Farming

5.1 Strategies for minimizing environmental impact

Raising Nile perch can adopt these environmentally friendly methods: firstly, using scientific breeding practices (BMP) and improving fish species, such as the Abbassa G9 variety, can significantly reduce environmental damage. Data shows that these methods can reduce pollution, water usage, and land use during the breeding process by 12% -36%. Secondly, improve the feed formula and use environmentally friendly ingredients (Henriksson et al., 2017; Cooney et al., 2021). Thirdly, a recirculating aquaculture system (RAS) is adopted, which saves water and land, but attention should be paid to controlling water quality and electricity costs. These methods can make fish farming more environmentally friendly.

5.2 Role of integrated aquaculture systems

A good way to raise fish is called integrated aquaculture (IMTA), which involves raising different types of fish, shrimp, and seaweed together. In this way, they can utilize each other's waste and reduce pollution. Research has found that this type of farming is more environmentally friendly, yields higher, and more profitable than traditional mixed farming (Biswas et al., 2020). For example, raising shellfish and seaweed together with fish can increase production and reduce nutrient pollution in the water (Kerrigan and Suckling, 2018). The water quality raised in this way is better, and the overall yield and income are also higher.

5.3 Case studies on successful sustainable practices

Nowadays, many places have achieved good results in raising fish with new methods. There is an IEIDEAS project in Egypt that teaches farmers better farming techniques and even provides them with improved G9 fish species, which reduces the environmental damage caused by fish farming compared to old methods. Indonesia plans to switch to better fish farming methods by 2030, which will produce more nutritious fish and reduce environmental pollution by 75% (Shepon et al., 2021). Kenya uses a circulating water system to raise tilapia. As long as the number of fish raised and the flow of water are controlled, more fish can be raised with less pollution (Wambua et al., 2020). These successful examples all illustrate that in order to raise fish that is both environmentally friendly and profitable, new methods and comprehensive approaches must be used.

6 Economic Viability of Sustainable Nile Perch Farming

6.1 Cost-benefit analysis of sustainable aquaculture practices

Using new methods for fish farming can protect the environment and earn more money. For example, using scientific fish farming methods (BMP) and improving fish species G9 have shown particularly good results. Research has shown that G9 fish species can reduce environmental pollution by 12% -36%, mainly because these fish feed more efficiently and grow faster (Henriksson et al., 2017; Zhao and Wu, 2024). Mixing tilapia and carp is also a good way to raise more fish and earn more money (Shrestha et al., 2018).

6.2 Role of government subsidies and financial support

Government funding support is important for fish farmers as it enables them to afford environmentally friendly fish farming methods. For example, if you want to switch to a circulating water fish farming system (RAS) or adopt scientific fish farming technology (BMP), it will cost a lot of money at the beginning, and government subsidies can be of great help. Bangladesh is a good example, where the local government provides funding to help fish farmers solve the problems of fry and fish diseases, so that fish farming can earn long-term profits (Chandan and Roy, 2023). The government manages well and uses the right method, which can not only produce fish but also protect the environment, so that the fish farming business can continue (Blanchard et al., 2017).

6.3 Opportunities for value addition and market expansion

To make raising Nile perch more profitable, the key is to find ways to increase the selling points of the fish and explore new markets. Combining fish farming with other businesses is a good approach, such as simultaneously raising fish and growing vegetables, which can earn more money and save water. Research has shown that this symbiotic relationship between fish and vegetables is particularly suitable for water scarce areas, as it saves water and can be produced all year round (Ibrahim et al., 2023). In addition, raising fish better and feeding them more scientifically can not only produce more fish, but also sell them more expensive (Teletchea, 2021). These methods can make the fish farming business longer and more profitable.

7 Case Studies on Sustainable Nile Perch Farming

7.1 Implementation of sustainable practices in Lake Victoria

Victoria Lake is an important source of food and income for East Africans, but now it is facing a big problem - the number of fish caught is decreasing and the lake water is getting dirtier. In order to solve these problems, local people have started to try more environmentally friendly methods of fish farming. One of the projects called VicInAqua is very special. They built a tilapia nursery in Kisumu, Kenya, using a recirculating aquaculture system (RAS). This system is very flexible and can be freely adjusted in size. It not only uses clean energy such as solar energy, but also adopts advanced water purification technology. The most impressive thing is that they use membrane bioreactor (MBR) technology to turn urban sewage into clean fish water. There are two benefits to doing this: one is saving money on buying drinking water, and the other is turning wastewater into treasure. This nursery not only provides good fish fry for local farmers, but also teaches everyone how to raise fish environmentally friendly (Figure 2) (Clough et al., 2020). In addition, studies have found that in order to sustain the Nile perch fishery in Lake Victoria, Tanzanian fishermen need to find other ways to make money while protecting the environment (Mkuna et al., 2020).

7.2 Innovative Nile Perch farming techniques in Egypt

Egypt is the country with the most fish farming in Africa, mainly raising tilapia and African catfish. However, this industry also faces some problems, such as low technology usage and high feed prices. To increase production, new technologies such as better fish farming systems and methods need to be adopted. This approach ensures that people have fish to eat and also promotes the recovery of wild fish species (Kaleem and Sabi, 2020). In addition, studying the genes of Nile perch is important as it can help Africa better develop its fish farming industry (Basiita et al., 2018).

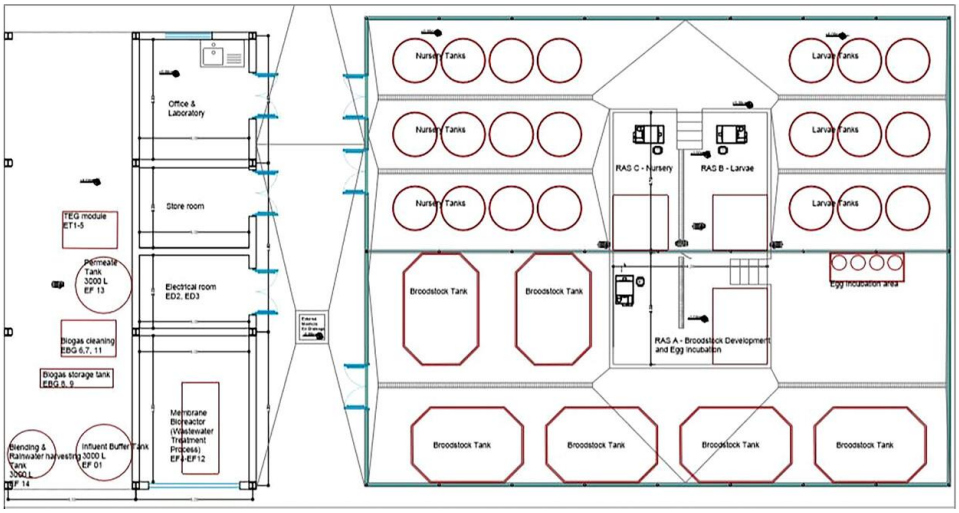

Figure 2 General plan view of the RAS showing the 3 systems, each with their independent water treatment areas. Additionally, ancillary buildings including the membrane bioreactor building and associated equipment are also shown (Adopted from Clough et al., 2020)

7.3 Collaborative aquaculture initiatives in East Africa

East African countries need to work together to promote sustainable aquaculture. For example, Lake Victoria has started using net cages to raise fish because there are fewer and fewer wild fish. But cage fish farming may affect the environment and must be carefully managed. Research has found that improper installation and use of net cages can pollute lake water and damage the ecology. So, it is necessary to conduct environmental assessments and comply with regulations to ensure that cage fish farming does not damage the environment (Nyakeya et al., 2022). In addition, Ugandan fishermen adjust their methods when fishing for Nile perch. Fishery managers should pay attention to the practices of fishermen, so that the policies formulated can not only protect fish resources but also help fishermen maintain their livelihoods (Mpomwenda et al., 2022).

8 Social and Community Dimensions of Nile Perch Aquaculture

8.1 Involvement of local communities in aquaculture practices

It is important to involve local residents in Nile perch farming, as this can help ensure the long-term success of fish farming projects. Around Lake Victoria, it has been found that involving villagers is a good way to help fishermen find stable income. Research has shown that allowing fishermen to try different ways of making money while developing fish farming is the most effective strategy (Mkuna et al., 2020; Zhu and Li, 2024). Using new technologies for fish farming, such as circular water aquaculture systems, can bring many benefits. This can ensure that local people have fish to eat without overfishing wild fish. This is helpful for protecting fish resources and improving the lives of villagers.

8.2 Training and capacity building for small-scale farmers

Teaching small farmers fish farming techniques is important as it can help them raise fish better and more environmentally friendly. In Egypt, there is a project called IEIDEAS that teaches farmers better fish farming methods and provides improved fish species, resulting in increased yields and a more environmentally friendly environment (Henriksson et al., 2017). Kenya also has similar projects. The VicInAqua project has built a tilapia nursery specifically for training farmers. Here, farmers can learn environmentally friendly fish farming techniques (Clough et al., 2020). These trainings not only teach farmers how to raise fish, but also make them understand why they need to protect the environment.

8.3 Addressing gender equality in aquaculture development

Gender equality is crucial in the development of fish farming, as it can benefit more people. Research has found that household income and gender can affect people's willingness to try new fish farming methods. For example, in the Solomon Islands, families with better conditions and multiple sources of income are more likely to try

raising tilapia (Blythe et al., 2017). Therefore, training programs should take into account the needs of women more. Enable women to learn fish farming techniques, so that they have the same opportunity to participate in the fish farming industry and earn income. This can not only help women, but also promote the development of the entire fish farming industry.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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