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Lake Victoria's bounty: A case for riparian countries' blue economic investment

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People residing in Lake Victoria's basin and riparian countries benefit from ecosystem services provided by the lake. However, the lake's resources, particularly fish, are under threat from pressures caused by humans such as overfishing, alien species invasion, rising eutrophication, and climate change. In this assessment, we look at how to maximize the lake's benefits through product diversification, value addition, and sustainable use of its fisheries. We show that minimizing post-harvest losses of the silver cyprinid (*Rastrineobola argentea*), locally known as *Dagaa*, will provide more high-quality fish for human consumption, while significantly increasing fishing earnings. Furthermore, by utilizing biowaste (frames, skin, and fish mouth), revenues from Nile perch could be increased up to thrice. Furthermore, if fishing could target maximum sustainable yield (MSY), landings of Nile perch and *Dagaa* could increase significantly in the long run. These, combined with investments in other areas such as lacustrine tourism and recreation, as well as fish cage culture, can help the Lake Victoria region's blue economy expand.

KEYWORDS

ecosystem services, blue growth, sustainable, value addition, fish maws

Introduction

The blue economy (BE) concept is widely being promoted as a means of gaining both concrete (economic development, improved livelihoods, and employment) and intangible (carbon storage, coastal protection, cultural values, and biodiversity) benefits through the sustainable use of ocean resources (Okafor-Yarwood et al., 2020; The World Bank, 2017). The African Union (AU) expands this to encompass "commercial exploitation of oceans, lakes, rivers, and other bodies of water and aquatic ecosystem conservation" (AU-IBAR, 2019). The key components of the AU BE strategy for promoting blue economy development on the continent are fisheries, aquaculture, and ecosystem conservation; shipping, maritime safety, and trade; climate change, environmental sustainability, and ecotourism; sustainable energy and extractive mineral resources; and governance, institutions, gender, and job creation (AU-IBAR, 2019).

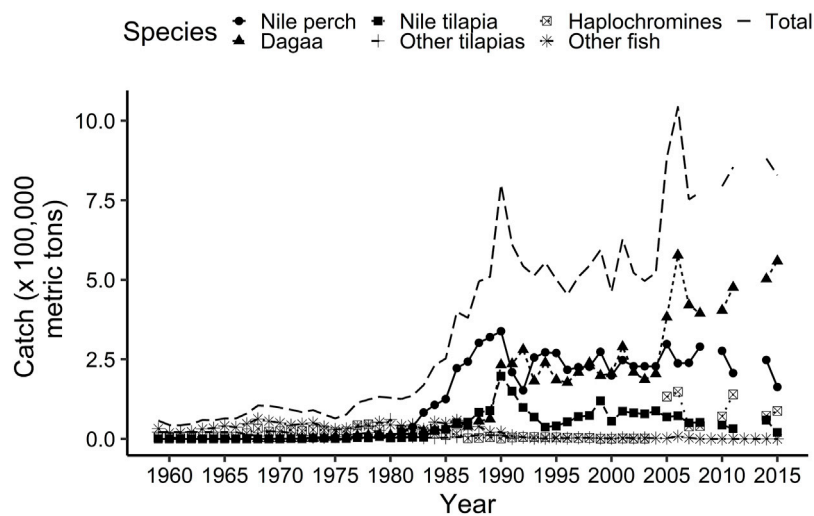


FIGURE 1
Annual fish landing trend in Lake Victoria. Source LVFO (2016).

Under the East African Development Strategy, the Lake Victoria basin has been identified as an area of common economic interest and an economic development zone to be developed collectively by the partner states. Lake Victoria is the largest freshwater lake in the tropics and second in the world. The lake provides ecosystem services such as water for domestic and industrial use, transport, hydropower generation, and food to over 40 million people (Swallow et al., 2009; Downing et al., 2014; Nyamweya et al., 2016; Awange, 2021). Because of its large size (surface area of approximately 680,000 km²), the lake also plays an essential role in modulating regional climate (Stager and Johnson, 2008; Nyamweya et al., 2016). By far, the most important economic activity for lakeside inhabitants is fishing (UNEP, 2006). In 2021, around 1.48 million tonnes of fish were landed from the lake, with a beach value of USD 1.14 million (LVFO, 2022). The fishery employs over three million people in fisheries-related activities (Awange, 2021). Despite an abundance of resources, residents in the Lake Victoria region are among the poorest in the world, with the majority surviving on less than USD 1.25 a day, as a result of inefficient and unsustainable resource use. Such unsustainable practices deteriorate ecosystem functioning and precipitate the collapse of resource elements (Mackinson, 2010).

Over the last century, Lake Victoria has undergone many changes, stemming from human activities such as overfishing (Graham, 1929; Nyamweya et al., 2020), the introduction of Nile perch (Ogutu-Ohwayo, 1990; Pringle, 2005; Marshall, 2018), population growth, pollution (Juma et al., 2014), and climate change (Awange et al., 2013). For the last two decades, the three riparian countries have harvested 1 million tonnes of fish annually despite the increasing human population and fishing pressure. The national population growth rates in Kenya, Uganda,

and Tanzania are 2.2, 3.6, and 3.0%, respectively (Population Reference Bureau, 2021), while the Lake Victoria region is 3.8% (Bremner, 2013). Projections show that the population in the three riparian countries will at least double by 2050. Herein, we examine exploitation trends (emphasizing fisheries) and point out possibilities of improvement and diversification of benefits derived from the lake to drive blue economic development.

Fishery evolution in Lake Victoria

Lake Victoria fishery has transformed over time from the one dominated by indigenous fish species to the one dominated by the introduced Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*), and the native silver cyprinid (*Rastrineobola argentea*) locally known as *Daggaa* (Figure 1). According to Opondo (2016), during the precolonial era, the main fish species caught by the local communities were *Oreochromis esculentus*, *Labeobarbus victorianus*, *Synodontis* spp., *Mormyrus kanume*, and *Clarias gariepinus*. Fishing at that time was managed by clan-based rules, for fishing had to be observed by all fishers. Compliance to the controls included target species, sizes, fishing gear, fishing areas, and season-guaranteed future supply of fish (Opondo, 2016).

The advent of new fishing gear and an influx of immigrants resulted in fish harvest rates that threatened the sustainability of the fishery, with evident signs of overfishing by the 1920s (Graham, 1929). The decline in the catch of native tilapias (*O. esculentus* and *O. variabilis*) necessitated dialogue and the eventual introduction of new species (*L. niloticus* and *O. niloticus*) in the 1950s and 1960s to boost the fishery that was yielding ca 100,000 tonnes annually. The consequences of the

TABLE 1 Proportion and average regional processors' purchase prices for Nile perch products from Lake Victoria.

Item	Proportion by weight (%)	Cost per kg (USD)	Total cost (USD)
Frame	42	0.61	11.7
Skin	8	0.26	3.2
Gut	5.7	0.6	1.71
Swim bladder	2.3	187	172.5
Fillet	42	4	84

species introduction are well-documented (Marshall, 2018), but notably, total fish landings increased significantly, steady at over 1 million tonnes (LVFO, 2018) amid increasing fishing capacity. The initial boom of catches of the introduced species attracted investment mainly in industries that support the fishery value chain. The catches for the lucrative Nile perch peaked in the 1990s and started declining from 2005 (Nyamweya et al., 2020), as attested by the closure of some fish processing factories throughout the region (Njiru et al., 2008; Kayanda et al., 2009; Nunan, 2010).

Diversification of fish and fishery products

An analysis of landings and fishing effort trends reveals that Nile perch in Lake Victoria are currently overfished (Nyamweya et al., 2020), with no chance of increasing landings unless harvesting pressure is reduced in the short-term to allow stock recovery and achieve maximum sustainable yield (MSY) in the long term (Nyamweya et al., 2017). That notwithstanding, more value can be derived from Nile perch by diversifying the products. Fillet accounts for 37–40% of the total Nile perch and the remaining 60–63% are byproducts. Frames or skeletons with adhering flesh account for 40–43% of the byproducts' weight, followed by skin (8%), gut (5.7%), and swim bladder or fish maw (2.3%) (Kabahenda and Hüskén, 2009). Table 1 shows a theoretical breakdown of monetary value that a 50 kg Nile perch can attract. The potential earnings from Nile perch byproducts could be two times more than those from the fillet (Bagumire et al., 2018). With appropriate technology and investment, these “wastes” can be transformed into premium products that attract high-end consumers. For instance, when handled properly, fish skin can produce high-quality leather (Muyonga et al., 2004; Muralidharan et al., 2013). Various studies have shown that viable quantities of oil can be extracted and refined from Nile perch viscera (Okoth et al., 2015), belly flaps (Ogwok et al., 2009), and heads (Turon et al., 2005). The resulting oils are rich in Omega 3 fatty acids, which are in great demand globally. (Okoth et al., 2015).

Nile perch swim bladder (maw) is among the precious aquatic products (Shelley, 2004). There are about 500 million consumers of fish bladder in China and Hong Kong (LVFO, 2015). Fishers can be paid ten times more for the bladder than the price they can achieve for fish flesh (Brierley, 2018). Currently fish maws on an average attract a

retail value of USD 127 to 287 per kilogram. Although this trade has been going on in Lake Victoria since the 1990s, it is restricted to a few traders. If this value chain is formalized and optimized, it could give the lake edge communities an additional income.

Optimization of fish harvesting and post-harvest management

The catch per unit effort (CPUE) for Nile perch in Lake Victoria has progressively dropped since effort has increased. Indeed, the species' lowest annual landings in the previous two decades were 165,083.4 tonnes in 2015, significantly below the predicted maximum sustainable yield (MSY) of roughly 212,000–323,000 tonnes (Kayanda et al., 2010). A gradual increase in fishing effort in a fishery will increase the fish output until a maximum is achieved (MSY level). If fishing effort is increased further, the overall fish output will more or less plateau around the MSY level for a time before beginning to fall, as shown with Nile perch in Lake Victoria. According to Kayanda et al. (2017), the Nile perch is overfished. Fortunately, in 2017, authorities in Uganda and Tanzania, where the bulk of Lake Victoria is situated, initiated a strict enforcement to eradicate illicit fishing gear (LVFO, 2021), offering a chance to examine the effect of such efforts on fish populations. In 2021, the species' catches were much higher (221,640 tonnes) and within the MSY level. The increase in landings might have been a response to the decrease in effort as a result of the management initiatives; thus, implying that production and income can be improved if the fishery is sustainably managed.

On the other hand, the catch of *Dagaa*, which accounts for most of the landings in the lake, is lower than the MSY. Natugonza et al. (2016) indicate that *Dagaa* and haplochromines are underexploited, having exploitation rates of less than 15%. Nonetheless, haplochromines are considered as low-value fish. Their true worth is found in their ecological function. Indeed, simulations using the Atlantis ecosystem model have revealed that minimizing haplochromine harvesting results in optimum ecosystem function, improved yield of economically significant species, and probably the least “socioeconomic” cost implications. Given these findings, there is

an opportunity to increase landings from Lake Victoria that currently produces about 8% of the total inland capture landings globally (Nyamweya et al., 2017).

Dagaa catches have been on an upward trajectory since the early 1980's. This species has a high turnover rate and can be resilient to heavy predation and exploitation (Irvine et al., 2019; Kolding et al., 2019). Currently, *Dagaa* accounts for ca 60% of the total catch, but substantial quantity and quality is lost due to poor post-harvest handling (SmartFish, 2011; Odoli et al., 2019). Lake Victorian *Dagaa* is traditionally dried in the Sun on the ground, grass, matting, or old fishing nets. The procedure provides no protection for the product against rain, animals, insects, and soil contamination. As a consequence, *Dagaa* fishermen face significant post-harvest losses (Ibengwe and Kristofersson, 2012). Post-harvest loss types for the species are mainly rotting or spoilage (79.3%), followed by *Dagaa* being swept back to the lake by rain (10.3%) and loss of color (3.4%) (Odongkara et al., 2016). The reduction of post-harvest losses for the species will provide more quality fish for human consumption and contribute to food and nutrition security for the riparian communities. If the deterioration of *Dagaa* is halted right from capture, earnings from the fishery could increase appreciably.

Other areas of potential investment

In the last 10 years, landings of the main commercial species in Lake Victoria have either declined or stagnated. The stagnation of production from the captured fisheries presents an opportunity for entrepreneurs to bridge the large gap between the amount of fish consumed (≤ 6 kg person⁻¹ year⁻¹) and that recommended by the World Health Organization (17 kg person⁻¹ year⁻¹) (Kirema-Mukasa, 2011). The growing number of fish in cages in Lake Victoria could be a response to fill the deficit in fish production (Hamilton et al., 2019). Sustainable cage-fish farming offers an opportunity for investment in the venture's value chain. Presently, cage-building materials are sourced from Far East and Europe, an undertaking that is quite costly. Potential entrepreneurs can take on producing these materials locally and cheaply. Other potential investment areas in the cage culture value chain include fish seed and feed production, cold storage, value addition, consultancy, and marketing (Njiru et al., 2019).

The diversity of haplochromine cichlids in Lake Victoria is among the greatest found elsewhere in the world (Goldschmidt and Witte, 1992). Because of the vivid colors they display, haplochromine cichlids are considered to have a high level of aesthetic value (Theis et al., 2012; Maan and Sefc, 2013; Sefc et al., 2014). Despite this, people in East Africa often see them as being of little economic worth or as trash fish. There is a window of opportunity to convert the haplochromines, which are currently on the path to recovery (Figure 1), into a cash crop by capitalizing on the more profitable ornamental fishery (Andrews, 1990; Chapman et al., 1997; Wabnitz et al., 2003).

In many parts of the world, lakes play a vital part of recreation and tourism as both are locations for leisure activities, as well as an attraction in their own right (Hall and Härkönen, 2006). Certainly, the lacustrine tourism has potential in Lake Victoria, which has a shoreline of more than 7,000 km, offering a huge waterfront (Hamilton, 2016), and a desirable attribute in the tourism and hospitality industry (McCarthy, 2004). The lake offers unique recreation opportunities like sport fishing for the Nile perch, windsurfing in the expansive open waters, boat racing, and getaway holidays in many of its exotic islands (Awange and Ong'ang'a, 2006).

Conclusion

For a long time, Lake Victoria has been known for its vibrant fishery. However, considering the population growth rate, it is unlikely that fishing activities will satisfy the nutritional, income, and employment needs for the region. Fortunately, amid the looming crisis occasioned by declining wild stocks of some commercial species lie tangible solutions to propel the region to economic prosperity. Possible solutions include but are not limited to optimizing fish harvesting, eliminating or reducing post-harvest losses along the fishery value chain, and biowaste utilization. It will also entail diversification of investments to include the development of fish maw trade, ornamental fishery, tourism and recreation, and fish cage culture.

Data availability statement

The original contributions presented in the study are in the article. Further inquiries can be directed to the corresponding author.

Author contributions

CN conceptualized, analyzed the data, and wrote the manuscript; HN analyzed the data and wrote sections of the manuscript; CA interpreted the data and participated in writing; KM conceptualized and participated in writing; EM provided the data and participated in the analysis; CO interpreted the data and participated in writing; and JN interpreted data and participated in writing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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