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LAKE VICTORIA´S NILE PERCH ON THE BRINK OF COLLAPSE

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ABSTRACT

Lake Victoria supports Uganda´s fisheries sector, with Nile perch (*Lates niloticus*) representing its most economically important species. However, its population has been under pressure, with some studies suggesting a decline and others arguing otherwise. This study investigates the current trends in Nile perch stock, forecasts future catches, and evaluates the implications of continued stock reduction. It also outlines the immediate and long-term strategies for sustainable species management. The study utilised simple linear regression to analyse stock trends, complemented by secondary data from key informant interviews. Regression analysis helped identify historical patterns and project future scenarios under the assumption of no significant management strategies. The results indicate a continuous decline in Nile perch stocks, suggesting a potential collapse by 2033 if current practices persist. The study concludes that overfishing is the primary driver of the decline and highlights the socio-economic consequences, including reduced contributions to GDP and job losses in the fishery sector. In response, this study recommends several key interventions, including reducing fishing effort, regulating the open-access nature of the fishery, aggressively tackling illegal fishing practices, and instituting closed seasons to allow for stock recovery. The interventions aim to rebuild Nile Perch populations in Lake Victoria, ensure long-term sustainability, and safeguard the economic, social, and biological value.

Keywords: Lake Victoria, Nile perch, overfishing, resource management, Uganda.

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ACRONYMS

BMU	Beach Management Unit
CAS	Catch Assessment Survey
CEO	Chief Executive Officer
DFR	Department of Fisheries Resources
FAO	Food and Agriculture Organisation
GLM	Generalised Linear Models
GDP	Gross Domestic Product
IUU	Illegal, Unregulated Unreported
LVFO	Lake Victoria Fisheries Organisation
MSY	Maximum Sustainable Yield
MCS	Monitoring Control Surveillance
NDP	National Development Plan
NP	Nile Perch
UFPEA	Uganda Fish Processors and Exporters' Association
UNECIA	Universities of England Consortium for International Activities
UNESCO	United Nations Education Scientific and Cultural Organisation
USD	United States Dollar

1. INTRODUCTION

1.1 The fisheries sector in Uganda

Fisheries are important to Uganda’s economy, ensuring food security, generating employment, and driving income for millions of people. This aligns well with Sustainable Development Goals (SDGs) 2, 8, 12, and 14, which leverage fisheries to reduce poverty, enhance nutrition, provide employment and conserve the environment. Lake Victoria, Uganda’s largest lake, is central to this sector and supports three primary fish species: dagaa/mukene (*Rastrineobola argentea*), Nile perch (*Lates niloticus*), and tilapia (*Oreochromis niloticus*) (Kimani et al., 2020). These species are central to both the lake’s ecosystem and the commercial fishing industry, with the fisheries sector accounting for 3% of Uganda’s national GDP and 12% of its agricultural GDP (Guloba M, Birabwa, Mbowa, & Kahunde, 2023). Among these, Nile perch emerges as a critical player, accounting for over 60% of the country’s fish export earnings, as highlighted by Kimani et al. (2020). This valuable species drives Uganda’s fish exports to international markets in Europe, Asia, and the Middle East. At the same time, over 50% of fishers and fishing crafts directly target Nile perch, underscoring its immense economic and social significance (Kimani et al., 2020).

According to Mpomwenda et al. (2022), more than 90% of Uganda's fish exports are Nile perch products. Nile perch are intentionally targeted by commercial fishermen for fish factories that prepare them into fillets and other products for export. On the other hand, small-scale Nile perch fishermen cater to local and regional markets, where the fish is sold fresh, smoked, or deep fried. The primary regional destinations for Nile perch exports are the DR Congo, Rwanda, Burundi, and South Sudan (LVFO, 2021).

Despite the vital role of fisheries, fish stocks have generally declined over the years. Musinguzi, Olokotum, & Natugonza (2020) indicated that Nile perch populations are facing recruitment challenges and are progressively nearing an overfished and collapsed state. Hauge, Cleeland, and Wilson (2009) identified several factors contributing to fisheries depletion and collapse, including overfishing, habitat destruction, pollution, climate change, and invasive species. They also emphasised the challenge of pinpointing a single primary cause for the declining fish stocks. According to Nyamweya *et al.* (2023), various management strategies have been established, including slot size regulation and gear size restriction; most measures aim to regulate fishing and not catch. Therefore, there is less regulation on output and more focus on the input, which has further contributed to the continued decline since the 1950s when Nile perch was introduced.

However, there are economic losses due to leakage; for example, fish are lost due to illegal fishing methods and illegal fish trade. Ogutu-Ohwayo, Wandera, and Kamanyi (2002) identified the lack of regulation of fishing gear and methods as a key factor in the collapse of Uganda's fisheries. The use of destructive and non-selective equipment, such as beach seines and gill nets that trap immature fish, has exacerbated this issue. Additionally, the inshore operation of seine nets for Mukene leads to the unintended bycatch of juvenile Nile perch and Nile tilapia.

The illegal fish trade through regional markets is mainly for small immature fish, as mentioned by Kimani et al. (2020). In addition, the quantities and types of Nile perch products are largely unknown in the region. This study highlights that the absence of regional and local market data on the Nile perch fishery may obstruct the formulation of effective management and development strategies, limiting socio-economic benefits and jeopardising the fishery's sustainability.

Aside from regulating fishing gear and methods, Uganda can reduce pressure on Nile perch populations by maximising the economic benefits of its trade. These strategies not only alleviate pressure on resources but also create opportunities for higher revenue generation and economic resilience within the fisheries sector.

Table 1. Number of fishermen (in employment) targeting different species in Lake Victoria by gender in Uganda. Source: Guloba, Birabwa, Mbowa, & Kahunde, 2023).

	2014			2016			2020		
Fish type	Male	Female	Total	Male	Female	Total	Male	Female	Total
Nile perch (Mpuuta)	33,116	248	33,364	36,064	218	36,282	34,119	85	34,204
Tilapia (Ngege)	13,665	62	13,727	14,155	79	14,234	15,475	175	15,650
Silver fish (Mukene)	14,506	32	14,538	17,448	45	17,493	10,175	42	10,217
Others	1,224	22	1,246	1,724	7	1,731	473	8	481
Uganda	**62,511**	**364**	**62,875**	**69,391**	**349**	**69,740**	**60,242**	**310**	**60,552**

1.2 Rationale

Nile perch (*Lates niloticus*) is an important economic and ecological resource in Lake Victoria, Uganda. Economically, it is the most valuable, as it provides most of the export earnings. According to Kimani et al. (2020), fisheries sustain millions of livelihoods, make a substantial export contribution to Uganda's GDP, and are essential to the region's food security.

Kyomuhendo (2002) described Lake Victoria as an open-access fishery, making it highly susceptible to increasing fishing pressure over time. This escalating effort has complicated management efforts, resulting in fluctuations in fish stocks. In another study, Taabu-Munyaho et al. (2015) suggested that although Nile perch stocks have declined, the lake's condition has remained stable since 2000. This is partly due to an increase in the biomass of other fish species, which has risen to at least 2×10^6 t, compensating for the lost biomass and supporting ecosystem recovery. Likewise, Mpomwenda *et al.* (2022) noted that despite extensive research on Lake Victoria, opinions on fish abundance vary widely; some argue that it is overfished, while others disagree.

This study is therefore relevant because it will provide insights into Nile perch stock trends, predict future catches, and examine the consequences of the continued decline in Nile perch catches. It also proposes immediate and long-term actionable strategies to enhance and manage Nile perch fishery stocks.

1.3 Research Objectives

1.3.1 General Objective

The study aims to analyse Nile perch stock trends in Lake Victoria, forecast future changes, discuss their implications, and suggest sustainable management strategies for the fishery

1.3.2 Specific Objectives

i. To analyse the trends of Nile perch stocks in Lake Victoria, Uganda, and project their future dynamics and impacts

ii. To propose sustainable fisheries management practices for the Nile perch fishery

2. LITERATURE REVIEW

2.1 Trends of Nile perch stocks in Lake Victoria

The Nile perch (*Lates niloticus*) stands out as Uganda's most economically significant fish species (Guloba, Birabwa, Mbowa, & Kahunde, 2023). Nile perch were initially introduced into Lake Victoria in the 1950s, followed by an official introduction in the 1960s. Aloo et al. (2017) note that while the primary goal was to enhance fishery production, a goal that was successfully met, the introduction also led to unintended negative consequences. By preying on native fish, Nile perch have contributed to the extinction of several species, including haplochromines. The paper further mentions that Nile perch changed the local economy's dependence on native fish species to Nile perch in the 1980s when its stock rose. Recent trends indicate a significant decline in Nile perch stocks, raising concerns about sustainability (Mpomwenda, Tomasson, Petturson, & Kristofersson, 2023). In contrast, Mpomwenda *et al.* (2022) reported conflicting opinions regarding the state of fishery stocks in Lake Victoria. Kimani et al. (2020) observed significant improvements based on a hydro-acoustic survey conducted in September 2017, which recorded a 31.6% increase in Nile perch biomass that year. This increase was linked to intensified MCS measures in Tanzania and Uganda. The status of Nile perch stocks remains a debate; while many consider them overfished, there is no definitive data to support this claim.

FAO (2009) reported that over half of the monitored fish stocks are fully exploited, yielding catches near their maximum sustainable limits, with no possibility for further expansion. Additionally, more than 25% of fish stocks are overexploited or depleted. Certain species are targeted by illicit fishing due to their significant commercial value and may face extinction if steps to curtail these practices are not implemented (Etiegni et al., 2010). The Nile perch fishery is a major commercial industry in East Africa, generating approximately US$250 million annually through exports. However, Nile perch stocks have been unclear since there are no specific studies to address key questions regarding its status and exploitation. Over the past decade, the fish stocks in Lake Victoria have steadily declined. According to Namwenya et al. (2023), hydroacoustic surveys conducted in 2022 revealed that Nile perch accounted for 67% of the total catch by weight, while haplochromines accounted for 23%. However, Nile perch dominance had decreased compared to the previous three years, when it comprised 91% of the catch in 2019. In contrast, haplochromine catches in 2022 were significantly higher than in the years 2017-2021.

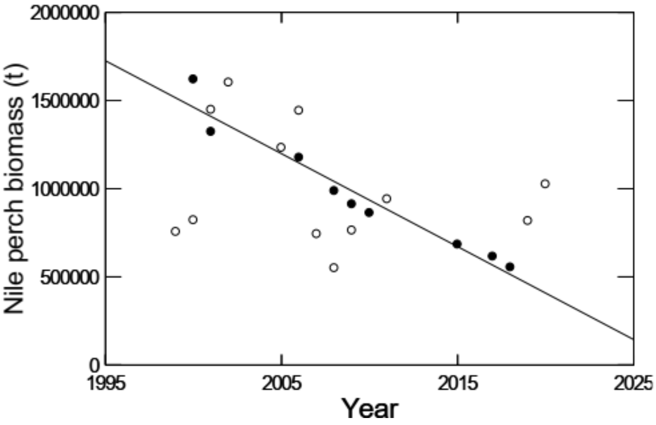

Figure 1. Nile perch biomass estimates for both the mixed (open circles) and stratified (solid circles) lake periods from 1999 to 2020, with a linear regression model applied to the stratified lake period estimates (LVFO, 2021).

This index reflects the predator-prey dynamics, where the significant decline of Nile perch as a predator has allowed haplochromine catches to increase. There is strong evidence that the lake has been overexploited, as illustrated in

Figure 1. Similarly, Buyinza (2023) states that despite the economic benefits of Nile perch and maw, the perch is at a great risk of depletion.

Mkumbo and Marshall (2014) suggested that the lake exhibited signs of overfishing, as the average fish size declined sharply in 2007, when the stock biomass dropped by 50%. This decline was linked to fishers shifting from large-meshed gillnets to small longline hooks. A recent stock assessment indicated a low level of recruitment, which is an indicator that the breeding stock may have declined. Recent trends show a decline in the number of fishermen, an indicator of decreased catch in Lake Victoria, as presented in *Table 1*. The number has continued to decrease, which is mirrored in the number of factories that have decreased from 35 in 2005 to 26 in 2014 and are currently five (5) in number. *Figure 2* emulates this by showing a recent sharp decline in fish exports. As populations grow, there is an increasing demand for fish and fish products, as mentioned by Thiao and Bunting (2022). This will only increase overfishing unless fundamental measures are taken to save the industry from collapse.

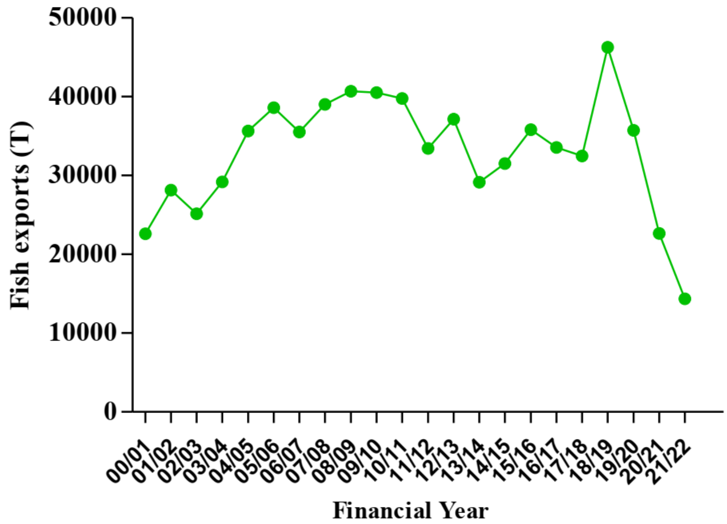

Figure 2: Fish Exports in Uganda from 2000 to 2022 (Dheyongera, 2024).

According to Hauge, Cleeland, and Wilson (2009), over 25% of the world's fish stocks have been overfished or completely depleted. In addition, many experts believe that marine resources have been used to their limit, if not beyond it. This decline is linked to excessive fishing efforts, illegal practices and inadequate fisheries management (Rebufat, 2007). The collapse of several once-thriving fisheries, including the Californian sardine fishery in the 1950s, the Atlanto-Scandian herring fishery in the late 1960s, the Peruvian anchovy fishery in 1972, the Northern cod fishery off Canada’s east coast in 1992, and the North Sea cod fishery in recent years, illustrates the unsustainable nature of fishing methods in many regions and the mismanagement of fish stocks (Hauge, Cleeland, & Wilson, 2009).

Therefore, the sustainability of fisheries is at risk (LVFO, 2021), and declining stocks should be a great concern among consumers, policymakers, scientists, conservationists, and the entire fishing industry. Sustainable development goals have also not been achieved; Sustainable Development Goal 14, which aims to conserve and sustainably manage oceans, seas, and marine resources, set Target 14.4 to eliminate overfishing by 2020. However, global fisheries have strayed from this objective, with overfishing increasing from 35.4% in 2019 to 37.7% in 2021 (FAO, 2024).

2.2 Factors contributing to the declining trends of Nile perch

2.2.1 Overfishing and Unsustainable Fishing Practices

Overfishing has been identified as a major cause of fish stock decline. FAO (2024) describes overfishing as fishing that causes the reduction of stock abundance to below the level that can produce MSY. Matsuishi et al. (2006) reported that Nile perch exhibit signs of overfishing, including a decline in biomass and a reduced age at first maturity. This not only threatens biodiversity and disrupts ecosystem balance but also lowers fish production, leading to negative social and economic impacts.

The fact that fishery resources are open access and are a common property resource creates a situation known as the 'tragedy of the commons' and hence are vulnerable to overexploitation. Kolding *et al*. (2008) indicated that intense fishing pressure significantly reduces the number of large breeding individuals, leading to lower reproductive rates. The introduction of unregulated fishing methods, including the use of undersized nets and illegal fishing gear, has further exacerbated this problem (Mkumbo & Marshall, 2014). The study highlighted fishing effort as the primary driver of fishery issues and the only controllable factor, while other challenges, such as environmental problems, remain beyond direct management efforts.

Fishermen have increasingly used illegal fishing methods, including undersized nets and monofilament gillnets, to capture juvenile fish before they reach maturity (Balirwa et al., 2003). Earlier studies allude to the same; Ogutu-Ohwayo (1990) highlights overfishing and illegal fishing practices as the primary drivers of Nile perch stock reduction within Lake Victoria and Kyoga. The increased demand for Nile perch in international markets has exacerbated the pressure on fish stocks (Njiru et al., 2008). This is further driven by the increased demand for fish maw (processed swim bladder), a highly valuable product of Nile perch. Aside from market forces, other drivers leading to the decline are related to the lake's environment and ecology.

Various studies have pointed to a combination of factors contributing to the decline in the Nile perch population. Action (2020) similarly emphasises that fishing pressure on an inland fishery is influenced by factors such as human population density, the primary and secondary productivity of the waterbody, the fishery's accessibility, socio-economic reliance on inland fish, and the availability of alternative food sources and livelihoods.

2.2.2 Climate and Environmental Change

Environmental and climate variability have influenced the Lake Victoria ecosystem, impacting fish reproduction and growth rates (Kayombo & Jorgensen, 2006). A recent analysis has shown that the dynamics of fish production in Lake Victoria are, to a large extent, driven by environmental factors. Rising water temperatures and pollution from industrial and agricultural activities reduce oxygen levels, affecting the survival of fish species, including Nile perch. Shifts in land-use practices have contributed to a higher nutrient influx, leading to a two-fold increase in primary production since 1969.

This agrees with Njiru et al. (2008), who attributed the increase in algal blooms and eutrophication to environmental degradation and nutrient inputs. This, in turn, leads to deteriorating water quality, loss of fish habitats, anoxia, and the eventual displacement of some fish and fish kills, especially when mixing occurs.

2.2.3 Competition and Predation

From an ecological perspective, the spread of invasive species and the resurgence of predatory and competitive species, such as native cichlids and the invasive water hyacinth (*Eichhornia crassipes*), have disrupted the ecological equilibrium of the lake (Witte et al., 2013). Moreover, water hyacinths serve as a favourable habitat for lungfish, aiding in their resurgence and partially competing with Nile perch for food. These changes have disrupted the food chain, reducing the availability of prey species essential for Nile Perch sustenance. In addition, the resurgence of native fish species and the introduction of invasive species have contributed to competition for resources. Balirwa et al. (2003) observed that as Nile perch populations declined, haplochromine cichlids, once a key prey species, began to recover. The reduction in food availability has forced Nile perch to shift their diet, thereby affecting their growth and reproduction. Additionally, the emergence of new predators, such as the African catfish (*Clarias gariepinus*), has further stressed the Nile perch population (Witte et al. 2013).

2.2.4 Pollution and Habitat Destruction

The lake receives nutrient inputs primarily from domestic and industrial wastewater, solid waste, sediments from catchment area soil erosion, agricultural runoff and atmospheric deposition. Consequently, certain areas of Lake Victoria, particularly its deeper sections, have become dead zones, where oxygen depletion makes it impossible to sustain aquatic life (Kayombo & Jorgensen, 2006). Pollution from industrial and agricultural activities has led to habitat degradation in the lake. Ogutu-Ohwayo *et al.* (2016) highlighted that heavy metal contamination and increased sedimentation have affected breeding and spawning grounds, reducing juvenile survival rates. The destruction of wetlands, which serve as critical spawning and nursery habitats, has further exacerbated this problem.

2.2.5 Policy and Management Factors

Poor fisheries management and weak enforcement of fishing regulations have enabled unsustainable practices. Fisheries management in the lake now stands at a critical juncture. In November 2015, the government dismantled the co-management system and temporarily deployed the military to oversee enforcement efforts (Mpomwenda et al., 2021). Balirwa (2007) emphasised the inadequate integration of ecological, environmental, and socioeconomic aspects of fish population management. Other influential factors include co-management, administrative boundaries and policy connections.

Limited monitoring, control, and surveillance (MCS) have led to the limited impact of the existing policies. Additionally, efforts to curb illegal fishing practices have been undermined by socio-economic challenges, including high poverty levels that drive local communities to exploit fisheries unsustainably.

2.3 Consequences of declining catches of Nile perch

2.3.1 Economic consequences: Decline in fisheries revenue

Nile perch is a major export commodity for Uganda, contributing significantly to the country's GDP, foreign exchange revenue, and employment generation. The fish sector is the second-largest foreign exchange earner after coffee, contributing USD 200 million per year in 2020. However, in the same year, informal fish exports contributed an additional USD 50.6 million (Guloba et al., 2023). The fisheries sector contributes 3% to the national GDP each year and provides significant revenue to local authorities through boat registration and licencing fees (Odongkara et al., 2005).

A decline in fish stocks would reduce income from fish exports, thereby affecting the national economy. Since Nile perch contributes to 60% of Uganda´s export earnings and significantly contributes to the fisheries' GDP, a decline in catches would decrease this input. LVFO (2021) confirms that Nile perch is an important value chain providing about two million Ugandans with jobs, which will not remain the same with the current trends in fisheries.

2.3.2 Impact on related industries

Industries such as fish processing, transportation, and export trade would suffer, leading to broader economic ripple effects in the country. The number of fish processing factories has reduced from 12 to five because of a limited supply of raw fish material. The operating factories are operating below their full capacity, as highlighted by the LVFO (2021).

2.3.3 Loss of Livelihoods

The Nile perch has the highest commercial and recreational fish value in Uganda. In 2020, over half of the fishers in Lake Victoria, Uganda, primarily targeted Nile perch. Their earnings surpassed both the minimum state thresholds and those of casual labourers. Crew members typically earned between $6,000 and $7,000 annually, whereas boat owners earned between $7,000 and $15,000 per year. Fish processors saw incomes ranging from $10,000 to $18,000, whereas traders generated between $17,000 and $19,000 annually. These relatively high earnings likely explain the significant increase in fishing effort and will probably attract further participation in the fishery in the future (LVFO, 2021).

As such, the increased entry leads to declining total catches, which directly affects the people who are employed, either directly or indirectly, in it. This is supported by Guloba et al. (2023), who mentioned that the Nile perch value chain is known for being complex, with more activities and players, as shown in *Figure 3*, in comparison to other major fish species. In addition, it covers all markets, including local, regional, and international (Guloba et al, 2023). The activities in the Nile perch industry show that opportunities have decreased, including fishing, grading, collecting, trading, transportation, and processing (filleting, smoking, salting), with all nodes having different players. In addition, the highly valuable fish maw, a product of Nile perch, further increases its complexity.

In Uganda, women play a crucial role in the post-harvest fishery sector, representing 80% of the artisanal processing workforce, 39% of fresh market retailers, 36% of processing factory employees, and 40% of those who process fish maw.

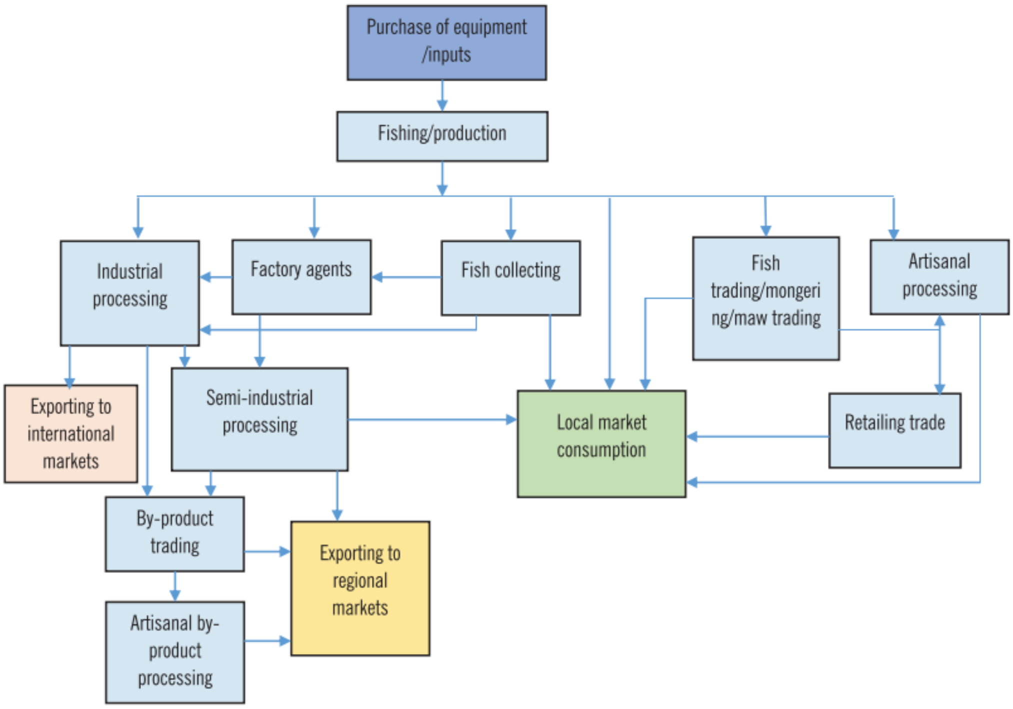

Figure 3. Nile perch value chain for local, regional, and international markets (Guloba et al, 2023).

2.4 Social effects

2.4.1 Food security

Nile perch is an important source of protein for people in Uganda and neighbouring states. This is confirmed by Natugonza (2024), who appreciates that Nile perch fuelled a lucrative fishery that revolutionised the lake's contribution to human well-being regarding food security and income. Therefore, food security and nutrition concerns arise as Nile perch populations decline in Lake Victoria. In contrast, some studies have shown that Nile perch export increases malnutrition because the industry is mainly manned by men, and their income does not trickle back to their households (Geheb et al., 2008). Local fish consumption patterns have shifted towards smaller, less nutritious fish species, such as dagga (*Rastrineobola argentea*), affecting household nutrition (Goudswaard et al., 2008). Moreover, Nile perch accounts for approximately 7% of the total fish consumption in Partner States (LVFO, 2021). Furthermore, the decline in catches has led to an increase in fish prices; as such, the affordability of fish has also decreased, thus impacting low-income consumers.

2.4.2 Poverty and Migration

Fisheries are essential for nutrition, employment, and poverty reduction in rural communities (Nyejo & Wiium, 2004). Fisheries-related jobs are the most prevalent form of employment in communities near water bodies. Natugonza (2024) confirms that the number of fishers increased when Nile perch stocks boomed; the number of entrants increased threefold between 1999 and 2005. According to the LVFO (2021), Lake Victoria directly employs approximately 220,000 individuals as boat owners and fishing crew members, while an additional 600,000 people find indirect employment in roles such as processing, trading, and manufacturing fishing gear and boats.

Additionally, approximately three million people rely on the lake's fisheries for their livelihoods and sustenance. However, with declining fish catches, profits are expected to decrease, and some fishers will lose their jobs, which will lead to migration. Guloba *et al.* (2023) reported that fisheries-related employment has experienced significant periodic declines over the years.

2.4.1 2.4.3 Conflict Over Resources

Declining fish stocks can intensify competition among fishermen, leading to conflicts over dwindling resources. Ameyaw et al. (2021) similarly emphasised that the reduction in fish production caused by overfishing contributes to various conflicts, particularly between Nile perch and Dagaa fishers. Since Dagaa fishers have Nile perch juveniles as bycatch, they have been blamed for the decline in Nile perch stocks. Ndinda et al. (2022) acknowledged that illegal fishing in inshore areas and illegal fishing of Dagaa contributes to the decline of Nile perch.

2.4.4 Increased Illegal Fishing Practices

Declining fish stocks can lead to increased overfishing and illegal fishing practices in the future. As fish populations dwindle, the pressure to meet demand and maintain livelihoods can drive fishers to exploit the remaining stocks unsustainably (Lethonen, 2025). This often results in overfishing, where fish are harvested faster than they can reproduce, further depleting their population. Illegal fishing practices may become more prevalent as fishers seek to bypass regulations and catch limits. Illegal fishing may include fishing in shallow waters and breeding areas to adapt to declining catch. These practices threaten marine ecosystems and undermine efforts to manage fisheries sustainably and protect the livelihoods of fishing communities.

2.5 Sustainable fisheries management strategies

Uganda's fisheries management is primarily guided by the National Fisheries and Aquaculture Policy (NFAP) of 2018, which aims to establish a modern, efficient, profitable, and sustainable fishery and aquaculture industry (Kimani et al., 2020). Additionally, the 2010 fishing regulations include specific provisions for the Nile perch fishery, outlining a slot size of 50-84 cm, a mesh size of seven inches, a hook size of nine inches, and designated licencing requirements, among other stipulations. Quality is regulated by the Fisheries and Aquaculture (Quality Assurance) Rules of 2017. Finally, the BMU rules of 2016. Ssubi, Mukisa, and Muyanja (2024) investigated compliance with existing fisheries laws, regulations, and standards in fresh Nile perch catch. The study identified notable differences across sectors, with processing demonstrating the highest compliance and fishing demonstrating the lowest. To address these challenges, various enhanced practices for sustainable fishery management have been proposed.

2.5.1 Co-management approaches

Incorporating local fishing communities through Beach Management Units (BMUs) has been highlighted as an effective method. According to Njiru et al. (2008), the centralised management approach and the implementation of varying regulations by the riparian states pose significant challenges to the sustainable management of the lake. They advocated for a transformative approach, stressing the importance of viewing the lake as a unified, interconnected ecosystem in which all key stakeholders actively engage in decision-making.

However, Mpomwenda et al. (2023) suggested that fisheries co-management (BMU), designed as a collaborative strategy for sustainable fisheries, was ineffective, leading to the implementation of coercive enforcement measures in 2015. Ultimately, efforts to boost catch and export beyond the BMU period failed. As a result, reinstating BMU arrangements at landing sites has become necessary.

2.5.2 Gear regulation and enforcement

Mkumbo and Marshall (2014) note that management authorities have faced criticism for focusing solely on regulating fishing efforts instead of adopting a more comprehensive approach. They justified this strategy by arguing that fishing effort is the primary driver of fishery issues and the only controllable factor. However, controlling the environment is more challenging.

Other studies indicate that artisanal fish production in many developing countries is experiencing 'Malthusian over-fishing,' where economic hardship compels fishermen to adopt destructive harvesting techniques (Ochiewo, 2004). Fishermen use technologies that threaten sustainability; for example, they use beach seines that destroy the seabed and are associated with the bycatch problem. Strengthened surveillance and enforcement are necessary to curb illegal fishery activities.

According to the LVFO (2021), the LVFO questioned the effectiveness of the upper slot size landing restriction, citing several concerns. Hooks, the primary fishing gear, lack strong size selectivity, and larger fish often suffer high mortality rates upon capture. Furthermore, fish exceeding 85 cm are often underreported by both fishers and processing factories, resulting in inconsistencies in the harvest and post-harvest data. Many of these fish end up in unregulated markets, reducing product safety, value and export revenue. Given Uganda's non-recognition of this limit, adjustments are needed to ensure that all catches are properly reported.

2.5.3 Alternative Livelihoods

Encouraging fishers to engage in alternative economic activities reduces their dependence on Nile perch, thus relieving fishing pressure. Kimani *et al.* (2020) explain that the intense inflow into the fishing industry as a source of income indicates the deterioration of alternative incomes. The consideration of more lucrative alternative incomes should be done as a way of reducing fishing effort. Projects such as fish farming or poultry keeping can be alternative sources of income.

2.5.4 Emphasising regional cooperation

There is increasing agreement on the necessity of regional collaboration among the riparian nations of Uganda, Kenya, and Tanzania to safeguard the long-term sustainability of the fisheries of Lake Victoria. Like all shared resources, managing this effectively is a complex challenge, further intensified by the high economic stakes in the Nile perch export market. The LVFO's mandate is to establish a unified system for resource management (Mpomwenda et al., 2023).

2.5.5 Promotion of value addition and reducing wastage

Value addition for the fisheries sector will be prioritised as one of the drivers to boost Uganda´s economy by tenfold growth. This is supported by the National Development Plan IV (NDPIV) of 2026 to 2030, which envisages the national GDP increasing to USD 581 billion by 2030.

Full utilisation is a promising approach to mitigate the decline of Nile perch stocks because fewer fish can be captured, but with a higher value. Full utilisation of fish (zero wastage) can be achieved through various ways, but mainly by increasing value addition on fish and fish products, which provides a better economic value compared to an unprocessed product. As consumers increasingly care about their health, the demand for safe and nutritious food increases. Fish and fish products are the best options. Fish is thus referred to as blue food and is in increasing demand. All fish, fish products, and fish by-products should be fully utilised to maximise revenue from fish and reduce waste in the environment, thereby reducing pollution.

Fish by-products, including skin, viscera, scales, heads, bones, and fins, are valuable sources of protein and other useful compounds. Yuan et al. (2024) emphasised the importance of systematically extracting and synthesising proteins from these by-products. Other fish products include fillets, smoked products, ready-to-eat meals, bones for bone mills, and fish stomachs for enzymes to tenderise tough meat products. All of this can lead to the opening of new markets and increased profitability, as well as reduce environmental degradation.

Furthermore, the economic value of Nile perch can be increased by improving export packaging and fostering new markets to sustain profitability. Additionally, developing sustainable branding strategies for Nile Perch products and enhancing quality control measures can boost their market appeal and economic contribution.

Losses due to poor handling mainly arise from the failure to maintain a cold chain. Therefore, post-harvest losses may be reduced by providing improved storage, processing, and transportation cold chain infrastructure. This can significantly enhance the value of Nile perch products in the market. This is further confirmed by LVFO (2021), who highlights that catch quality normally deteriorates due to failure to maintain cooling and minimal processing aboard vessels and during transportation. On-board bleeding provides good quality products and increases the fish's shelf life.

2.5.6 Regulating by-catch

The bycatch of juvenile Nile perch in the Dagaa fishery has been a major issue and has led to conflict between the two fisheries. Ndinda *et al*. (2022) mentioned that illegal fishing in inshore areas and illegal fishing of Dagaa contribute to the decline of Nile perch. Policies and guidelines exist to regulate bycatch; however, surveillance and enforcement are limited in their effectiveness.

Strengthening fishery management, regulation, and improved enforcement, including size limits and gear restrictions, is essential to curb illegal fishing (Njiru et al., 2008).

2.5.7 Conservation Efforts and Closed Seasons

Introducing fishing moratoriums or closed fishing seasons during breeding periods and establishing fish breeding zones can help replenish fishery resources. Some researchers advocate controlled restocking programs and the protection of breeding grounds to enhance natural population recovery (Balirwa et al., 2003). This can be adapted from other countries, such as Iceland, where high-value Cod is given ‘maternity leave’ during the breeding season.

2.5.8 Promotion of aquaculture

Diversifying the fisheries sector by promoting aquaculture as an alternative to wild-capture fisheries can reduce the pressure on Nile Perch stocks. Similarly, Mukuna *et al.* (2020) recommended promoting aquaculture as an income diversification intervention to ensure Nile perch sustainability.

Implementing effective fishery management policies, conservation initiatives, and diversification strategies is crucial to ensuring the sustainability of Uganda’s fishery resources. Additionally, increasing the economic value of Nile perch by ensuring zero wastage, improving processing, expanding markets, and adding value to products can help mitigate economic losses.

3. METHODOLOGY

This study used a mixed-methods approach, combining quantitative and qualitative research methodologies. This study aimed to thoroughly investigate the patterns, origins, and effects of the diminishing Nile perch populations in Lake Victoria (Figure 4). The results will be used to inform management decisions.

3.1 Study area

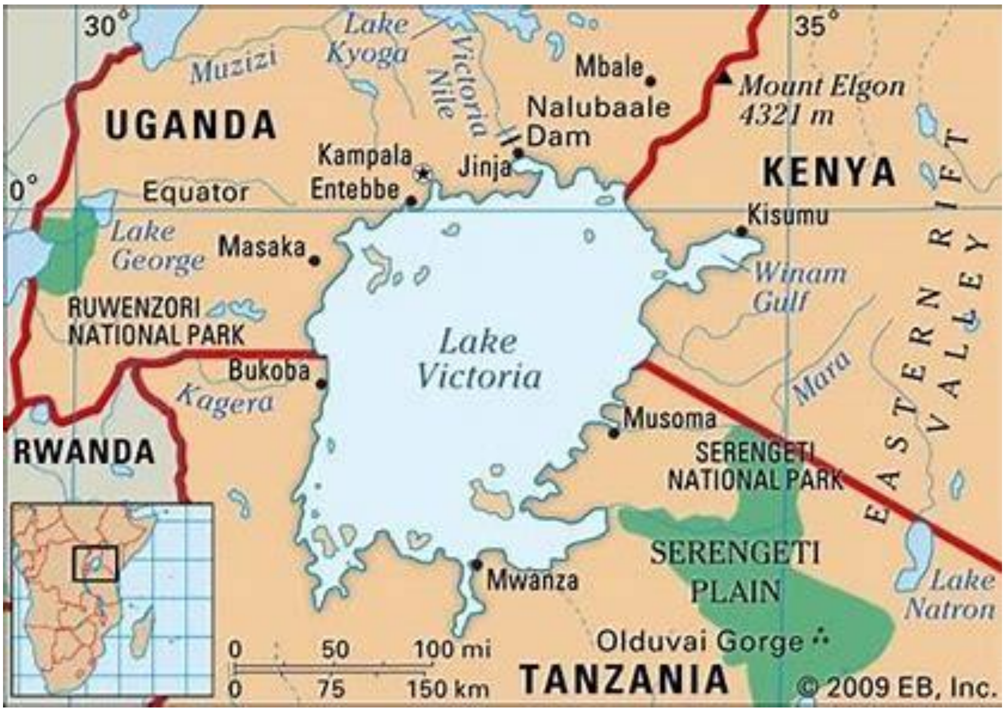

Figure 4. Map of Lake Victoria Source: https://www.britannica.com/place/Lake-Victoria

Lake Victoria is the study area (68,000 km^2) and is shared by the three East African countries i.e. Uganda (43%), Kenya (6%), and Tanzania (51%). The lake supports Africa's largest inland fishery, with catches dominated by three species: Nile perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus),* and Dagaa (*Rastrineobola argentea*). The focus areas were the 43% area covered by the lake on the Ugandan side, and the main species of interest was the Nile perch.

3.2 Data Sources and collection

For secondary data and information, a literature review was conducted using reputable online academic databases such as Web of Science**,** Scopus**,** and Google Scholar. Additional data were obtained from institutional sources, including Uganda's Department of Fisheries Resources (DFR), Lake Victoria Fisheries Organization (LVFO)**,** and Food and Agriculture Organization (FAO)**.** LVFO reports, including frame, hydroacoustic, and catch assessment surveys (CAS), were crucial. However, a notable challenge encountered was the inconsistency of data across different years, which posed limitations on carrying out a comprehensive analysis during this study.

3.3 Quantitative analysis

To understand the trajectory of the Nile perch population, a simple linear regression was applied to identify and assess historical and ongoing trends in the Nile Perch fishery. These trends were extrapolated to project future scenarios, helping visualise the potential trajectory of fish stocks if no significant management interventions are implemented. Notably, if the catches reach zero, it suggests a possible collapse of the stock, highlighting the urgency of adopting sustainable fishery management practices before reaching that worrying state.

The efficiency of fishing methods and fish stock abundance were measured using the Catch Per Unit Effort (CPUE). A consistent decline in CPUE often signals fish stock depletion and a drop in fishing efficiency, potentially driven by overfishing, habitat degradation, environmental change, or behavioural shifts in fish populations. Although CPUE standardisation using Generalised Linear Models (GLMs), as recommended by Bentley et al. (2011), is ideal for controlling variables such as gear type, vessel capacity, and environmental factors, it was not applied in this study because of data limitations. Consequently, while the CPUE data provided valuable insights, it may carry some biases, such as overestimating stock abundance if fish were caught in areas where they were aggregated. To mitigate this, CPUE data were interpreted alongside biological and environmental information and knowledge of fishing technology and gear use.

The catchability of the common vessel gear combinations for Nile perch was analysed for trends using data from CAS 2005-2021. The fishing gears were multifilament gillnets, and the longline hooks were used on either Sese paddled boats or Sese motorised boats.

3.4 Qualitative Analysis

To supplement the quantitative findings and gain deeper insight into the current dynamics of the Nile Perch fishery, purposive sampling was used to select stakeholders for key informant interviews that were conducted with a variety of stakeholders. These included four (4) fisheries officers from Mukono, Buikwe, Kalangala, and Wakiso districts; two (2) officials from the DFR and the National Fisheries Resources Research Institute (NaFFIRI); ten (10) local fishers; and the manager from the Uganda Fish Processors and Exporters Association (UFPEA).

These interviews offered valuable insights into Nile Perch stock trends and impact, and the challenges facing the Nile perch industry. The interviews further provided views on current enforcement gaps in Monitoring, Control, and Surveillance (MCS) and suggestions for policy and operational improvements.

4. RESULTS

4.1 The Nile perch catches are declining in Lake Victoria

4.1.1 Estimated average monthly fish catches from 2005-2021

Figure 5 shows a general decline in the monthly trends for the catches of Nile perch stock from an estimate of 8,000t in 2005 to 5000t and below by 2021.

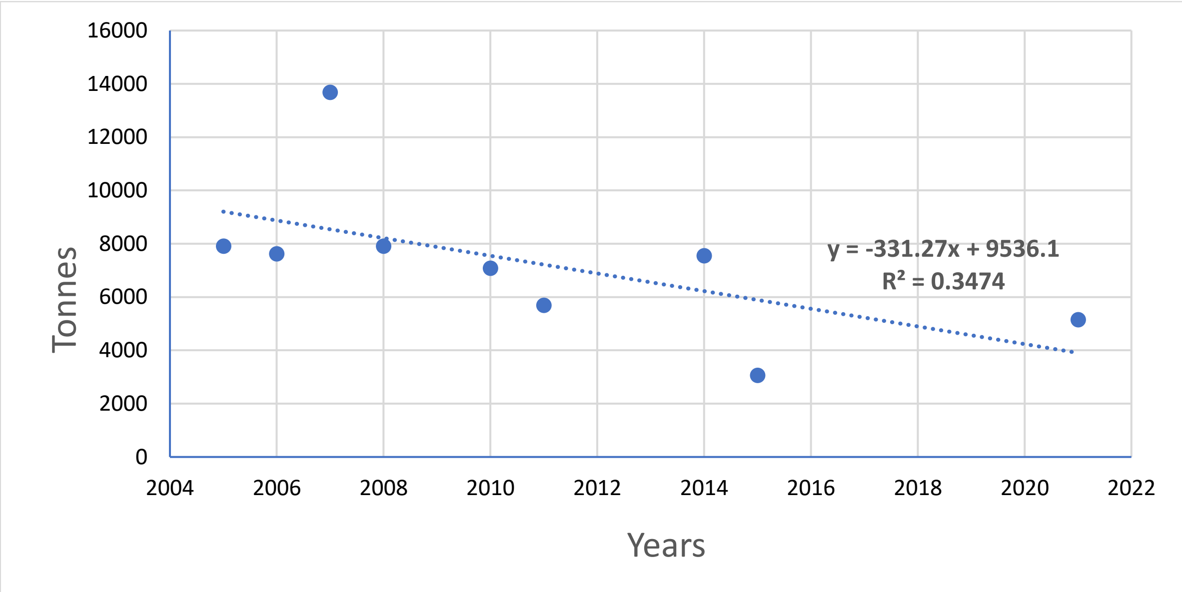

Figure 5. Estimated average monthly catch per year for Nile perch in Lake Victoria, Uganda (Source CAS 2005 to 2021)

However, the catches fluctuated along the declining trend with some increments for some years, such as 2014, and then decreased in 2015 by 34% before slightly increasing. Some years deviate significantly from the trend line, but time alone cannot explain the decline in catches since the R-squared is 0.34. Therefore, only 34% of the decline can be explained by time alone. The estimated catch beach value of different species for 2021; *Figure 6* explains the economic importance of Nile perch despite the declining trend in its catch.

In Figure 6, we consider the estimated annual catch beach value for 2021. The graph shows that the beach value of Nile perch was USD 164,000, more than twice the value of Dagaa in 2021, although Dagaa had a higher volume in terms of catch. Tilapia and haplochromines were ranked third and fourth, respectively. Haplochromines reappeared, which had been almost wiped out in previous years.

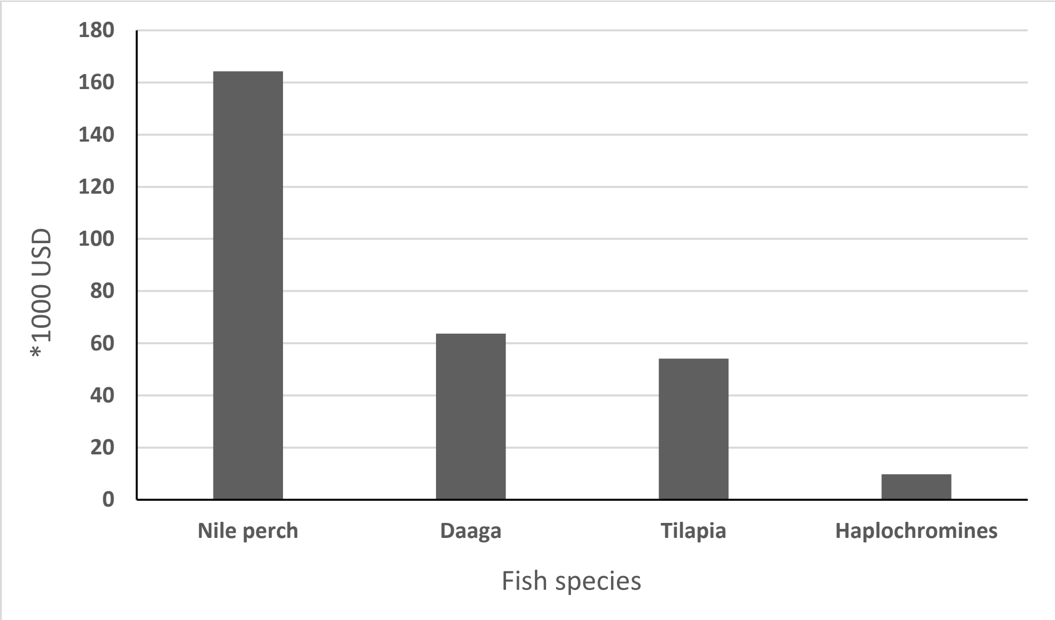

Figure 6. Estimated annual catch beach value for 2021. (Source CAS 2005 to 2021)

4.2 Further evidence of the declining trend of the Nile perch fishery

4.2.1 Size at maturity of the Nile Perch

Table 2 displays the different size trends when Nile perch first reach maturity. As a result, Nile perch matured at a smaller size earlier, between 1964 and 1977, when populations were limited, as opposed to between the 1980s and the early 2000, when biomass was large.

Table 2. Size of Nile Perch at first maturity (total length in cm) in male and female Nile perch in Lake Victoria, 1964-2007 (Kayanda et al., 2009).

Year	Females	Males	Source
1964-67	45.3	32.2	Okedi (1970)
1968-77	54.7	41.9	Ogutu-Ohwayo (2004)
1982	93.3	46.8	Ogutu-Ohwayo (2004)
1988-92	93.3	62.2	Ogutu-Ohwayo (2004)
2001	75.8	57.7	UNECIA (2001)
2007	58.0	52.5	LVFO (2007a)

Later, when the Nile perch population declined in 2007, it reached a smaller maturity when the biomass was reduced due to various factors, key among them being overfishing. The reduction in size at first maturity is a sign of reduced fish biomass. The catches of fish lower in the food chain were observed to increase, as shown in Figure 7.

4.2.2 Increase in the annual catch of other species.

The same period that registered a decline in Nile perch witnessed a rise in Dagaa and haplochromines in proportions of 11.2% and 20%, respectively (*Figure 7*).

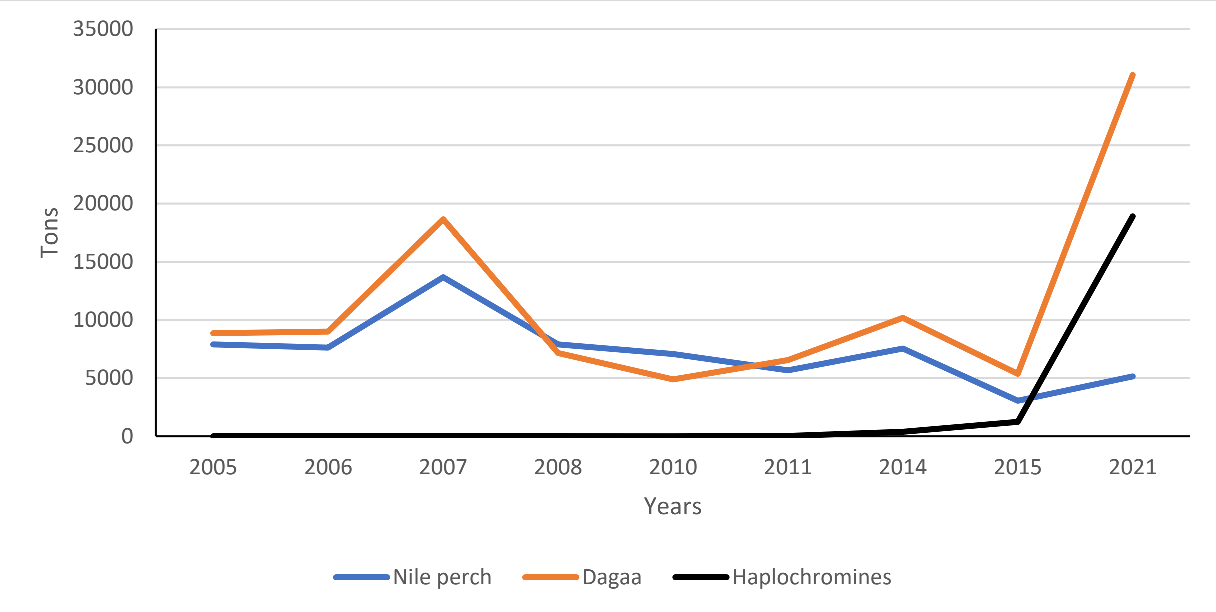

Figure 7: Average monthly catches of Nile perch, Dagaa, and Haplochromines in Lake Victoria, Uganda (Source CAS 2005 to 2021).

Haplochromines had low catches for most of the period but experienced a sharp increase after 2015; this perhaps signifying changes in fishing techniques or the ecosystem. In contrast, Nile perch catches remained steady, reflecting either stable population dynamics or consistent fishing efforts. Daga catches showed peaks around 2007 and 2021, adding an interesting layer of variability.

4.3 The Nile perch will continue to decline

4.3.1 Projected annual catches of Nile perch

Figure 8 shows a linear trend analysis of data points representing fish production (in tonnes) from 2005 to 2021, with an extrapolated forecast up to 2033. The equation suggests that fish production decreases by approximately 331.27 tonnes per month. The R-squared value was 0.3474, indicating a weak correlation between the year and fish production. Only approximately 34.74% of the variation in production can be explained by this linear model.

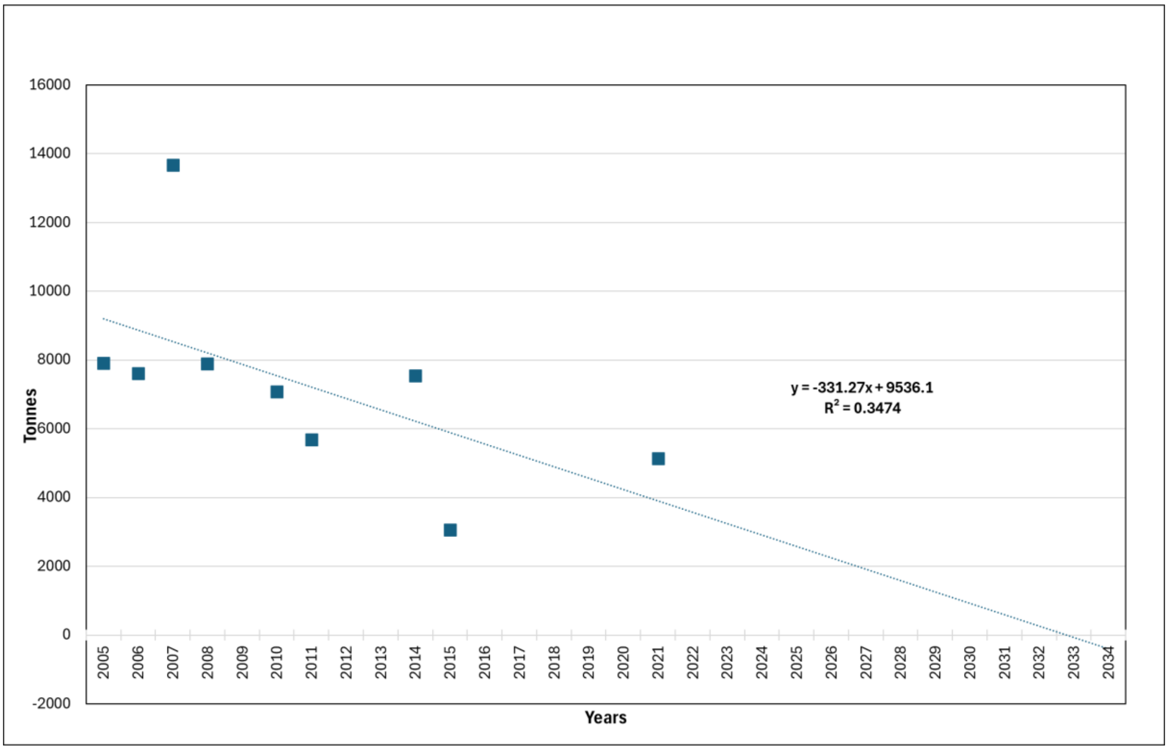

Figure 8. Estimated average monthly catches of Nile perch in Lake Victoria with extrapolation until the catches are zero (Source: CAS 2005 to 2021).

4.3.2 Findings that the stock will be depleted by 2033

From 2021 onwards, the trend line projected future values (extrapolation), suggesting a continued decline in fish production if the current trend persists. If the trend continues, the model predicts zero or even negative production by 2033, which may not happen, but it indicates that the stock may be depleted by then.

4.3.3 Limitations of the model

The model does not directly account for the potential causes of this reduction, which could include overfishing, environmental deterioration, or ineffective policies. The R-squared value indicates that the model explains only 34.74% of the variation in the data, indicating a poor fit. Other factors (e.g. policy changes, climate, and illegal fishing) were not captured.

Linear assumption: The use of a straight-line model simplifies trends that may be non-linear, such as sudden increases due to interventions (policy interventions) or collapses due to ecological limits.

Sparse data: Data points were missing for several years between 2005 and 2021, reducing the robustness of the trend line.

4.4 Fishing Effort

4.4.1 Biomass and fishing effort (number of fishers)

The graph (*Figure 9*) indicates that the biomass of Nile perch in Lake Victoria has a strong linear inverse (negative) relationship with fishing effort (number of fishermen). Nile perch biomass steadily declined as fishing effort increased.

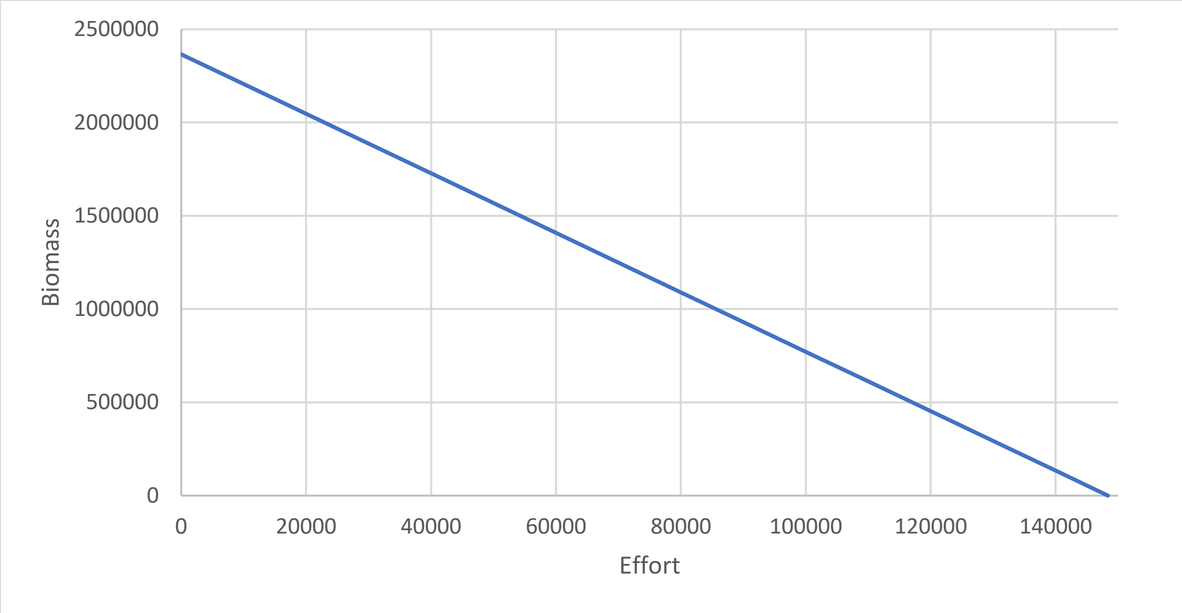

Figure 9. Nile Perch biomass plotted against fishing effort (estimated number of fishers)-(CAS data 2005-2021)

This likely demonstrates the impact of overfishing, as higher fishing activity reduces the overall fish population in the lake. Initially, with low effort, the biomass was at its peak, indicating a healthy stock. However, as the effort intensifies, the biomass decreases, emphasising unsustainable practices.

Figure 10 indicates that the biomass of Nile perch in Lake Victoria has a strong linear inverse (negative) relationship with fishing effort (the number of fishermen). Nile perch biomass steadily declines as fishing effort rises.

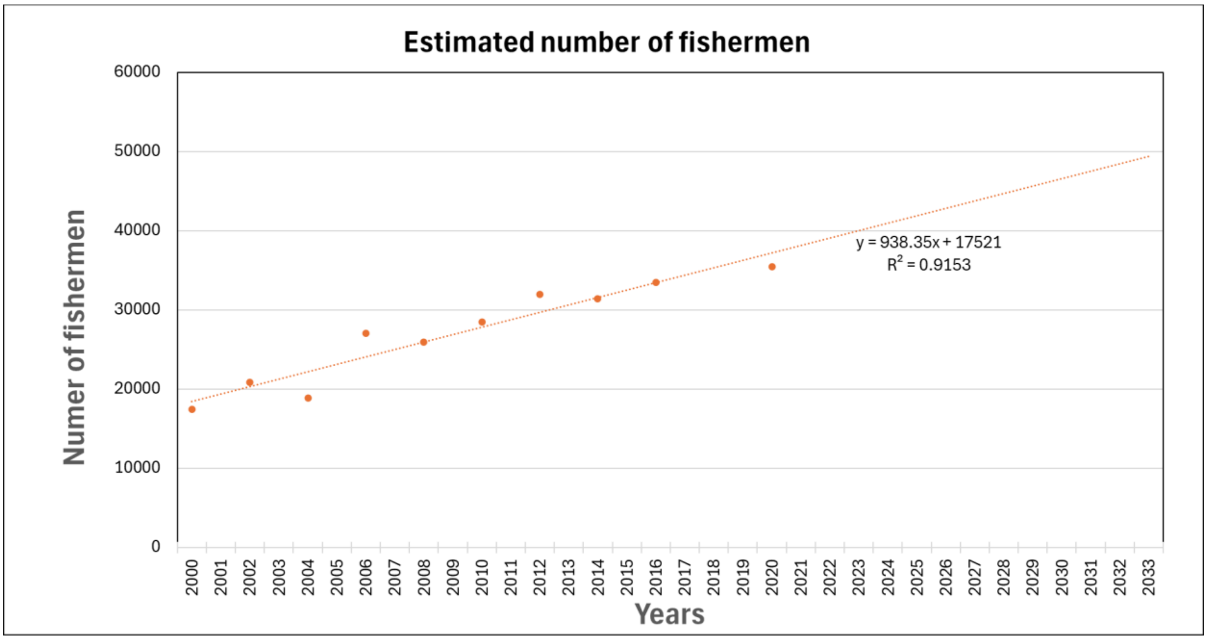

Figure 10. Estimated total number of Nile perch fishers on Lake Victoria, Uganda (CAS data 2005-2021)

The slope of 938.34 indicates that approximately 938 new fishers join annually. According to *Figure 11*, the CPUE per fisherman is steadily decreasing, implying that the fishermen are catching fewer fish per year, possibly because of declining stock and increasing effort. However, the R-squared value is 0.5342, indicating a moderate fit; therefore, despite the downward trend due to the increased number of fishermen, there are other factors influencing catch rates. The CPUE for fishermen would hit zero by 2030 if no action is taken; however, other factors could either quicken or slow the process.

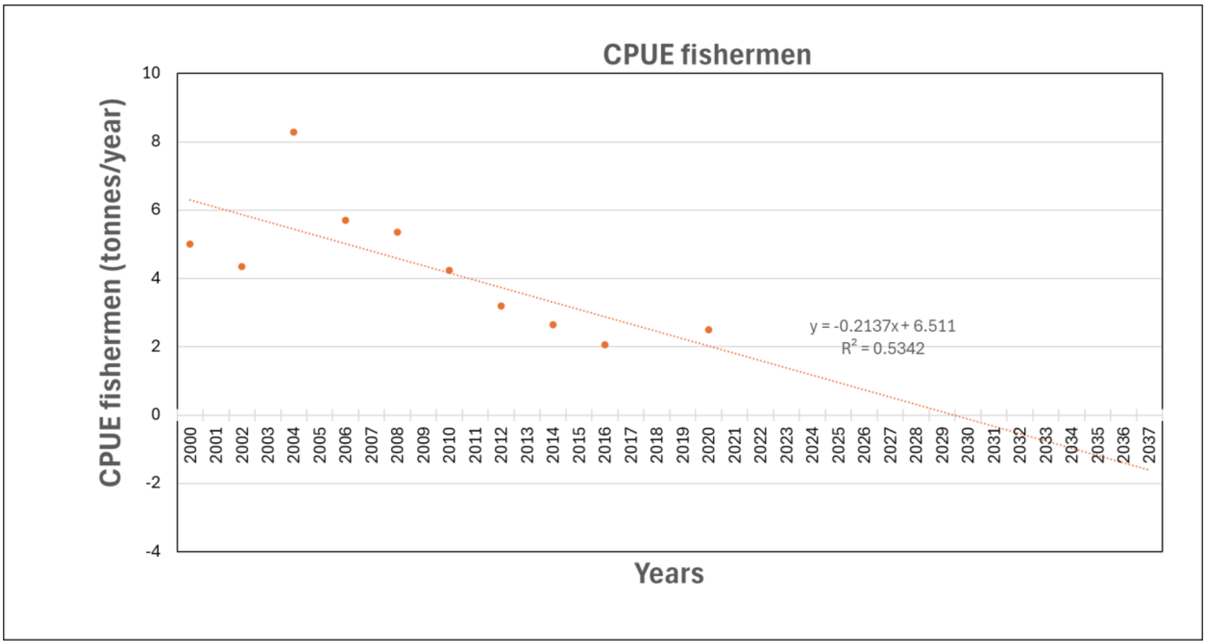

Figure 11. CPUE for fishers of Nile perch (CAS data 2005-2021)

According to Figure 12, the CPUE per boat is rapidly declining; the significant drop suggests significant pressure on the fish stock or increased competition among the boats. The R-squared value was 0.82, which means that 82% of the variability in CPUE is explained by the year.

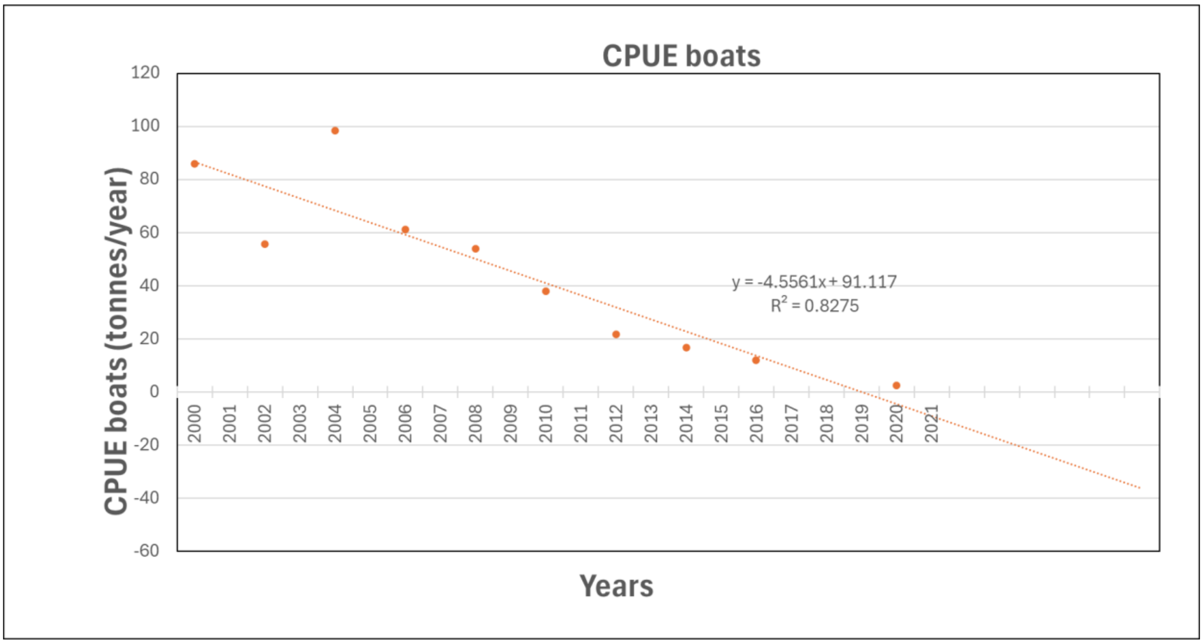

Figure 12. CPUE of boats fishing Nile perch (CAS data 2005-2021)

The trend was strong and reliable over the entire period. There is an extrapolation, and the CPUE hit zero around 2020-2022 and further went deeper into negative values. This may not be the case, but it is a clear indicator that there is a great depletion of the fishery, and it is only getting worse every year. This situation indicates a high possibility of overfishing, stock depletion, and competition from boats for fish.

4.4.2 Fishing gears and Vessels

Nile perch is caught using two main gears: multifilament gillnets and long line hooks. The boats used are mainly Sese-paddled and Sese-motorised boats. *Figure 13* shows the catch rates (kilograms per boat per day) for four gear combinations: Sese paddle boats using long line (SP-LL), Sese paddle boats using gill net (SP-GN), Sese boats using gill net (SMS-GN), and Sese boats motorboats using long line (SMS-LL).

Nile perch catch rates in Uganda have generally declined, particularly in Lake Victoria. The catch rate has decreased over time, reflecting reduced fish abundance. Motorised boats using long lines achieved the highest catch rates compared to other vessel gear combinations.

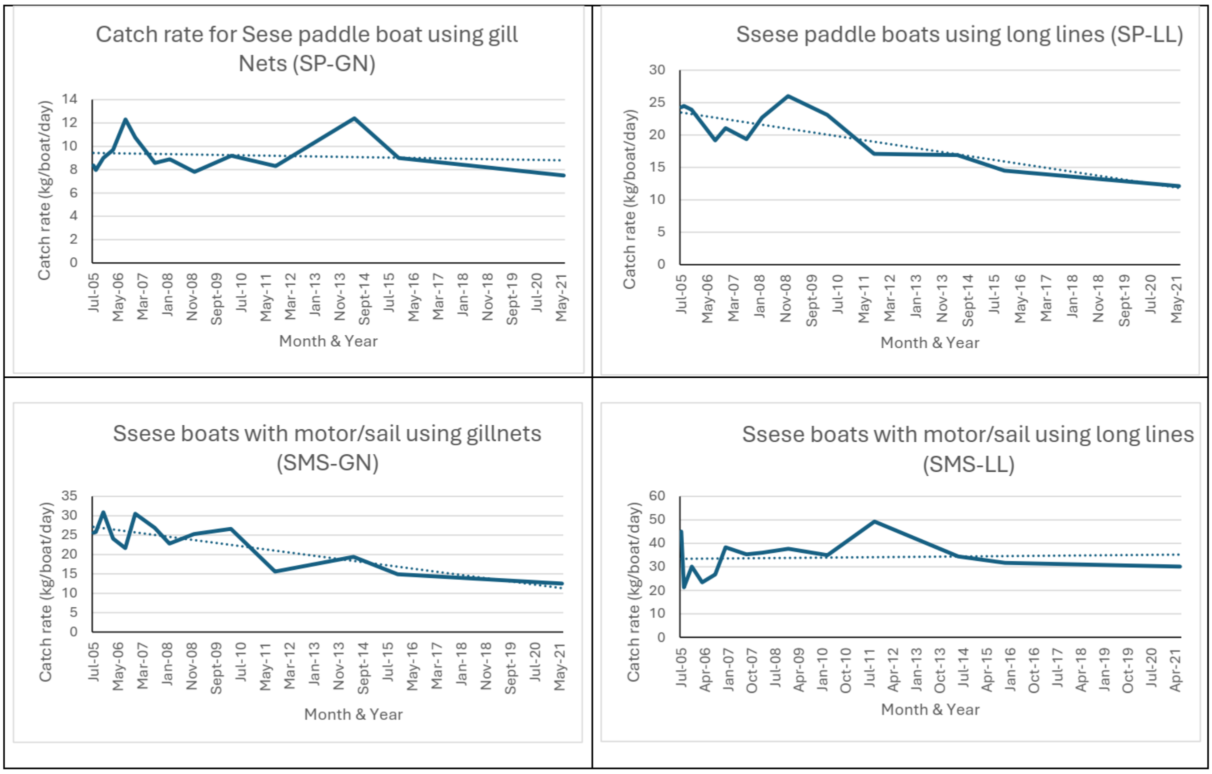

Figure 13. Catch rate (kg/boat/day) of Nile perch for vessels in Uganda – gear combinations. Data from Catch survey 2005 to 2021

4.5 Key informant interviews

4.5.1 Causes of the declining trends of Nile perch

Key informant interviews were conducted with a variety of stakeholders. These included four (4) fisheries officers from Mukono, Buikwe, Kalangala, and Wakiso districts; two (2) officials from the DFR and the National Fisheries Resources Research Institute (NaFFIRI); ten (10) local fishers; and the manager from the Uganda Fish Processors and Exporters Association (UFPEA). Tables 3 and 4 record the ranking of the reasons for declining trends and their recommendations for the management of Nile perch stock.

Table 3: Ranking for causes of declining trends of Nile perch catches

Factor	**Rank**
Overfishing	1
Climate Change	3
Pollution and habitat destruction	2
Other factors (weak enforcement, natural mortality)	4

4.5.2 Recommendations for the management of Nile perch stock

Table 4: Weighted recommendations for Nile perch fisheries management

Recommendation	**Score 1-5 (low – very high importance respectively)**
Research and data collection	4
Reduction of open-access fisheries and enforcement	5
Co-management	4
Alternative livelihoods	4
Regulate illegal fish and gear trade	3
Closed seasons	1
Protecting breeding areas	3
Others: Financing fishers to get legal fishing gear	3

4.5.3 Other issues raised from the Key Informant Interviews.

According to the Chief Executive Officer (CEO) of UFPEA, 14 establishments process fish, 12 of which are primarily engaged in Nile perch processing for international markets. Eight of these establishments are operational but below half their full capacity, whereas four are non-operational. He further reported a decline in the weight of fish processed from 28,672 t in 2001 to 8,427 t in 2024. This is equivalent to a 70% decline in the past two decades. DFR and fisheries officers raised cases of a high increase in illegal fishing and trade of Nile perch, which causes revenue loss. Illegal fishing is mainly by beach seines and excessive by-catch from the fishing of Dagaa. Illegal trade is mainly for smoked and sun-dried illegal Nile perch, which ends up in regional markets. Inadequate staffing was also mentioned as a major challenge, and MCS was not efficient because of this limitation.

5. DISCUSSION

The study's conclusions highlight important shifts in patterns and difficulties in the Nile perch fishery in Lake Victoria, Uganda, particularly with respect to diminishing catches, variations in maturity size, rising fishing effort, decreased catch per unit effort (CPUE), and decreased catch rate.

The analysis of historical catch data, as shown in *Figure 5*, revealed a linear decline in Nile perch landings between 2005 and 2021. Despite the limitations of the linear model, further projection of the trend indicates that fish catches will be depleted by 2033. However, there were fluctuations along the trend line, such as a temporary increase in 2014, followed by a decline in 2015. These years deviated significantly from the trend line, probably due to biased sampling, where fish were collected from densely populated waters for one year and then from less densely populated waters in another year.

In addition, the low R^2 value (0.34) in *Figure 5* suggests that time alone does not fully explain the decline in fish catches. The decline in catch can be explained by natural or anthropogenic factors. Natural causes which occur over time include predation, diseases and parasites, seasonal changes in oxygen when mixing occurs, climate variability, and natural population cycles. These factors explain 34% of the decline; thus, 64% is explained by anthropogenic factors, which affect both stock and catches.

This agrees with Etiengni *et al.* (2011), who suggested that anthropogenic (human-influenced) factors are more frequent and severe, with long-lasting impacts, than natural causes. These factors include overfishing, pollution, and habitat destruction. However, anthropogenic factors have been the main cause of declining trends, with overfishing singled out as one of the main causes (FAO, 2024). Overfishing was ranked by the respondents as the principal cause of the deteriorating trends for Nile perch from the key informant interviews (Table 3).

Overfishing of Nile perch is expected to continue, considering its economic significance. Similarly, Kimani *et al.* (2020) reported that, in addition to the high value of Nile perch, the growing trade in fish maws contributed to an increase in overfishing.

Nile perch overfishing is caused by different factors, including high fishing effort and illegal fishing practices. The study results indicated an inverse relationship between fishing effort and Nile perch biomass (*Figure 9*). This relationship strongly suggests that overfishing is a key driver of stock depletion. As the number of fishers increased, growing by approximately 938 annually (*Figure 10*), the biomass declined, indicating unsustainable exploitation, with a prediction of the biomass being depleted if the effort exceeded 140,000 fishers.

Likewise, the CPUE for both individual fishermen (*Figure 11*) and fishing boats (*Figure 12*) sharply declined, reinforcing the fact that overfishing was occurring. The CPUE for fishermen continued to decrease over time, but had an R^2 of 0.53, thus, rendering the effect of the number of fishermen moderate on the stock over the years. However, with an R^2 of 0.82, the CPUE per boat showed a particularly concerning trend, indicating that pressure from the growing number of fishing boats was mostly responsible for the 82% reduction. The rate of increase in fishing effort suggests a near-commercial collapse of the fishery if current trends continue at the same rate. However, the worrying state is prevented by conditions such as fishermen not being able to reach all points of Lake Victoria. This is emphasised by Musinguzi et al. (2020), who state that the high fecundity of 16.8 million and the pseudo-protected zones offshore, where fishing is limited by distance and weather severity, save the Nile perch, which is thought to be in worse condition than it is currently.

The rate of fishery decline is also slowed by the fact that fishing may not happen regularly because of limiting factors such as the scarcity of Nile perch during the breeding season of competing species (*Sydonodontis* species), harsh weather, inadequate bait, and evasion of law enforcement officers during operations. Furthermore, vessel-gear combinations determine the fishing effort.

According to *Figure 13*, the gear combinations studied were only for legal fishing gear. However, two dominant modes of propulsion, paddle and motorised outboard engines, were considered. Sese paddle boats using long lines (SP-LL), Sese paddle boats using gill nets (SP-GN), Sese boats using gill nets (SMS-GN), and Sese motorboats using long lines (SMS-LL). Of these, SMS-LL had the highest catch rates, indicating that gear efficiency influences exploitation levels. Gill net use on motorized boats has decreased as a result of the hooks' increased effectiveness as fishing gear. According to Mkumbo and Marshall (2014), fishermen are increasingly using small hooks on long lines instead of large-meshed gillnets because they are more successful at capturing Nile perch.

It is crucial to remember that motorised boats target deeper places, which are home to legal-size Nile perches, while paddle boats mostly explore shallow waters and stay away from deep waters. Similarly, Mpomwenda et al. (2022) reported that the number of motorised vessels increased by more than threefold from approximately 3000 to over 10,000 between 2004 and 2014. However, the number of paddled increased by 40% between 2004 and 2006, but their numbers stagnated later. Furthermore, the paddled watercraft targeted both tilapia and Nile perch in equal amounts, whereas the motorised vessels primarily targeted Nile perch (>80%). Consequently, motorised boats have higher catch rates than paddle boats. However, paddled boats are reported to target undersized fish in shallow waters (Mitullah, 2011).

The rise in Dagaa and the revival of haplochromines (*Figure 7*), alongside the decline in Nile perch, indicate an ecological shift. Haplochromines, which were nearly wiped out due to Nile perch predation in previous decades, reappeared, possibly due to reduced pressure from the Nile perch. This shift could reflect changes in the lake's trophic dynamics, where reduced Nile perch abundance allows smaller fish species to thrive. This agrees with Hauge, Cleeland, & Wilson (2009), who suggest that overfishing causes changes in the stability of marine ecosystems. They further mentioned that fishing can cause changes in trophic relations by affecting the abundance of predators, prey, and competitors and their genetic makeup (Balirwa, 2007). This phenomenon was also reported by Nyamweya *et al.* (2023), who explained that the increase in haplochromines was due to predator-prey relationships between the Nile perch (predator) and haplochromines (prey). Mkumbo and Marshall (2014) mentioned that management should give the Nile perch fishery the highest priority.

To manage fish species separately, Kayanda et al. (2009) proposed creating a fishery-specific concept in Lake Victoria to ensure the sustainable exploitation of all species. Therefore, as we manage the Nile perch, we should also be concerned about their diet, that is, small pelagic fish.

Furthermore, overfishing causes size differences among species. Kayanda et al. (2009) stated that the Nile perch's size at first maturity (*Table 2*) varied with time, reflecting changes in population dynamics. In the 1960s and 1970s, Nile perch matured at smaller sizes, likely because of lower population densities. However, when biomass was high in the 1980s and the early 2000s, maturity sizes increased significantly (females reached up to 93.3 cm). By 2007, maturity sizes decreased again (females: 58 cm, males: 52.5 cm), suggesting a response to declining biomass, possibly due to overfishing. This pattern aligns with fisheries theory, which states that fish mature earlier under high fishing pressure to compensate for reduced survival rates. This is consistent with a similar study by Yongo *et al.* (2018), who noted that the Nile perch stock sizes in Lake Victoria had significantly decreased. In a similar study by Namwenya *et al.* (2023), the size distribution of Nile perch was primarily composed of classes under 50 cm TL, accounting for 93.3%; the modal length was observed to be 20 cm. The species biomass was only 6.6% accounted for by Nile perch greater than 50 cm. This is an indicator that most of the harvested biomass is from juvenile stock.

Lake Victoria, being an open-access fishery, the licences only do partial regulation since any fisherman can access the resource without a license. Etiegni *et al.* (2010) and LVFO (2021) highlight that as there is limited control over the number of licences one can possess, licences serve more as a tool for revenue collection than as a regulatory tool. There are also no restrictions on the quota or quantity of fish that can be harvested.

As such, the number of fishermen and boats has increased every year. Similarly, LVFO (2021) indicates that one-third of the boats are now motorised, which is three times more than they were in 2000. Additionally, the number of gears increased. For instance, the average number of hooks per boat surpassed 300, and the number of hooks quadrupled.

In addition, illegal fishing, which was not studied in this project, affects Lake Victoria's stock. According to Etiegni et al. (2010), illegal, unreported, and unregulated (IUU) fishing makes up 15–25% of all captures worldwide; hence, it is not exclusive to Uganda. For Nile perch, many fish catches are under IUU because fishers have shifted towards the use of small-sized hooks and net meshes to target smaller Nile perch. The same pattern is hinted at by Nyamweya et al. (2023), who blame the growth of the fish maw business in East Africa and Asia for the high fishing pressure on Nile perch, particularly large Nile perch.

Despite the critical economic, social, and nutritional roles of fisheries in Uganda, the sector faces growing challenges. The Nile perch fishery, which is the leading fish exporter, is experiencing a notable decline in stock levels (Namwenya et al., 2023). Onyango (2007) highlights the consequences of declining Nile perch stocks, such as lower earnings, job losses, and the closure of several fish processing industries, while others operate at a lower capacity.

The reduction of Nile perch raw material is not unique to Uganda; factories and fishers face the same dilemma of a lack of full-size Nile perch in Kenya (Mitullah, 2011).

Nile perch exports accounted for 60% of the region's total fish exports in 2020, necessitating careful management. In 2021, the beach value of Nile perch was USD 164,000, more than twice the value of Dagaa (*Figure 6*), despite Dagaa registering higher volumes. Guloba *et al.* (2023) highlighted the contribution of the fisheries sector to the national GDP as being 3% and 12% to the agriculture GDP. Kimani *et al.* (2020) add that Nile perch contributes 60% to the country´s export earnings, whereas Mpomwenda *et al.* (2022) state that perch products account for over 90% of the exports in Uganda. Its contribution to food security will also be affected. The contribution of Nile perch to the economy is at risk and is expected to diminish with its decline.

6. CONCLUSION

In conclusion, it is not enough to say that there is a decrease in Nile perch catches, but there is a rapid decrease, with most of the catches being below the minimum legal slot size of 50 cm. The Nile perch stock has been overfished and will probably collapse by 2033 if the status quo is not managed quickly. This is evident from the reduction in stock size, reduced size at maturity, and increase in the biomass of lower trophic level fish (haplochromines and Dagaa). However, the trend will be augmented by the increasing demand for high-value Nile perch and its products, increased fishing effort, destruction of breeding grounds, climate change, and pollution, among others. The national economy will thus be affected, with a reduction in revenue, loss of jobs, and distortion of the fish ecosystem. As a result, the lake fishery runs the risk of reverting to its pre-Nile perch status, when low-value fish made up most of the catch.

As mentioned in the recommendations below, there is a need for immediate action with a focus on reducing overfishing, as it has been isolated as the main cause of the decline.

7. RECOMMENDATIONS

i. Emphasis should be placed on regulating open access to the Nile perch fishery while focusing on eliminating illegal fishers and fishing gear.
ii. Closed seasons should be embraced during spawning periods to enhance the stock recovery.
iii. Demarcating, protecting, and managing breeding areas should be prioritised.
iv. Providing alternative livelihoods is a remedy that is worth considering. Activities such as fish farming and small-scale poultry farming are possible options.
v. Illegal fish trade should be controlled, especially the trade of small-sized fish both locally and regionally.
vi. Co-management should be reinstated by revamping BMUs.
vii. Value addition should be promoted, including the full utilisation of Nile perch and the production of high-value products such as fish oil.
viii. The data collection system requires improvement, and facilitation should be provided for research and annual data collection studies. Transparency and data sharing on public websites should also be emphasised.
ix. Ecosystem-based management should be practiced; however, Nile perch should be prioritised over other fish species. For example, haplochromines, which form a large part of the Nile perch diet, should be fished in limited numbers.
x. Strengthening fisheries monitoring: Technology, such as the use of drones for monitoring, can be adopted to cover the existing staff aps and increase efficiency in MCS.
xi. Enforce regulations on Dagaa fishing to reduce Nile perch bycatch.
xii. Strong political and financial support for these activities should be secured.
xiii. Regional collaboration should also be strengthened, as Lake Victoria is a shared resource.
xiv. Future research should investigate additional stressors, such as climate change, pollution, and habitat degradation, to develop a holistic recovery strategy for Nile perch stocks.
xv. Other necessary studies include the current stock biomass of Nile perch in Lake Victoria, bio-economical models to predict its future trends, and studies to increase the economic efficiency of Nile perch as a strategy to reduce pressure on Nile perch stocks while maintaining economic efficiency.

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