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REVIEW ARTICLE

Mind the gaps for the best practices: Enhancing the management of Lake Victoria fisheries resources

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Abstract

Fisheries resources face a confluence of socio-ecological challenges, the resolution of which requires interdisciplinary scientific information for sustainable utilization and management. The present study assessed gaps and challenges in Lake Victoria fisheries resources management for better research focus, policy formulation and improved governance of the fishery towards sustainability. Using key informant interviews and a plenary discussion with trans-disciplinary experts regarding Lake Victoria fisheries research, management and policy sectors, the present study identified current management challenges, gaps and priorities. The present study results indicate a constantly increasing fishing effort, poor enforcement of existing regulations and pollution and invasive weeds pose the greatest threats to the sustainability of Lake Victoria's fisheries resources. Policy gaps include a lack of regulations on emerging technologies (e.g. cage culture) and an absence of implementation guidelines and framework for some existing policies. The aspects and gaps of each challenge are discussed, using available literature for the lake, with policy and capacity interventions recommended under each section for sustainable management of Lake Victoria fisheries resources.

KEYWORDS
challenges, gaps, Lake Victoria, management, sustainability

1 | INTRODUCTION

Lake Victoria, shared by Kenya, Tanzania and Uganda, constitutes one of the largest freshwater fisheries in the world (Aura, Nyamweya, et al., 2020). The lake provides a blended artisanal-commercial fishery largely traditional in terms of fishing methods and vessels. At the same time, it also supports a large Nile perch (*Lates niloticus*) fish export industry, coupled with substantial domestic trade in many endemic species. Its annual economic contribution to the region is about €710 million. A significant proportion of economic benefits resulted from introduction of the fast-growing Nile perch in the 1960s, exports of which now contribute more than a third (€250 million) of the total fisheries income (LVFO, 2017). The fishery is estimated to directly or indirectly support the livelihoods and protein availability for around 40 million people (Mkumbo & Marshall, 2015).

Understanding the Lake Victoria fisheries requires an understanding of the Nile perch ecology and conservation, wherein the native species-based fishery has been diminishing in response to intense fishing (Aura et al., 2013; Nyamweya et al., 2016; Powell, 2020). The cichlids *Oreochromis niloticus* (L), *Oreochromis leucosticus* (Trevawas), *Coptodon rendalii* (Boulenger) and *Coptodon zillii* (Gervais) were also introduced in the early-1950s and late-1960s during the colonial era (Ogutu-Ohwayo, 1990). The introduction of Nile perch was intended to improve the fisheries, as well as provide a sport fish to attract tourism. The Nile perch took some 20 years to become established in the lake and changed the fisheries scenario in the 1980s into a multi-million-dollar commercial fishery that accounted for 90% of the fish exported by the surrounding countries (Kenya, Uganda and Tanzania) (Odongkara et al., 2005).

The economic windfall from the introduction of Nile perch in Lake Victoria came with an ecological price. The introduction provides one of the most dramatic examples of the negative impacts on endemic fishes from introducing exotic fish species into a lake (Njiru et al., 2005). The explosion of Nile perch population led to a dramatic decrease in fish species diversity and biomass. Nile perch has been credited for the disappearance of >200 species of haplochromines, and the decline of other native species such as *Oreochromis esculentus*, *Oreochromis variabilis*, *Bagrus docmak*, *Alestes* spp, *Barbus* spp. and mormyrids (Marshall, 2018). The fishery has changed from a multispecies fishery to one of three species of commercial importance, namely, *L. niloticus*, *O. niloticus* and *Rastrineobola argentea* (Njiru et al., 2005). The complete change in commercial fish species is easily attributed to the introduction of new species in Lake Victoria (van Zwieten et al., 2016). The negative correlation between introduced and native fish species through predation and competition mechanisms in Lake Victoria has been previously highlighted (Aura et al., 2013; Nyamweya et al., 2016). Accordingly, understanding and making targeted decisions on the population dynamics of the three major fisheries and other fishes in relation to the Lake Victoria ecology will help to balance the ecological integrity of the lake basin for further development.

Fish cage culture has been introduced into Lake Victoria as a promising venture that might increase fisheries productivity, offer employment and promote socio-economic well-being (Aura, Nyamweya, et al., 2020; FAO, 2016; Musinguzi et al., 2019). Ideally, cage farming offers high production per unit volume of water, with a relatively low investment per unit of production providing prospects for high profitability (Edwards, 2015). Its use of existing water bodies reduces pressures on land use, while also significantly reducing the capital costs relative to land-based aquaculture (Aura et al., 2018). The lake currently contains approximately 3000 cages stocked with at least 3 million tilapias valued at US$ 12 million (Njiru et al., 2018). Unsuitable site selection for cage installations, however, might result in resource use conflicts and disturbance of fish breeding grounds. Additionally, eutrophication from waste fish feed, and pollution from degraded cage equipment and materials, might enhance the growth of algae and invasive water hyacinth, requiring coordinated management to reduce the potential negative environmental impacts (Njiru, Knapp et al., 2018). The undesirable impacts of cage culture should be controlled or mitigated within the lake through an adaptive and integrated management framework for industry sustainability.

Furthermore, Lake Victoria has been experiencing ecosystem changes over the last couple of years that have impacted ecological systems and climate-sensitive activities (Kizza et al., 2009). These changes have been attributed to anthropogenic and climate shifts in the East Africa region, making human and climate–lake interactions a critical issue (Nyamweya et al., 2016). Timely data and information will play a critical role in helping to better understand how these shifts will impact different fisheries sectors. Details of food security, land use planning, hydrologic modelling and resource management planning, for example will require robust fisheries data for predictive purposes (Saah et al., 2019). Accordingly, national and transboundary development plans use resource data as a basis for understanding changes in a country's natural capital which, in turn, forms the basis for budget priorities and allocations (Foley et al., 2005; Jung et al., 2006; Running, 2008). Fisheries resource information also underpins the requisite models used by governments to inform the level of preparedness and build resilience to various impacts (Gong et al., 2013; Imaoka et al., 2010; Tolentino et al., 2016). In addition, fisheries resource managers and stakeholders can use the resource information to develop sustainable harvest management plans, integrate biodiversity conservation for sustainable management and develop appropriate mitigation measures (Potapov et al., 2019). Nonetheless, some important information about the lake's resources are often disjointed and nation-specific, thereby requiring integration in a regional database as the basis for a holistic management approach for the shared resource.

The Lake Victoria region is experiencing an acceleration in the rate of land cover change, population growth and ecosystem changes that are impacting the long-term sustainability of key ecosystem services, including food, water and energy (Mgaya & Mahongo, 2017). Local decision makers are using infrequently updated transboundary and national maps, with little ability monitor in a timely or integrated fashion (Balirwa et al., 2003). Furthermore, existing classification systems do not always meet the needs of fisheries stakeholders, data products are often not widely shared between agencies and institutions, and accuracy assessment is often lacking. The users and developers of this needed information are typically from different organizations exhibiting different priorities and differing technical understandings (LVFO Pers. Comm., 2019). These differences and variations pose a variety of challenges that often create roadblocks to the effective use of appropriate fisheries data for policy formulation, planning, management and other decision contexts. Such inconsistencies hinder more widespread and effective use of existing data to contribute substantially to policy formulation, planning, management and other processes wherein effective, transparent and defensible decisions are known to lead to better real-world outcomes.

Lake Victoria is well known globally for its productive fishery and ecological attributes (Aura, Nyamweya, et al., 2020). The status of Lake Victoria has been previously discussed with the objective of examining how the physical, chemical and biological properties of the

lake determine the response of the ecosystem to human activities at national and regional levels (e.g. Balirwa et al., 2003; Nyamweya et al., 2016; van Zwieten et al., 2016). Nevertheless, minimal attention has been given to a comprehensive fisheries needs assessment of the lake resources for the purpose of ascertaining who, where and what sustainability aspects are required for future goals and preferences. Accordingly, the present study undertook a targeted assessment of the needs required to define sustainable utilization of Lake Victoria fisheries resources, wherein the perspectives of interdisciplinary experts and existing data were integrated to enhance our understanding of the sustainability of fisheries resource use in Lake Victoria.

2 | MATERIALS AND METHODS

2.1 | Study area

The current study focused on Lake Victoria in East Africa. With a surface area of over 68,500 km^2, Lake Victoria is the world's second largest freshwater lake. It lies at an elevation of 1134 m above sea level and is relatively shallow, with a maximum and average depth of about 84 m and 40 m, respectively (Aura et al., 2013). The highly indented shoreline of the lake is estimated to be about 3440 km in length (LVFO, 2017).

2.2 | Data sources and analyses

The present study mainly utilized Key Informant (KIs) interviews to collect primary data. Key informant interviews are most useful when first-hand information is required on sensitive topics and/or complex phenomena, and where expert opinion in a specific subject of investigation is appropriate (Aura et al., 2021). Unlike questionnaires and focused group discussions, KIs can candidly discuss issues without the limitation of ignorance or group dynamics (Aura et al., 2018). As in-depth answers were required in the present study, experts with particular knowledge and understanding of the lake's fishery, its management and the policy environment were preferred. Thus, selection of respondents was purposive, prioritizing the lake stakeholders from research, management, operations (e.g. fishers) and policy sectors (Aura et al., 2021). A total of seven KI interviews were conducted, comprising four research scientists, one policy/regulatory director, one fisheries manager and one regional Beach Management Unit (BMU) leader. The institutional affiliation of the respondents included Kenya Marine and Fisheries Research Institute (KMFRI), National Fisheries Resources Research Institute (NaFIRRI), Kenya Fisheries Service (KeFS), State Department of Fisheries, Aquaculture and the Blue Economy—Kenya, Lake Victoria Region BMU Network and the Lake Victoria Fisheries Organization (LVFO).

The present study also utilized consolidated expert deliberations from a Lake Victoria socio-environmental synthesis

TABLE 1 Socio-demographic features of participants in the socio-environmental synthesis workshop for Lake Victoria in Maryland, USA, conducted under the stewardship of the National Socio-Environmental Synthesis Center (SESYNC), February 2020

Title	Number	Country	Institution	Sector
Resource manager	1	EAC	Lake Victoria Fisheries Organization	Fisheries management
Professor	2	USA	Cornell University, University of Nebraska—Lincoln	Academia/research
Programmer	1	USA	University of California, Santa Cruz	Environmental modelling
Toxicologist	1	USA	Centre for Global Health, University of Oregon	Environmentalist/research
Researcher	6	Kenya, Uganda, Tanzania	KMFRI, NaFIRRI, TAFIRI	Lake Victoria Research (fisheries, limnology and socioeconomics)
Ethnographer	1	Kenya/USA	Northwestern University	Advocacy/NGO - Lake Victoria
Health official	1	Tanzania	Nelson Mandela Africa Institute of Science and Technology	Public Health

workshop conducted under the stewardship of The National Socio-Environmental Synthesis Center (SESYNC), which took place in Maryland, USA in February 2020 (SESYNC – Pursuit 3, 2019). The workshop was convened for Lake Victoria research, management and policy actors in order to identify the lake's management challenges, emerging socio-ecological issues and policy gaps. The goal of the pursuit was to gather a diverse, international, multi-disciplinary team of scientists to examine the social and environmental connections and feedbacks that impact and define aquatic resource use in Lake Victoria. As the workshop setting was multi-institutional and multi-disciplinary, comprising senior level researchers, resource managers and academicians, their discussions provided a holistic dimension to the management framework (Table 1).

The expert opinions were corroborated by published literature and discussed within broader lake management themes, namely, balancing conservation and fishery development, climate change, ecosystem and biodiversity benefits, health and environment and governance, management and financing. Accordingly, the major aspects of the lake fisheries resource management were integrated within a socio-ecological framework in order to guide the description of Lake Victoria fisheries resource issues.

As the data acquired from all the sources were largely qualitative, thematic analysis was used to gain insights from the responses. The data were grouped into categories relating to management and policy challenges, emerging themes in the fishery and possible interventions. Radar diagrams, word clouds and tabular categorizations were subsequently used for ease of presentation of findings.

3 | RESULTS

3.1 | Socio-demographic features

The key informants exhibited an average work experience of 11 years in different sectors of Lake Victoria fisheries resource utilization and management. Their experience ranged from three to 24 years, indicating a generally long duration of involvement in various aspects of the lake's resources. Knowledge and interaction with a resource is key to gaining an holistic understanding of the lake systems (Edwards, 2015). Thus, the relatively long work experience of the respondents could enhance the credibility of their insights into Lake Victoria's management efforts and needs (Etiegni et al., 2017). Furthermore, given the KIs included two research directors, one fisheries management director, one policy/regulation deputy director and a BMU network leader in the EAC region, these KIs were able to respond appropriately to lake-wide issues requiring policy attention. In fact, 86% of the KIs affirmed Lake Victoria resources faced significant ecosystem and socio-economic challenges requiring policy and management interventions. They then provided a thematic priority (ranked) list of policy and management challenges requiring interventions in Lake Victoria, as summarized by proportions (Figure 1).

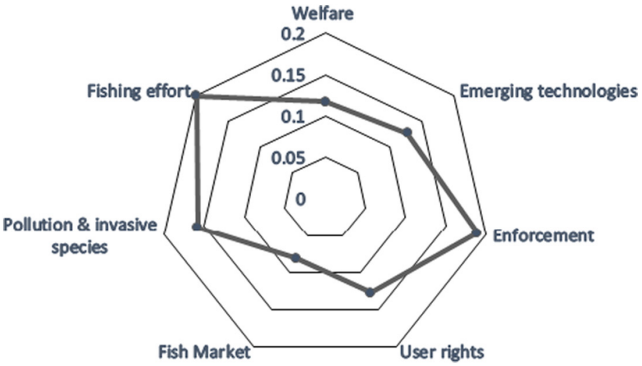

FIGURE 1 Radar plot for relative percentage ranks of Lake Victoria management and policy challenges (lower percentage = lower relative priority; higher percentage = higher relative priority)

3.2 | Management challenges and policy gaps

According to the respondents, fishing effort was the major challenge to management and policy efforts for Lake Victoria, a finding supportive of previous literature reports (Nyamweya et al., 2016). It included issues of gear selection, catch limits and illegal, unregulated and unreported (IUU) fishing activities. Enforcement, the second-most rated challenge, related to implementation of existing policies and laws, as well as rampant corruption that compromised the efficiency of arrests and prosecution of fisheries' offenders. The fish market and the welfare of producers (capacity building and support, security and insurance, health and safety and gender issues) were perceived to be the lesser challenges to management and policy for Lake Victoria.

Furthermore, all the KIs unanimously perceived gaps in the current policy and management documents for Lake Victoria. The cited gaps included the absence of regulations for such emerging technologies as cage culture, lack of clear implementation guidelines and capacity for some policies that affected their enforcement, and the dilemma of user rights in light of increasing diversity of investments in the lake by various users (Figure 2). From the fish word cloud, the most glaring policy gap mentioned by most respondents related to cage culture, which currently lacks any policy guidelines for the lake.

3.3 | Expert discussions

The experts engaged in a plenary discussion entitled 'Sharing perceptions of Lake Victoria'. The facilitators asked each expert similar questions during the discussion and collected their individual responses (Table 2). It was clear from the responses that the experts had different perceptions of key issues related to the lake. The greatest challenges affecting the lake, as perceived by the experts, related to the welfare of actors, poor enforcement of regulations, emerging technologies, challenges of open access and environmental and climatic issues. As the experts varied on their preferred priority areas and gaps, their answers fell into six different categories as shown in questions three and four (Table 2).

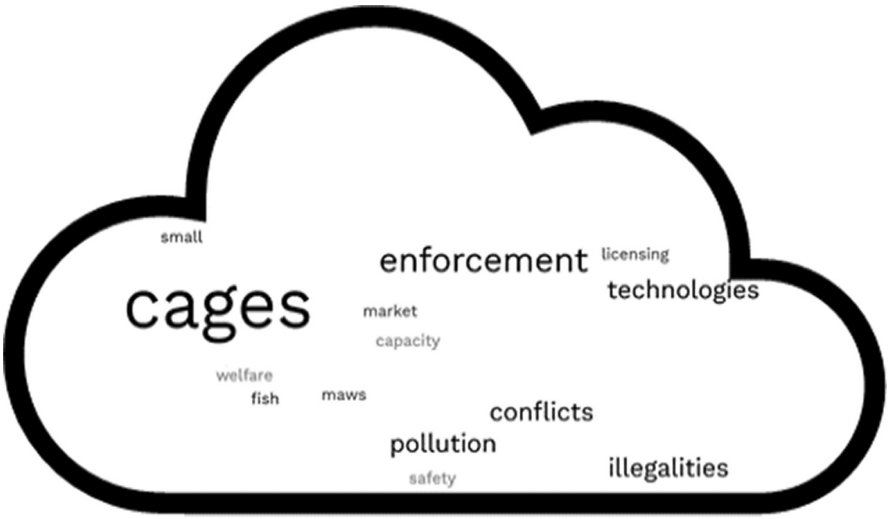

FIGURE 2 Word cloud showing perceptions of prioritization of management policy gaps in Lake Victoria regulations (repetitions = higher priority)

TABLE 2 Selected perceptions of experts on Lake Victoria socio-ecological system

No.	Question	Summary responses
1	What do you or your organization see as the greatest challenges facing the Lake Victoria region?	• Welfare of actors (capacity building and support; security and insurance; health and safety; gender issues) • Emerging technologies (e.g. cage culture) • Enforcement of regulations and corruption • User rights & resource use conflicts (e.g. open access) • Fish market and trade • Pollution and invasive species • Fishing effort, catch and Illegal, unregulated and unreported fishing activities (IUU) • Climate change
2	What are the greatest assets of the Lake Victoria region?	• Use values (e.g. water abstraction; fishing) • Non-use values (e.g. cultural identity; tourism) • Hydrological balance • Aquatic biodiversity (flora and fauna) • Maritime activities (transport and trade) • Artisanal fishing communities
3	What areas (either regions, sectors or programme areas) do you prioritize?	• Cage culture • Control of pollution and invasive weeds • Post-harvest loss reduction in dagaa fishery • Control of fishing effort • Climate smart technologies • Alternative livelihoods • Data management • Water quality and fish safety
4	For which regions, areas, sectors, do you think exhibit the largest information gaps?	• Safety of aquatic fish food • Resource use conflicts • Cage fish farming • Fishing technologies • Data management • Resource valuation
5	Do you think there are regional variations? If so, what do you think they are?	• Implementation strategies (regulations) • Socio-cultural diversity • Investment priorities • Market niches

4 | DISCUSSION

Sustainable management of the Lake Victoria ecosystem and its resources depends on how well the riparian states will respond to current socio-ecological challenges and policy gaps relating to the lake (Edward et al., 2011; Etiegni et al., 2017). To this end, potential strategies, policy gaps and challenges in Lake Victoria are discussed in the following section.

4.1 | Adaptive management strategies

Lake Victoria has exhibited significant species and ecosystem changes over the past 20 years (Figure 3). As an example, while the Nile Perch was the most caught fish species from the year 1980 to 2006, dagaa catches have been the highest since the year 2006 to the present time, as reported by Aura, Nyamweya et al. (2020a). The lake has also experienced a re-emergence of haplochromine species since the early years of the Millennium. Fish catches had generally increased by nine times in 2015 compared with 1980, although the tilapine species landings have generally decreased. Based on the results of the present study (Figure 1), fishing effort and poor enforcement of fishing regulations were ranked as the highest management challenges for the lake. A good and sustainable management regime would need to capture the fish catch dynamics exhibited by species landings as exhibited by the long-term trends. Necessary readjustments in the management regulations should be applied at the species level as a means of reflecting changes or declines in their abundance to facilitate their sustainable utilization. Current fishing regulations for Lake Victoria only focus on the fishing gear and size of the species, having no regulations regarding catch quantities or number of fishers. By expert intuition, this management strategy is insufficient in controlling the challenge of fishing efforts since as the number of fishers increase, fish catches will also increase in spite of fishing gear regulations. Thus, the introduction of allowable catch quantities representative of species abundance and dynamics is a proposed as a viable management option.

Similarly, Lake Victoria has experienced a sharp increase in cage aquaculture since the year 2005. A study by Aura et al. (2018) indicates cage culture in the lake could lead to increased eutrophication, as well as resource use conflicts with capture fisheries. To date, however, there still are no clear regulations to guide this investment for Lake Victoria, meaning current management regulations must be updated to reflect the lake's changing fisheries environment in response to the introduction of cage culture. Furthermore, efforts should be made within the proposed regulations to define eutrophication limits the lake can withstand without compromising its ecological health. The limits should also facilitate guidance regarding the number of allowable cages in Lake Victoria. This aspect is important because a hydroacoustic survey by the LVFO (2017), as well as findings by Mkumbo and Marshall (2015), indicate an emerging instability in Lake Victoria's ecosystem since 2010, which increases the possibility of an ecological tipping point in the foreseeable future. Although the present study indicates the primary drivers of the ecological challenges for Lake Victoria are mainly economic and institutional, other external stressors such as climate change and decreased water levels have also been found to exacerbate the situation (Njiru et al., 2006). Noting that cage culture has been increasing in Lake Victoria for up to 15 years without regulation, the policy environment is not adequately responsive in a timely fashion to changes in the lake, thereby furthering the need for a more adaptive management approach.

4.1.1 | Increasing fishing effort

The Lake Victoria fisheries are open access whereby fishers have unrestricted access to the lake's fisheries resources. For a lake exhibiting an instability in fish stocks, this culture poses a challenge to the management of fishing effort within the lake. A more favourable management option is required to guarantee the sustainability of this fishery (Aura, Nyamweya, et al., 2020). One possible approach could be a rights-based fisheries management strategy as an option to open access fisheries in the lake (Edward et al., 2011), which would require the delineation of fishing areas and possibly a determination of a sustainable fishing effort based on the optimum number of fishers, vessels and/or gears.

Fisheries managers still use paper-based records to capture information about fishers and fishing boats during the licencing

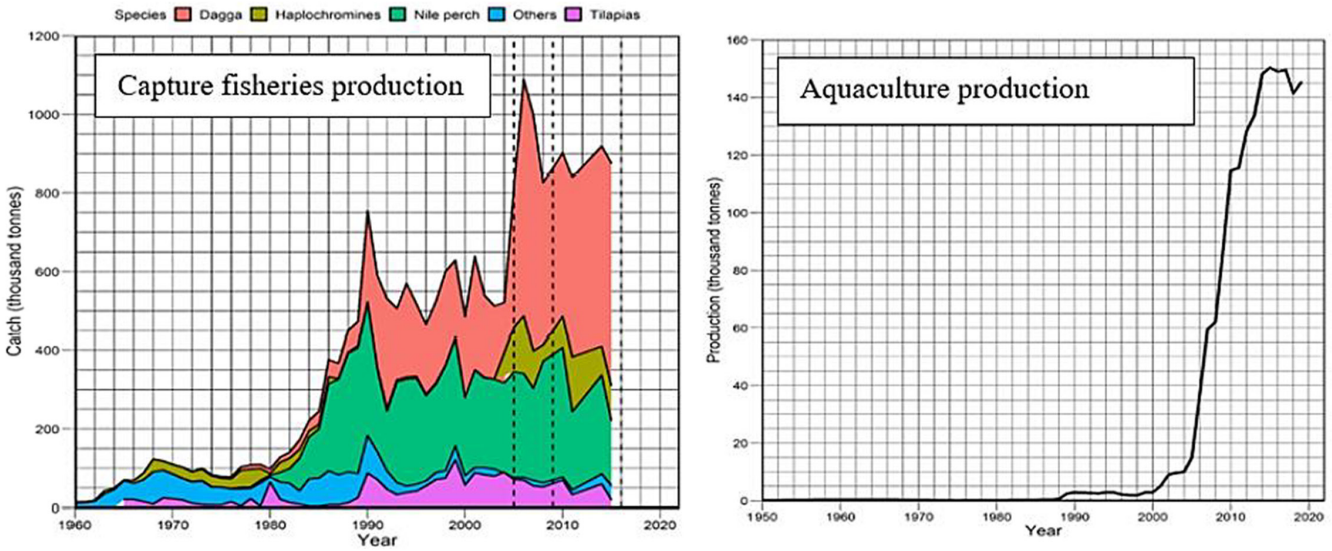

FIGURE 3 Trends in capture fisheries and cage culture production in Lake Victoria (LVFO, 2021)

process. Paper-based records, however, are tedious to update within an open access fishery wherein entrance and exit is currently barely regulated. Accordingly, such challenges as double entries of fisher details in various landing sites (especially for migrant fishers), and a relatively slow process of establishing a fisher's history when they migrate to a new beach management unit (especially in the case of banished illegal fishers) are rampant (Aura, Nyamweya, et al., 2020). Fisheries co-managers in Lake Victoria require a shared database for resource users, and can utilize the benefits offered by information technology systems to improve their record keeping and sharing (Aura et al., 2019). Accordingly, a departure from paper-based fisher records to an integrated computer-based system is proposed to enhance accuracy, accountability and sharing among fisheries resource managers.

Onyango et al. (2021) and Glaser et al. (2019) observed that fishing pressures in Lake Victoria are also associated with unemployment, poverty and a rapidly growing population in the lake basin. The reality is that poor, rural riparian communities with have limited livelihood options are nevertheless highly dependent on Lake Victoria fisheries resources. Thus, any effort to regulate fishing pressure should also be responsive to the livelihood needs of these communities. This translates into developing a good balance between the economics and the ecology of resource utilization. Regulations that might limit access of fisheries resources by riparian communities should be equally tempered with support for viable livelihood options for the excluded resource users. Thus, the resource management environment for Lake Victoria should incorporate attractive alternative livelihood strategies that could divert labour mobility to capture fisheries. Although cage culture has proven to be viable in this regard, it has largely attracted wealthy investors that can afford capital and operational costs (Aura et al., 2018). Accordingly, fishers need better strategies to mobilize resources for alternative livelihoods such as cage culture or pond aquaculture, which could be possible through the promotion of fisher co-operatives and increased financial or credit access for them.

4.1.2 | Poor enforcement of regulations

Riparian governments should improve the capacity of fisheries agencies to enforce existing regulations. Although many resources are devoted to reviewing existing fisheries laws and regulations, the enforcement institutions continue to suffer from understaffing, lack of modern equipment and skills, minimal funding and rampant corruption. Fisheries institutions often grapple with minimal resource allocations despite the vast contribution of fisheries and its multipliers to the government economies (Aura et al., 2019). Beach Management Units (BMUs), the community-based co-management organs of fisheries management for Lake Victoria, often depend on projects from development partners to undertake any meaningful developments within their landing sites. With no government funding and little revenue collected through fees on fish landings, these units are unable to implement required infrastructural developments at fish landing sites. Many BMUs still operate without a building, electricity, running water or modern fish processing equipment. The Lake Victoria Environment Management Program (LVEMP), a World Bank funded project implemented in different phases since 1996, has been main avenue through which many landing site facilities have been built across the lake's sectors. Nevertheless, financial and resource limitations continue to curtail the ability of these agencies to effectively enforce fisheries regulations. In his study of the economic and financial impacts of Lake Victoria fisheries, Onyango et al. (2021) recommends improving management cost recovery and revenue allocation framework in the fisheries sub-sector. He further argues this would increase funding to the sector, thereby facilitating re-investment in infrastructure at fish landing sites. Accordingly, the results of the present study suggest increased funding from the governments is required for effective Monitoring, Control and Surveillance (MCS).

4.1.3 | Pollution and invasive weeds

Rapid population growth, urbanization and industrial growth have led to environmental degradation to Lake Victoria water quality, noting increasing nutrient levels and decreased water clarity, despite relatively steady primary productivity levels (Juma et al., 2004; Simoniti & Perrings, 2011; Sitoki et al., 2010). This environmental degradation has also negatively impacted the lake's water availability (Awange et al., 2013; Koutsouris et al., 2010).

The main pollutants are carried by rivers and streams draining into the lake, with the near-shore areas being heavily polluted (Juma et al., 2004; Nantaba et al., 2020; Wang et al., 2012). The main pollution sources are raw and partially treated municipal and industrial effluents (Chirikona et al., 2015; Kimosop et al., 2016; Oguttu et al., 2008), contaminated urban surface runoff, unsanitary conditions of shoreline settlements (Nzengya, 2015) and pollutants transported to the lake in eroded sediments, particularly nitrogen (N) and phosphorus (P) (Kundu et al., 2017; Shayo & Limbu, 2018), synthetic pyrethroids and organophosphates (Musa et al., 2011). These pollutants result in the fisheries being negatively impacted by coliforms of faecal origin, oxygen-demanding organic substances, heavy metals and pesticide residues (Kundu et al., 2017).

More generally, other degradation activities are attributable to enrichment of the lake from water body encroachment via settlement and agricultural activities, urban-riverine-basin challenges such as over-abstraction, increased watershed degradation and increased water pollution from industries, livestock, agriculture, mining and urban runoff (Shayo & Limbu, 2018). If not addressed, receiving water bodies such as urban streams will deteriorate in both quality and quantity, with a resultant imbalance in the lake fishery ecosystem (Aura, Odoli, et al., 2020). The results of the present study indicate that with clear delineation of watershed needs, public–private partnerships (PPPs) can be bridged to improved water quality over the short term for human use through treatment plants and/or low-cost filters and treatment, as well as long-term preventative

measures to reduce future nutrient and pollutant loadings to the lake (Njiru, Knapp et al., 2018; Obosi, 2017).

Environmentally, invasive weeds such as the water hyacinth, which have gained much attention for their undesirable socio-ecological impacts (Mailu, 2001; Ongore et al., 2018; Villamagna & Murphy, 2009), could actually be considered for alternative uses, examples being biogas and energy production, making of mats, production of furniture, fish feed, biodegradable paper and charcoal, among others (Reddy & D'Angelo, 1990). Such alternative uses, however, might only be realized after review of the Obnoxious Weed Act that prohibits economic use of aquatic weeds such as water hyacinth.

4.2 | Policy gaps

The most glaring policy gap in Lake Victoria is related to cage culture. Cage culture has been introduced at Lake Victoria as a promising venture to increase fisheries productivity, offer employment and promote socio-economic well-being (Aura, Nyamweya, et al., 2020; FAO, 2016; Musinguzi et al., 2019). Ideally, cage farming offers high production per unit volume of water, with relatively low investment per unit of production, thereby providing prospects for high profitability (Edwards, 2015). Its use of existing water bodies reduces pressure on land use while significantly reducing capital costs relative to land-based aquaculture (Aura et al., 2018).

Lake Victoria currently contains approximately 3000 cages stocked with at least 3 million tilapias valued at US$ 12 million (Njiru, Aura et al., 2018). Unsuitable site selection for cage installations, however, might result in resource use conflicts and disturbance of fish breeding grounds. Furthermore, eutrophication resulting from waste fish feed and pollution from degraded cage equipment and materials might enhance the growth of algae and invasive water hyacinth, thereby requiring coordinated management to reduce the resulting potential negative environmental impacts (Njiru, Knapp et al., 2018). The undesirable impacts of cage culture must be controlled or mitigated within the lake through an adaptive and integrated regulatory framework for the industry's sustainability. However, there are still no clear regulations to govern cage investments in the lake, which needs to be developed urgently using scientific information from the region's research organs and sources.

5 | CONCLUSION AND RECOMMENDATIONS

The present study has established existing management challenges and gaps in Lake Victoria resource management that must be addressed. These mainly include the cage culture industry, the influence of pollution, climate change and invasive species, and a poor enforcement framework for existing policies and laws. Furthermore, a proper balance between conservation and development must be achieved for sustainability in cage establishments within the lake. To this end, there exist several recreational, innovative and value addition opportunities remaining untapped for Lake Victoria, but which could reduce fishing pressures and increase incomes by providing alternative livelihoods. Accordingly, the present study recommends:

1. Development of appropriate policy and regulations to ensure sustainability in cage culture investments in Lake Victoria;
2. More investment towards alternative livelihood opportunities such as aquaculture and non-use livelihood opportunities in the lake such as eco-tourism; and
3. Enhancement of the capacity of the Lake Victoria management institutions through financial and infrastructural support that will facilitate the efficient enforcement of existing regulations.

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CONFLICT OF INTEREST

The authors have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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