Assessing cage fish farming practices in Lake Victoria, Kenya, for sustainable lake utilization and community well-being

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Abstract

The proliferation of cages in the Great Lakes of Africa is accompanied by the potential socio-economic outcomes which underscores a significant trend in the aquaculture industry that is supplementing the traditional fisheries production. In light of these considerations, the study herein was undertaken to comprehensively evaluate the potential impacts of high intensity of cages at a site in Lake Victoria, Kenya with the leading numerical focus. Anyanga Beach has consistently registered the highest number of cages, making it a focal point for assessing the broader implications of cage aquaculture in the region. The survey exclusively targeted cage aquaculture farmers with the use of structured three-part questionnaires involving the particulars of cages, socio-demographic features and farm operations and investments. Majority of the cages surveyed were found to be locally fabricated, accounting for 93.3% (n = 28), with the main materials used for constructing cage frames being metallic. The use of locally sourced and fabricated materials may indicate a practical approach motivated by considerations such as ease of accessibility, cost-effectiveness and locally-sourced knowledge. Most of the cage aquaculture farmers reported managing between 1 to 6 cages (n = 20; 66.7%), with the most common dimensions being small-sized measuring 2.5 m × 2.5 m × 2 m, suggesting the need to create cohorts of firms that could lead to the development of cooperatives and ease the implementation of regulatory frameworks. Fish escapees from the cages were also reported, with approximately 60% of respondents indicating that they had experienced such incidents. Such occurrences pose a significant risk, which may result in genetic disruption and adversely impacting the overall fisheries. The study recommends for the need to enhance awareness and engagement with key institutions to foster a more informed and compliant approach, while ensuring that practice of cage culture intensification is aligned with legal and environmental guidelines.

Keywords: cage culture, intensification, biosecurity, Great Lakes, Kenya

Introduction

Aquaculture is the world's fastest-growing food industry, with over 600 aquatic species farmed globally (FAO, 2018). Over the past two decades, this sector has undergone a remarkable transformation, shifting from a relatively minor role to playing a mainstream part in the global agri-food system (Simmance *et al.,* 2022). Forecasts indicate that future expansion of fish food production will mainly come from aquaculture (Anderson *et al.,* 2017; Aura *et al.,* 2018). For instance, aquaculture production is projected to increase from 60 million in 2010 to 100 mt in 2030, and up to 140 mt by 2050 (FAO, 2020). In Africa, the fisheries and aquaculture sectors support the livelihoods of approximately 6 million people, a number that has been steadily increasing over the last decade. In many Sub-Saharan African (SSA) countries, including Kenya, aquaculture is dominated by both extensive and semi-intensive practices (Béné *et al.,* 2016), resulting in low unit production and often falls short of meeting the projected demand for the growing human population. Since 1970, aquaculture production has been exceeding the growth rate of any other food production system, including poultry, beef, pork, dairy or cereal crops, growing at an average annual rate of 8.4% worldwide (FAO, 2016). This growth has been attributed to the increase in cage aquaculture (Hall, 2011).

Cage culture, a component of aquaculture, is the practice of growing fish in existing water resources while enclosed in a net cage that permits free passage of water (Aura *et al.,* 2021). It is an established and profitable system in many countries and is considered a major remedy to increase fish supply in the face of declining wild fish stocks to meet rising demand for fish. Cage culture globally is hugely varied, ranging from subsistence-level, holding of a few kilos of fish in small nets, to salmon farms producing more than 5,000 mt per year. Cage culture was introduced in several African countries in the 1970s, though only few of these early attempts proved to be sustainable (FA0, 2016). Since 1995, the production of farmed fish in SSA has expanded more than sixteen fold (FAO, 2018), mostly due to the expansion of tilapia cage aquaculture (Satia, 2011). Lake Victoria in Kenya (Aura *et al.,* 2018), Lake Victoria in Uganda (Blow and Leonard, 2007), Lake Volta in Ghana (Asmah *et al.,* 2016), Lake Kariba in Zimbabwe (Berg *et al.,* 1996), and Lake Malawi in Malawi are all notable examples of the rapid spread of cage fish farming in SSA (Blow and Leonard, 2007).

Despite the existence of aquaculture through pond and cage fish farming for supplementing the supply of white proteins, Kenya still fails to meet the demand, necessitating the importation of fish from other countries (Munguti *et al.,* 2014; Opiyo *et al.,* 2018). This imbalance has economic ramifications, since a decline in fish supply leads to increased demand, hence driving prices up (Brander, 2007). The dwindling diversity of fish in Lake Victoria has aggravated the problem, with some species, such as *Oreochromis niloticus*, becoming increasingly scarce (Njiru *et al.,* 2018). This shift in species availability has had a considerable impact on household feeding choices in Kenya's riparian counties along Lake Victoria. For instance, species such as Omena (*Rasterineobola argentea*), which were earlier regarded inferior, are now considered a superior food option. Reduced fish harvests have an impact not only on local diets, but also on the fisheries food system's ability to provide sustainable nutrition, because fish is an important source of nutrients recognized in most national dietary requirements (Burlingame and Dernini, 2012).

The proliferation of cages in Lake Victoria, accompanied by the documented potential benefits, underscores a significant trend in the aquaculture industry (Aura *et al.,* 2018; Orina *et al.,* 2018). Unfortunately, a concerning aspect is the inconsistent adherence to the cage aquaculture guidelines by some investors during cage installation in the lake. To ensure maximum economic benefits and long-term sustainability of the cages, it is important to understand the biosecurity measures employed and the sources of inputs for cage aquaculture business. In light of these considerations, this study was undertaken to comprehensively evaluate the potential impacts of cages in Lake Victoria, with a specific focus on Anyanga Beach. Notably, Anyanga Beach consistently registers the highest number of cages, making it a focal point for assessing the broader implications of cage aquaculture in the region.

Materials and methods

Study area

Figure 1 shows where the study was carried out in the Kenyan potion of Lake Victoria. Lake Victoria provides important ecosystem services to over 40 million inhabitants in the three riparian countries, *viz.* Kenya, Tanzania and Uganda. These include fisheries, transport and water for domestic, agricultural and industrial uses (LVFO, 2015). The lake is the largest tropical and the second largest freshwater lake in the world with a surface area of 680,000 km^2. The surface is partitioned between Tanzania (51%), Uganda (43%) and Kenya (6%) (Aura *et al.,* 2013). In Kenya, it is the second largest inland water body after Lake Turkana, covering 4,100 km^2 with an average depth of 6-8 m (within the Winam Gulf) and a maximum depth of 70 m (in the open waters) (Odada *et al.,* 2004). The lake is monomictic, experiencing complete annual mixing between the months of June to August (MacIntyre, 2012). In addition to the annual mixing, wind induces strong shear in the lake bottom and vigorous vertical mixing within the gulf especially around the mid-Gulf area (Okely *et al.,* 2010; Guya, 2013).

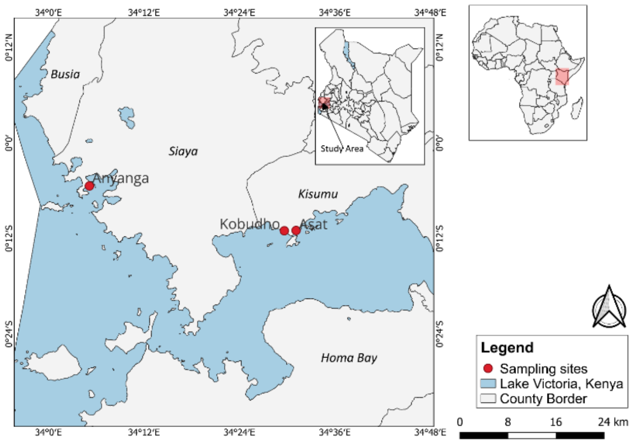

Figure 1. Map showing the focal point of cage aquaculture activity at Anyanga, Asat and Kobudho in Lake Victoria, Kenya (Source: Authors).

Data collection and analysis

The survey was conducted in the Kenyan waters of Lake Victoria in November–December 2023. The specific sites were Anyanga beach in Siaya County and Asat and Kobudho beaches in Kisumu County. The selection of these sites was deliberate, taking into account their significance as representative sites for cage aquaculture operations within the region. The survey

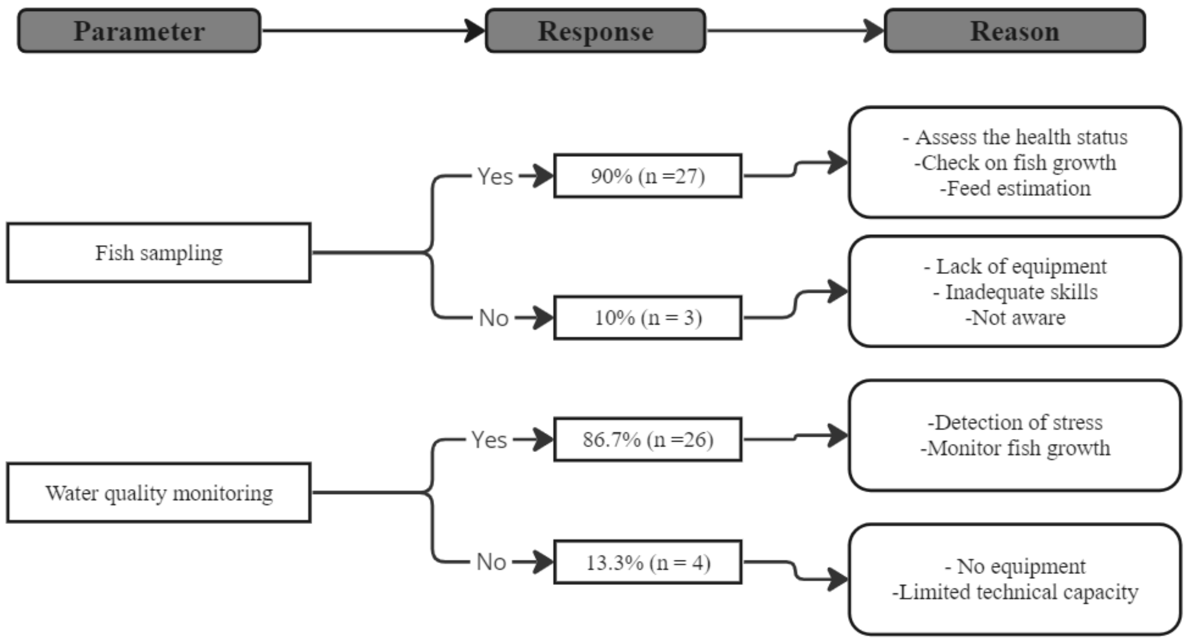

Figure 2. Respondents' feedback on the operational practices adopted within their enterprises.

exclusively targeted cage aquaculture farmers and it involved the use of structured three-part questionnaires (particulars of cages, socio-demographic features and farm operations and investments), and interviews as well as mapping the presence of cages in the lake. Global Positioning System (GPS) coordinates indicating the cage culture sites and the number of cages at all the stations were recorded. All the socioeconomics data were entreted into Microsoft Excel spreadsheets and eventually analyzed using Microsoft Excel and R statistical software version 3.6.0.

Results and Discussion

Socio-demographic characteristics of individuals in cage aquaculture operations

Table 1 shows the characteristics of cage farmers. Majority of the cages were individually owned (n = 28; 93.3%), and among the respondents, 53.3% were cage owners (n = 16), 26.7% were managers (n = 8) and 20% were feeders (n = 6). About 97% (n = 29) were males suggesting that the cage industry is male-dominated (Aura *et al.,* 2018). The majority of the respondents were between the age of 18 to 35 (n = 20; 66.6%), signifying a substantial representation of the youth. Some youth were reported as cage owners suggesting a trend where the industry is attracting young generation as an alternative source of employment (Aura *et al.,* 2018; Obiero *et al.,* 2022). Most of the respondents are married (n = 22; 73.3%), a trend suggesting that married individuals may be drawn to the cage aquaculture business due to the stable employment opportunity provided by the sector, enabling them acquire income to support their families (Orina *et al.,* 2018).

Education levels varied among respondents with 60% (n = 18) having attained primary education, potentially influencing various aspects with cage aquaculture establishments, including the nature of responsibilities performed and decision-making processes. The high number of respondents with primary-level education may imply that these people are largely involved in practical and hands-on tasks within the venture, contributing to the overall operational dynamics of cage aquaculture activities. Furthermore, their level of education may affect their access to and use of information, thereby influencing managerial practices and decision-making in the business (Odende *et al.,* 2022). In addition to their involvement in cage aquaculture operations, a considerable proportion of respondents (73.3%, n = 22) were fishermen. This dual position shows that the respondents have a diverse skill set, with experience in traditional fishing practices supplemented by participation in cage aquaculture business (Aura *et al.,* 2018; Anjejo, 2019). This may indicate an expansion of livelihood activities, implying a potential shift toward more sustainable and economically viable practices in the broader fisheries sector.

Table 1. Socio-demographic characteristics of cage aquaculture farmers in L. Victoria, Kenya.

Variable	Category	n	Proportion
Gender	Male	29	96.70%
	Female	1	3.30%
Age	18 - 25	10	33.3%
	26 - 35	10	33.3%
	36 - 45	8	26.7%
	46 - 55	1	3.3%
	>56	1	3.3%
Marital status	Married	22	73.3%
	Single	7	23.3%
	Widow/er	1	3.3%
Education	Certificate	1	3.3%
	Diploma	1	3.3%
	Primary	18	60.0%
	Secondary	9	30.0%
	Undergraduate	1	3.3%
Main occupation	Businessperson	3	10.0%
	Fish trader	3	10.0%
	Fisherman	22	73.3%
	Community Health Services	1	3.3%
	Welder	1	3.3%

Dynamics of cage aquaculture operations

Majority of the cages surveyed were found to be locally fabricated accounting for 93.3% (n = 28), with the main material used for constructing cage frames being metal. The use of locally sourced and fabricated materials may indicate a practical approach motivated by considerations such as ease of accessibility and cost-effectiveness of these materials (Obwanga *et al.,* 2020). Metal frames are used because they are affordable and durable (Aura *et al.,* 2018; Mwamburi *et al.,* 2021). Furthermore, it was observed that cage net materials were mostly sourced locally, with the primary supplier being Monasa Limited Company in Kisumu. This selection of local suppliers emphasizes the use of locally available resources, contributing to the sustainability of the industry (Orina *et al.,* 2018).

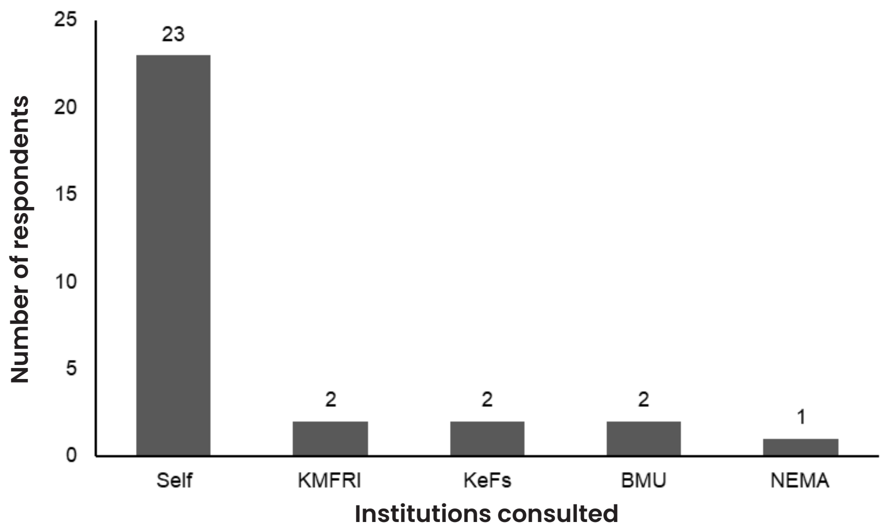

Figure 3. Institutions consulted before installing the cages in the Lake. (KMFRI = Kenya Marine and Fisheries Research Institute; KeFs = Kenya Fisheries Service; BMU = Beach Management Unit and NEMA = National Environment and Management Authority).

Most of the cage aquaculture farmers reported that they are managing between 1 to 6 cages (n = 20; 66.7%) with the most common dimensions being 2.5 m × 2.5 m × 2 m. Majority of the cages were active with only a few reported as dormant, primarily attributed to the recent fish harvesting activities. This observation is a common operational cycle within the cage aquaculture system, in which periodic dormancy aids in the management of fish populations as it leads to flushing of accumulated nutrients within the cages, thus improving the overall effectiveness of the aquaculture practices (Mwamburi *et al.,* 2021).

Key Practices in Cage Aquaculture

The farmed fish is Nile tilapia and the fingerlings are mainly sourced locally from hatcheries in close proximity. The fingerlings stocked are mainly mono-sex (n = 28; 93.3%). Farmers stocked between 600 to 70,000 fingerlings depending on the size of the cage. This adaptability could be influenced by factors such as available resources, market demand or specific production goals (Opiyo *et al.,* 2018; Orina *et al.,* 2021). About 96.7% (n = 29) of the farmers reported having only one production cycle per year, a finding that corroborates similar studies conducted on cage aquaculture in Kenya (Aura *et al.,* 2018; Orina *et al.,* 2018; Obiero *et al.,* 2022). In terms of fish health, 90% (n = 27) monitor fish growth mostly after every 3 months while 86.7% (n = 26) test the water quality after every 2 months but they do this individually through observation. This reliance on observational water quality assessment raises concerns about the accuracy of the monitoring process. In addition, no proper water quality equipment is used for monitoring, which suggests a potential gap in awareness regarding the importance of accurate water quality monitoring for improved fish production. Given its critical role in fish growth (Opiyo *et al.,* 2018; Okechi *et al.,* 2022; Musa *et al.,* 2023), accurate monitoring of water quality is essential.

Figure 2 shows a schematic representation of respondents' feedback onto the operational practices adopted within their practices. The diagram is divided into three main parts: the first part lists parameters such as whether respondents perform sampling and water quality monitoring. The second part displays the responses, which are categorized as either "yes" or "no". The third part details the reasons behind respondents' choices, including why they do or do not engage in fish sampling and water quality monitoring. In addition, reasons for not sampling or monitoring are provided if the response is negative.

Market dynamics of farmed fish in cages

The respondents indicated that the size of fish preferred by the market ranged between 0.25 kg to 0.5 kg, although the average weight of harvested fish is usually 0.5 kg (n = 20; 66.7%). This small disparity can be a sign that farmers are deliberately maximizing their output to satisfy the needs and expectations of the market (Aura *et al.,* 2018; Opiyo *et al.,* 2018; Obiero *et al.,* 2022). The annual harvest of fish varied among respondents, with majority harvesting between 100 to 500 kg (n = 12; 40%). This variation implies a diverse scale of operations among cage aquaculture farmers (Aura, 2020; Orina *et al.,* 2021), which could be attributed to factors such as the number of cages per farmer, stocking density and general management practices (Njiru *et al.,* 2019; Kyule-Muendo *et al.,* 2022; Okechi *et al.,* 2022). Understanding these differences is critical for tailoring support mechanisms and interventions to the individual needs of farmers operating at various scales of production.

Biosecurity management

About 60% (n = 18) of respondents reported having experienced fish diseases in their farms, with symptoms such as white spots and scratches on the skin. According to Mwainge *et al.* (2021), these infections may stem from bacterial, parasitic or fungal sources. Fungal infections have been reported to occur when fish are stressed or have wounds on their skin, which often lead to the development of white, cotton-like growths on the skin (Opiyo *et al.,* 2020; Mwainge *et al.,* 2021). The identified symptoms were managed at the farm using salt bath. The use of salt is a recommended measure to control the spread of infections in the production systems (Sadhu *et al.,* 2014; Opiyo *et al.,* 2020; Mugendi *et al.,* 2022).

Fish escapees from the cages were also reported, with approximately 60% of respondents indicating that they had experienced such incidents. Such occurrences pose a significant risk, which may result in genetic disruption - adversely impacting the overall fisheries (Arechavala-Lopez *et al.,* 2018). The escape of fish from cages not only has immediate consequences for the individual fish but also raises concerns about potential long-term effects on the genetic integrity of local fish populations and the ecological balance of the fishery (Blow and Leonard, 2007). In addition, 40% (n = 12) of surveyed farmers reported instances of fish mortalities. Fish mortalities can have implications for aquaculture operations and the broader fisheries environment. The causes of fish mortalities vary and may include factors such as disease outbreaks, poor water quality, nutritional issues and stress during handling or sampling (Kyule-Muendo *et al.,* 2022; Otachi *et al.,* 2022).

Cage aquaculture guidelines

The cages were installed at approximately 100 m to 600 m (n= 18; 60%) with an average depth of 6.2 m. Notably, the majority of farmers (76.7%, n = 23), used self-sourced information from fellow cage farmers and personal knowledge to locate suitable cage installation sites (Fig. 1), while some respondents sought advice from external entities such as the Kenya Marine and Fisheries Research Institute (KMFRI, n = 2; 6.6%), Kenya Fisheries Service (KeFS, n = 2; 6.6%), National Environment Management Authority (NEMA, n = 1; 3.3%) and Beach Management Units (BMU, n = 2; 6.6%). The relatively low consultation rates indicate that the legally mandated agencies in charge of cage aquaculture establishment were not adequately consulted. This suggests a potential communication breakdown between farmers and regulatory entities, which might hinder proper management of cage aquaculture (KMFRI-ABDP Unpublished Report, 2022).

Figure 3 shows the number of respondents that consulted relevant institutions before installing the cages in the Lake. Before installing cages, investors are required to consult with key institutions overseeing the management of the Lake's resources. This process entails obtaining the necessary approvals from responsible institutions such as KMFRI, KeFs, NEMA and County governments. Furthermore, establishing a Memorandum of Understanding with the BMUs is critical for compliance and coordination (LVFO, 2018).

Conclusions and Recommendations

This study provides an insight into the dynamics of cage aquaculture development in Lake Victoria, Kenya. The growth of the sector offers economic opportunities, particularly for the youth, who have a significant representation in the venture. However, concerns exist about adherence to cage aquaculture regulations during installation, which could jeopardize long-term sustainability of cage aquaculture development. Enhancing awareness and engagement with key institutions could foster a more informed and compliant approach to cage aquaculture establishment, ensuring that practices align with legal and environmental guidelines. This study highlights an opportunity for improved communication channels and knowledge dissemination within the cage aquaculture community.

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