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Integration of mapping and socio-economic status of cage culture: Towards balancing lake-use and culture fisheries in Lake Victoria, Kenya

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Abstract

Mapping of lacustrine aquaculture and socio-economic assessment of cage farmers operations can be employed as decision support tools in an integrated fashion for fisheries management. We simultaneously mapped and reported the location of cages and characterized socio-economic and indicators of cage farming in Lake Victoria, Kenya. Structured questionnaires and interviews from cage farmers generated socio-economic data and management information. Vital water quality parameters were analyzed in selected sampling sites. Cage culture was found to be a male-dominated activity with the majority of owners aged <45 years (n = 23; 59%). Siaya County had the highest cage establishments (n = 20) and number (n = 1,343). Proximity to Dominion Farm, pioneers of cage culture, as well as decreased presence of water hyacinth (*Eichhornia crassipes*) coverage may have contributed to high cage numbers in Siaya County. The only species cultured was *Oreochromis niloticus*. Most cage establishments (n = 30; 76%) were located within 200 m from the shoreline. Total operational costs for a cycle (8 months) amounted to USD 465,250 worth a total production value of USD 8,827,000, farmers often realizing a mark-up of >100%, indicative of its robust viability within "The Blue Economy" concept. With the increasing number of cages in the lake, there is the need for policy and regulations to guide its investment, both to protect local economies through improved business practices and to ensure sustainability for the lake ecosystem due to the likelihood of exacerbation in water quality deterioration in cage culture sites.

KEYWORDS
Blue Economy, cage culture, Lake Victoria, mapping, socio-economics

1 | INTRODUCTION

A major contributor to water flow in the Nile River Basin, Lake Victoria provides domestic, industrial, irrigation and power-generation water to Kenya, Uganda, Tanzania, Sudan and Egypt. The lake supports numerous opportunities within water transport, industrial, domestic and agriculture uses, and hydroelectric power generation for >30 million people in the basin and greater East Africa region (Abila, 2000). The lake basin has been designated as an economic growth zone by the East African Community (EAC) (Abila, 2000). Yet, to facilitate sustainable growth, both the socio-economic and water quality impacts must be incorporated into management decisions and priorities shared between countries in the region (Pacini & Harper, 2016; Whittington, Wu & Sadoff, 2005).

Lake Victoria originally supported at least 12 major commercial fish species. However, multiple stressors such as over-exploitation, species introductions, eutrophication, pollution and habitat change have reduced the number of commercial fish species to only three. These comprise two introduced species Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*) (Hecky, Mugidde, Ramlal, Talbot & Kling, 2010) and one native fish species, the silver fish (*Rastrineobola argentea*) (Njiru et al., 2007). The catches and biomass of fish in the lake are currently dominated by the commercially less valuable species *R. argentea* and haplochromines, indicating that the catches of the Nile perch (*L. niloticus*) and Nile tilapia (*O. niloticus*) that are preferred for export and domestic consumption are declining (Hecky et al., 2010).

While natural fish stocks in Lake Victoria are declining from overfishing among other factors, demand for fish protein has been on a gradual increase as a result of rapid human population growth and awareness of benefits of eating fish (FAO, 2014, 2016). Aquaculture is viewed as an alternative to reducing the widening gap between fish demand and its supply. Sustainable development of aquaculture necessitates consideration of a combination of social, environmental and economic costs for local communities, as well as fisheries health. The contribution of sub-Saharan Africa to total global aquaculture productions relies mostly on the culture of tilapia (Kaliba, Ngugi, Mackambo & Quagrainie, 2007). Tilapia is the most preferred culture species due to faster growth, disease resistance and ability to withstand low dissolved oxygen (DO) levels (Fitzsimmons, 2000). Global tilapia aquaculture production volumes have escalated in recent decades, increasing from 28,000 tonnes in 1970 to 1.2 million tonnes in 2000, more than 2.5 million tonnes in 2007 (FishStat, 2009), and reaching 4.5 million tonnes in 2012 (FAO, 2014). In Kenya, tilapia capture production stood at 28,890 tonnes while culture stood at 18,072 tonnes for the year 2013 (FAO, 2014). With dwindling stocks (Standard Newspaper, 2016), new opportunities for investment under "The Blue Economy" concept and the potential return promised by cage culture, this new industry could help supplement capture production.

Blue economy, a concept that holistically focuses on valuation and sound utilization of resources linked to rivers, lakes and oceans has emerged and is important to economic growth and sustainable development (FAO, 2014). The lake is a regionally important resource as reserves of freshwater are dwindling away in most parts of the continent (Odada, Olago, Kulindwa, Ntiba & Wandiga, 2004). However, the asset base of Lake Victoria has diminished drastically due to overfishing, biodiversity loss and eutrophication (Njiru et al., 2007). In this case realizing the full potential of the lake requires a paradigm shift to embrace a new, responsible and sustainable approach that is more environmentally, socially and economically effective. This comes at a crucial time when the need for food and resources from the lake is increasing rapidly to meet the needs of the growing population. It is by widely consensus that the Blue Economy will fulfil the requirements to this approach majorly through the cage culture economic sector and the potential of people directly involved to act as resource users.

Fish cage culture dates back many centuries in China (Bao-Tong, 1994). Recently, this practice has expanded throughout the world because of its advantages. Cage farming has many advantages over other methods of fish culture, including: very high production per unit volume of water; relatively low investment per unit of production; the anticipated high profitability levels; the use of existing water bodies thus reducing the pressure on land; the requirements of relatively low capital outlay; the ease of movement and relocation; the reduced effect of drought on production in relation to the availability of water; and the flexibility of management (De Silva & Phillips, 2007; EL-Sayed, 2006). In most African countries, cage farming seems to be a new technology (FAO, 2004). In East Africa to some extent, cage farming of Nile tilapia has been practiced for a while now by the Source of the Nile (S.O.N), a private company based in Uganda. The profitability of cage culture depends, among other things, on which species is cultured, management level, input costs, and market prices. With the availability of scant data on cage culture operations, it is critical to evaluate robust tools with which to collect data on profitability across diverse environmental and socio-economic scenarios.

Generally, cage farming may have negative environmental consequences. The possible consequences associated with cage culture include discharge of particulate and dissolved nutrients through uneaten waste feed, faecal matter and excretory products (Masser, 2008). Such consequences may negatively impact the environment by causing anoxic conditions in sediments (due to organic enrichments) underlying the cages, thus changing invertebrate abundance and composition (Ngupula & Kayanda, 2010). Cage culture may cause eutrophication from nutrient enrichment of the water column (Ngupula, Ezekiel, Kimirei, Mboni & Kashindye, 2012). Farmed fish may escape and interact with other fish in the wild resulting into spread of diseases and parasites. All these may result in ecological simplicity, decrease in genetic diversity (due to genetic dilution), and increased mortality of the wild stocks. These impacts can, in turn, decrease local catch of wild fish, creating a conflict between cage culture and fishermen. Cage culture may also raise lake-use conflicts with fishers and boat transporters caused by increased demand of shared lake-space.

Cage culture in Lake Victoria dates back to 2005 when Dominion Farm Limited successfully harvested fish from cages constructed within their farm. Earlier trials had been undertaken by Lake Basin Development Authority (LBDA) in 1988 at Dunga beach in Kisumu (T. Guda, pers. comm.). In 2007, an EU funded cage culture project "BOMOSA" conducted trials on cage culture in small water bodies in Lake Victoria Basin. Cage culture attempts in Lake Victoria have also been done in Dunga and Obenge beaches by the Fisheries Cooperative Societies under the Beach Management Units (BMUs) in Kisumu and Siaya Counties, respectively, during 2008 and 2011–2013. This initiative was under the support of Association for Strengthening Agriculture Research in East and Central Africa (ASARECA) project. The ASARECA project was titled "building public private sector partnership to enhance the productivity and competitiveness of aquaculture in the Eastern and Central Africa (ECA) region". This cage culture consisted of small cages measuring 3.375–8 m^3. The fish species used in the trial included Nile tilapia (*O. niloticus*) and indigenous Victoria tilapia (*Oreochromis esculentus*). The trial at Dunga beach was aborted as a result of destruction of the cages by water hyacinth (*Eichhornia crassipes*) while the trial at Obenge was abandoned after the cages were destroyed from low quality netting and rocky substratum. Cage culture picked up in the lake in 2013 at Anyanga and Usenge beaches in Siaya County (J. Etyang', pers. comm.). Cages are now spread across the five riparian counties along the Kenyan side of Lake Victoria. The cage culture industry is now gaining ground at a faster pace in the lake, and in the face of isolated cases of fish kills in cages (KMFRI, 2016), there is need to develop baseline data to help in decision-making.

Although the current activities in cage farming constitute the infant stages of the industry, results have indicated that cage culture in Lake Victoria is a promising viable economic venture. Considerations that have to be taken into account include regulatory and environmental frameworks. This can be achieved through formulation of guidelines and Standard Operating Procedures (SOPs) to guide investments in cage farming and in the delineation of the lake for other uses. The objectives of these regulatory and environmental frameworks are to minimize resource use conflicts and protect the environment. They will also ensure safe and quality fish and fishery products. It is envisaged that cage culture may reduce poverty, provide food and boost income of the fishers, while reducing pressure on capture fisheries. Contribution from cage culture is anticipated to make inputs to the national and regional economies within the East Africa Community (EAC). Other benefits to be realized include industrial linkages involving sectors such as manufacturing, retail and wholesale trade, construction, transportation, and business services along the value chain. Therefore, it is vital to develop and map the socio-economic indicators of cage culture farmers for possible decision-making by the managers of the lake and fishery to ensure viability and sustainability. The present study aimed to map the presence of cages and to profile the socio-economic characteristics of their owners in Lake Victoria Basin, Kenya as baseline information to aid in the formation of policies to manage the integration of capture and culture fisheries.

2 | MATERIALS AND METHODS

2.1 | Study area

The investigation was carried out in the five riparian counties of Lake Victoria within the borders of Kenya (Figure 1). Lake Victoria provides important ecosystem services to over 40 million inhabitants

TABLE 1 Summary of demographic data from cage farmers in the assessment of socio-economic status of cage culture in Lake Victoria, Kenya

Characteristic	*n*	Proportion (%)
Gender		
Male	35	90
Female	4	10
n	39	100
Age		
≤25	2	5.1
26–35	10	25.6
36–45	11	28.2
46–55	9	23.1
>55	7	17.9
Education		
Primary	5	12.8
Secondary	17	43.6
Diploma	8	20.5
Degree	8	20.5
Masters	1	2.6
Cage Ownership		
Individual	24	62
Group	15	38

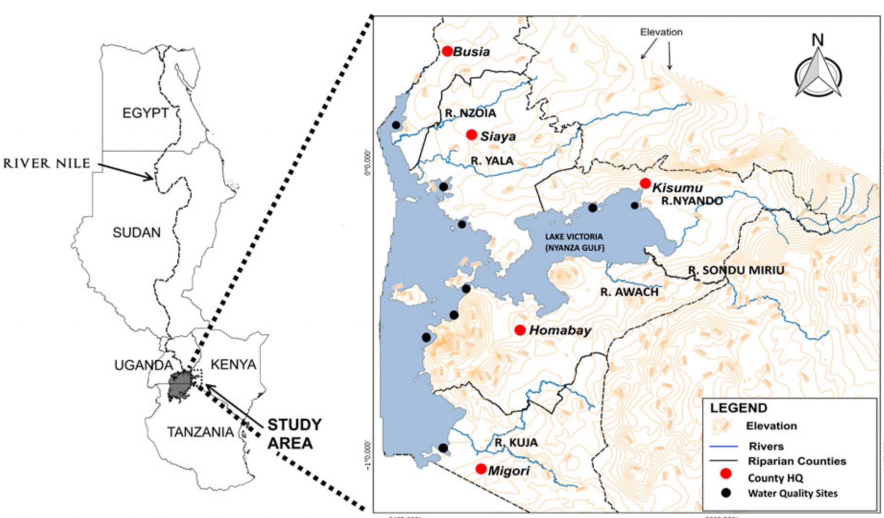

FIGURE 1 Riparian counties of Lake Victoria, Kenya where the survey was conducted. Mapping and socio-economics data were collected in the five riparian counties while a snapshot of water quality data were evenly spread in the lake in cage culture and fishing grounds sampling sites[Colour figure can be viewed at wileyonlinelibrary.com]

in the three riparian countries of Kenya, Tanzania and Uganda. This includes 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 68,000 km^2. The surface is partitioned between Uganda (43%), Tanzania (51%) and Kenya (6%) (Aura, Musa, Njiru, Ogello & Kundu, 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. In addition to the annual mixing, wind induces strong shear in the lake bottom and vigorous vertical mixing within the gulf especially around mid Gulf area (Guya, 2013; Okely, Imberger & Antenucci, 2010).

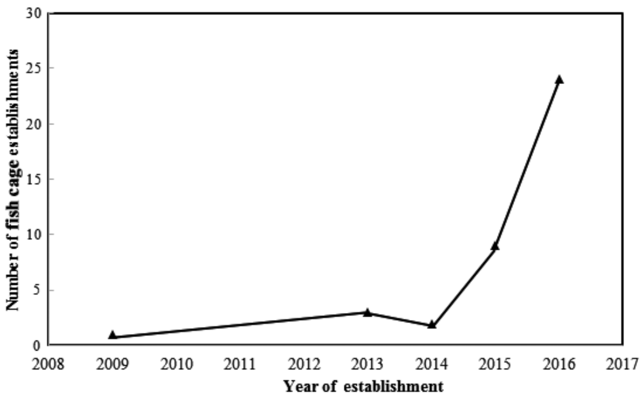

FIGURE 2 Number of fish cage establishments between the years 2008 and 2017 in Lake Victoria, Kenya

2.2 | Data collection

A survey was conducted in the Kenyan waters of Lake Victoria in November–December 2016. Survey teams targeted and interviewed 100% of cage culture farmers either in groups or as individuals. The study involved 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 marked cage culture stations as well as the number of cages at all stations. A snapshot of selected water quality parameters that are vital to aquaculture was undertaken in specified sampling sites (Littoral = Lit, Near cages = Nea, Off-shore = Off) for the assessment of water quality change due to cage culture establishments using standard sampling methods (APHA, 2005). For instance, most pristine waters have a 5-day biological oxygen demand (BOD) below 1 mg/L, moderately polluted waters have values in the range of 2–8 mg/L and water is considered severely polluted when values exceed 8 mg/L (APHA, 2005). A 5-day BOD in this case is a measure of the amount of oxygen that bacteria will consume while

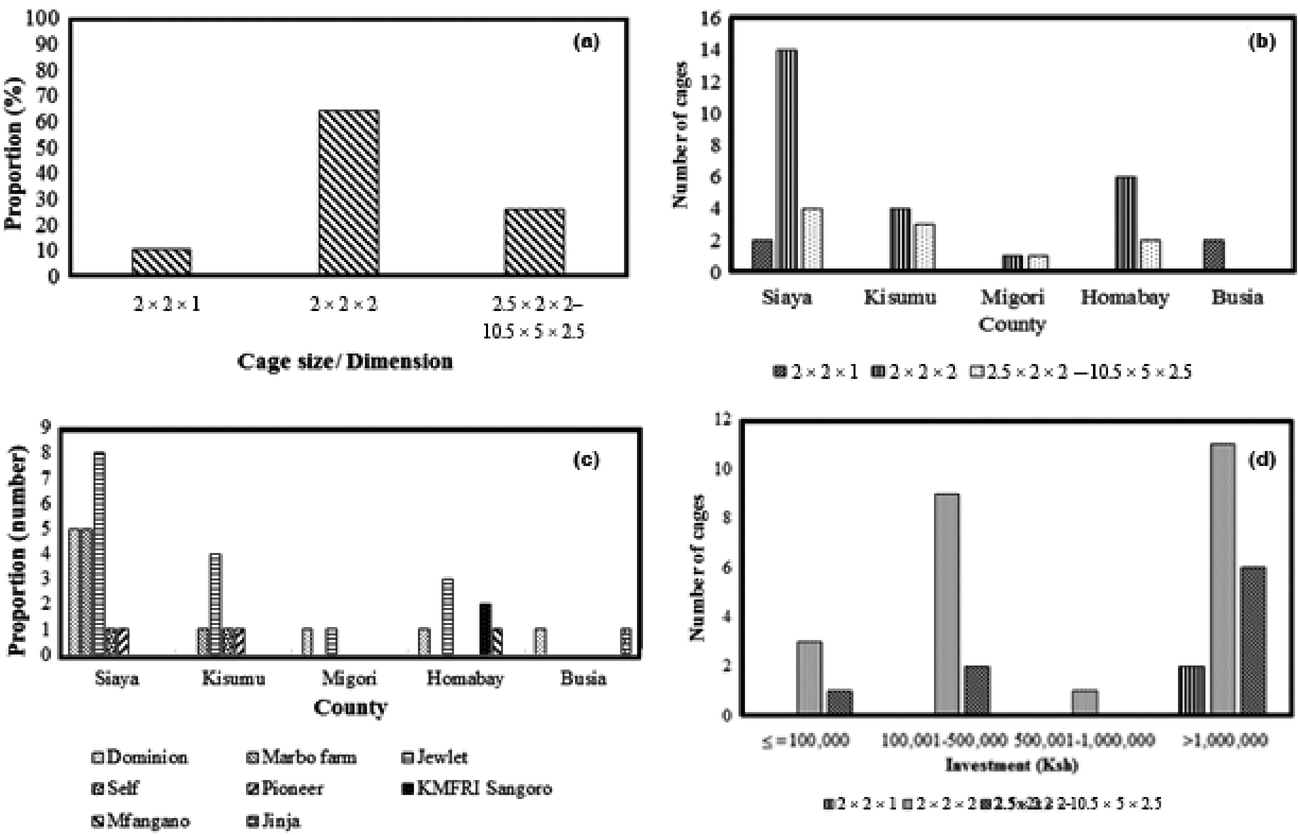

FIGURE 3 Cage culture farming in Lake Victoria, Kenya indicating (a) percentage distribution of cages by sizes; (b) distribution of cage sizes per county; (c) sources of fish fingerlings per county; and (d) investment in cages in relation to sizes

decomposing organic matter under aerobic conditions. The findings were compared with those of November–December 2014–2015 (previous 2 years) in selected fishing grounds (Fishing ground = Fsg) prior to the increment in the number of cage establishments in the lake.

2.3 | Mapping and data analyses

Structured questionnaires and interviews from cage culture farmers generated socio-economic data and management information. Primary data were entered in Microsoft Excel, coded and transferred to Statistical Package for Social Sciences (IBM-SPSS Inc. version 20.0 IBM Corp. Released 2011, IBM SPSS Statistics for Windows, Version 20.0, Armonk, NY, USA) for analysis. Descriptive and inferential statistics were used to summarize the data sets on socio-demographic indicators such as cage number, sizes, gender and investment. Cross-tabulations were used to assess groupings such as stocking densities of the five riparian counties and to categorize gender according to their education level. Correlation analysis were used to compare the relationship between the initial investment and fish harvest, amount of feed used, amount of wages paid to workers and productivity. Chi square test (χ^2) was applied to compare the relationship between education and productivity, type of feed and productivity, level of productivity and management measures of the cages by the farmers. Level of significance was at $p < .05$. Mapping involved geo-referencing of the number of cages per station based on the GPS locations established for cages presence in the lake using Arc GIS 10.0 (The Environmental System Research Institute, USA) for integration with socio-economic findings. Vital water quality parameters in aquaculture analysis was undertaken in selected sampling sites (Littoral = Lit, Near cages = Nea, Off-shore = Off) for the assessment of water quality change due to cage culture establishments and fishing grounds for capture fisheries. This was meant to obtain comparable gradient of selected water quality parameters in relation to the cages.

3 | RESULTS AND DISCUSSION

3.1 | Socio-demographic indicators

The survey covered 39 respondents which constituted the number of all cage establishments. Altogether, we counted 1,663 cages. Cage culture in the lake is a male-dominated industry as in capture fisheries (Table 1). Out of 39 respondents, only four (10%) were women. This follows the tradition in the local communities that women do not own property (Mbenga, 1999; Modesta & Wilson, 1996), especially in the fisheries sector where men play the dominant role in decision-making about fish production. Evidence has shown that despite all the cultural and economic diversity in many developing economies, the position and perception of women regarding the fisheries sector presents a considerable degree of commonality (Lwenya, Mbilingi, Luomba & Yongo, 2009). Thus, women feel unwelcome in the fishing sub-sector, but have little interest in participating anyway. In aquaculture, women feel discriminated against, but to a much lower extent. Fish processing is the one sub sector where women are over-represented, but mainly because they predominate in low-grade unskilled jobs (Ikiara, 1999; Medard, 2000; Medard, Sobo, Ngatunga & Chirwa, 2002; Mutoro, 1997).

Of the four women interviewed all of them had at least secondary education and above (Secondary $n = 1$; 25%, Diploma $n = 2$;

TABLE 2 Distribution of cage culture establishments in the five riparian counties of Lake Victoria, Kenya with their respective number of fish per cage

County/cage location	Number of cage establishments	Number of cages	Number of fish cage^{-1}
Busia	2	40	3,000
Bukoma	1	20	2,000
Mulukoba	1	20	1,000
Homabay	7	193	19,000
Dunga-H	1	1	2,000
Homaline	1	10	2,500
Likungu	1	4	2,000
Mitimbili	1	1	2,500
Nyandiwa	1	150	2,500
Rasira	1	11	5,000
Sindo	1	16	2,500
Kisumu	7	83	10,800
Asat	2	8	3,500
Bao	1	22	0
Dunga-K	2	15	4,800
Ogal	1	25	0
Othany	1	13	2,500
Migori	2	4	8,000
Matoso	1	1	6,000
Ngore	1	3	2,000
Siaya	20	1,343	44,500
Anyanga	3	726	7,000
Honge	1	12	2,000
Kamumbo	3	45	6,000
Lwanda DC	1	16	2,000
Nyenye Got Agulu	1	151	2,000
Oele	2	39	3,000
Sika	1	35	2,000
Siungu	1	45	2,000
Ugambe	1	170	2,000
Ulanda	1	20	2,500
Usenge	1	1	3,000
Utonga	2	59	4,000
Uwaria	1	16	2,000
Uyawi	1	8	5,000
Grand Total	39	1,663	85,300

Zero (0) implies not yet stocked.

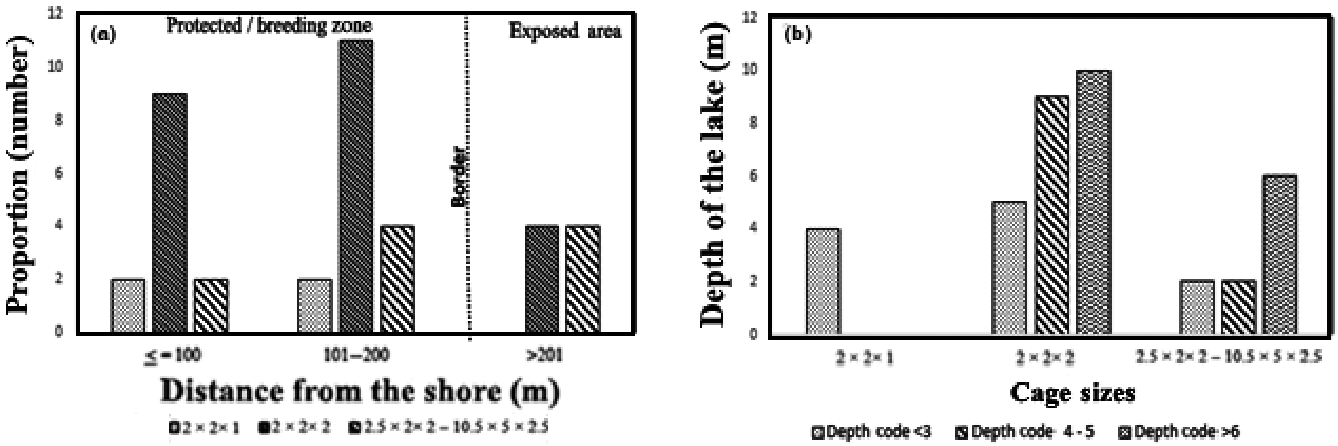

FIGURE 4 Location of cages in Lake Victoria, Kenya based on (a) distance from the shore; and (b) the lake depth in relation to cage sizes

50%, Degree *n* = 1; 25%). While few women were engaged in primary production in the fishery sector, they seemed to get involved at production and management levels due to their educational level.

Most of the cages were individually owned (*n* = 24; 62%), while others were owned by groups (*n* = 15; 38%). Thus, the sector appeared to attract individual investment more than groups.

In terms of fish farming as an occupation, the respondents were categorized as fulltime fish farmers (*n* = 17; 43%), part-time fish farmers (*n* = 10; 26%), fishers/fish farmers (*n* = 5; 13%) and others (*n* = 7; 18%). Others in this case referred to persons who owned cages but were neither fulltime fish farmers nor part-time fish farmers of fishers (fishers who regularly go fishing). In this case, they could have been teachers, shopkeepers or businessmen owning fish cages but were not part of the fish cage culture process. Mean household monthly income of the respondents was USD 2,832 month^{-1} with the majority of the respondents living in the rural areas (*n* = 32; 82%). Given that cage culture is rural based, this will improve rural livelihoods and hence spur economic development of the rural areas.

3.2 | Trends of cage culture establishment

The netting materials used in the cages were of polyethylene type. Most (*n* = 32; 82%) materials were sourced locally from Kisumu, mainly from Kavirondo, Monasa outlets and from Oele beach in Siaya County. All the cages were floating and mostly comprised of metal frames with only a few PVC frames noted.

The survey revealed that successful commercial cage culture technology was started in 2005 by Dominion Farm Limited. Earlier trials that failed had been undertaken by Lake Basin Development Authority (LBDA) in 1988 at Dunga beach in Kisumu (J. Etyang', pers. comm.). In 2008, low-input cage culture was tried at Obenge beach, Siaya County in 2007 in which the fish were stocked at low density without feeding (H. Charo-Karisa, unpublished report). After a slump, cage culture picked up in the lake in 2013 at Dunga and Anyanga beaches in Kisumu and Siaya Counties, respectively, (J. Etyang', pers. comm.) and the culture is increasingly being adopted (Figure 2).

Most of the cages had a dimension of 2.0 m× 2.0 m× 2.0 m (*n* = 1,031; 62%) with a total number of 2,000 fingerlings stocked per cage giving a total number of 2,062,120 fingerlings stocked at current capacity in Kenyan waters (Figure 3a). This cage size was preferred due to ease of assembling, feeding, monitoring and management. The bigger cage sizes were expensive to make, difficult to secure and launch on the site. Larger types of cages measuring 10.5 m× 5.0 m× 2.5 m frames were vulnerable to damage during strong winds hence heavy loses to the farmers. Thus, most farmers preferred the 2.0 m× 2.0 m× 2.0 m (Figure 3a,b).

Siaya County had the highest number of cage culture establishments (*n* = 20; 51%), with a total of 1,343 cages of varied cage sizes (Table 2; Figure 3b). Migori county had the lowest number of

TABLE 3 Cage sizes within the five riparian counties and their respective stocking densities in Lake Victoria, Kenya

	Stocking density of fish per cage size	
Cage size (m)	# Of cages; fingerlings	Average stocking density
2 × 2 × 1	*n* = 230; 2,250	563
2 × 2 × 2	*n* = 1267; 2,500	313
2.5 × 2 × 2–10.5 × 5 × 2.5	*n* = 166; 3,000	434
	Average stocking density	359

TABLE 4 Reported diseases and parasites in cages based on farmer observation in Lake Victoria, Kenya

Disease/parasites	Respondents
Cloudy eyes	*n* = 1; 3%
Fin rot/fungal	*n* = 11; 28%
Skin lesions	*n* = 7; 18%
leeches	*n* = 1; 3%
None	*n* = 19; 49%

cage culture establishments (n = 2; 5%), with a total of four cages. The reason for high number of cages in Siaya County in comparison with other counties is not clear. Four hypotheses have been proposed: first, the county was fully mapped for cage culture suitability in 2013. Secondly, the county is in close proximity to the Dominion Farm which could have favoured transfer of cage culture technology. The third reason is that Dominion Farm was also a major supplier of seed to farmers during Economic Stimulus Programme (ESP) (Musa et al., 2012). Fourthly, the minimal coverage of the county with water hyacinth (*E. crassipes*) may have given room for establishment of cages without worrying about destruction of cages by the weed.

There were seven hatcheries from which cage culture farmers sourced their fingerlings: these were Dominion, Mabro, Jewlet, Pioneer, KMFRI-Sangoro, Lake View Mfangano, and S.O.N in Jinja. The remainder were procured by "Self" (Figure 3c). With exception of Busia County where farmers sourced their supply from S.O.N in Jinja, Uganda, most farmers in other counties were supplied by Jewlet enterprises in Homa Bay County (n = 8; 40%). This could be as a result of the supplier reliability and experience. The supplier had worked at the Dominion Farm prior to embarking on his own enterprise (E. Were, pers. comm.).

Findings from the cage culture respondents showed more preference in investment in the cages with dimension of 2.0 m× 2.0 m× 2.0 m (Figure 3d). The least investment among cage culture farmers was recorded in the 2.0 m× 2.0 m× 1.0 m cage sizes. The shallow height/depth (i.e., 1.0 m) of the 2.0 m× 2.0 m× 1.0 m cage allows the cage to be placed very near to the shore. The downside to the short height of 1.0 m is that it would not contain as much fingerlings as compared to the 2.0 m× 2.0 m× 2.0 m.

Most cages (n = 30; 76%) were located within 200 m from the shore (Figure 4a). This was mainly because most farmers prefer such zones due to ease of access, close supervision, and are sheltered from potentially damaging strong winds and currents (KMFRI, 2016). Cages set up in shallow areas that act as nursery and breeding areas for fish threaten to disrupt natural recruitment thereby affecting natural fish populations. Some of such regions (≤200 m) are demarcated breeding zones and thus protected from fishing. The relationship between the depths of the lake at the cage location and the cage sizes was significant (χ^2 = 16.779; df = 4; p < .05) with larger cages predominantly in deep water and smaller ones predominantly in near shore, shallower areas. A critical amount of distance between the cage bottom and the lake bed is necessary to avoid high turbidity associated with clogging of the cage nets and fish gills. Most (n = 1,497; 90%) cages were located within lake depth of 4–10 m. The rest (n = 166; 10%) of the cages were located at a depth of <3 m.

3.3 | Species cultured and stocking densities

The only species cultured was Nile tilapia symptomatic of consumer preference for it (Musa, Aura & Kundu, 2014; Obiero et al., 2014). Cage culture operators could also have preferred tilapia due to its

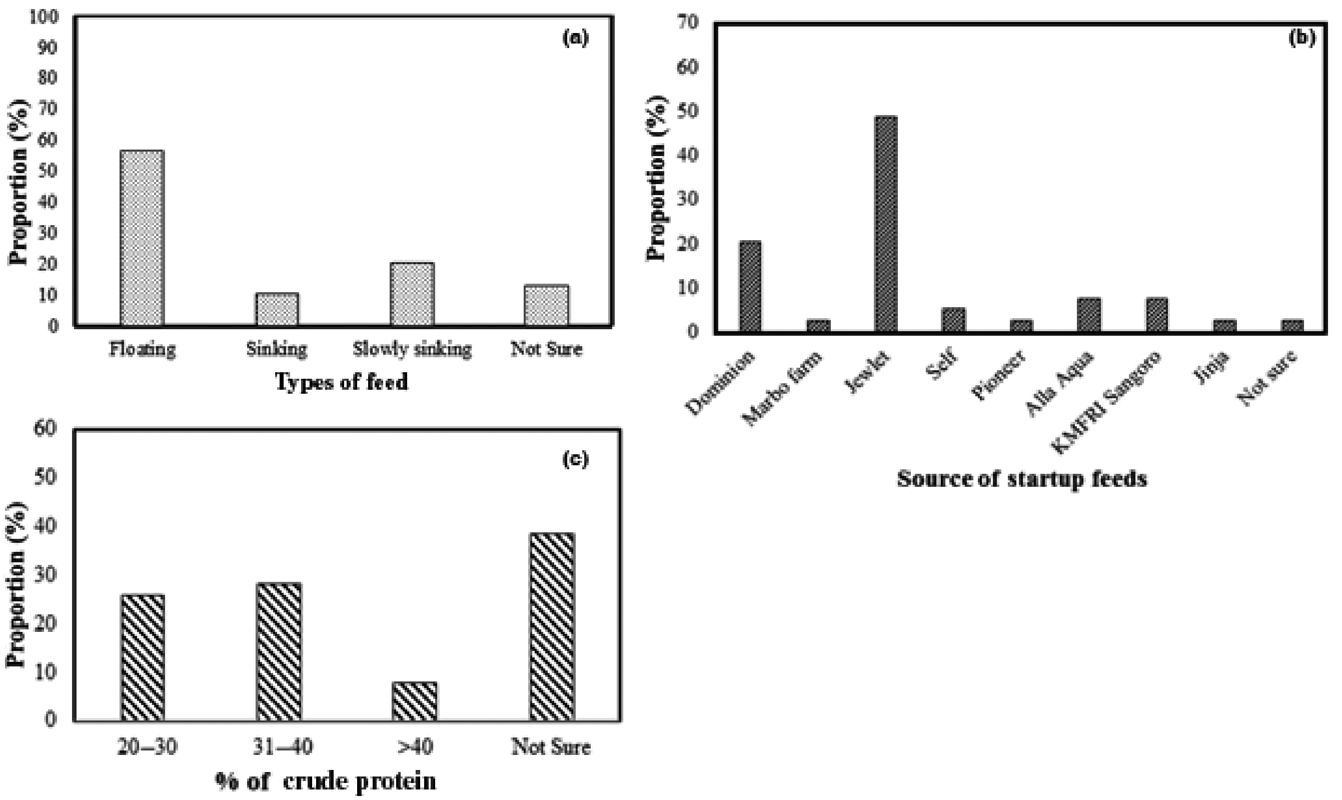

FIGURE 5 Feeds used by cage culture farmers in Lake Victoria, Kenya in terms of (a) type of feeds; (b) sources of fish startup feeds; and (c) percentage of crude protein in feeds

fast growth rate, tolerance to crowded conditions, amenability to farm in cages and because of its high market value. Nile tilapia is also native to Lake Victoria hence the recommended species for cage fish farming. Cage culture farmers used an average stocking density of 359 fingerlings/m^3 (Table 3). The current stocking density used in the Kenyan portion of Lake Victoria can be classified as Low Volume High Density (LVHD) cages (S. Musa, pers. comm.). The ever-increasing stocking density is one of the problems for lack of adequate space and resources for culturing fish. Stocking density is an important factor that affects growth, efficiency and growth performance in fish. Specific stocking density can have positive and negative effects on fish growth (Niazie, Imanpoor, Taghizade & Zadmajid, 2013). The maximum recommended standing crop at harvest for Nile tilapia is 80 kg per cubic metre while at stocking is

TABLE 5 Distribution of cage culture establishments within the five riparian counties in Lake Victoria, Kenya and their respective numbers stocked in relation to yield

County/cage location	Initial investment (USD)	Number of cages	Number fish/cage	Size of cages (m)	Expected total production (kg)
Busia	**34,000**	**40**	**1,500**		**30,000**
Bukoma	34,000	20	2,000	2 × 2 × 1	
Mulukoba		20	1,000	2 × 2 × 1	
Homabay	**83,000**	**193**	**2,715**		**262,000**
Dunga-H	1,800	1	2,000	2 × 2 × 2	
Homaline	13,000	10	2,500	2 × 2 × 2	
Likungu	14,800	4	2,000	4 × 4 × 4	
Mitimbili	1,000	1	2,500	2 × 2 × 2	
Nyandiwa	1,200	150	2,500	2 × 2 × 2	
Rasira	50,000	11	5,000	5 × 5 × 2.5	
Sindo	1,200	16	2,500	2 × 2 × 2	
Kisumu	**347,900**	**83**	**2,160**		**89,640**
Asat	5,900	8	3,500	2.5 × 2.5 × 3	
Bao		22	0	3 × 3 × 3	
Dunga-K	252,000	15	4,800	2.5 × 2.5 × 2.5	
Ogal	80,000	25	0	6 × 6 × 4	
Othany	10,000	13	2,500	2 × 2.5 × 3	
Migori	**4,300**	**4**	**3,000**		**6,000**
Matoso	2,100	1	6,000	10 × 5 × 2.5	
Ngore	2,200	3	2,000	2.5 × 2.5 × 2.5	
Siaya	**591,220**	**1,343**	**3,178**		**2,134,027**
Anyanga	118,000	726	2,000	2 × 2 × 2	
Honge	10,800	12	2,000	2 × 2 × 2	
Kamumbo	36,000	45	6,000	2 × 2 × 2.5	
Lwanda DC	10,240	16	2,000	2 × 2 × 2.5	
Nyenye GotAgulu	90,000	151	2,000	3.5 × 2 × 2	
Oele	4,800	39	3,000	2 × 2 × 2	
Sika	19,000	35	2,000	2 × 2 × 2	
Siungu	27,000	45	2,000	2 × 2.5 × 2	
Ugambe	650	170	2,000	2.5 × 2.5 × 2	
Ulanda	10,230	20	2,500	2 × 2 × 1	
Usenge	900	1	3,000	4 × 2.5 × 2	
Utonga	33,600	59	4,000	2 × 2 × 2	
Uwaria	30,000	16	2,000	4 × 2.5 × 2	
Uyawi	200,000	8	5,000	6 × 6 × 2	
Grand Total	1,060,420	1,663	–		2,521,667

KSh.100 ≈ 1 USD; Bold values represent summation per county; missing values under initial investment indicate absence or not yet harvested; average weight at harvest ≈0.5 kg based on the respondents opinion; and expected production was for a cycle of about 8 months with an assumption of 100% fish survival.

250 fingerlings/m^3 (Ofori, Dankwa, Brummett & Abban, 2009) and species-specific considerations are critical. However, stocking density also depends on the quantity and quality of the feed to be used, water quality, expected yield and average size desired at harvest. Sites with good water exchange can have higher stocking densities, while those with poor water exchange should use lower stocking densities (Garcia de Souza, Solimano, Maiztegui, Baigún & Colautti, 2015).

There was no relationship between the stocking density and the amount of fish feed used in the cages ($\chi^2 = 242$; $df = 224$; $p = .195$). The farmers seemed to feed the cultured fish using almost uniform amount and duration, regardless of the number stocked.

3.4 | Disease/parasite occurrences in cages

The majority of cage establishments ($n = 20$; 51%) noted that there were diseases and parasites occurring in their cages (Table 4). About 49% ($n = 19$) reported the absence of disease/parasites from their establishment. Fin rot was the most common disease condition observed by the cage farmers ($n = 11$; 28%). There was a significant relationship between the stocking densities and the disease occurrence with most diseases occurrences mainly in the 2 m× 2 m× 2 m cages ($\chi^2 = 206$; $df = 160$; $p < .05$). The reported incidences of observed diseases/parasites could result from poor water quality and management practices such as over-stocking of cages. Poor water quality affects the fish, promotes disease and parasite outbreaks and can cause fish kills. A non-stressful water environment inside the cage is fundamental to good fish health and production performance (Ofori et al., 2009).

3.5 | Types and sources of feed

There were three main types of feed that the farmers used (Figure 5a). They were categorized as floating, slowly sinking and sinking. Four (10%) of the farmers were not sure of what feed types they used. Floating feeds are often recommended for feeding tilapia since they are easy for the fish to pick while the sinking ones often end up as waste. The uncertain respondents were mainly using home-made feeds, predominantly dried fresh water shrimp (*Cardina niloticus*) in their cages.

Cage farmers obtained feeds from nine sources (Figure 5b). The main source of feeds was from Jewlet Enterprises in Homa Bay County which accounted for 50% of feeds that were used by the farmers, followed by Dominion Farm Limited, accounting for 20% of feeds used by the farmers. There were other sources such as Mabro Farm, Aller Aqua (imported from Germany), KMFRI-Sangoro, Uga Chick from S.O.N in Jinja, Uganda and "Self-formulated/provided" which contributed to 30% of the sources of feed supply.

Most respondents ($n = 24$; 61%) were aware of the level of crude protein levels in the diet used in their cages (Figure 5c). About 39% ($n = 15$) of the respondents were not aware of the level of crude protein in the feeds. The lack of awareness of the crude protein levels could be as a result of some farmers formulating their own feeds and others were attendants who did not know the protein composition of the feed they were using.

3.6 | Economic status of cage culture

There was significant relationship ($\chi^2 = 93.17$; $df = 72$; $p < .05$) between the size of the fish preferred at the market and the size of the fish harvested at the farm. This relationship could imply that cage farmers consider market preferred sizes before harvesting their fish. The mean individual mean weight of the fish harvested from cages was similar to that preferred by the market at 500 g.

TABLE 6 Operational costs (USD) per cycle of cage culture in Lake Victoria, Kenya as per December 2016

County/cage location	Sum of feed per cycle	Sum of wages per cycle	Sum of any other cost
Busia	**6,000**	**400**	
Bukoma	6,000	400	
Mulukoba			
Homabay	**73,210**	**430**	**500**
Dunga-H	50	40	
Homaline	250	360	
Likungu	70,000		500
Mitimbili	60	30	
Nyandiwa	1200		
Rasira	450		
Sindo	1200		
Kisumu	**18,954.19**	**10,490**	**2,668**
Asat	1960		120
Bao	24.19	450	
Dunga-K	3,550	3,160	1,388
Ogal	9,000	6,400	1,000
Othany	4,420	480	160
Migori	**950**	**810**	
Matoso	500	720	
Ngore	450	90	
Siaya	**308,117**	**36,209.50**	**6,512**
Anyanga	241,440	10,960	400
Honge	1,296	5,760	120
Kamumbo	1,777	2,152	1,000
Lwanda DC	840		
Nyenye Got Agulu	220	680	60
Oele			
Sika	3,600	2,400	300
Siungu	18,000	300	160
Ugambe	250	6,000	3,472
Ulanda	7,840	2,160	
Usenge	90	130	
Utonga	1,014	2,867.50	
Uwaria	27,000	1,800	1,000
Uyawi	4,750	1,000	–
Grand Total	407,231.19	48,339.50	9,680

KSh.100 ≈ 1 USD; Bold values represent the summation per county; missing values indicate respondents did not provide information.

The total start up investment amounted to USD 1,060,420 (Table 5). The intensity of cage culture investment was observed to be high in Siaya County with a total start up investment cost of USD 591,220. The high investment in Siaya County is attributed to highest number of cage establishments (*n* = 20; 51%) which require higher value of investment. The lowest investment in cage culture was observed in Migori County (USD 4,300) with only two establishments whose cage inputs were sourced locally.

Total operational costs for a cycle of about 8 months amounted to USD 465,250.69 (Table 6). The operational costs included wages, seed and feed, and security. In all five counties, feed costs constituted the main operational expenditure, consistent with previous findings that reported feed costs account for more than 60% of the production cost (Craig & Helfrich, 2002; De Silva & Phillips, 2007; Ogutu, 1992). Cage culture farmers in Lake Victoria, Kenya produced about 2,522 tonnes of fish per cycle worth a total of USD 8,827,000. On the other hand, in 2015, capture fishery landed 118,145 tonnes valued at about USD 94.4 million (KMFRI, 2016). This is an indication of cage culture in Lake Victoria as a viable candidate for “The Blue Economy” concept.

3.7 | Institutional and management framework of cage culture

None of cage culture establishments was insured. Most farmers (*n* = 22; 56%) were not aware of the importance of insuring their enterprise while 23% (*n* = 9) of the respondents cited the high costs involved. Respondents noted that many existing insurance companies (*n* = 4; 8%) were not ready to insure aquaculture. Lack of insurance for the cage culture operations implies that the operations are not cushioned against risks and losses. Incidences of loss of fish from cages were reported in 2016 in Siaya County (KMFRI, 2016).

On the other hand, a majority (*n* = 22; 56.4%) of the cage culture operators had a business plan with a smaller proportion (*n* = 16; 41%) lacking a business plan (Figure 6a). Lack of a business plan decreases likelihood for adequate comparison of inter-cycle performances critical for securing bank loans. At the start of cage culture venture, approximately half (*n* = 18; 46%) of the investors consulted KMFRI/Fisheries Department (Figure 6b), whereas 28% (*n* = 11) of the respondents consulted NEMA for technical advice and siting of the cages. The survey

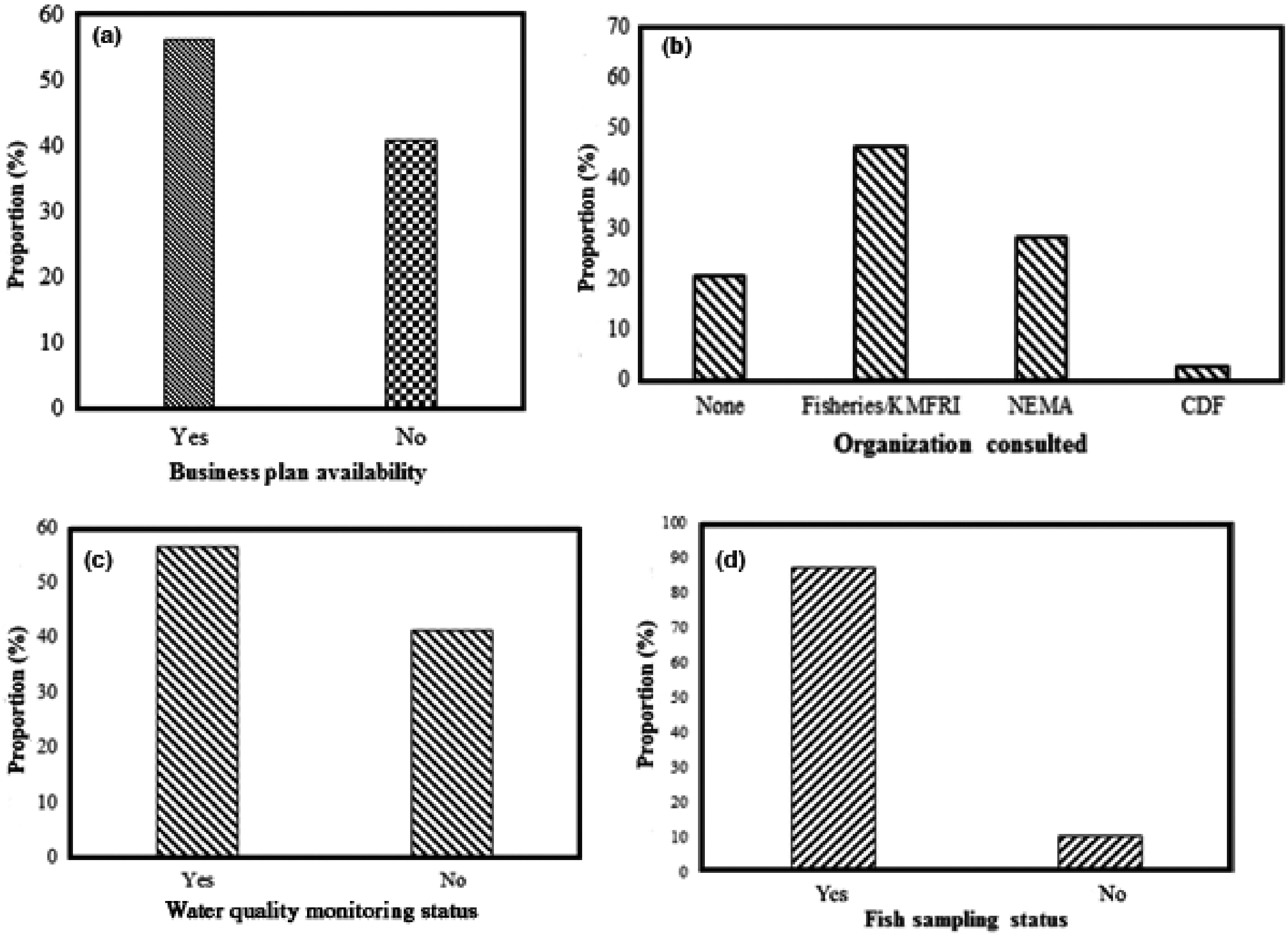

FIGURE 6 Setting and operations of cage culture in Lake Victoria, Kenya depending on (a) the availability of business plan; (b) organization consulted; (c) whether farmers did water quality monitoring; and (d) whether farmers sampled fish in cages

further revealed that 2.6% of the respondents consulted the CDF while 21% of the respondents did not consult for technical advice at all.

Most of the cage operators were monitoring water quality (n = 34; 57%) and a few were sampling fish (n = 4; 89.2%) to check for health status at the cages (Figure 6c). Environmental monitoring entails a routine activity in which fish cage culture farmers can proactively take preventive measures to minimize risks of fish mortality. According to Alam and Al-Hafedh (2006), the overall performance of any aquaculture system is partly determined by its water quality parameters. The cage culture operations in the lake are likely to be successful if farmers are aware of the relevance of water quality monitoring. A majority (n = 20; 52%) of the cage culture operators indicated that they were cleaning the cage nets to reduce clogging and fouling, implying effort at proper management practices of the cages to enhance water quality and performance of fish (Shoko, Limbu, Mrosso & Mgaya, 2014).

Water quality analysis in selected fisheries capture and culture sampling sites showed varying trends. The highest DO occurred in all the fishing grounds sampled (Figure 7a). The DO levels were >4.0 mg/L except in Nyandiwa littoral zone which recorded DO of

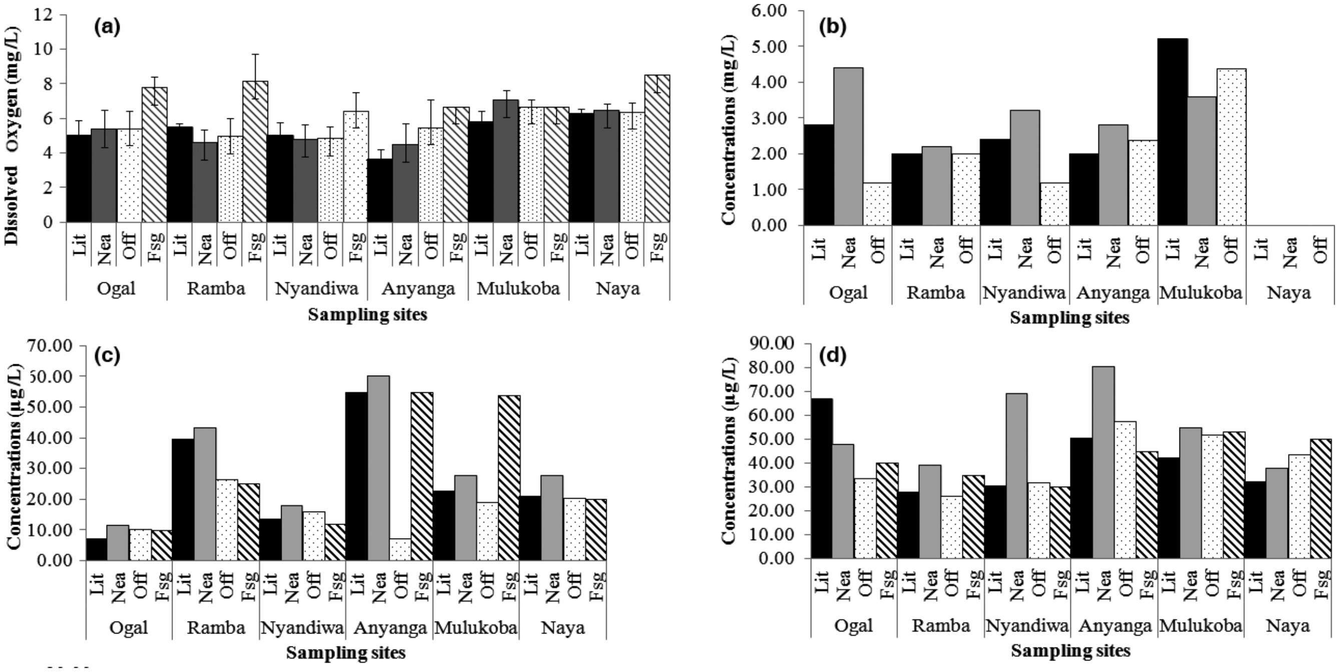

FIGURE 7 Selected and vital water quality parameters in cage culture and fishing ground sites in Lake Victoria, Kenya showing (a) Dissolved Oxygen (b) biochemical oxygen demand = BOD, (c) total ammonia = NH_3^+–N, and (c) Total Phosphorus = TP, in Littoral zone (Lit), Near cage sites (Nea), Off-shore (Off) and fishing grounds (Fsg)

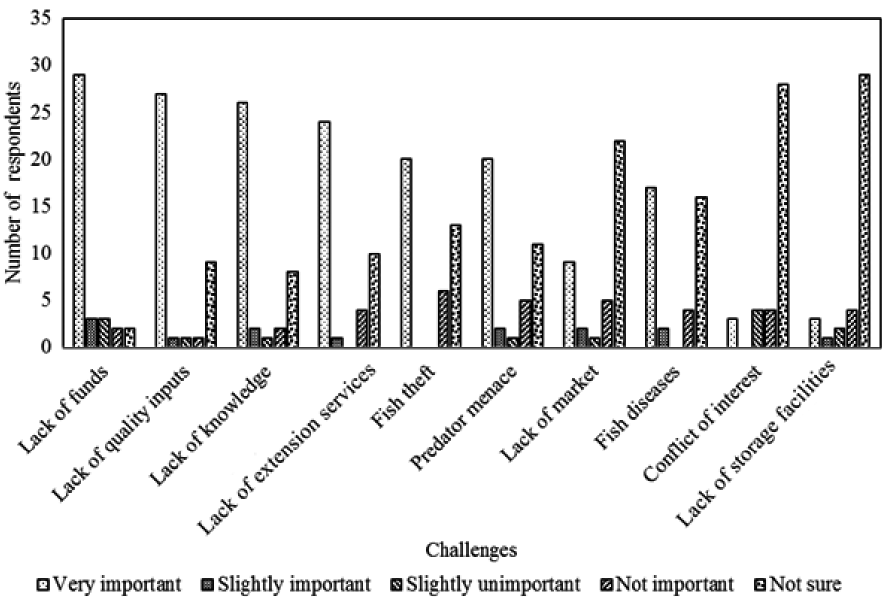

FIGURE 8 Types of challenges experienced by fish cage culture establishments (n = 38) in Lake Victoria, Kenya

3.64 ± 0.56 mg/L. There were no significant variations ($p > .05$) in DO levels between littoral, near cages, and off-shores zones in all the sites. The DO levels in cage sampling sites were significantly lower ($p < .05$; 5.64) that in fishing grounds. Low DO levels in the cage culture sampling sites were attributed to increased consumption of DO by the cultured fish and the decomposition of the organic waste (Longgen, Zhongjie, Ping & Leyi, 2009). The aforementioned could have been the reason for higher DO levels in fishing grounds than in the cage culture sampling sites, and could be considered as one of the main setbacks of cage culture in the longrun.

Biochemical oxygen demand (BOD) observations ranged between 1.2 and 5.2 mg/L and with a mean of 2.8 mg/L (Figure 7b). BOD observations were mainly high in samples from the near cages sites (Nea) followed by Littoral sites (Lit). The BOD results of the survey indicated that all sampled sites were moderately polluted. The second highest BOD_5 and total ammonia reported mainly within littoral sites can be ascribed to shoaling wave currents from off-shore through the cages to the littoral zones.

Total Ammonia (NH_3^+–N) ranged between 7.1 and 60.3 μg/L with a mean of 24.8 μg/L (Figure 7c). Total ammonia observations were highest in all near cages sampling sites (Nea) than in littoral and off-shore sites. Littoral sites were majorly second in concentration after near cages sampling sites. Total ammonia concentrations were relatively higher from cage culture sampling sites relative to fishing ground sites (Fsg). Increased BOD_5 and total ammonia are believed to result from the decomposition of metabolic wastes and uneaten feeds. The feeding rates therefore need to be controlled in order to manage BOD_5 escalation and nutrient buildup within cage culture sites. Ammonia has a tendency of adsorption upon sediment surface and is not leached readily from the soils (APHA, 2005). The buildup of ammonia in sediments in the littoral site is prone to remineralization. Total Phosphorus (TP) concentrations exhibited a range 26.3–80.6 μg/L with a mean of 45.8 μg/L (Figure 7d). The concentrations were generally higher in near cages than littoral and off-shore sites; indicative of an accumulative effect of cage culture which could excercibate in the long run.

Lack of quality inputs was cited by majority of the respondents as a very important challenge affecting the cage culture operation (Figure 8). This is true of the entire sector: inadequate quality of inputs was identified as one of the key factors limiting fish

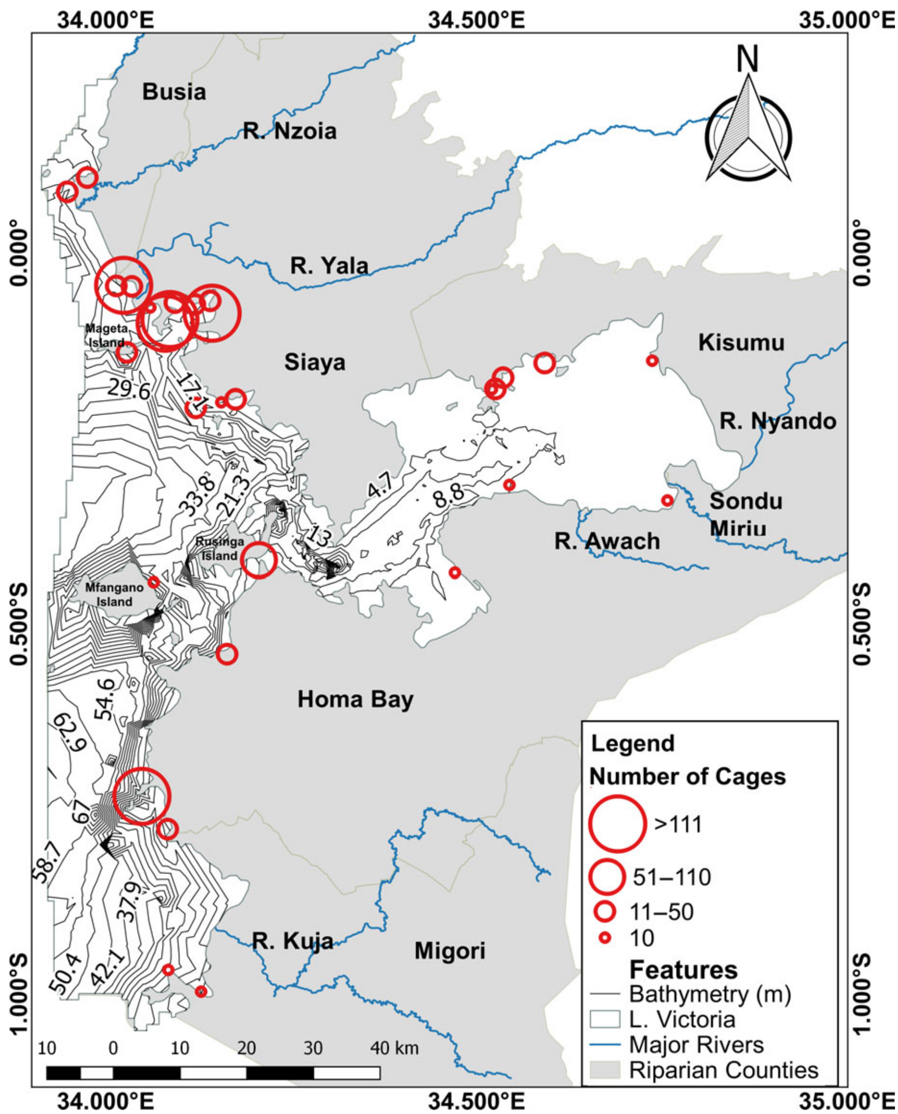

FIGURE 9 Mapped cage culture abundance and locations in the entire Lake Victoria, Kenya [Colour figure can be viewed at wileyonlinelibrary.com]

production in the cage culture sector (Munguti et al., 2014). Lack of market was not an important challenge in cage culture operation. The current findings contradict previous reports that farmed fish have a low acceptability due to taste (Dasgupta, Eaton & Caporelli, 2010; Drake, Drake, Daniels & Yates, 2006; Musa et al., 2014). The high market acceptance of cage cultured fish as compared to pond fish could result from the fish being reared in natural water bodies and perception of being “wild-like” and tasty.

There was high concentration of cages in <5 m depths areas (Figure 9). Siaya County had a high concentration of cages and the least concentration was in Migori County. The mapping output had similar results with socio-economic data herein. Thus, mapping of cages could be integrated with socio-economic inventory of farmers as well as water quality status to improve and guide management decisions on policies and frameworks of cage culture and could be replicated in other scenarios.

4 | CONCLUSION AND RECOMMENDATIONS

Cage culture in Lake Victoria, Kenya appears to be an emerging and viable economic investment that could be adopted into “The Blue Economy” concept. However, based on the GIS mapping, most of the cage establishments ($n = 30$; 76%) were located within 200 m from the shoreline and at a depth of less than 10 m, despite some of these areas being demarcated as fish breeding zones. In addition, most cage culture operators ($n = 32$; 82) use locally formulated feeds which crumble easily once in water and seemed to cause increased water quality deterioration. A good number ($n = 20$; 52%) of cage owners seldom clean the cages leading to fouling and clogging. These practices all threaten the sustainability of cage culture for the communities and the lake fisheries. The combination of data from socio-economic surveys, water quality assessment and GIS suggest that management agencies should make the following recommendations to cage owners in order to guide investment and development of cage culture under a “The Blue Economy” concept.

- Move cages to deep waters (≥10 m depth) with good water exchange and mixing. This could be undertaken by use of GIS and suitability map as a tool to assist farmers know the right site and location with the correct depth and chemical properties to install their cages.
- Guide this movement in a manner to protect navigation, protection of breeding zones and fishing to avoid conflicts with other stakeholders.
- Clean cage netting regularly to avoid fouling and clogging.
- Recommend use of floating feeds to avoid excessive accumulation of uneaten feeds.
- Develop business plans for their cage enterprises to track their operations and monitor progress and make adjustments for improved performance.
- Involve a good number of vulnerable communities such as women through dissemination on possible sources of capital for cage culture for socio-economic development.
- Insure their operations against risks and losses.

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REFERENCES

Abila, R. O. (2000). *The development of the Lake Victoria fishery: A boon or bane for food security? Socio-economics of the Lake Victoria Fisheries*. Report 8. IUCN Eastern Africa Programme. 15 pp.

Alam, A., & Al-Hafedh, Y. S. (2006). Diurnal dynamics of water quality parameters in an aquaculture system based on recirculating green water technology. *Journal of Applied Sciences and Environmental Management*, *10*, 19–21.

APHA (2005). *American Public Health Association Standard methods for the examination of water and wastewater* (21st ed.). Washington, DC: APHA-AWWA-WEF. ISBN 0875530478.

Aura, M. C., Musa, S., Njiru, J., Ogello, E. O., & Kundu, R. (2013). Fish-restocking of lakes in Kenya: Should solemnly be an environmental issue. In W. A. Adoyo & C. I. Wangai (Eds.), *African political, social and economic issues: Kenya political, social and environmental issues* (39–60 pp.). New York, NY: NOVA Science Publishers, Inc. ISBN: 978-1-62081-085-9.

Bao-Tong, H. U. (1994). Cage culture development and its role in aquaculture in China. *Aquaculture and Fisheries Management*, *24*, 305–310.

Craig, S., & Helfrich, L. A. (2002). *Understanding fish nutrition, feeds and feed management*. Petersburg, VA: Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University.

Dasgupta, S., Eaton, J., & Caporelli, A. (2010). Consumer perception of freshwater prawns: Results from a Kentucky farmers market. *Journal of Shellfish Research*, *29*, 19–23.

De Silva, S. S., & Phillips, M. J. (2007). A review of cage aquaculture: Asia (excluding China). In M. Halwart, D. Soto & J. R. Arthur (Eds.), *Cage aquaculture – Regional reviews and global overview* (pp. 18–48). FAO Fisheries Technical Paper. No. 498. Rome: FAO. 241 pp.

Drake, S. L., Drake, M. A., Daniels, H. V., & Yates, M. D. (2006). Sensory properties of wild and aquaculture Southern Flounder. *Journal of Sensory Studies*, *21*, 218–227.

EL-Sayed, A. F. M. (2006). Intensive culture. In A. F. M. EL-Sayed (Ed.), *Tilapia culture* (62 pp.). Wellingford, Oxfordshire, UK: CABI Publishing.

FAO (2004). FAO regional technical expert workshop on cage culture in Africa. Entebbe.

FAO (2014). *The state of world fisheries and aquaculture 2014*. Rome, Italy: FAO Fisheries Department, Fishery Information, Data and Statistics Unit.

FAO (2016). *The state of world fisheries and aquaculture 2016. Contributing to food security and nutrition for all*, Rome, Italy.

FishStat (2009). Retrieved from www.fao.org/fishery/statistics/en

Fitzsimmons, K. (2000). *Tilapia and penaeid shrimp polycultures*. Pond Dynamics/Aquaculture CRSP, Aquanews, Fall 2000.

Garcia de Souza, J. R., Solimano, P. J., Maiztegui, T., Baigún, C. R. M., & Colautti, D. C. (2015). Effects of stocking density and natural food availability on the extensive cage culture of pejerrey (*Odontesthes bonariensis*) in a shallow Pampean lake in Argentina. *Aquaculture Research*, *46*, 1332–1344. https://doi.org/10.1111/are.12286

Guya, F. J. (2013). Bioavailability of particle-associated nutrients as affected by internal regeneration processes in the Nyanza Gulf region of Lake Victoria. *Lakes and Reservoirs: Research and Management*, *18*, 1–15.

Hecky, R. E., Mugidde, R., Ramlal, P. S., Talbot, M. R., & Kling, G. W. (2010). Multiple stressors cause rapid ecosystem change in Lake Victoria. *Freshwater Biology*, *55*, 19–42.

Ikiara, M. M. (1999). *Sustainability, livelihoods, production and effort supply in a declining fishery: The case of Kenya's Lake Victoria Fisheries*. PhD thesis, University of Amsterdam.

Kaliba, A. R., Ngugi, C. C., Mackambo, J., & Quagrainie, K. K. (2007). Economic profitability of Nile tilapia (*Oreochromis niloticus* L.) production in Kenya. *Aquaculture Research*, *38*, 1129–1136.

KMFRI (2016). *Fish Kills in Cages off Beaches in Lake Victoria, Kenya: Imprinting the Possible Causes*. Technical Report for Kenya Marine and Fisheries Research Institute (KMFRI) Kisumu. 12 pp.

Longgen, G., Zhongjie, L., Ping, X., & Leyi, N. (2009). Assessment effects of cage culture on nitrogen and phosphorus dynamics in relation to fallowing in a shallow lake in China. *Aquaculture International*, *17*, 229–241.

LVFO (2015). *Lake Victoria (Kenya) Biennial Fisheries Frame Survey 2014 National Report*. Ministry of Agriculture, Livestock and Fisheries, Kenya.

Lwenya, C., Mbilingi, M., Luomba, J., & Yongo, E. (2009). Gender intergration in the management of the Lake Victoria Fisheries. *African Journal of Tropical Biology and Fisheries*, *12*, 59–66.

Masser, M. (2008). *What is cage culture?* SRAC publication No. 160.

Mbenga, C. A. (1999). *Informal power*. Gender, globalisation and fisheries workshop. 6–12 May, 2000. St. John's NF.

Medard, M. (2000). *Community-based organisations on Lake Victoria: A lesson from the Tweyambe Fishng Enterprise in Muleba District, Kager Region, Tanzania*. Paper presented at a workshop on Gender, Globalisation and Fisheries. 6–14 May 2000, University of Newfoundland, Canada.

Medard, M., Sobo, F., Ngatunga, T., & Chirwa, S. (2002). Women and gender participation in the fisheries sector in Lake Victoria. In M. J., Williams, N. H., Chao, P. S., Choo, K., Matics, M. C., Nandeesha, M., Shariff, I., Siason, & J. M. C., Wong (Eds.), *Global Symposium on Women in Fisheries* (pp. 155-68). *Sixth Asian Fisheries Forum, 29 November 2001, Kaohsiung, Taiwan*. Penang: ICLARM- WorldFish Center.

Modesta, M., & Wilson, D. C. (1996). Changing economic problems for women in the Nile perch fishing communities on Lake Victoria. *Anthropologica*, *XXXVIII*, 149–172.

Munguti, J. M., Musa, S., Orina, P. S., Kyule, D. N., Opiyo, M. A., Charo-Karisa, H., & Ogello, E. O. (2014). An overview of current status of Kenya fish feed industry and feed management practices, challenges and opportunities. *International Journal of Fisheries and Aquatic Studies*, *1*, 128–137.

Musa, S., Aura, C. M., & Kundu, R. (2014). Wild-Caught fish versus aquaculture fish products: A fish marketing concept for aquaculture quality improvement, a case study of Nyanza Region, Kenya. *International Journal of Science and Research*, *3*, 2319–7064.

Musa, S., Aura, C. M., Owiti, G., Nyonje, B., Orina, P., & Charo-Karisa, H. (2012). Fish farming enterprise productivity program (FFEPP) as an impetus to *Oreochromis niloticus* (L) farming in Western Kenya: Lessons to learn. *African Journal of Agricultural Research*, *7*, 1324–1330.

Mutoro, B. A. (1997). *Women working wonders: Small-scale farming and the role of women in Vihiga District, Kenya: A case study of North Maragoli*. Amsterdam, the Netherlands: Thela Publishers Amsterdam, Print.

Ngupula, G. W., Ezekiel, C. N., Kimirei, I. A., Mboni, E., & Kashindye, B. B. (2012). Physical and chemical characteristics of the Tanzanian inshore and offshore waters of Lake Victoria in 2005–2008. *African Journal of Aquatic Science*, *37*(3), 339–345.

Ngupula, G. W., & Kayanda, R. (2010). Benthic macrofauna community composition, abundance and distribution in the Tanzanian and Ugandan inshore and offshore waters of Lake Victoria. *African Journal of Aquatic Science*, *35*(2), 185–192.

Niazie, E. H. N., Imanpoor, M., Taghizade, V., & Zadmajid, V. (2013). Effects of density stress on growth indices and survival rate of goldfish (*Cassius auratus*). *Global Veterinian*, *10*(3), 365–371.

Njiru, M., Nzungi, P., Getabu, A., Wakwabi, E., Othina, A., Jembe, T., & Wekesa, S. (2007). Are fisheries management, measures in Lake Victoria successful? The case of Nile perch and Nile tilapia fishery. *African Journal of Ecology*, *45*, 315–323.

Obiero, K. O., Opiyo, M. A., Munguti, J. M., Orina, P. S., Kyule, D., Yongo, E., . . . Charo-Karisa, H. (2014). Consumer preference an marketing of farmed Nile tilapia (*O. niloticus*) and African catfish (*C. gariepinus*) in Kenya: Case study of Kirinyanga and Vihiga Counties. *International Journal of Fisheries and Aquatic Studies*, *1*(5), 67–76.

Odada, E. O., Olago, D. O., Kulindwa, K., Ntiba, M., & Wandiga, S. (2004). Mitigation of environmental problems in Lake Victoria, East Africa: Causal chain and policy options analyses. *AMBIO: A Journal of the Human Environment*, *33*, 13–23.

Ofori, J. K., Dankwa, H. R., Brummett, R., & Abban, E. K. (2009). *Producing Tilapia in Small Cage in West Africa*. WorldFish Center Technical Manual No. 1952 (16 pp.). Penang, Malaysia: The WorldFish Center.

Ogutu, G. E. M. (1992). Socio-economic conditions of artisanal fishermen and fish Traders. In Ogutu, G. E. M. (Ed.), *Artisanal fisheries of Lake Victoria, Kenya: Options for management, production and marketing* (pp. 15–44). Proceeding of a workshop held in Kisumu, Kenya. Nairobi: Shiriisho Publishers for the Artisanal Fisheries (Kenya) Project.

Okely, P., Imberger, J., & Antenucci, J. P. (2010). Processes affecting horizontal mixing and dispersion in Winam Gulf, Lake Victoria. *Limnology and Oceanography*, *55*, 1865–1880.

Pacini, N., & Harper, D. M. (2016). Hydrological characteristics and water resources management in the Nile Basin. *Ecohydrology & Hydrobiology*, *16*, 242–254.

Shoko, A. P., Limbu, S. M., Mrosso, H. D., & Mgaya, Y. D. (2014). A comparison of diurnal of water quality parameters in Nile tilapia (*Oreochromis niloticus*, Linnaeus, 1758) monoculture and polyculture with African sharp tooth catfish (*Clarias ariepinus*, Burchell, 1822) in earthen ponds. *International Aquatic Research*, *6*, 56.

Standard Newspaper (2016). *Assembly adopts bill to address dwindling fish stocks in Lake Victoria*. Retrieved from www.standardmedia.co.ke/article/2000225853

Whittington, D., Wu, X., & Sadoff, C. (2005). Water resources management in the Nile basin: The economic value of cooperation. *Water Policy*, *7*, 227–252.

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