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11 authors, including:

Sagwe Orina
Kenya Marine and Fisheries Research Institute (KMFRI)

Elijah Migiro Kembenya
Kenya Marine and Fisheries Research Institute (KMFRI)

Cecilia Githukia
Kenya Marine and Fisheries Research Institute (KMFRI)

Safina Musa
Kenya Marine and Fisheries Research Institute (KMFRI)

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The state of cage culture in Lake Victoria: A focus on sustainability, rural economic empowerment, and food security

Paul Orina[1*], Erick Ogello[2], Elijah Kembenya[2], Cecilia Muthoni[1], Safina Musa[1], Veronica Ombwa[3], Venny Mwainge[3], Jacob Abwao[4], Robert Ondiba[2], John Kengere[3], Stephano Karoza[5]

[1]*Kenya Marine and Fisheries Research Institute, Kegati Aquaculture Centre, P.O. Box 3259-40200, Kisii, Kenya*
[2]*Kenya Marine and Fisheries Research Institute, Sangoro Aquaculture Station, P.O. Box 136-40111, Pap-Onditi, Kenya*
[3]*Kenya Marine and Fisheries Research Institute, Kisumu Research Centre, P.O. Box 1881-40100, Kisumu, Kenya*
[4]*Kenya Marine and Fisheries Research Institute, Sagana Aquaculture Centre, P.O. Box 451-10230, Sagana, Kenya*
[5]*Sokoine University of Agriculture, Department of Animal, Aquaculture and Range Sciences, P. O. Box 3000, Morogoro, Tanzania*
**Corresponding author: paulorina@gmail.com*

Capture fisheries and aquaculture have remained important sources of food, nutrition, income and livelihoods to millions globally, with annual per capita consumption of fish in developing countries having increased from 5.2 kg in 1961 to 18.8 kg in 2013. On the contrary, low income food-deficit countries annual fish per capita consumption rose from 3.5 to 7.6 kg against 26.8 kg among industrialized countries. Increased demand for animal protein and declining capture fisheries has seen aquaculture grow rapidly than any other food production sector over the past three decades. Rapid global aquaculture growth is directly related to levels of technological advancement, adoption and adaption prompting aquaculture transition from semi-intensive to intensive and super intensive production systems among developing and developed countries. In light of the aquatic environment economic potential, cage culture in Lake Victoria is fast gaining prominence in aquaculture production contribution. This began with trials by Kenya Marine and Fisheries Research Institute and Uganda's National Fisheries Resource Research Institute and later by private investors at Dunga and Obenge beaches of Kenya, Source of the Nile in Uganda and Bulamba Beach Management Units in Bunda District of Tanzania. However, only Kenya has so far documented cage culture development recording 3,696 cages across the five riparian counties with an estimated production capacity of 3,180 MT valued at Kshs 955.4 Million (9.6 million USD), created over 500 jobs directly and indirectly created income opportunities for over 4,000 people. The sub-sector's value chain, its supportive value chains and associated enterprises are rapidly expanding thus creating jobs, enhancing incomes and ensuring food security in rural and urban areas. As cage culture commercialization takes root, there is urgent need to address issues such as introduction of alien species, diseases, marine parks and maximum carrying capacity among other aspects. This will require trans-boundary policy to ensure sustainable utilization of the lake as a common resource.

Keywords: aquaculture, employment, transformation

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Introduction

Aquaculture, despite being a millennium old, began commercializing 30 years ago resulting in the current contribution of 82 million tonnes representing 45.8% of the global sea food production worth USD 250 billion (FAO, 2020). As global aquaculture production grows against limited land area and water, there has been a technological advancement from the traditional ponds and pens to pens to re-circulative aquaculture systems, aquaponics, in-pond race ways and cages all aimed at increasing aquaculture production (Brown et al., 2010; Cardia and Lovatelli, 2015). Cage culture commercialization is a gradual transitioning of cage farmers from family sustenance production levels to market oriented with the aim of making profits. There are a number of factors affecting the commercialization process in aquaculture including rapid economic growth, technological adoption and adaption, market expansion and liberalization, urbanization and infrastructural growth, increased demand for food against decreasing farming population, liberalized and open economic policies, bilateral and multilateral economic agreements as well as government agricultural policies (Asiedu et al., 2015; Tschirley et al., 2015; Kassam and Dorward, 2017).

Kenya's capture fisheries is fast declining just like the rest of the world against a growing human population. This has resulted in the growing aquaculture interest giving rise to cage culture the latest entrant among aquaculture technologies in Kenya (Blow and Leonard, 2007). Even though cage culture in Kenya is relatively recent, it is rapidly growing mainly in Lake Victoria based on the factors aforementioned in addition to rising demand due to health benefits associated with fish eating. Cage culture in Lake Victoria, Kenya focusing mainly on Nile tilapia (*Oreochromis niloticus*) dates back to 1980s but with minimal documentation of it's success. The trials by Dominion Fish Farms and Lake Basin Development Authority (LBDA) experienced drawbacks but latter picked up in 2010 through a participatory action research approach by Kenya Marine and Fisheries Research Institute (KMFRI) and Dunga Beach Management Unit (BMU) in Kisumu County (Munguti et al., 2017). Cage technology is fast growing in Lake Victoria with significant contribution to national fish production (Aura et al., 2018). Through cage culture, the sub-sector anticipates increased job opportunities, enhanced food security and incomes for both rural and urban dwellers along the value chain.

However, as the Blue Economy, the riches in our water bodies under the Blue Growth Initiative (FAO, 2018) is exploited through cage culture, there is not only the need to sustainably manage the resource (Njiru et al., 2018) through sound stakeholder consultative policies but also enlighten investors on how their investment can transit their livelihoods from small scale to large scale market size tilapia production levels. According to Temm et al. (2008), despite the small-scale fisherfolk's contribution of more than half of the global seafood catch and 70-80% of aquaculture actors operating at small scale (FAO, 2013), majority face persistent poverty. Mwanja et al., 2006, reemphasises this by stating that rural aquaculture in Kenya has overtime been characterized by low input-low output production systems a finding further confirmed by low production in 2015 and 2016 despite government support through the Economic Stimulus Program (Munguti et al., 2017; Macharia and Kimani, 2016).Therefore, the current study was aimed at analyzing the potential for cage investors economic transitioning from subsistence to commercial levels of livelihood and overall cage culture contribution to gross domestic product (GDP) through cutting edge technological approach with an overall aim on the 2030 Agenda and the global SDGs.

Methodology

Total cage culture population sampling technique was employed through questionnaires to 40 cage owners in the five Lake Victoria riparian counties in 2018. The questionnaires were administered to both groups and individually owned cage farms along L. Victoria Kenya side with a focus on date of establishment, cage design, source of seed, stocking density, feed used and feeding regimes, survival, weight at harvest, market and market prices, fish health and investment challenges. The questions were formed by the concerns raised from previous stakeholder engagements. The data generated helped in calculating the commercialization potential of cage culture under different cage designs, sizes and stocking. Further to this, the data was checked for normality using Shapiro Wilks W-test and outliers and no violations were detected. There after the data was edited into specified variables, classified by coding, and entered into Microsoft Excel sheets. The data was transferred into 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 to obtain descriptive, correlation and inferential analyses. Research findings and presentation were communicated through bar charts and tables. Secondary data from FAO and Agriculture Sector Development Support Programme (ASDSP), as well as farm records, were used to assess income levels for various cage investment levels.

Results

Cage culture suitability sites and actual location

Good site selection for cages is critical as it may considerably affect construction, operating costs, growth, survival rate and durability of the cages (Agyakwah et al., 2020). The survey determined that cages were located where there were weak currents (Bays) with an average of 2 m gap between cage bottom and the lake bottom thus limiting better water circulation. Using bathymetry tools, suitability mapping sites for cages were developed by KMFRI (Aura et al., 2018) for L. Victoria Kenya side and the recent cage assessment exercise has shown the current location of cages in the lake (Figure 1). Even though it is recommended to avoid cage placement in river mouths, fishing and breeding grounds, navigation routes, and other critical habitats for fish as well as water hyacinth and floating islands (floating mats of papyrus) prone areas. During the assessment, it was however noted that cage investment in Lake Victoria was not cognizant to this factors (Musinguzi et al., 2019; KMFRI, 2017) demanding for sustainable policies on cage culture investment in L. Victoria.

Cage culture commercialization concept

Cage culture is the fastest growing aquaculture production technology in Kenya with 3,696 cages located along the shores of the five Lake Victoria riparian counties. For investors to achieve their desired profits from cage culture, there is need to conceptualize the value of technology and its supportive enterprises for faster transformation

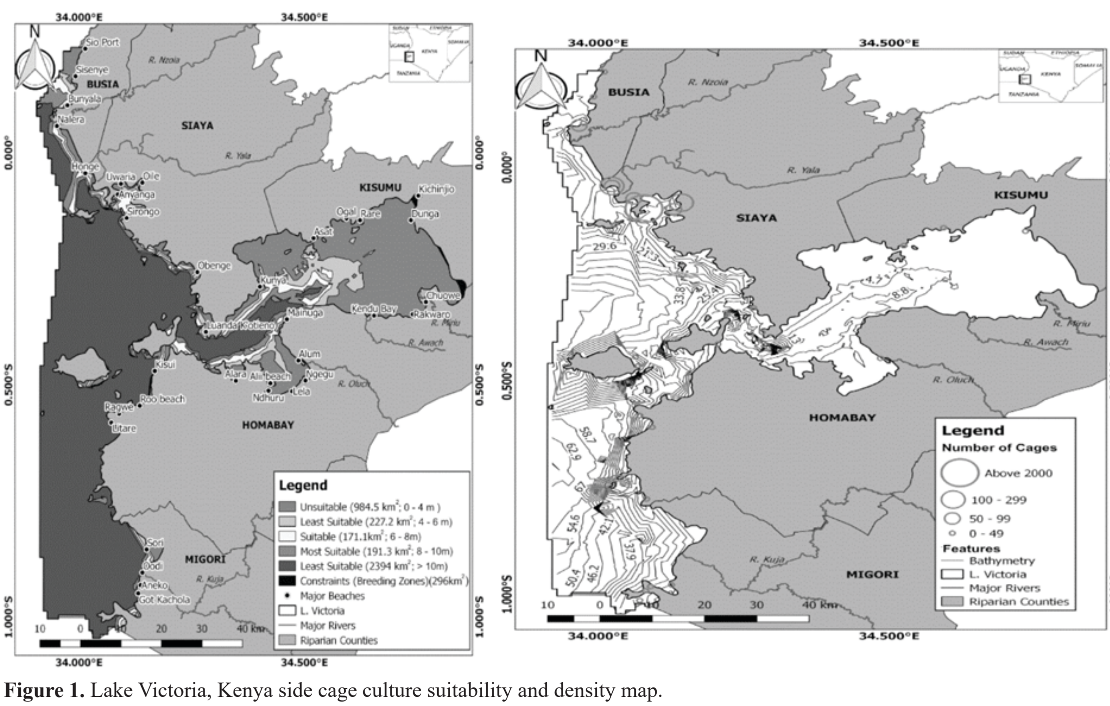

Figure 1. Lake Victoria, Kenya side cage culture suitability and density map.

Table 1. Transitioning households from poverty to commercial based income status.

Variable		**Level of Commercialization**					
Distribution	Frequency	Emerging		Lower Commercial		Upper Commercial	
		USD	Kshs	USD	Kshs	USD	Kshs
Per capita income	Daily	2	200	5	500	10	1000
	Monthly	60	6,000	150	15000	330	33,000
	Annual	730	73,000	2000	200,000	4000	400,000
Household income	Daily	12	1,200	30	3000	60	6,000
	Monthly	360	36,000	900	90000	1980	198,000
	Annual	4,380	438,000	12000	1,200,0000	24,000	2,400,000

* Household has an average of 6 members (ASDSP Baseline findings, 2013)
* USD conversion to Kshs based at 1 USD = KShs 100
* Middle income status (Kenya's Vision 2030) is attained at 4,000 USD per capita per annum.

Table 2. Income at subsistence, emerging and commercial levels in land based pond Tilapia culture.

	No Technological Enhancement			**Solar Powered Aeration**	
Variable	**Subsistence**	**Emerging**	**Commercial**	**Aerated_ Emerging**	**Aerated_ Commercial**
Pond Size	300m^2	300m^2	300m^2	300m^2	300m^2
No of Ponds	1	20	50	1	4
No of fish stocked per pond	1000	1000	1000	8400	8400
Survival Rate	0.9	0.9	0.9	0.9	0.9
Total weight at Harvest (Kg)	297	5940	14850	3402	13608
Cost of pond construction	10,000.00	200,000.00	500,000.00	10,000.00	40,000.00
Cost of production (Kshs)	95,460.00	1,504,200.00	4,008,000.00	688,360.00	2,837,440.00
Value of fish per harvest (Kshs)	118,800.00	2,376,000.00	5,940,000.00	1,360,800.00	5,443,200.00
Gross Margin (Kshs)	23,340.00	871,800.00	1,932,000.00	672,440.00	2,605,760.00
Annual Income/HH (Kshs)	3,890.00	145,300.00	322,000.00	112,073.33	434,293.33
Monthly Income/HH (Kshs)	324.17	12,108.33	26,833.33	9,339.44	36,191.11
Daily Income/HH (Kshs)	10.81	403.61	894.44	311.31	1,206.37

from subsistence to commercialization. This will greatly contribute towards a more vibrant value chain leading to increased jobs, poverty alleviation and food security. The Blue Economy commercialization concept is geared towards transiting aquaculture value chain actors from their current livelihood status to middle income levels pegged at an annual per capita of USD 4,000 (Table 1).

Kenya's aquaculture sub-sector has experienced in the last one decade, major growth making significant contribution to the food fish security (Munguti et al., 2017). However, much of this contribution was achieved through land based fish farming with the highest recorded ponds being 69,194 in 2013, a 30% increase from 48,000 ponds constructed under Fish Farming Enterprise Productivity Programme a component of the national Economic Stimulus Programme (ESP-FFEPP) between 2009 and 2012. The increase resulted in a further rise in fish production to 24,096 MT in 2014 from 4, 895 MT in 2009. Land based fish productions have however experienced a drop in numbers from 69,194 to 60, 277 in 2015

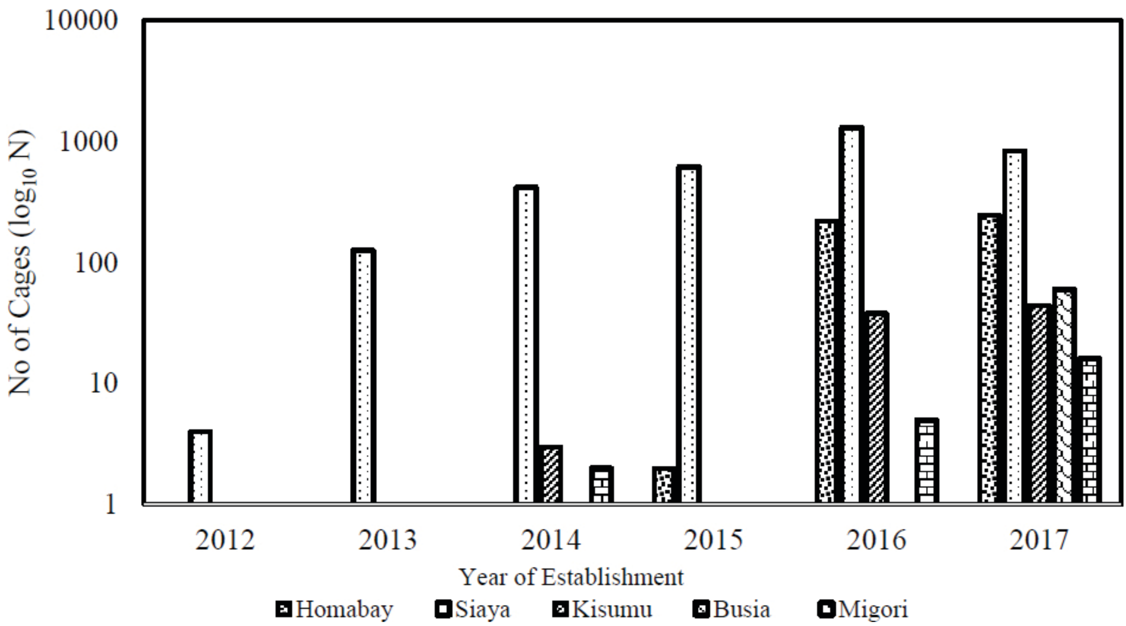

Figure 2. Annual cage establishment growth in Lake Victoria, Kenya.

(Macharia and Kimani, 2016) a reason for the drop in land based aquaculture production from 24,096 MT in 2014 to 14,952 MT in 2016 (Munguti et al., 2017). This trend can be attributed partly to lack of commercialization with the one pond per farmer concept. To achieve commercialization there is need to employ a technological package approach to the land based fish farming such as solar powered aerated and water quality regulator system which will lead to high stocking densities (ASDSP, 2018; Adam et al., 2017; Liu et al., 2016). The combination of solar powered aeration system coupled with high quality feeds and stocking density transits the same one (1) pond (300m^2) farmer from subsistence to emerging and further to lower commercial with only five (5) ponds (Table 2).

Cage culture though a recent concept in Kenya has attracted rapid investment interest with a variety of cage designs since 2015. Cages currently in use in the lake take different shapes, dimensions, construction materials and stocking densities. The most dominant cage design and material is the locally fabricated galvanized metal cage measuring 2x2x2m (8m^3), an approach dominated by Siaya County followed by Homa Bay County (Figure 2). The investors started with a stocking density of 250 m^{-3} but have drastically dropped to 125 m^{-3}. Based on the current stocking density (125 m^{-3}), a cage farmer can only emerge with a seven (7) cages of 2x2x2m and further transit to upper commercial with 30 cages (Table 3).

The locally fabricated galvanized metal cage has very fast been adapted from 2x2x2m size to 3x3x2m, 3x3x2.5, 5x5x2.5 and 10x10x4m among others with better production results (>450g). The increased production coupled with growth uniformity is due to right stocking density and ease of management of fewer cages. This implies that the cage farmers do complete harvest upon fish attaining market size a factor necessitated by fish size market acceptability (Kshs 400 kg^{-1}). A 5x5x2.5m galvanized metal cage with a fish stocking density of 80/m^3 leaves the cage fish farmer at subsistence with a daily income of Kshs 192 when operating with one cage and can only transit to emerging with a daily income of Kshs 395 at three cages operational level and commercializes at 10 cages capacity with a daily income of Kshs 1, 196 (Table 4). This calculations were based on data generated from the interviews.

Cage investors have in the recent further adapted to eco-friendly cage technology from locally fabricated galvanized metal cage to more commercial oriented high density polyethlene (HDPE) cages majority being circular. A HDPE

Table 3. Cage Culture Income at Emerging and Commercial Levels.

Variable	Subsistence	Emerging	Commercial
Cage Size	2x2x2 ($8m^3$)	2x2x2	2x2x2
No of Cages	1	7	30
No of fish stocked per Cage	1000	1000	1000
Survival Rate	0.9	0.9	0.9
Total weight at Harvest (Kg)	450	3150	13500
Cost of Cage (Kshs)	16,250.00	113,750.00	487,500.00
Cost of production (Kshs)	126,250.00	763,750.00	3,227,500.00
Value of fish per harvest (Kshs)	180,000.00	1,260,000.00	5,400,000.00
Gross Margin (Kshs)	37,500.00	496,250.00	2,172,500.00
Annual Income/HH (Kshs)	6,250.00	82,708.33	362,083.33
Monthly Income/HH (Kshs)	520.83	6,892.36	30,173.61
Daily Income/HH (Kshs)	17.36	229.75	1,005.79

Table 4. Cage culture income at emerging and commercial levels.

Variable	Subsistence	Emerging	Commercial
Cage Size	5x5x2.5	5x5x2.5	5x5x2.5
No of Cages	1	2	6
No of fish stocked per Cage	5000	5000	5000
Survival Rate	0.9	0.9	0.9
Total weight at Harvest (Kg)	2250	4500	13500
Cost of Cage (Kshs)	31,250.00	62,500.00	187,500.00
Cost of production (Kshs)	485,250.00	946,500.00	2,815,500.00
Value of fish per harvest (Kshs)	900,000.00	1,800,000.00	5,400,000.00
Gross Margin (Kshs)	414,750.00	853,500.00	2,584,500.00
Annual Income/HH (Kshs)	69,125.00	142,250.00	430,750.00
Monthly Income/HH (Kshs)	5,760.42	11,854.17	35,895.83
Daily Income/HH (Kshs)	192.01	395.14	1,196.53

cage measuring 18 m diameter with an 80 m^{-3} stocking density will immediately transit the cage farmer to lower commercial with similar stocking density (80 m^{-3} with a daily income of Kshs 3,972 and transits further to upper commercial of Kshs 12,138 under three (3) cages and Kshs 40,759 under 10 cages production level (Table 5).

Cage culture contribution to national gross domestic product

In the year 2013, total fishery and aquaculture production amounted to 186.7 MT, with 83% (155 MT) coming from inland capture fisheries of which Lake Victoria contributed about 90% (139.5 MT). In the same year, aquaculture production rose from 21,500 MT the previous year to 23,501 MT and hit the peak with 24, 096 MT in 2014 (FAO, 2013). The 2014 production contributed to the 0.8% National GDP from fisheries and aquaculture. A total of 3,696 cages were recorded by November, 2017 along the Kenyan shores of L. Victoria with current production estimated at 3,180 MT valued at Kshs 955.4 Million (9.6 million USD). Cage Culture in L. Victoria has created over 500 jobs directly and indirectly created income opportunities for over 4,000 people in rural and urban settings.

Table 5. Cage culture income at subsistence, emerging and commercial levels.

Variable	Commercial	Commercial	Commercial
Cage Size	18m Diameter	18m Diameter	18m Diameter
No of Cages	1	3	10
No of fish stocked per Cage	100000	100000	100000
Survival Rate	0.9	0.9	0.9
Total weight at Harvest (Kg)	45000	135000	450000
Cost of Cage (Kshs)	500,000.00	1,500,000.00	5,000,000.00
Cost of production (Kshs)	9,420,000.00	27,780,000.00	91,960,000.00
Value of fish per harvest (Kshs)	18,000,000.00	54,000,000.00	180,000,000.00
Gross Margin (Kshs)	8,580,000.00	26,220,000.00	88,040,000.00
Annual Income/HH (Kshs)	1,430,000.00	4,370,000.00	14,673,333.33
Monthly Income/HH (Kshs)	119,166.67	364,166.67	1,222,777.78
Daily Income/HH (Kshs)	3,972.22	12,138.89	40,759.26

Conclusions and recommendations

The aquaculture value chain has potential to transit from subsistence to full commercialization (upper commercial) if cage culture value chain actors adapt commercial size cages (>60m^3) with a minimum stocking density of 80 m^{-3}. To fully achieve this, a cage farmer is expected to source for affordable high quality seed and feed and ensure good management practices throughout the growth period. It is therefore critical that the fish fingerlings hatchery operators and feed manufacturers ensure quality, affordability and accessibility. The government on the other side should ensure availability and full implementation of fish seed and feed standards in the country. Lake Victoria being a shared resource demands that all the three East African Countries research bodies such as Kenya's KMFRI, Uganda's National Fisheries Resources Research Institute (NAFFIRI) and Tanzania Fisheries Research Institute (TAFIRI) urgently compile similar data in their respective countries to inform lake management. Regional and domesticated country cage culture investment regulations and full implementation are inevitable. All tthese will in turn create sustainable job opportunities, increase incomes and food security across the aquaculture value chain through small and large water bodies.

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