State of Cage Culture in Lake Victoria, Kenya.

Sagwe Orina
Kenya Marine and Fisheries Research Institute (KMFRI)

Erick Ochieng Ogello
Maseno University Kenya

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

Cecilia Muthoni
Kenya Marine and Fisheries Research Institute (KMFRI)

State of Cage Culture in Lake Victoria, Kenya

State of Cage Culture in Lake Victoria, Kenya

KENYA MARINE AND FISHERIES
RESEARCH INSTITUTE

STATE OF CAGE CULTURE IN LAKE VICTORIA, KENYA

COPYRIGHT PAGE

Cover Image: Series of images taken during the assessment. Photos by Dr Paul Orina

Citation:
Orina PS., Ogello E., Kembenya E., Githukia C., Musa S., Ombwa V., Mwainge VM., Abwao J., Ondiba RN and Okechi JK (2018). *STATE OF CAGE CULTURE IN LAKE VICTORIA, KENYA*.

Copies are available from:

The Director
Kenya Marine and Fisheries Research Institute
P.O. Box 81651– 80100
Mombasa, KENYA

Telephone: 0208021560/1
FAX: 254 41 475157

E-mail: director@kmfri.co.ke
Internet: http://www.kmfri.co.ke

EDITORS
Prof James M. Njiru
Prof Charles C. Ngugi

DISCLAIMER

ACKNOWLEDGEMENT

The authors wish to thank the freshwater aquaculture research and technical team under the Aquaculture Division of Kenya Marine and Fisheries Research Institute (KMFRI) for their valuable contributions to this edition. Special thanks go to KMFRI Board and Institute management for resource and moral support towards addressing this subject. We recognize the immense contribution made by the aquaculture value chain actors and more specifically cage culture investors, fish feed suppliers and the fisher folk in Lake Victoria, Kenya. The achievements in the Aquaculture sub-sector would not have been realized without the support of the Kenyan Government through the Ministry of Agriculture, Livestock and Fisheries (MoALF) and the Lake Victoria riparian County Governments.

PREFACE

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. In the contrary, low income food-deficit countries (LIFDCs) annual fish per capita consumption rose from 3.5 to 7.6 kg against 26.8 kg among industrialized countries. Between 2000 and 2011 Kenya recorded a decrease in the per capita fish consumption from 6.0 to 4.5 kg, a factor closely linked to low capture and aquaculture fish output (fisheries and aquaculture contributing paltry 0.8 percent to the country's GDP) against a growing population. 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 accompanied with considerable social and economic benefits. The contribution of aquaculture to the world total fish production reached 43.1%, up from 42.1% in 2012. The rapid global aquaculture growth is directly related to technological advancement and levels of technological adoption and adaption specifically in the Asian continent. This has seen most developed and developing countries transit from semi-intensive to intensive and super intensive aquaculture production systems. The advancement has further seen an increase in use of race ways, re-circulating systems and use of automated aerators in ponds. In light of the Blue Economy potential, cage culture is fast gaining prominence in aquaculture production contribution. It is based on the investment and production scales, ease of management and underlying economic benefits that the Lake Victoria Kenyan side has since 2009 experienced a rapid growth on cage investment. This began with trials at Dunga and Obenge beaches by the Fisheries Cooperative Societies under the Beach Management Units (BMUs) in Kisumu and Siaya Counties respectively. However there has been limited documented success on these trials. Nonetheless, cage culture picked up in the lake in 2012, through a participatory research approach by KMFRI who engaged Dunga BMU using locally fabricated mild metal frame cages (8m3) with great success. This later attracted interest resulting in the current 3696 cages across the five riparian counties with an estimated production capacity of 3,000 MT/year. 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. To commercialize cage culture activities, technological investment and its associated enterprises are gradually experiencing adaption to overcome competition from capture fisheries and imported fish. As cage culture commercialization takes root in

Lake Victoria, there is urgent need to address issues such as conflicting interests in shared resource, introduction of exotic culture species, disease and parasite invasion, marine parks, and maximum carrying capacity among other aspects. This will require a trans-boundary and cross-border policy in light of devolution and the neighboring countries to ensure sustainable utilization of the lake as a common resource.

FOREWORD

Aquaculture in Kenya has in the last decade experienced fast growth contributing significantly to food security, poverty alleviation and job expansion along its value chain. For many years, aquaculture was limited to extensive small holder production scales with the sole purpose of food security in the rural areas. Production facilities were confined to excavated earthen ponds along springs, rivers and swamps with limited or no extension service resulting in poor fish management. However, this has undergone a transformation courtesy of the Government's efforts through the then Ministry of Fisheries, Fish Farming Enterprise Productivity Programme (FFEPP) under the National Economic Stimulus Programme (ESP) initiated in 2009. The programme resulted in not only on acreage increase under aquaculture but also the vibrancy of the aquaculture value chain. The pond number increased from 4,000 in 2009 to 69,194 in 2013. Notably, the program resulted to an increase in the number of fish seed production units to an all-time regional high of 150 private and public hatcheries. The sub-sector also had cottage and commercial fish feed manufacturers increase to meet the fish feed demand across the country. This resulted in increased job opportunities with the aquaculture value chain, its supportive value chains and enterprises. However, this has not been able to meet the population demand for food fish in the country resulting in a fish consumption per capita drop from 6.0 kg in 2000 to 4.5 kg in 2011.

Aquaculture is fast moving away from extensive to intensive production systems to meet the ever rising local demand for food fish. To achieve this, aquaculture has embraced various production technologies including use of liner material in porous soils, use of concrete and plastic tanks, indoor re-circulating facilities and cages. However, it is the high profitability potential of cage aquaculture that has shifted attention of fisher folk and investors to cage farming. Cage culture dates back to 1980s with drawbacks and latter picked up in 2010. Cage technology is fast growing in Lake Victoria with significant contribution to national fish production. Through cage culture the aquaculture sub-sector anticipates increased job opportunities, enhanced food security and incomes for both rural and urban dwellers.

However, as the Blue Economy is exploited through cage culture, there is need to sustainably manage the resource through sound stakeholder consultative policies.

Prof. James M. Njiru (PhD)

Director/KMFRI

ABBREVIATIONS

ASARECA	Association for Strengthening Agriculture Research in East and Central Africa
ASDSP	Agricultural Sector Development Support Programme
BE	Blue Economy
BMU	Beach Management Units
CCTV	Camera Connected Television
***Chl*a**	Chlorophyll a
DO	Dissolved Oxygen
ESP	Economic Stimulus Programme
EU	European Union
GDP	Gross Domestic Product
GPS	Geographical Positioning System
HACCP	Hazard Analysis and Critical Control Points
HDPE	High Density Polyethylene
JOOUST	Jaramogi Oginga Odinga University of Science and Technology
KMFRI	Kenya Marine and Fisheries Research Institute
LBDA	Lake Basin Development Authority
LIFDCs	Low Income Food-Deficit Countries
NEMA	National Environment Management Authority
ORP	Oxygen Reduction Potential
PVC	Polyvinyl Chloride
SACCO	Savings and Credit Cooperative Organization
SDF	State Department of Fisheries
SDGs	Strategic Development Goals
TDS	Total Dissolved Substances
VC	Value Chain

Aquaculture	Fish Farming (breeding, rearing, harvesting)
Adaptive Assessment	Learning by doing exercise
Agricultural Sector (Narrow sector)	Agriculture, Livestock and Fisheries
Agro-ecological zone	Refers to geographical areas exhibiting similar climatic conditions
Agro-processor	An organization or individual involved in the transformation of any agri-value chain commodity
Anchor Technology	Driving technology in a value chain
Assessment Tool	Data collection instrument
Cage Culture	Farming of fish in cages in water
Capture Fisheries	Commercially important fish caught from the wild
Cold Rooms	Chilling facilities provided along the chain
Consumer	End user of a value chain product or service
Emerging	Transitioning from poverty (<$ 2 per person) to lower commercial (= $2/person/day)
Escapee	Loss of live fish from cages during growth or harvest time
Feeding Regimes	Is the frequency of feeding fish under a culture facility
Fish seed	Fingerlings produced by hatcheries
Market	Is where VC commodities are bought or sold. The area may be within the county, inter- county, regional, urban (in cities) or international.

Value Chain Node	Is a segment occupied by value chain actors
Organizational Level	An individual, group or co-operative involved in production of agricultural produce
Organization Size	The number of aquaculture investors at a given beach location
Riparian Counties	Busia, Siaya, Kisumu, Homa Bay and Migori
Small Scale	Cage investors with less than 15 cages of $8m^3$ each with an income of less than Kshs 500 per HH/day
Supportive Enterprise	Business initiative that provides the finished products or services for the development of the prioritized value chains
Supportive Value Chain	That value chains that provides the raw materials for the development of the prioritized value chain
Technological Packages	A set of technologies that complement one another to improve production level on value chain nodes

Note: *Definitions are given in context within which they are used in the study. They may not necessarily take the conventional or literal meaning*

CONTENTS

List of Tables

List of Figures

List of Plates

Chapter 1

1.0 INTRODUCTION

1.1. Background Information

Fishery development is one of the key global development goals embodied in agenda 2030 under the fourteenth Sustainable Development Goal (SDG), in which countries seek to support the restoration of fish stocks to improve safe and diversified healthy diets. Lake Victoria's capture fishery has gradually been on the decline over the last three decades due to overfishing, ecosystem degradation, environmental pollution and climate change (Ogello et al., 2013a; FAO 2016). Consequently, fish production for human consumption has declined, leading to nutritional insecurity and poverty in the larger East African region. Today, there have been both national and regional efforts to address the declining fish stocks through innovative technologies and expanded culture species (Orina et al., 2018). At the national level, fish cage culture and aquaculture parks have been identified as strategic cutting edge technologies with the potential to increase fish production and as potential mitigation measures to reduce fishing pressure on the lake and bridge the gap between fish demand and supply. Aquaculture, through its value chain linkages has become an important pillar for rural livelihoods in situations where increasing population pressure and environmental degradation limit catches from wild fisheries (Ogello et al., 2013b; Munguti et al., 2014; Ogello and Munguti 2016).

Over the years, pond-based fish farming has dominated the aquaculture sector while cage and pen culture systems are relatively new. Pond-based aquaculture is characterized by technical and functional challenges such as faster water quality deterioration, surface scam, flooding menace, water and land scarcity. Notably, ponds demand large amounts of water, making them inefficient and vulnerable to climate change leading to low productivity. These challenges have necessitated a regional shift to cage culture, which is functionally more productive than pond-aquaculture. Fisher-folks in Lake Victoria are turning to cage culture, which is expected to offer alternative livelihoods to fishing and at the same time, utilize the large expanse of the now under stocked waters left behind by the dwindling capture fisheries. The cage system allows free exchange of water and removal of wastes from the cage into the surrounding waters. In addition to high productivity, cage systems have other advantages such as ease of harvesting, monitoring and allow the usage of other water resources such as reservoirs, ponds and Oceans.

While the financial success of cage culture has been reported in Europe, America and Asian continents, cage culture is still at its infancy in the African region (De Silva and Anderson 1995). Cage culture was first introduced in several African countries in the 1970s but only few of these early attempts proved to be sustainable (FAO 2007). Some of the recurrent barriers to sustainable cage investment in Africa include disease problems, high initial investment costs combined with difficult access to credits and necessary materials for cage construction, unavailability of cost-effective high quality feeds, resource use conflicts and challenges in marketing of cage reared products. In extreme cases, cage operators have had their cages stolen or vandalized.

In Kenya, cage culture was first practiced in 2005 by Dominion Farm Limited in Siaya County within their farms. In 1988, the Lake Basin Development Authority (LBDA) initiated first cage culture trials in Lake Victoria at Dunga beach in Kisumu County (Aura et al., 2018). In 2007, cage culture trials projects were conducted in small water bodies within Lake Victoria Basin courtesy of the EU funded 'BOMOSA' project. Since then, cages have been initiated in several beaches along the Kenyan Lake Victoria belt, with Dunga Fishermen Co-operative Society (supervised by Kenya Marine and Fisheries Research Institute) being the first group to adopt cage culture in 2009 in Kisumu County. In 2012, other Fisheries Cooperative Societies under various Beach Management Units (BMUs) in Kisumu and Siaya Counties ventured in cage culture under the support of Association for Strengthening Agriculture Research in East and Central Africa (ASARECA). However, due to some challenges (cited earlier), some of the cage ventures became unsustainable leading to low adoption levels in some areas while some private investors have continued with cage investment. Despite being a relatively recent technology in Kenya, cage culture is gaining great interest among fishermen now turning into fish farmers and investors along the Lake Victoria belt in response to pressure from growing demand for fish. Currently, cage culture is receiving more attention from research, fishers, fish farmers and commercial investors' almost in equal dimensions and has spread rapidly in all riparian Counties, thus prompting the intervention of government agencies to formulate cage culture regulation policies. In addition, there are lucrative prospects to explore Blue Economy (BE) under cage culture in other un-exploited inland waters such as rivers, dams, ponds, reservoirs, but such options are yet to be exploited. BE initiatives support the creation of a low-carbon, resource-efficient, socially-inclusive society and reduction of environmental risks and ecological scarcities. As capture fisheries stocks dwindle in Lake Victoria, new opportunities for investment as stipulated in the BE concept and the potential yield of cage culture promises to supplement capture production and boost food security in the East African region. It is increasingly becoming evident that without intensified sustainable management efforts for all the water bodies, they, in turn, will be unable to sustain the human population that depends on them particularly in the developing nations and more precisely sub-Saharan Africa.

1.2. Purpose and Objectives of the Assessment

1.2.1. Purpose

Lake Victoria is a shared resource that supports the livelihood of over 30 million people directly or indirectly through provision of domestic and industrial water, fishing ground, transport and subsistence agriculture. To facilitate sustainable fisheries and aquaculture growth in the region, socioeconomics of Lake Victoria fisheries including prospects of cage culture should be assessed and regional policies formulated for all the lake riparian states. Due to the increasing interest in cage culture along Lake Victoria, the Kenya Marine and Fisheries Research Institute (KMFRI), which is the body mandated to do research in all aquatic ecosystems in Kenya initiated an assessment exercise for all the cages in the five riparian counties of Lake Victoria.

1.2.2. Objectives

i. To map out all existing cages and cage investment sites in Lake Victoria, Kenya.

ii. To assess existing cage technologies, ownership structure and management options.

iii. To determine the effects of commercial and cottage feeds on water quality and growth performance and production capacity of caged tilapia.

iv. To assess the commercialization potential of cage technology.

v. To document the emerging issues in cage culture and their mitigations cage culture policy recommendation on cage culture in Lake Victoria.

Chapter 2

Ogello E. O., Githukia C.M., Kembenya E.M ., Ombwa V., Musa S.

2.0 SITE SELECTION AND MAPPING OF CAGES

2.1. Introduction

Cages are normally located in oceans, lakes, reservoirs, ponds and rivers. However, strict criteria should guide cage site location since each site may have specific laws governing the use of public waters. Further to this, poor cage siting may lead to unprecedented poor fish growth, mortalities as well as conflict with other water users. Some factors to be considered before placement of cages in public water bodies include: 1) the water surface area should be at least one half acre and must have good water quality, 2) the cages should not be close to erodible watershed to avoid accumulation of large amounts of organic debris, 3) the area should not have chronic problems with aquatic weeds, surface scums, or oxygen depletion problems, 4) the area should be open with adequate prevailing winds blowing across it. Problems such as water quality deterioration, low oxygen, ammonia or nitrite buildup, and excessive algal blooms frequently arise when sheltered bays are used for cage culture. Adequate space below the cage (at least 3 m) ensures maintained water circulation through the cage and minimizes uneaten feed and fish fecal matter accumulation directly below the cage. It has also been established that the hydrodynamics of lake ecosystems have direct influence on cage site location. Nyamweya et al. (2016) reported prevailing climatic and weather conditions influence hydrodynamics of Lake Victoria on diel, seasonal and annual scales. Simulations of Lake Victoria show that the water column exhibits annual cycles of thermo-stratification (September–May) and mixing (June–August) and, an under flow current that creates upwelling and down welling spots (Nyamweya et al., 2016). Areas prone to intensified mixing of the lake with limited water currents should be treated with caution by cage investors as upwelling currents expose anoxic bottom waters that can cause mass fish mortalities.

2.2. 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. 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 was done for Lake Victoria (Figure. 2.1) and the recent cage assessment exercise has shown the current location of cages in Lake Victoria, Kenya (Figure 2.1). 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, cage investment in Lake Victoria was noted during the assessment not to take cognizant of this factors.

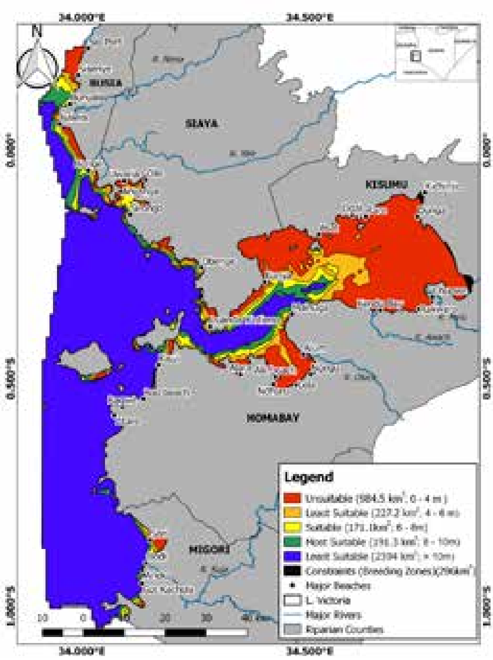

Figure 2.1: Cage culture suitability map in Lake Victoria, Kenya

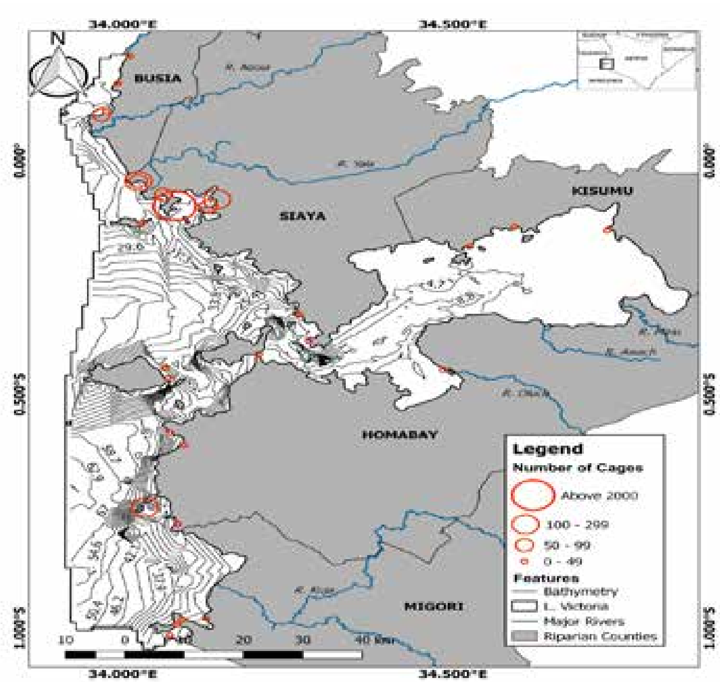

Figure 2.2: Cage density map by Counties in L. Victoria, Kenya

2.3. Cage Numbers and Geographic Positioning per County

It was established that the Kenyan side of Lake Victoria has a total of 3,696 fish cages, of which majority (n=3141; 85%) were located in Siaya County (Table 2.1). The main reason for higher cage culture investment in Siaya County could be attributed to a special support from the Ministry of Devolution, which funded a project titled "Western Kenya Community Driven Development and Flood Mitigation Project", in which several sub-counties were funded up to Ksh 1.5 million to articulate projects geared towards poverty alleviation and community development. The community invested in cage fish farming, which was considered as more financially viable to fishing. The success stories in Usenge and Mageta caused rippled effect of cage culture in other beaches in Siaya County. In addition, Jaramogi Oginga Odinga University of Science and Technology (JOOUST) is working with the local community to encourage cage culture projects within Bondo sub-county. In Busia county, the survey noted a marginal rise in number of cages from 80 in 2017 to the current 120 (Figure 2.3). This slowed cage technology uptake could be attributed to an influx of capture fisheries fish from Uganda (Per comm BMU Chairman-Sio Port). Migori County similarly demonstrated slow cage culture adoption level a trend attributed to major capture fisheries fishing activities in Sumba beach and Migingo Island in Kenya as well as an influx of wild caught fish from Uganda and Tanzania (Per comm Chairman Sumba Beach. In Homabay County, cage culture is on the rise particularly due to suitable cage sites and relatively clear water. Cage culture in Kisumu County is gradually increasing but many ecological issues including pollution challenges are rampant.

Table 2.1: Distribution of cage culture establishments per county

County	Beaches	Cage Establishment(s)	Number of Cages	No. of Fish. Cage $^{-1}$
Busia	Mulukoba	1	60	2000
	Sio Port	1	20	0
	Sisenye	1	20	0
	Busembe	1	20	0
HomaBay	Alum	1	3	7000
	Likungu (Ramba)	1	10	115000/21000/9000
	Litare	1	2	21000
	Nyagwedhe	1	22	14000

	Nyandiwa	1	286	1200/1600/1800/7680
	Lukwiri	1	2	21000
	Rasira	1	26	5000/25000
	Sena	1	3	21000
	Utajo	1	7	2000/6000
	Sindo	1	118	5000/23000
Kisumu	Bao	1	26	2500/8000
	Dunga	1	22	5000/10000
	Ogal	1	37	6000/10000/16000
Migori	Kithegunga	1	7	2500
	Matoso	1	5	2000
	Ngore	1	6	2000
	Sumba	1	5	2000/3800
Siaya	Anyanga	3	2160	2000/90000
	Got Agulu	2	52	1500/2000
	Lwanda K'Otieno	3	43	2000/2500/5000
	Misori	1	38	3000
	Ndisi	1	0	0
	Nyenye Got	1	31	2000
	Sika	1	30	2000/4000
	Ugambe	1	170	1500/2000
	Usenge	2	65	1500/2500
	Utonga	1	90	1000/1500/2000
	Uwaria	1	16	3500
	Uyawi	1	17	8500
	Waria	1	250	1500/3000
	Oele	1	20	1800
	Otono	1	7	1800
	Total	**40**	**3696**	

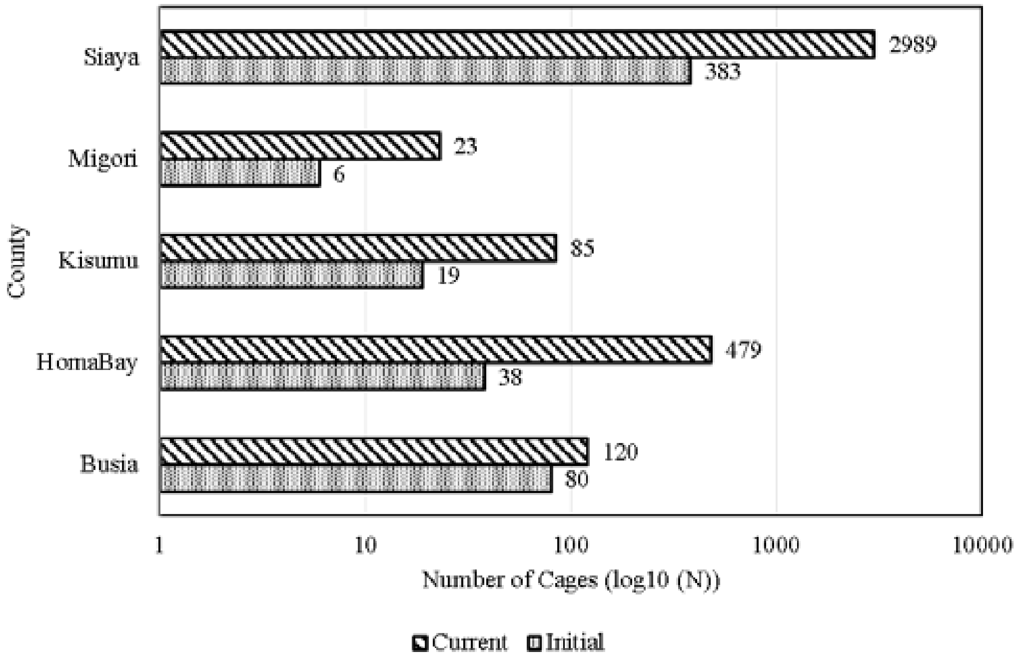

Figure 2.3: Cage number per County in Lake Victoria, Kenya between 2016 and 2017

2.4. Conclusions and Recommendations

The Kenyan side of Lake Victoria has a total of 3,696 fish cages, of which majority are locatedin Siaya County. Most of these cages are located relatively along the shoreline due to highoperation costs of accessing the open waters regularly. However, research data on cage sitinghave shown that poor cage siting leads to unprecedented fish mortalities and conflict with otherwater users. Lake Victoria exhibits annual cycles of thermo-stratification (September–May) andmixing (June–August) and, an under flow current that creates upwelling and down welling spots.Such areas should be avoided by cage investors as upwelling currents expose anoxic bottomwaters that can cause mass fish mortalities. It is recommended that the cage investors shouldadhere to the guidelines of good cage farming practices that includes proper siting for betterproductivity.

Chapter 3

Orina P.S., Githukia C.M., Ondiba N. R., Abwao J.

3.0 CAGE TECHNOLOGY

3.1. Introduction

All investors in Lake Victoria used floating cage technology but varied significantly on cage frame material (Figure. 3.1). The cost of cage construction is relative to size and the material used. Though wooden, polyvinyl-chloride (PVC), mild and galvanized metal cages are fairly affordable and material easy to access, they are less durable and prone to damage when exposed to strong water currents. Unlike the wooden, PVC, mild and galvanized metals cages, HDPE cages are traditionally large in size (≥10 m diameter) and are designed to withstand very strong water currents. A 1-2 inch nylon netting is mounted on the various cage frames to hold the culture fish over the growth period. Different netting approaches are normally employed by cage culture investors. While other cage investors prefer having the entire cage mounted with the nylon netting (including cage top), others have the cage top surface covered with 2 inch metal wire mesh. Cage investors have also designed walkways to ensure safety of their staff feeding the fish and also allow for observation of fish behavior over the growth period. The walkways mounted on the cages are either made of HDPE pipes or fabricated mild or galvanized metal. The cage management levels are as varied as cage designs, materials and associated management technologies employed thus having a significant effect on cage production. Large cages require least human labor and are exposed to less damage risks unlike the small cages. Further to this, large cages demand deeper open waters thus exposing the cultured fish to better water quality through frequent flushes a major factor to caged fish survival and growth.

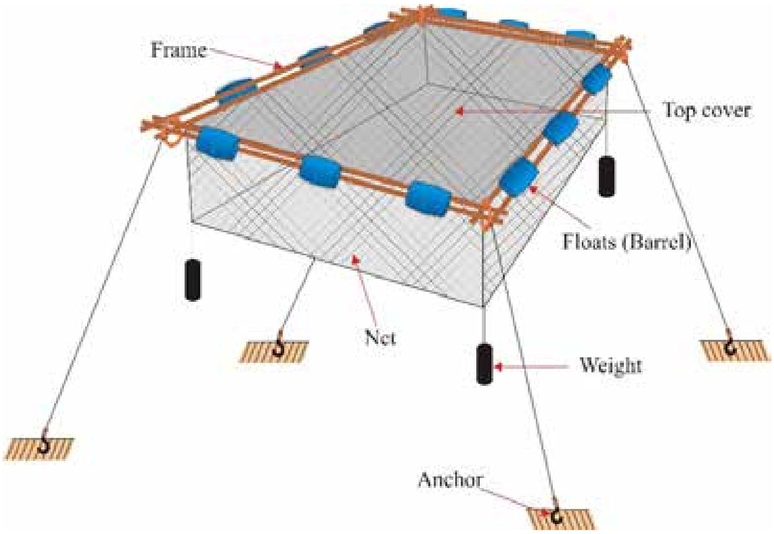

Figure. 3.1: Layout of small-scale fish cage showing suspended anchors, nets and cover

3.2. Cage Designs

Fish cage design is determined by several factors including site, water currents, cost, investment period and desired investment level. It was evident that during cage design, the investors consider the safety of the fish and the people who use the cages. The parts of a floating cage unit are designed and constructed in a manner that provides suitable anchorage, buoyancy, strength and stability. The investors mostly use plastic drums (Plate 3.1) or sealed polyvinyl-chloride (PVC) pipes (Plate 3.2) as buoyancy materials while anchors are used to hold the cages from strong currents.

Plate 3.1: Locally fabricated mild metal cages at Tie Got Beach, Siaya County

Plate 3.2: PVC cages at Mageta Island, Siaya County

During cage design, investors reported that factors such as cage operating staff safety, stocking density, fish feeds load and water currents are considered. It was also clear that the cage investors conduct routine maintenance inspection specifically after storms. The most popular (n =3,696; 90%) cage sizes were 2x2x2 and 3x3x3 (8-27m^3), an indication that most cage farmers are small-scale investors mainly designed using mild metal frames and PVC pipes. However, an adaption of 2x2x2m (8m^3) wooden framed cages operated by low income small scale cage investors were documented during the assessment in Migori County (Plate 3.3). Even though small cages are cheap to construct and stock, larger cages (Plate 3.4) are more productive, damage resistant and easy to manage than small cages.

Plate 3.3: Wooden frame cages at Muhuru Bay, Migori County

Plate 3.4: Imported HDPE 20 meter diameter cages at Likungu Beach, Homa Bay County

The assessment further established that nets for cage construction are supplied by Monasa Nets Kenya Ltd. and Kavirondo Fishnets Sundry and Hardware Ltd. all located with Kisumu town. Cage mesh size has a significant impact on fish retention in the culture cage, water quality, fish's survival and growth and overall production. Thus, the choice of cage mesh size should put into consideration cage spacing, levels of water mixing at the site of choice, stocking density, size of fish at stocking and the anticipated growth period. Most cages that were assessed have mesh sizes of between (0.5 and 1.5 inches). These mesh sizes provide open space for good water circulation through the cage to allow water exchange to supply dissolved oxygen and remove wastes, a major factor in the success of tilapia cage culture. Even though larger mesh size facilitates good water circulation through the cage to renew supply of oxygen and removal of metabolites, they may allow the cultured fish to escape from the cage and/or allow wild fish to enter the cage. In the contrary, small mesh size netting demands regular cleaning to avoid clogging and subsequent water fouling in and around the cages.

3.3. Cage Ownership and Management

Cage establishment organizational structure in Lake Victoria, Kenya was quite varied. Majority of cage establishment (n=22; 64%) were group owned while the least (n=1; 3%) was individual ownership (Table 3.1). However, there was no link between cage ownership and cage sizes in all the five counties. Management levels varied based on the production managers education level and not age and gender. Majority of the managers (n=21; 52%) had secondary level education, followed by Diploma graduates (n=8; 20%) and University graduates (n=6; 15%). It was noted that a significant number of investors employed primary level of education managers (n=5; 13%) with no previous aquaculture training. Management position in cage culture was male dominated (n=26; 87%), while a majority (n=29; 73%) of the managers were below the age of 45 years.

Table 3.1: Demographic of cage culture investors in Lake Victoria, Kenya

		n	**Proportion (%)**
Gender	Female Male n	4 26 40	13 87 100
Age	19-35 36-45 >45	8 21 11	20 53 27
Education	Lower Primary Upper Primary Secondary Diploma Degree	1 4 21 8 6	3 10 52 20 15
Cage Ownership	BMU Company Cooperative Family Group Individual	2 2 3 1 22 3	6 6 9 3 64 9

Unlike other counties, Busia had only one cage design (locally fabricated galvanized metal cages). Siaya County has the highest number of cages (2989) with the highest concentration (2160) localized within Bondo Sub County (Anyanga Beach) followed closely by Homa Bay County (Figure 3.1).

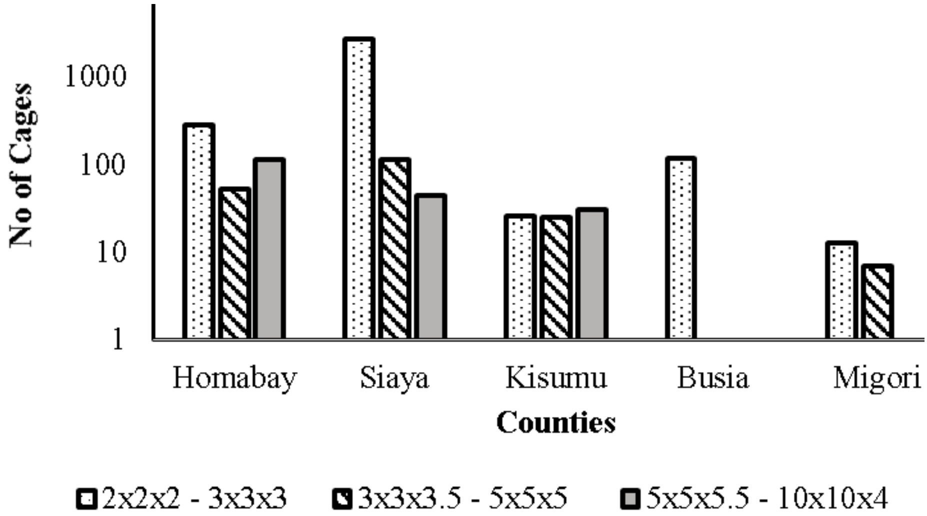

Figure 3.2: Cage culture investment levels by sizes in the L. Victoria riparian Counties

Unlike other counties, Busia had only one cage design (locally fabricated mild metal cages). Siaya County had the highest number of cages (2989) with the highest concentration (2160) localized within Bondo Sub County (Anyanga Beach) followed closely by Homa Bay County (Figure 3.2).

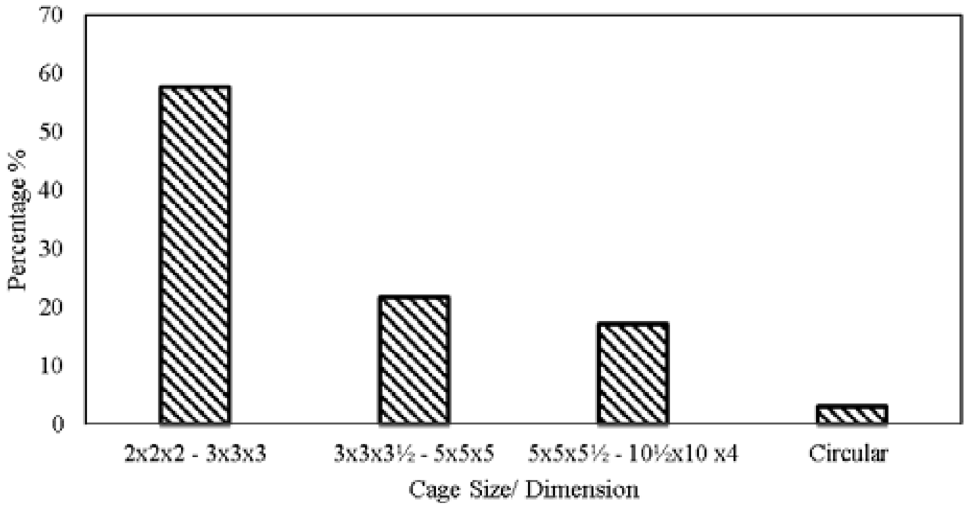

Figure 3.3: Cage design and sizes in Lake Victoria, Kenya

3.4. Conclusion and Recommendations

Cage design, sizes and materials vary significantly among cage investors in L. Victoria Kenya, a factor of either capital investment or operational cost. The quality of cage material, feed management and security of cultured fish against escaping to the wild are environmental critical factors for investor's consideration. The cage design and size plays a key role not only in production capacity but also on the survival and growth of the cultured fish. It is recommended that cage investors gradually transit from the traditional fabricated mild metal and wooden cages to more environmentally friendly galvanized metal and HDPE cages. Due to the high capital and operational costs of HDPE cages, the small cage investors are highly recommended to form groups or Savings and Credit Cooperative Organizations (SACCO's) to enable them have the financial capacity to purchase and operate them.

Chapter 4

Kembenya E.M., Ogello E. O., Githukia C.M., Ombwa V., Okechi J.K

4.0 EFFECTS OF COMMERCIAL AND COTTAGE FEEDS ON TILAPIA GROWTH PERFORMANCE AND WATER QUALITY

4.1. Introduction

In fish farming, nutrition is critical because feed constitutes over 50% of the production costs (FAO, 2014). Feeding of fish in cages aims at producing the maximum weight of marketable fish within the shortest time at a low cost. The feed should be able to supply the necessary energy for movement and provide nutrients for body maintenance and growth. Good nutrition in fish production is essential to economically produce high quality fish.

Fish stocked at high densities in cages require feed in adequate quantity and quality to promote fish growth. When the fish are fed, water exchange is needed to bring oxygen into the cage and to remove waste products from the cage generated by the fish as a result of feeding. Waste removal becomes more critical when water temperatures are high and water circulation from wave action is minimal.

Caged fish may be subject to chronic environmental stress such as blooming of macrophytes, lake mixing and runoff from the watershed resulting to poor water quality. Wastes can also pollute the water leading to severe algal blooms, water quality deterioration, and eventual fish mortalities. However, this is common in small or shallow water bodies and or sheltered bays. Furthermore, high amount of organic matter washed into the lake can result in oxygen depletions due to rapid bacterial decomposition (Dias et al., 2012).

Some of the important water quality parameters include; turbidity, dissolved oxygen, ammonia, temperature and pH. Turbidity due to total suspended solids (TDS) around the cages is associated with fish feed dust, river influx, lake mixing and fish wastes.

4.2. Feeding and stocking density

There seems to be no standard stocking density for cages as reported by most farmers. Some farmers have known (by experience) quantity of fish to be stocked in a given cage size for better yields. Nonetheless, fish are mostly stocked at lower densities of about 100 -125 fingerlings m^{-3}. The survival rates of fish in cages also vary significantly across the farmers and counties. Whereas other farmers have reported high mortalities of about 20-30% mostly within the first month after stocking, others have reported low mortalities (1-5%) within similar periods. Mortality causes varied among cage investors but was not related to Counties. The reported cage fish mortalities were mainly associated with site selection a factor closely linked to water exchange rate. Disease incidences were rarely reported and further to this, cage investors could not clearly diagnose the disease due to lack of knowledge in fish diseases.

In terms of feeding regimes, most farmers preferred feeding their fish twice daily while others vary (Figure 4.1). Most fish farmers feed their fish based on body weight (Figure 4.2), while other farmers use feeding charts, experience and satiation level. Some of the factors that guided feeding regimes were availability of quality feeds and logistics (boat, fuel and personnel) to and from the cage sites. The assessment confirmed that majority (n=40; 80%) of the cage investors had no feeding records for their fish over production cycles.

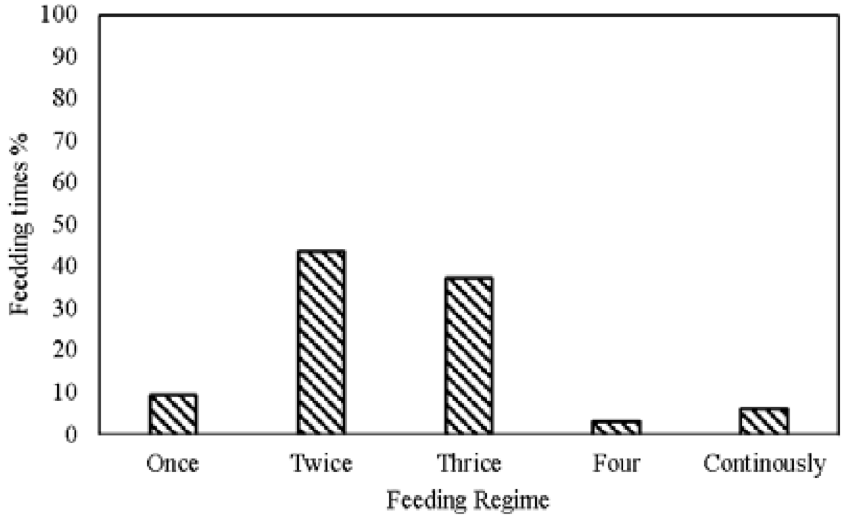

Figure 4.1: Various cage feeding regimes in L. Victoria, Kenya

There were a total of twelve feed suppliers along the L. Victoria cage sites with an average fish feed cost for every growth stage as presented below (Table 4.1).

Table 4.1: Average Cost of Feed at Different Growth stage

Stage	Fingerlings	Post Fingerlings	Juvenile	Market Size
Average Price (Ksh/kg)	180	154	125	110

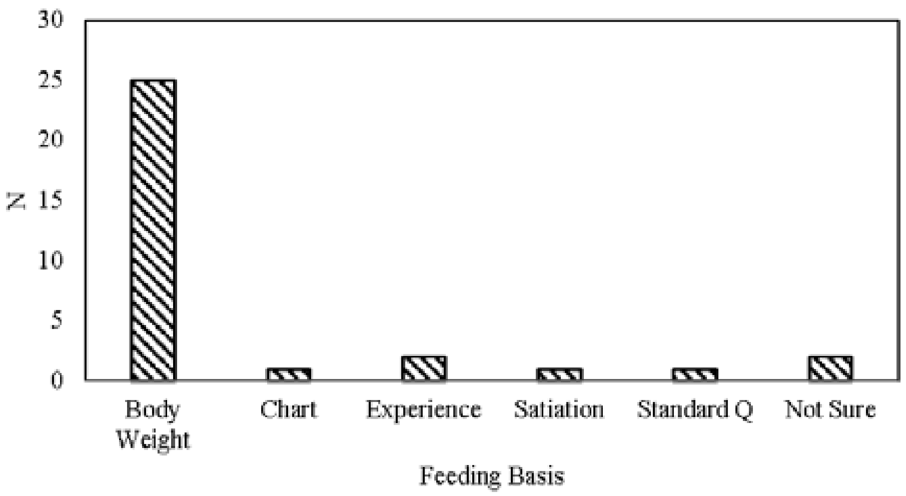

Figure 4.2: Cage fish feeding approaches in L. Victoria, Kenya

4.3. Cage Productivity

With varied stocking densities and feeding regimes, some successful farmers have reported yields of between 10-14 kg m^{-3} at 300-600 g body weight in 6-8 months. Although the resultant production is lower than in intensive tilapia cage culture systems which report yields of up to 330 kg m^{-3} at 500 g in four months (Rojas and Wadsworth, 2007) cage culture is cheaper, and much higher than production from ponds.

Cage productivity of Nile tilapia (tonsyr^{-1}) in all the five riparian counties of Lake Victoria Kenya side varies according to the investment levels (Figure 4.3). Siaya County is leading followed by Homa Bay County and Migori is the least in productivity.

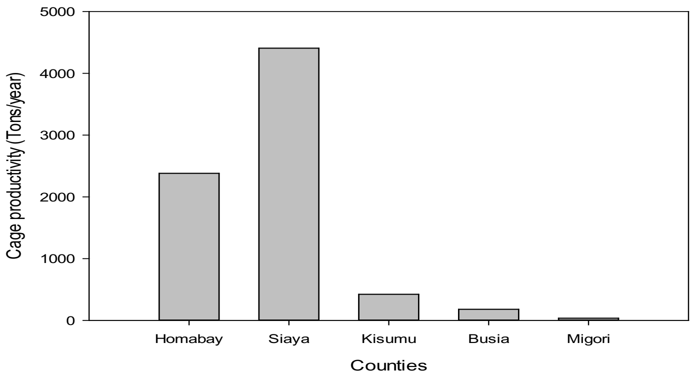

Figure 4.3 Cage productivity (TonsYr^{-1}) by investment level among riparian counties along L. Victoria, Kenya

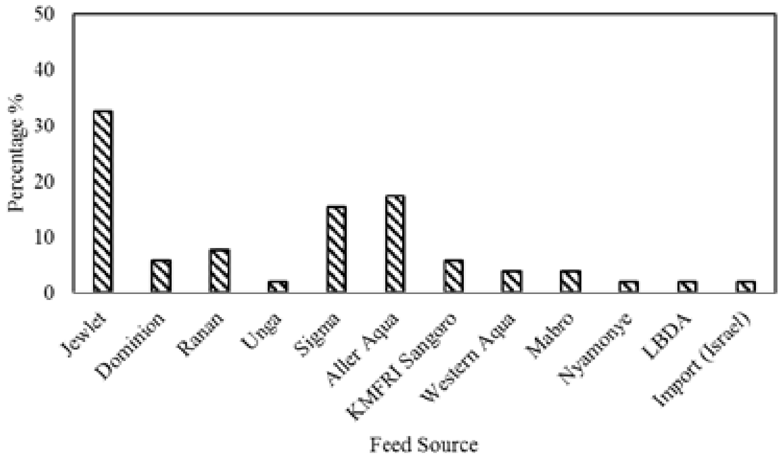

Figure 4.4 Various feeds used by cage investors in Lake Victoria Counties along L. Victoria, Kenya

During the survey, cottage and commercial fish feed samples were collected from the cage investors and taken to Kenya Bureau of Standards (KEBS) for proximate analysis (Table 2). This is important as it will help investors to make informed decisions when purchasing feeds. There was variation between analyzed and company declared nutrient contents of different feeds especially crude protein (CP). After analysis, feed A (commercial), feed D and feed E (cottage) had CP levels above what was indicated on the package. Feed C (cottage) had CP levels less than what was indicated on the package. However, company nutrient details for feed B and feed F were not available. Protein is the major determinant factor in fish feed and it is influenced by various factors such as fish species, age of fish, water temperature, feeding rate, availability and quality of natural foods (Wilson 2000). The fibre content for all the feeds was within the recommended range of between 8-12% in diets for fish (De Silva and Anderson 1995). High fibre content result to lower digestibility of nutrients in fish feeds (Ayuba et al., 2013). Lipid values for all the feeds were within recommended range in most freshwater fish below 20% for optimum growth rates of fish.

Aflatoxins were highest in feed B (17.14 μkg^{-1}) and lowest in feed F (0.71 μkg^{-1}). Aflatoxins are common contaminants of fish feeds. Their production in feeds is influenced by; environmental temperatures above 27°C, humidity levels greater than 62%, and moisture levels in the feed above 14%. These factors favor growth of aflatoxin producing molds (Russo and Yanong, 2013).

Table 4.2: Proximate analysis of cottage and commercial feeds collected from cage investors

Parameters	Feed					
	A	B	C	D	E	F
CP (%)	32	24.36	26.10	31.92	33.24	33.5
Crude fibre (%)	6.41	9.95	5.42	7.39	8.24	7.1
Crude fat (%)	6.75	5.16	5.0	5.82	6.84	10.7
Carbohydrates (%)	35.14	47.36	42.81	21.8	29.93	36.73
Moisture (%)	11.79	13.17	12.27	12.35	12.27	11.97
Aflatoxins (µkg-1)	2.82	17.14	1.34	3.36	8.12	0.71

4.4. Water quality

4.4.1. Physico-chemical parameters in cages

Feeding and water quality assessment of tilapia growth in cages focused on two sites; Asat and Rasira beaches in Kisumu and Homa Bay Counties respectively.

In Asat Dissolved oxygen (DO) levels were lower as compared to Rasira which is an open site. This may be associated with the sheltered nature of Asat beach. However, there was sufficient water flux through the cages. In both cage sites DO concentrations were within the recommended levels but concern still remain that cage culture may significantly decrease DO concentrations enough to cause negative effects. Tilapia requires DO concentration of above 4 mgl^{-1} to maintain good health. It can tolerate 1 mgl^{-1} DO for short periods of time but will die if the exposure is prolonged further. TDS were higher in Asat as compared to Rasira (Table 4.3). However, the levels were within recommended ranges for Nile tilapia cage culture. High flushing rates due to seasonal shifts in water currents disperse the feeds and wastes suspended in the water column thus minimizing turbidity in cages. Short-term turbidity spikes are not likely to have lasting impacts on water quality in the cages (Price et al., 2015).

Table 4.3: Mean values of physico-chemical parameters in cages.

SITE	DO (mgl^{-1})	Conductivity (μscm^{-1})	TDS (mgl^{-1})	pH	Temp (°C)	ORP*	Chl a ($\mu g\ l^{-1}$)
Asat	4.68 ±0.24	158.8±8.6	76.5±1.5	9.46±0.5	25.73±0.7	-151.97±7.0	0.016±0
Control	4.46 ±0.21	157.9±8.3	76.8±1.6	9.44±0.5	25.03±0.7	-151.97±7.0	0.016±0
Rasira	7.75 ±0.4	101 ±3.7	50 ±1.1	8.89±0.3	25.48±0.5	-200.38±9.4	0.016±0
Control	7.45 ±0.4	100 ±3.0	52 ±1.9	9.49±0.5	24.97±0.5	-200.47±9.2	0.016±0

*Oxidation Reduction Potential

Figure 4.5 shows the growth of Nile tilapia grown using three different diets from different companies under the same conditions. Commercial feed 1 performed better than commercial feed 2 and cottage feed. However there was no significant variation in growth performance on fish fed commercial diet 2 and cottage feed. Variation in growth of the experimental tilapia can be attributed to the type of diet and not the effect of environmental variables.

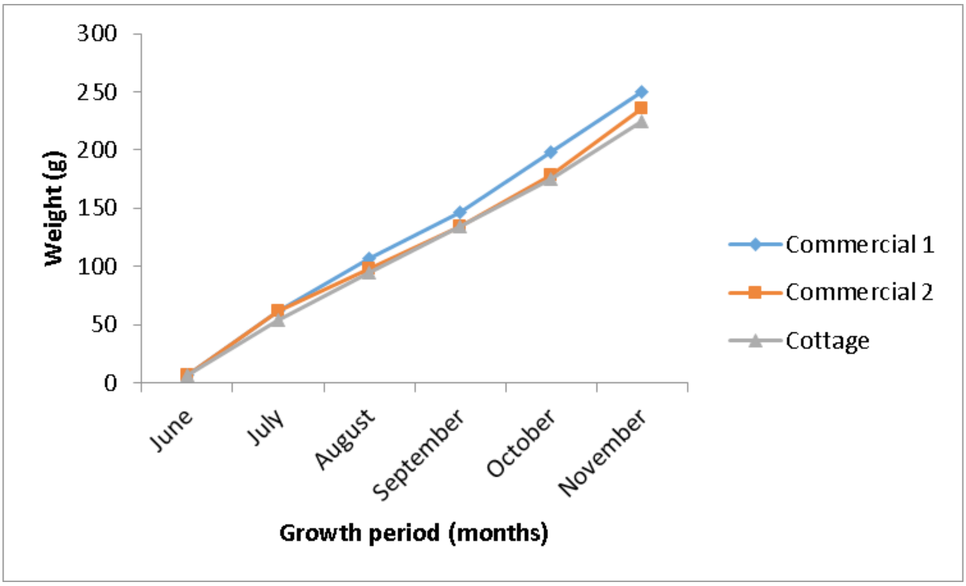

Figure 4.5: Growth of Nile tilapia fed on different diets at Aquapark, Asat, Lake Victoria, Kenya

4.4.2. Nutrients

Nitrogen and phosphorus are the limiting nutrients in natural responsible for water primary productivity. There were no significant differences in phosphorous in the cages and the control away from the cages. In Asat the mean levels of phosphorous was 100μgl^{-1} while in Rasira it was 98 μgl^{-1}. However, there was a significant difference in total nitrogen between Asat and Rasira (Figure 4.6). This may be attributed to the fact that Asat is more sheltered leading to less water circulation of nutrients in the cages. Dissolved nitrogen and phosphorus from uneaten feeds, fish excretes are often released and dispersed from the cages into the surrounding water. Although the nutrient levels were low cage intensification may significantly increase their levels in the surrounding waters. Therefore, cage investors need to be cautious on practices that may cause nutrient enrichment to the surrounding water column (Beveridge, 1984; 2013).

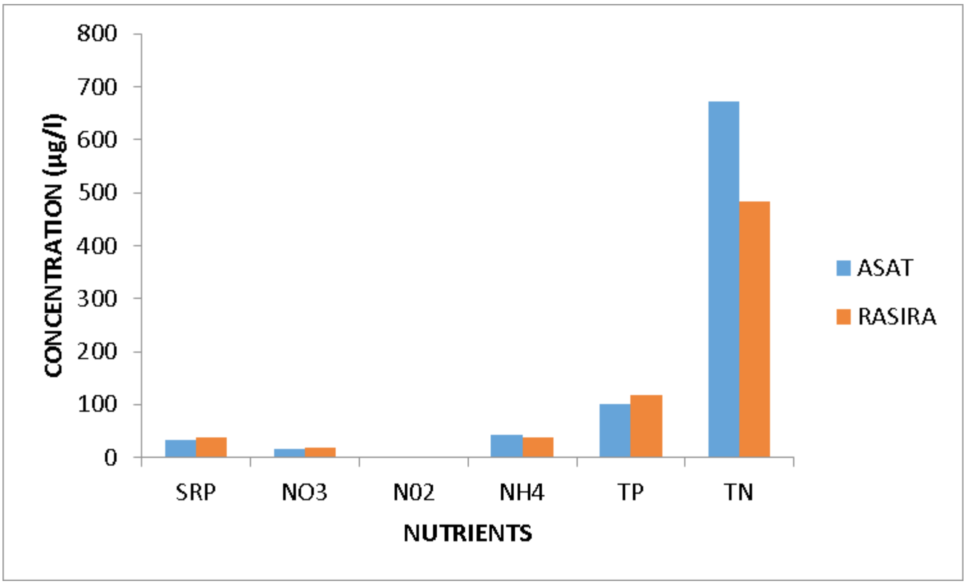

Figure 4.6: Nutrients concentrations at the cages in Asat and Rasira, L. Victoria, Kenya

4.5. Conclusion and Recommendations

It's recommended that regular close monitoring should be conducted in sheltered bays with highly concentrated cages. Te sediments beneath the cages are ofen subject to organic loading from fecal matter and uneaten feed. Regular monitoring of cage sites is highly recommended to check on possible ecological shifts that maybe associated with cage investment levels over time.

Further, it is important for the cage investors to use feeding chart and maintain proper records of all the activities undertaken from the start of the growing season to the end

Chapter 5

Orina P.S., Kembenya E.M., Abwao J., Ogello E.O.

5.0 COMMERCIALIZATION OF CAGE CULTURE IN LAKE VICTORIA, KENYA

5.1. Introduction

Aquaculture despite being a millennia old began commercializing 30 years ago resulting in the current contribution of 74 million tonnes representing 44.1% of the global sea food production worth USD 176 billion (FAO, 2016). As global aquaculture production grows against limited land area and water, there has been a technological advancement from the traditional ponds and pens to cages aimed at increased production (Cardia, 2015; FAO, 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

(Tschirley et al., 2015; Kassam and Dorward 2017). 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 decrease in capture fisheries. 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 under the Blue Growth initiative is exploited through cage culture, there is not only the need to sustainably manage the resource 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, 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. This will greatly contribute towards O. niloticus cage culture production avoiding the setbacks experienced in pond based aquaculture in Kenya despite huge government investment.

5.2. 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. In order for cage culture investors to realize the underlying objective (profits) for their investment, there is need to conceptualize the value of technology and its supportive enterprises for faster transformation 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 5.1).

Table 5.1: 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 (Vision 2030) is attained at 4,000 USD per capita per annum.

Kenya's aquaculture sub-sector has in the last one decade experienced 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 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 (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 system which will lead to high stocking densities. 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 5.2).

Table 5.2: Income 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

Cage culture though a recent concept in Kenya's Lake Victoria waters has not only attracted a lot of investment attention but also varied in technology adoption since 2015. Cages currently under production in the lake take different shapes, dimensions, construction materials and stocking densities. The most dominant cage design and material is the locally fabricated mild and galvanized metal cages measuring 2x2x2m ($8m^3$), an approach dominated by Siaya County followed by Homa Bay County (Figure 5.1). 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 5.3).

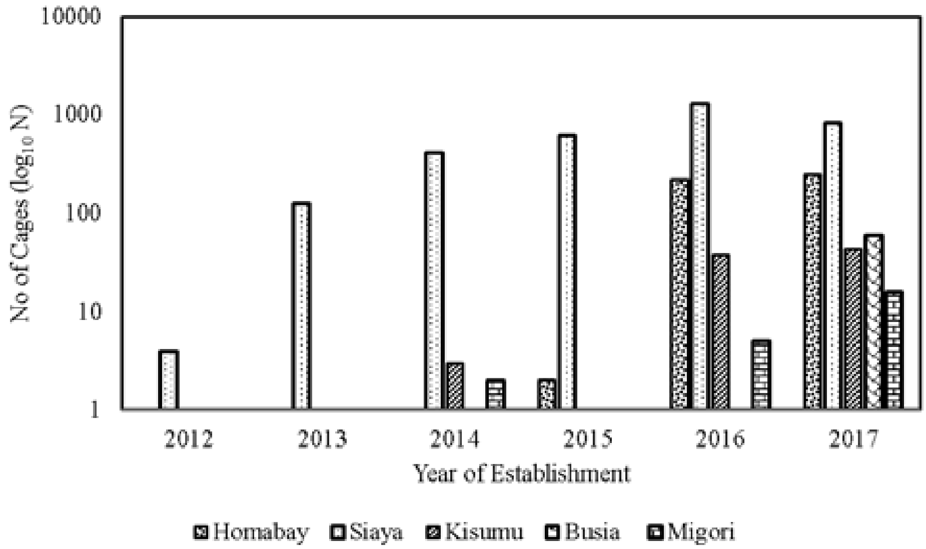

Figure 5.1: Annual cage establishment growth in Lake Victoria, Kenya

Tble 5.3: 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

The locally fabricated mild and galvanized metal cages have 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). A 5x5x2.5m mild or 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 5.4).

Table 5.4: 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 investors have in the recent further adapted to eco-friendly cage technology transiting from locally fabricated mild metal cages to less corrosive galvanized metal cages and further to more commercial oriented high density polyethlene (HDPE) cages majority being circular. A HDPE cage measuring 18m 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 production level and Kshs 40,759 under 10 cages production level (Table 5.5).

Table 5.5: 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

Variable	Commercial	Commercial	Commercial
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

5.3. Cage Culture Contribution to National GDP

In the year 2013, total fishery and aquaculture production amounted to 186,700 MT, with 83% (154,961 MT) coming from inland capture fisheries of which Lake Victoria contributed about 90% (139,465 MT). In the same year, aquaculture production rose to 23,501 MT from 21,500 MT the previous year and hit the peak with 24,096 MT in 2014 (FAO, 2016). The 2014 production contributed to the 0.8% National GDP from fisheries and aquaculture. However, this has recently (2016) experienced a major aquaculture production decline to 14, 952 MT. 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.

Plate 5.1: Advert on aquaculture value chain service in Bondo town, Siaya County

Plate 5.2: Orieco cage investors fish outlet in Nairobi, Kenya

5.4. Conclusion and Recommendation

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. These will in turn create job opportunities, increase incomes and food security across the aquaculture value chain.

Chapter 6

Githukia C.M., Mwainge V.M., Kembenya E.M., Orina P.S.

6.0 CAGE FISH VALUE CHAIN ANALYSIS IN LAKE VICTORIA, KENYA

6.1. Introduction

Fish is critically important to food security and serves as a good protein nutrition source (Beveridge et al., 2013). Fish cage farming is expected to bridge the gap in fish production as demand continues to outstrip production necessitated by rapid population rises and healthy eating habits (Githukia et al., 2014). Overfishing, use of illegal gears, pollution, destruction of breeding grounds and eutrophication among others factors have greatly contributed to the decline of Lake Victoria fish catches over the years resulting in increased fish commodity prices (FAO, 2016). Kenya like other countries across the globe has invested in land based aquaculture with the most recent being the Economic Stimulus Program (ESP) which contributed significantly to the 24,096 MT aquaculture production in 2014 but has still fallen short of meeting the local food fish demand (Munguti et al., 2017). The communities along the shores of Lake Victoria traditionally fishermen have embraced cage fish farming at much higher rate over a short period compared to land based fish farming. As a result, cage fish presents a promising lakeside aquaculture alternative due to its intensification potential. Cage fish farming in Kenya is an enterprise acknowledged by both urban and rural communities; it is gaining ground in Kenya and is expected to significantly contribute to the country's GDP.

Value occurs when needs are fulfilled in terms of supply of goods and services in a transaction. The supply chain denotes a series of activities in which a product or material is transferred from one actor to another in the value chain; instead of just transferring the product, value creation and addition is involved (Feller et al., 2006). Fish value chain like other agricultural value chains entails production, harvesting, sorting, processing and supply to the end consumers through the various chain nodes with the product experiencing upgrading at even level in the value chain. This process ensures quality, increased value and customer acceptability a process widely known as the value chain concept.

The 'value chain concept' describes the full range of activities which are required to bring a product from conception through the different phases of production (involving a combination of physical transformation and the input of various producer services) and delivery to final consumers (Knorringa and Pegler, 2006). Value chain is a very important aspect in production and economic development (Humphrey, 2004) and seeks to understand the sequence of activities stemming from product conception to the final consumer, stressing the importance of activities from the production to the consumption node. It also seeks to explain the potential to increase economic growth and reduce poverty. Several activities in the value chain are disintegrated to ensure efficiency and effectiveness in the production process since activities are executed by different actors in the chain. Other important aspects of the value chain development in cage farming include production, logistics and marketing supported by other value chains and enterprises.

In developing countries value chain is an opportunity for revenue generation, job creation and effective post-harvest management (Kruijssen et al., 2018). Kaplinsky and Morris, 2000) noted that the value chain is diverse with two main directions: from the input to output. At the input side, materials go through transportation and processing to be useful for fish cage growing. Upon fish harvesting subsequent chain nodes include processing, trade and end with consumers. Along the tilapia fish value chain, there exists opportunity on value addition (Ndanga et al., 2013) which not only increases the economic value of fish but also address market competition, consumer preference, post-harvest losses and food security. Use of cold rooms, smoking kilns and sun drying among other processes ensures reliability on market supply and quality of fish and fish products a process in the value chain that greatly contributes to improved profits.

6.2. The Input and Output Nodes

The input node refers to the materials and services that are provided for the production of the commodity while the output node refers to the processes involved in the supply and distribution of the end product. The input node of the value chain (feed, seed and cage material) and the output node (fish and fish products marketing and distribution networks) are relatively well developed in cage farming. In Kenya about 500 people are employed directly or indirectly in the aquaculture tilapia cage culture production technology. The technology uptake has also indirectly created income opportunities for over 4,000 people in rural and urban settings through supply of cage construction materials, feed and seed and in the distribution of the market fish to the various market outlets. Feed and seed was sourced from different hatchery operators within the locality of the cage site to reduce transportation costs and enhance fingerling survival. Jewlet Enterprises and Dominion Farms dominated supply of seed to tilapia cage farmers at 37% and 19% respectively (Figure. 6.1). 9% of the farmers produced seed on their own (self-production) from small land based ponds, while Pioneer and Mabro fish farms contributed 7% each. Majority (n=13; 46%) of the seed producers contributed a paltry 2% each as shown in Figure 1.

Feed is supplied by both local and international manufacturers. The main local manufacturers included Jewlet (33%) and Sigma Feeds Ltd (15%) who also doubles as distributors in the value chain. International feed manufacturers such as Aller Aqua and Raanan contributed 17% and 8% respectively. Worth noting is that they have contracted local and expatriate distributors of feed along the value chain (Figure 6.2). Cage materials take different forms and prices. The HDPE cages are mainly imported through middle men from China, while the galvanized metal cages and PVC fabricated cages are locally made by artisans. Most of the fabrication was noted to have major establishment in Kisumu and Siaya Counties, a trend that is closely associated with cage culture uptake in L. Victoria, Kenya. The local fabrication has not only engaged artisans but also increased sales for hardware materials and traditional capture fisheries fishing gear supplies by Monasa Limited and Kavirondo Fish Nets in Kisumu town.

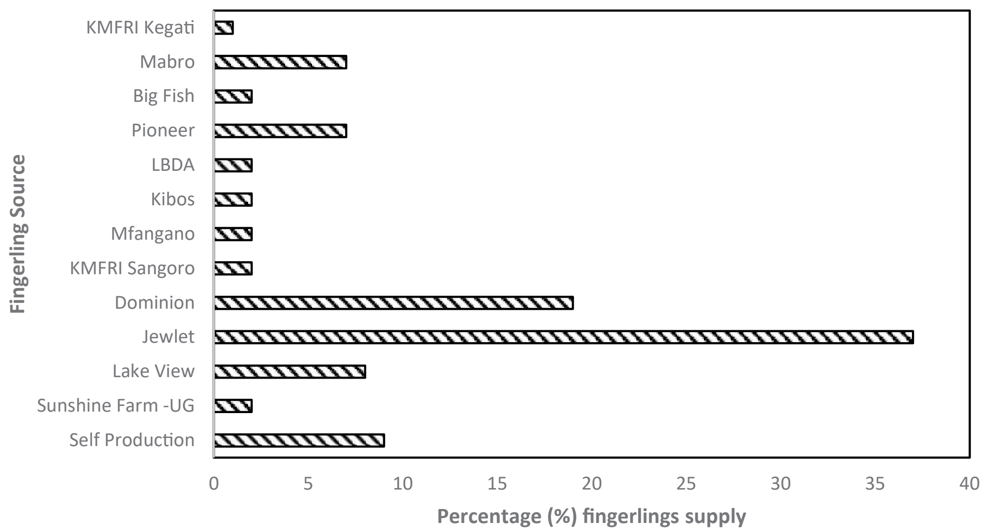

Figure 6.1: Source of seed

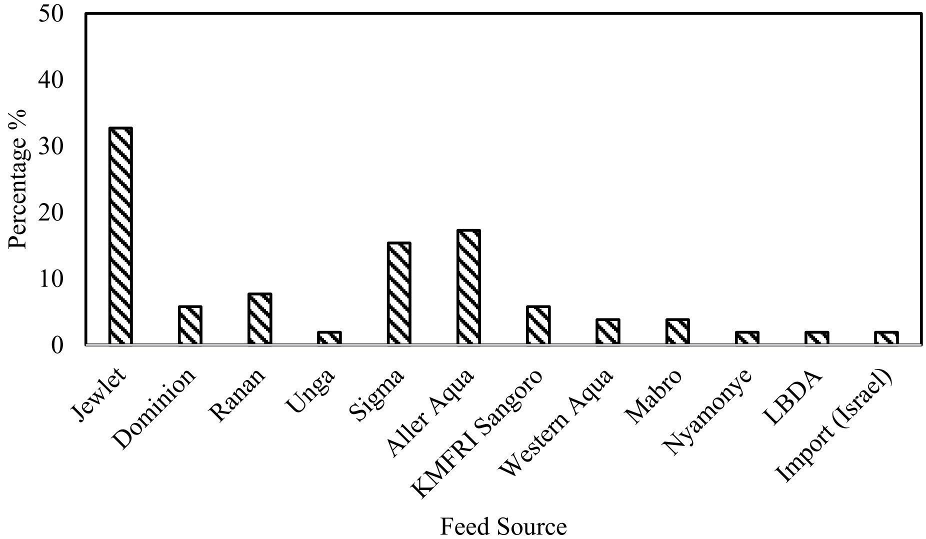

Figure 6.2: Sources of feed

At the output node, small-scale and medium-scale traders collect fish from farmers and sell through semi-structured distribution channels mainly composed of retailers at various local markets. Many large-scale cage investors have outlets in urban centres where they have freezers or cold rooms to ensure longer shelf life. The large-scale cage investors also transport their harvest in cooler vehicles to maintain freshness. They later sell their fish to wholesalers who in turn sell to traders in the market centres, hotels and restaurants.

There is high domestic demand of fresh fish in Kenyan markets. The main players of the cage fish marketing system comprise cage farmers, wholesale traders, retailers and the middlemen. The cage farmers play a role as producers, who are mostly involved in full-time jobs with high capital investment. It is worth noting that prices are determined by the cage farmer since fish are bought at the farm gate or at the outlets in different market centers. A majority of cage farmers only harvest fish when they have a ready market at the farm gate since cage harvesting is quite easy. Others have staggered their harvesting at intervals of two weeks coupled with refrigeration facilities or cold rooms at the outlets to minimize post-harvest losses in the absence of clients. Tilapia cage culture in L. Victoria has ensured reliable product supply at fairly stable prices (Kshs 350 per Kg). Majority (n=40; 72%) of the cage investors indicated that their clientele preferred whole fresh tilapia.

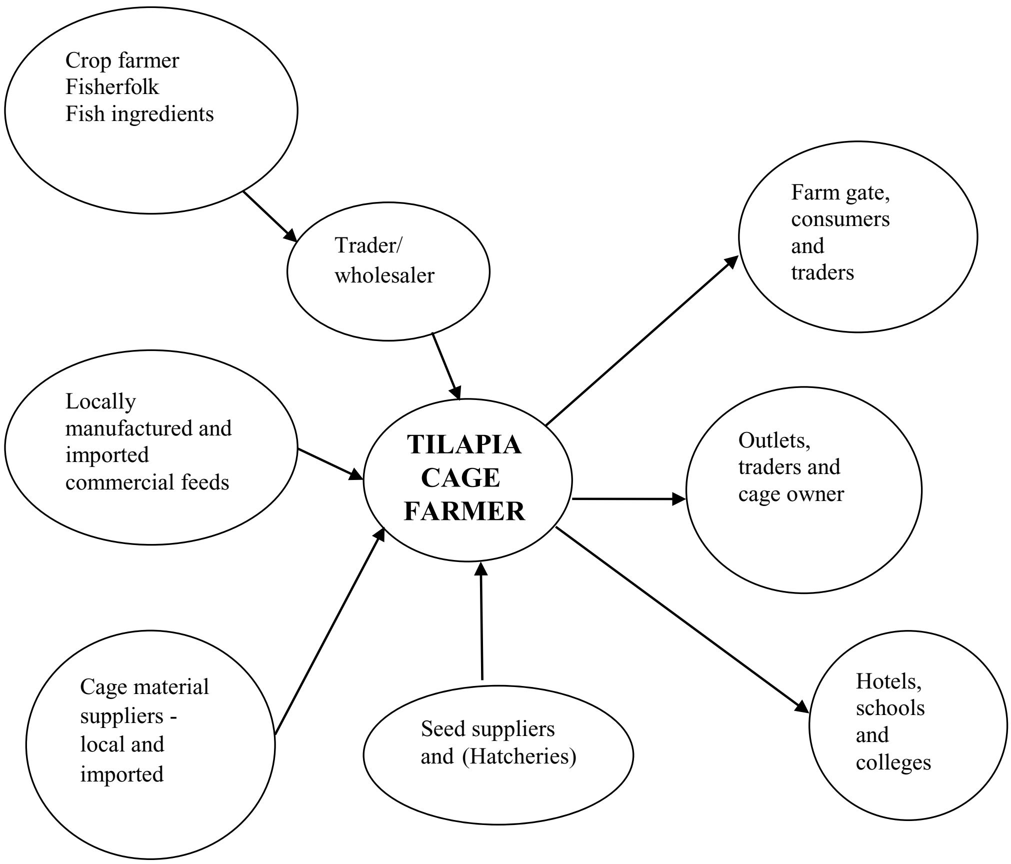

Figure 6.3: Cage fish value chain

6.3. Gender Roles in cage fish value chain in Kenya

Gender refers to the social, behavioral and cultural attributes or expectations and norms associated with being a woman or a man (World Bank, 2012). Gender is thus, not about women but about the relationship between women and men and their roles in the society. In the growing cage culture sector in Kenya, women roles are significant along the value chain, spanning all the way from production, processing and marketing. Their roles are very evident in the production of seed in the hatcheries, grow-out fish management (grading, feeding, sampling, harvesting) and overall farm supervision. In addition, women are majorly involved in processing of fish and distribution to various market outlets in the country ensuring constant product supply. In this case, they buy fresh/ frozen fish directly at the farm gate or from the wholesaler's cold rooms or chilling facilities at different outlets and value add to either fillets or fried before selling in the market. They also sell it fresh-whole depending on consumer preference.

In the present study, a significant number of respondents were men (n=40; 87%) while only 13% were women. This is a clear indication that more men are involved in the tilapia cage value chain than women. This is in agreement to the scenario in capture fisheries where fishing has been perceived to be predominantly men's work (Mbenga, 1999), where women are mainly engaged in postharvest activities such as smoking, frying, drying, and marketing. However, this contrast (Pierre et al., 2014) who in a study on value chain analysis of the fishery sector in Ghana found that more women are involved in aquaculture value chain than men because of cultural beliefs. To increase gender participation along the value chain, women and youth have been trained in different aspects of cage farming to improve productivity and profitability. This is meant to increase income, food security, employment and poverty reduction.

6.4. Cage fish processing

Cage culture production has currently shifted focus from aquaculture production to consumer demand, marketing and coordination of produce. Caged fish is either sold at farm gate and is currently limited to whole or goes through processing (gutting, chilling and freezing) before marketing. Processing not only improves profit margins but also adds value to fish through different methods. Some cage farmers transport the fish in refrigerated trucks to designated bulking outlets, store them in freezers or cold room before selling it to wholesalers and retailers as well as individual clients.

6.5. Form and value of Cage fish production in 2017

The investors interviewed gave varying values depending on the tonnage they harvested and price quoted per kilo. This was directly translated to the level of investment. The average market price of fish was Kshs 350kg^{-1}. 72% of the farmers reported that the customers preferred the fish fresh and whole. This is in agreement with Quagrainie et al., (2010) who in his study on supply chain and group marketing system in Ghana and Kenya found that Kenyans are used to purchasing fresh tilapia mainly because of the frequent supply from Lake Victoria. However, those distant from the production point (38%) could only get the fish when frozen or chilled. In total the caged fish was valued at Kshs 955.4 Million (9.6 million USD)

6.6. Conclusion and Recommendations

Cage culture value chain is fast growing and already indicates evolution of the value chain nodes for increased productivity, job creation and food security among the L. Victoria urban and rural communities. The evolvement of the value chain extends beyond the lakeside to the capital city of Kenya with fish outlets in Syokimau and Baba Dogo already in operation. The cage construction, material importation and supply as well as farm management with the outlets have contributed to increased job opportunities specifically for youth and women in line with vision 2030. The cage production now at an average of 3,180MT is a milestone towards addressing the fourth pillar for industrialization and food security for all Kenyans.

There is however need for sensitization of young graduates of all levels on the underlying opportunities along the aquaculture value chain more specifically in cage culture technology.

Chapter 7

Mwainge V.M., Ombwa V., Musa S., Ondiba R.N., Okechi J.K

7.0 CHALLENGES ASSOCIATED WITH CAGE CULTURE IN LAKE VICTORIA, KENYA

7.1. Introduction

Global statistics indicate that Aquaculture has been on an upward trend, surpassing capture fisheries (FAO, 2014) and is expected to contribute to fisheries significantly with increase of intensive cage culture uptake. Even though cage culture has been widely practiced globally, it is gradually picking in Kenyan waters though with limited documentation (Munguti et al., 2014). The rapid cage culture growth is likely to be faced by a number of challenges just like many other agricultural investments. The challenges include water quality, resource use conflict, theft and infections (Masser, 1997). In addition, lack of Good Aquaculture Practices (GAqP) coupled with increased water temperatures and low water exchange in and out of cages is a catalyst to diseases (FAO, 2007). Most importantly, disease occurrence is one of the main challenges cited to hinder sustainable cage culture production, whose risks increase with the rise in intensification as is observed in cage culture. Diseases affecting fish can be bacterial, viral, fungal and or parasitic. Various studies have established that high parasite load (ecto-parasites or endo-parasites) significantly contribute to decreased fish growth, mortalities and market unacceptability culminating to undesired aquaculture losses. Generally, fish diseases in cages can be attributed to infections due to introduction of infected fish, contamination by transportation containers, avian spread, intermediate host population rise, malnutrition, lack of seed traceability and disease ambient conditions (Okaeme et al, 1999). It is therefore imperative to ensure GAqP are sustained by all stakeholders to actualize cage culture as an investment. This can be achieved through development and implementation of national and regional guidelines on cage culture to avoid losses and limit resource use conflicts in L. Victoria.

7.2. Fish Health

Cage culture in Lake Victoria, Kenya is steadily gaining prominence for its culture of Nile tilapia (*Oreochromis niloticus),* but lacks clear management guidelines. *O. niloticus* is the main culture species due to its tolerance to a wide range of environmental conditions, ability to live on a variety of natural foods and formulated feeds, high culture potential, high growth rates under low input costs and disease resistance. However, there have been reported cases of fish kills in cages at selected beaches in L. Victoria's Kenyan side with limited causative documentation. According to KMFRI, (2016) report, the kills were associated with bacterial (*Colmunaris spp.*) and fungal (*Saprolegnia spp.*) infections. Their occurrence was closely linked to regular lake upwelling that caused anoxic conditions. Reported parasitic infestations included *Myxosporean* parasites, often attacking the host gills, parasitic copepods (of the family Lernaeidae), and parasitic crustacean (Argulidae) also known as fish lice (KMFRI 2016).

The reported infections coupled with lake mixing in the months of June, July and August resulted in mass fish kills that dampened the hopes of many investors. It is therefore vital to know about the occurrence, pathogenicity and prevalence of fish diseases and parasites in order to put in place the relevant control measures (Subasinghe et al., 2001; Akoll, 2005). The current cage culture assessment in L. Victoria Kenya recorded 80% cases of mortality among investors of which 34% were recorded monthly and 26% daily. A significant (63%; n=40) number of the cage investors experienced fish disease incidences with 25% reporting mass mortalities. Infections documented during the assessment were mainly fungal (38%) and bacterial (33%) with few (5%) investors reporting on parasitic infections. On average, 24% of the respondents could not tell apart the diseases or speculated mixed etiology.

In-situ assessment of caged fish demonstrated cotton-like growths from the mouth and tail, an indicator of fungal infections. Based on the infected fish condition and response from the farm managers, fish handling and nutrition were the main causative agents of the secondary infections. Cages located in Bays reported frequent algal bloom and hyacinth marooning resulting in lowered water quality which is another causative agent to bacterial incidences among caged fish. Fin rot and erosion which are a manifestation of bacterial infection were notable occurrences during the assessment among the caged fish and this was identified as the contributing factor to the sloughing-off of the fins. Fin rot occurrence can also be attributed to poor fish handling, water quality and feeding as well as bullying and nipping by siblings in the cage. Documented bacteria among L. Victoria caged fish include *Flavobacterium columnare, Pseudomonas fluorescence* and *Streptococcus spp.* The latter being symptomized by corneal opacity (cloudy eyes) as reported by 20% of the respondents. Other previously reported fish disease symptoms closely related to bacterial infections include swelling of the eyes and abdomen as well as red spots on the belly. Majority of the respondents (90%) had no fish disease training or clue on the treatment action necessary whenever fish diseases struck.

7.3. Lake Mixing

Thermal stratification occurs when surface waters warm up faster than the underlying layers. Lake Victoria experiences complete mixing once a year between June and July. This is when the established thermocline breaks down under the seasonal onset of the south-east trade winds. In July, the main body of the lake becomes isothermal with respect to depth. The water circulation patterns are influenced by inflow of the rivers feeding the lake. This determines the lake water quality spatial-temporally; an occurrence closely linked to the distribution of biota in the lake. Recently, isothermal conditions have been reported to begin in June and extend to August (Nyamweya et al., 2016). However, L. Victoria being a dimictic lake was noted to experience mixing in December and in both occasions, fish kills in cages have been reported every year (Plate 7.1). This leads to the formation of a thermocline which causes little exchange of water. When the water at the surface begins to cool down, the lake becomes isothermal and stratification breaks down. Currents arising from wind stress accelerate vertical mixing and breakdown of the thermocline (Macintyre et al., 2014).

Lake Victoria mixing locally known as "nyakoyi" is associated with anoxia and mass fish kills. This phenomenon has been witnessed at Anyanga, Nyenye Got Agulu, Mageta and other beaches in Siaya County but later spreads across the entire Kenyan side of the lake with minimal losses (pers.comm.).

Plate 7.1: Fish kills at Utonga beach, Siaya County

Other than increased water turbidity, cage investors and fishermen associated the population intensity of aquatic benthic snails on the lake surface as a biological indicator of lake mixing and subsequent reporting of fish kills (Plate 7.2).

Plate 7.2: Benthic mollusks migration to the lake surface

Despite Lake mixing being a natural phenomenon, its effects on cage aquaculture have been aggravated by a number of factors including high stocking density and cage crowding. This results to fast depletion of oxygen due to the high competition between the fish in the cages. Moreover, poor siting of the cages, for instance in lagoons where there is poor circulation of water prohibits proper flushing of the cages and acts as a catalyst to fish kills in those areas. Such problems can be avoided by proper site selection and placement of the cages.

7.4. Conflicts

Lake Victoria, just like all other water bodies, is a shared resource among various stakeholders with cage culture investors being the latest entrants. A significant number of the respondents (70%; n=40) had recorded conflicts during the assessment. The conflicts were between fishermen and cage investors. At all times, the fishermen accused cage investors of either obstructing them from fishing grounds, navigation route and or boats parking bays, an occurrence that was attributed to lack of stakeholder engagement through the BMU by the cage investors. On the contrary, cage investors complained of fishermen shifting from their traditional fishing grounds to around cages and in between cages; an action claimed by cage investor to cause fish stress. The cage investors therefore associated poor fish production to stress caused by the fishermen's fishing method (water beating) to aggregate wild stocks into their net traps. Being recent stakeholders in the Lake, cage investors must engage all stakeholders of the Lake before initiation so as to avoid any challenges arising from the investment.

Among them are briefcase farmers who, for logistical reasons (high initial investment costs, time constraints), are unable to undertake the daily management of the cages. This has driven them to invest in already established investors to manage a given number of cages on their behalf. Some unscrupulous investors have tapped into this and as a result end up assigning same cages to different people. Conflicts have thus emanated from the current unstructured cage investment approaches, a process that would be avoided by engaging formally.

7.5. Theft

Majority of the fish cages (98%, n=3,696) are located not more than 300m off the lake shores with only 2% having floating security houses with security personnel right by the cages. Only two cage investors had CCTV surveillance in Homa Bay County. The rest had incorporated the BMU and other locals in the investment under different organizational structures as a way of ensuring security for their investment. However, from the assessment, theft is gradually becoming a serious problem across the five counties resulting in the abandonment of cage culture in parts of Siaya and Migori Counties. According to investors and BMU leadership, theft was mainly linked to investment employees, group members and fishermen. A case in point was Nyenye-Got Agulu where investor suffered loss of an entire line of cages with 800 fish per cage, ready for harvest, leaving only 65 fish.. Generally, the survey confirmed that theft cases were reported to police and BMUs. Some investors opted to install CCTV cameras while others employed night guards to keep watch, an action that comes with significant cost implications.

7.6. Marketing and Finance

In Kenya, demand for tilapia is strong and growing across the country due to health reasons, high cost of other sources of animal protein and expanded acceptance by non-traditionally fish eating communities. Capture fisheries contributes significantly to the most preferred fish among them Nile tilapia (*O. niloticus)* and Nile perch (*Lates niloticus*) which are sold at relatively low prices. However, availability is declining due to over fishing, destruction of breeding grounds, use of wrong gears and eutrophication among other factors resulting in escalated prices. Currently, cage culture is targeting the local market for fresh and frozen whole fish and fillets in a bid to cushion the market from the declining capture fisheries stocks. Previous efforts such as ESP-FFEPP rolled out by the government between 2009 and 2012 with over 60,000 ponds dug in selected counties across the country has not met consumer demand. The government initiative saw production rise from 4,895 MT in 2009 to the highest ever recorded 24,096 MT in 2014. However, the aquaculture production has not met the expected food fish gap intervention from aquaculture with the most current productions recording a 37.9% decline (14,952MT in 2016). The decline in aquaculture production coupled with an already depleted capture fisheries has greatly contributed to the importation of cultured Nile tilapia from China with limited traceability documentation in public domain. L. Victoria cage cultured fish are sold at farm gate, through designated outlets and bulking warehouses at an average of Kshs 400/Kg (US$4) against the Chinese prices of Kshs 200/Kg (US$2). Even with the great disparity between imported and locally produced tilapia, majority of cage investors reported no market challenges, a clear indicator of how wide the tilapia fish market is in the country.

7.7. Fish Seed and Feeds

Cage culture up-scaling and out-scaling implies increased demand for quality seed and feeds. In Kenya, majority of the tilapia seed production hatcheries started during the Fish Farming Enterprise Productivity Programme, a sub-programme of the Economic Stimulus Programme (ESP-FFEPP) aimed at jumpstarting the economy (Orina et al., 2014). This equally saw feed demand rise resulting in a transformation from cottage processed slow sinking pellets to commercial high quality floating pellets.. Currently there are 18 documented local feed manufacturers and 5 importers. The cost of seed varies by hatchery agro-ecological location and size of fingerlings. Monosex fingerlings (0.5g) prices range between Kshs 3 and 10 (US$0.03 and 0.1) an affordable price by many cage owners. However, 30% of respondents in the assessment complained of poor growth (300g) and low survival (70%) over averagely seven months growth period. Quality commercial fish feeds cost is gradually coming down from an average of Kshs 200 (US$ 2) to Kshs 120/Kg (US$ 1.2/Kg), a cost considered still too high against the current growth rates with a reported FCR of between 1.2 and 1.8. Some cage farmers are reverting back to slow sinking cottage feeds and low dry shrimps due to unaffordable feed costs as was observed during the survey.

7.8. Conclusion and Recommendations

There exists huge knowledge gap among investors on disease management despite the huge investment cost on cage culture in Lake Victoria, Kenya. Throughout the belt, similar disease challenges were experienced with findings showing that knowledge sharing within and across counties existed. Investors who either incorporated the neighbors in investment or worked closely with the BMU had least resource use conflicts. It is therefore recommended that cage investors strongly consider stakeholder engagement at project conceptualization to minimize cage investment related challenges. There is urgent need for the formation of cage culture investors association to enable sharing of sub-sector related information on all aspects including marketing. The organization will also give the investors a bargaining power when seeking for tax waivers from the government or input suppliers among other value chain aspects.

WAY FORWARD

To sustainably utilize the Blue economy potential through cage culture, the following should be strongly put it consideration by all stakeholders;

National and Cross border fish health monitoring programmes should be developed to encompass preventive, regulatory and disease control measures. Coordination with international and national aquatic animal health organizations is also vital should there be outbreak of serious fish disease.

National and County governments ministries to offer cage culture investment and management guidance in view of aspects such as navigation, capture fisheries, marine parks, markets and tax on importation for sustainable resource utilization.

National and County governments ministries to reinforce data generation on fishery statistics, market surveys, fish quality assurance and control of import and export of fish and fishery products

National and County governments ministries to fully implement The Fisheries Management and Development Act 2016

REFERENCE

Akoll, P. 2005. Prevalence and pathology of protozoan and monogenean parasites from fry and fingerlings of cultured *C. gariepinus* (Burchell, 1882) in Uganda. Unpublished Msc thesis. UNESCO-IHE.

Aura, CM., Musa, S., Yongo, E., Okechi, JK., Njiru, JM., Ogari, Z., Wanyama, R., Charo-Karisa, H., Mbugua, H., Kidera, S., Ombwa, V. and Oucho AJ. 2018. Integration of mapping and socio-economic status of cage culture: Towards balancing lake-use and culture fisheries in Lake Victoria, Kenya. Aquaculture Research, 49:532–545.

Ayuba V.O & Lorkohol E.K. 2013. Proximate Composition of Some Commercial Feeds Sold in Nairobi. Journal of Fisheries and Aquatic Sciences, 8 (1): 248-252.

Beveridge, MCM. 1984. Cage and pen fish farming. Carrying capacity models and environmental impact. FAO Technical Paper 255. FAO, Rome.

Beveridge, MCM., Thilsted, SH.,. Phillips, MJ., Metian, M., Troell, M. & Hall, SJ. 2013. Meeting the food and nutrition needs of the poor: The role of fish and the opportunities and challenges emerging from the rise of aquaculture. Journal of Fish Biology, 83 (4): 1067–1084.

Cardia, F. & Lovatelli, A. 2015. Aquaculture operations in floating HDPE cages: A field handbook. FAO Fisheries and Aquaculture Technical Paper No. 593. Rome, FAO. 152 pp.

De Silva, SS & Anderson TA. 1995. Fish Nutrition in Aquaculture. Chapman and Hall, London, 208p.

Dias, DJ., Simoes, NR. & Bonecker, CC. 2012. Net cages in fish farming: A scientometric analysis, Acta Limnologica Brasiliensia 24 (1): 12-17.

FAO 2007. Cage Aquaculture. Regional Reviews and Global Overview. FAO Fisheries Technical Paper 498 (241).

FAO 2014. The state of world fisheries and aquaculture; Opportunities and challenges. United Nations, Rome.

FAO 2016. Fishery and Aquaculture Country Profiles. Kenya (2016). Country Profile Fact Sheets. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 2016. http://www.fao.org/fishery/.

Feller, A., Shunk, D and Callarman, T. 2006. *Value Chains versus Supply Chains.* BP.

Githukia, CM, Obiero KO., Manyala JO., Ngugi CC., Quagrainie, KK. 2014. Consumer Perceptions and preferences of wild and farmed Nile Tilapia (*Oreochromis niloticus* L.) and African Catfish (*Clarias gariepinus* Burchell 1822) in urban centres in Kenya International Journal of Advanced Research, 2 (7): 694-705.

Humphery, J. and Schmitz, H. (2004) 'Governance in Global Value Chains In: Schmitz, H. ed. 2004. Local enterprises in the global economy. Issues of Governance and Upgrading.

Kaplinsky, R. and Morris, M. 2000 'A Handbook for Value Chain Research', prepared for the IDRC, Institute of Development Studies: Sussex. Ottawa, Canada.

Kassam, L. and Dorward, A. (2017). Comparative assessment of the poverty impacts of the pond and cage aquaculture in Ghana. Aquaculture, 470: 110-122.

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 p.

Knorringa, P. and L. Pegler (2006) 'Globalization, firm upgrading and impact on labour,' Royal Dutch Geographical Society, 97:5, 470-479.

Kruijssena, F., McDougall C. L., and Asseldonk I.J.M (2018). Gender and Aquaculture value chains: A review of key issues and implications for research. Aquaculture, https://doi.org/10.1016/j.aquaculture.

Macharia, S. and Kimani, A. (2016). Kenya Fish Farming Enterprise Productivity Capacity Assessment and Gap Analysis Report. State Department of Fisheries and Blue Economy, Kenya. 48 p.

Masser, MP. 1997. Cage culture site selection and water quality. SRAC 161.

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

McIntyre, S., Romero, JR., Silsbe, GM. And Emery, BM. 2014. Stratification and horizontal exchange in Lake Victoria, East Africa. Limnology and Oceanography, 59:1805-1838. DOI: 10.4319/lo.2014.59.6.1805.

Munguti, JM., Kim, J., Ogello, E. 2014. An overview of Kenyan Aquaculture: Current status, challenges and opportunities for future Development. Fish Aquat. Sci. 17(1), 1-11.

Munguti, J.M., Obiero, K. O., Orina, P.S., Musa, S., Mwaluma, J., Mirera, D., Ochiewo, J. Kairo, J. and Njiru J.M. (Eds.) (2017). The State of Aquaculture in Kenya. WestLink Services Limited, Nairobi, Kenya. 133 p.

Mwanja, W.W., Akol, A., Abubaker, L., Mwanja, M., Msuku, S.C., Bugenyi, F., 2006. Status and impact of rural aquaculture practise on Lake Victoria basin wetlands. Afr. J. Ecol., 45: 165-174.

Ndanga, L. Quagrainie, K. & Dennis, J. (2013). Economically feasible options for increased women participation in Kenyan aquaculture value chain. Aquaculture. Vol. 414–415, 15 November 2013. p. 183–190.

Nyamweya, C., Desjardins, C., Sigurdsson, S., Tomasson, T., Taabu-Munyaho, A., Sitoki, L., et al. 2016. Simulation of Lake Victoria Circulation Patterns Using the Regional Ocean Modeling System (ROMS). PLoS ONE 11(3): e0151272. https://doi.org/10.1371/journal.pone.0151272.

Ogello, EO and Munguti JM. 2016. Aquaculture: a promising solution for food insecurity, poverty and malnutrition in Kenya. African Journal of Food Agriculture, Nutrition and Development, 16 (4): 11332 – 11351.

Ogello, EO., Frank, TM., Munguti, JM., Nyonje, BM., Charro-Karisa, H. 2013b. Can integrated livestock-fish culture be a solution to East African food insecurity? African Journal of Food Agriculture, Nutrition and Development, 13 (4): 1 – 22.

Ogello, EO., Obiero, KO., Munguti, JM. 2013a. Lake Victoria and the common property debate: is the tragedy of the commons a threat to its future? Lakes, Reservoirs and Ponds, 7 (2): 101-126.

Okaeme, AN., Olufemi, B., Amubode, F. 1999. A review of diseases associated with cage culture systems: Diagnosis and control in small scale fish farming. In: 13th Annual conference of the Fisheries Society of Nigeria (FISON), 3-8 November 1996, New Bussa, Nigeria, pp. 92-96.

Orina PS, Charo-Karisa H, Munguti JM, et al., 2018. A comparative study of Labeo victorianus (Bouelenger, 1901) and Oreochromis niloticus (Linnaeus, 1758) grown in polyculture systems. Lakes & Reserv. 2018;00:1–7. https://doi.org/10.1111/lre.12202.

Pierre F. Yolaine B and Asiedu B (2014). Value chain analysis of the fishery sector in Ghana with focus on quality, environmental, social, sustainable, food safety, organic requirements and its compliance infrastructure. Trade capacity building programme for Ghana. Final Draft Report, June, 2014.

Price C, Kenneth D. Black, Barry T. Hargrave, James A. Morris Jr (2015). Marine cage culture and the environment: effects on water quality and primary production. Aquacult Environ Interactions, 6: 151–174.

Quagrainie, KK., Dennis, J., Coulibaly, J., Ngugi, C., Amisah, S. 2010. Developing supply chain and group marketing systems for fish farmers in Ghana and Kenya. Aqua Fish Collaborative Research Support Program. Technical Reports, Oregon State University, Investigations 2007-2009, 2:198-210.

Rojas, A. and Wadsworth, S. 2007. A Review of cage aquaculture: In M. Halwart, D. Soto and Arthur, J.R. (eds). Cage aquaculture regional reviews and global overview. FAO Fisheries Technical Paper No. 498, 241p. Rome, Italy.

Russo, J.A.R. and Yanong, R.P.E. 2013. Molds in fish feeds and aflatoxicosis. University of Florida,IFAS Extension FA95, 1–3.

Subasinghe, RP., Bondad-Reantaso, MG., McGladdery, SE. 2001. Aquaculture development, health and wealth. In: Subasinghe RP, Bueno P, Phillips MJ, Hough C, McGladdery SE, Arthur JR (eds.) Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20–25 February 2000. NACA, Bangkok and FAO, Rome, pp 167–191.

Temm, R.G., Marshood R. and Stedman_Edwards, P. 2008. The Global Fisheries Crisis, Poverty and Coastal Small Scale-Fishers. Linkages, Impacts and Opportunities.

Tschirley, D., Reardon, T., Dolislager, M., Snyder, J. 2015. The Rise of a Middle Class in East and Southern Africa: Implications for Food System Transformation. Journal of International Development 27, 628–646. http://dx.doi.org/10.1002/jid.3107.

Wilson, R.P., 2000. Channel Catfish, Ictalurus Punctatus. In: Handbook of Nutrient Requirement of Finfish, Wilson, R.P. (Ed.). CRC Press, Boca Raton, U.

ANNEX 1: ASSESSMENT TOOL

DATA COLLECTION TOOL FOR ASSESSMENT OF CAGE CULTURE TECHNOLOGY COMMERCIALIZATION BY COUNTIES IN LAKE VICTORIA

Kenya Marine and Fisheries Research Institute is carrying out a documentation of Cage culture investment in Lake Victoria by County. The exercise entails identification and documentation of cage technology adaptive levels, stocking densities, fish growth performance, disease incidences, source and quality of seed and feeds as well as markets and market value. The assessment should overally demonstrate the role of cage culture on food security, job creation and poverty alleviation at the food fish production chain node. The outputs of the Assessment will inform the development of a strategy for up scaling and out scaling the identified technological packages to enhancing capacities of value chain actors to adopt and adapt for aquaculture commercialization.

You have been identified as a respondent in this important exercise. The Assessment will last a maximum of 30 minutes. Your support and responses will be highly appreciated.

Thank you.

Section 1: Profile of Enumerator

Name of Enumerator: ….……………………………………………….………………

Phone no. of Enumerator: ………………………………………………………………..

Section 2: Profile of Respondent

1. Name of Respondent: …………………………………...……………..
2. Phone no. of Respondent: ……………………………..………………
3. County: ………………………………………………………...……………
4. Sub County: ……………………………………………….....................
5. Name of Establishment: ……………………...………………………
6. GPS Coordinates: ………………………………………………………
7. Name of beach or nearby beach: ……………………………………..

Section 3: Socio-Demographic Information

8. Gender: Male ☐ Female ☐
9. Marital: Married ☐ Single ☐ Widow ☐ Widower ☐
10. Age (Years): Below 18 ☐ 19-35 ☐ 36 – 45 ☐ Above 45 ☐
11. Education Level: Lower Primary ☐ Upper Primary ☐ Secondary ☐ Diploma/Certificate ☐ Degree ☐ Post graduate ☐
12. Main Occupation: Full time fish farmer ☐ Part time fish farmer ☐ Fisherman ☐

    Others (Specify)……………………………………………………....……

Section 4: Profile of the Cages

13. Organization Level: Individual ☐ Group ☐ Cooperative ☐ Company ☐ County ☐

    Others (Specify)…………………………………………

14. Size of the Organization[1]: ……………………………………………………

15. Employee capacity[2]: …………………………………………………………

16. Production Manager Training Level:

    Lower Primary ☐ Upper Primary ☐ Secondary ☐
    Diploma/Certificate ☐ Degree ☐ Post graduate ☐

17. Production Manager Training: ………………………………………………..

18. Employee 1 Training Level:

    Lower Primary ☐ Upper Primary ☐ Secondary ☐
    Diploma/Certificate ☐ Degree ☐ Post graduate ☐

19. Employee 2 Training Level:

    Lower Primary ☐ Upper Primary ☐ Secondary ☐
    Diploma/Certificate ☐ Degree ☐ Post graduate ☐

20. Employee 3 Training Level:

    Lower Primary ☐ Upper Primary ☐ Secondary ☐
    Diploma/Certificate ☐ Degree ☐ Post graduate ☐

21. When was cage culture initiated? Month……………Year…………..

22. How many cages were installed at inception and the trend over time in growth

Year					
No of Cages					

24. Is the cage locally constructed or imported as complete set.

    Local ☐ Imported ☐

25. What material is used to construct the cage frame?

    Mild Metal ☐ Galvanized metal ☐ PVC ☐ HDPE ☐

---

1 *Enumerator to explain meaning of "Size" in terms of number of Farmers / Members / Groups etc.*

2 *Enumerator to explain meaning of "Employee capacity" in terms of number of workers / Members / Groups etc.*

26. What is the source of the cage net material:

………………………………………………

27. What is the size of cages (Length by width by depth / Circular Diameter by depth)

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

Section 5: Fish Management

28. What is the stocking density? ………………………………..........……
29. What is the feeding regimes Once ☐ Twice ☐ Thrice ☐ Other (specify)
30. On what basis are fish fed with a given quantity per feeding session

Body weight ☐…………… Satiation ☐

Other …………………………….......................………………………

31. What is the source of feeds (Company and CP)

………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………

32. What quantities are procured per given session?

…………………………………………

33. What is the cost of feeds at the different growth stages

Stage	Fingerlings	Post fingerlings	Juvenile	Market size
Price (Ksh) /Kg				

35. What is the source of fingerlings (Name of Hatchery/Hatcheries)

………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………

36. What is the size of fingerlings (g) at stocking ……………………………........
37. What is the price per fingerling (Ksh) …………...……………………………
38. Which is the transportation mode of fingerlings from hatchery to cages
…………………………………………………………………….……………
39. After how long do you harvest the stocked fish (months) …………………….
40. At what weight do you harvest the market size fish (g) ……………………..
41. Do you attain uniform size by cage YES ☐ NO ☐
42. What is the estimated amount of feed consumed per cage by harvesting time (Kg) ....……………………………………………………………
43. What is the survival rate at harvesting time (%) ……………………………
44. How many production cycles do you run per year …………………………
45. Do you receive extension services? YES ☐ NO ☐
46. If YES name them ……………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
…………………………………………..................……………………...
47. If yes, How frequent? Weekly ☐ Monthly ☐ Annually ☐ Not at all ☐

Section 6: Market Profile

48. What is the market price per kilogram (Ksh)/ Piece ………………………
49. Where is the market
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
50. Which is the preferred state of fish; Smoked ☐ Fried ☐ Fresh gutted ☐ Fresh whole ☐ Chilled ☐ Frozen ☐
51. What is the transportation mode of harvested fish to the market? …………
……………………………………………………………………………………
……………………………………………………………………………………
…………………...…….

Section 7: Diseases Incidences

52. Have you reported mortality cases YES □ NO □
53. If yes at what time of growth is mortality first recorded (month 1,2,3 etc)

    ………...………
54. How frequent are mortalities recorded

    Daily □ Weekly □ Monthly □
55. At what time of the day are mortalities recorded?

    Morning □ Midday □ Evening □
56. What magnitude of mortalities Few □ Mass □
57. How are the dead fish disposed? ………………………………………………

    …………………………………………………………………………………

    …………………………………………..............…………………………
58. Are there reported disease cases YES □ NO □
59. If yes, which disease? Viral □ Bacterial □ Fungal □ Parasitic □
60. Did you identify the source of infection YES □ NO □
61. If YES, what was the source of infection ……………………………………

    …………………………………………………………………………………

    ……………………………………….....……………………………………..
62. How frequent is the infection Weekly □ Monthly □ Annually □
63. Which month (s) of the year does the disease occur? ....
64. How did you manage the disease?

    …………………………………………………………………………………

    …………………………………………………………………………………

    …………………………………...
65. Do you have any training in disease management YES □ NO □
66. If yes, to what level? Module □ Certificate □ Diploma □

    Undergraduate □ Post-graduate □

Section 8: Resource Use Conflict

67. Have you experienced resource conflicts YES □ NO □
68. If yes, which ones

………………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

69. Have you experienced theft cases YES ☐ NO ☐

70. How often is theft experienced?

    Daily ☐ Weekly ☐ Monthly ☐ Annually ☐

71. Have you identified the thieves? YES ☐ NO ☐

72. If yes, who are they? Fishermen ☐ Group members ☐

    Others……………..………

73. How have you addressed theft cases? ………………………………………

    ……………………………………………………………………………………

    …………………………............……………………………………………………

74. Have you experienced fish escapees? YES ☐ NO ☐

75. If yes? How often? Daily ☐ Weekly ☐ Monthly ☐ Annually ☐

76. How have you managed the escapee problem? ……………………………

    ……………………………………………………………………………………

    ……………………………………………………………………………………

    ……………………………………………………………………………………

Aquaculture is fast moving away from extensive to intensive production systems to meet the ever rising local demand for food fish. To achieve this, aquaculture has embraced various production technologies including use of liner material in porous soils, use of concrete and plastic tanks, indoor re-circulating facilities and cages. Tilapia cage culture in Kenya dates back to 1980s with drawbacks and latter picked up in 2010. However, it is the high profitability potential of cage aquaculture that has shifted attention of fisher folk and investors to tilapia cage farming in Lake Victoria, Kenya. Cage technology is fast growing with significant contribution to national fish production. Through cage culture the aquaculture sub-sector anticipates increased job opportunities, enhanced food security and incomes for both rural and urban dwellers.This book synthesizes information on the cage suitability sites, cage designs, stocking densities and management, commercialization, value chain and emerging issues. The book winds by giving policy guidance on the fastest growing aquaculture production technological approach.This publication is thus a public and private aquaculture managers, research scientists, academicians and development partners, potential investors, students, banking sector, insurance firms and other professionals who may be interested in cage aquaculture development.

Designed and Printed By:

LaXpress services

ISBN 978-9966-114-79-2

9 789966 114792