ECONOMIC PERFORMANCE AND EFFECT OF CAGE-FISH FARMING ON LIVELIHOODS OF LAKE VICTORIA BASIN COMMUNITIES IN SIAYA COUNTY, KENYA

BY

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DECLARATION

I declare that this thesis is my original work and has not been presented to another University or any other institution of higher learning for any award. All the work in this thesis has been carried out by myself and quoted sources of information are well acknowledged by way of referencing.

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To my parents,

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My daughters, Abigael Ondiso Maina and Berice Milembe Maina

ABSTRACT

Cage fish farming has been considered as an important approach in increasing productivity and improving livelihoods and has grown rapidly along the Lake Victoria shores and is projected to increase productivity significantly in order to address the diminishing fish supply. Efficient utilization of limited resources is paramount to increasing productivity as well as the impacts of cage farming on livelihoods. However, despite its potential to increase productivity, there still exist a supply gap between the actual achieved yields and the potential yields. Moreover, there is dearth information on effect of cage fish farming on livelihood capitals as well as perception of stakeholders. The overall study objective was to evaluate the economic performance and effects of cage-fish farming on the livelihoods of the communities in Siaya County. Specifically, the study assessed technical efficiency, determined factors influencing technical efficiency of cage-fish farming, evaluated the effects of cage-fish farming on livelihoods of communities and assessed the perceptions of fish stakeholders on cage-fish farming in Siaya County. The study adopted Cobb-Douglas production theory and Sustainable livelihood approach. Descriptive research design was used and multistage sampling technique employed to select the two datasets. Data was collected from cage-fish farmers (n= 292) and from fish stakeholders (n= 217). Primary data was collected using structured questionnaires. Descriptive statistics, Stochastic Frontier Approach and censored to bit regression were used to determine technical efficiency and factors influencing technical efficiency. Sustainable Livelihood index was used to evaluate the effect of cage-fish farming on livelihoods, whereas Principle Component analysis was used to assess the perceptions of fish stakeholders on effects of cage-fish farming. Mean technical efficiency was estimated to be 65%, indicating a possible enhancement of production at the present state of technology and input level to achieve in the short run increased technical efficiency by 35% through adoption of best practices. The combined effect of operational and farm-specific factors that influences technical efficiency significantly were labour, feed, cage size, age, education level, source of capital and cage location (beach and geographical). Sustainable livelihood index of 57% was derived from the study. This demonstrates that the livelihoods in the region had improved from cage-fish farming. Physical capitals were most improved at 73.3%, followed by financial capitals (59.1%) and social capital was least at 44.9%. The study revealed that economic, health, social and environmental perceptions on cage-fish farming were the key considerations and had a total explained variance of 61%. From this study, it is evident that cage-fish farming is important to the livelihoods of both cage farmers and other fish stakeholders due to its positive effect on livelihood changes thus cage-fish farming is a critical strategy for investment. It is therefore important to address the efficient utilization of inputs and factors that influence technical efficiency for increased productivity. Cage-fish farming should be encouraged by providing the necessary production skills for improved cage performance. Furthermore, farmers should diversify their sources of capital to facilitate the adoption of larger cages and enhance marketing for enhanced bargaining power. There is a need for government ministries, departments and agencies, stakeholders, and financial institutions to come up with initiatives or formulate financial products for cage-fish farming investment to provide easy access to farming capital.

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LIST OF ACRONYMS AND ABBREVIATIONS

ASDSP	-	Agriculture Sector Development Program
BMU	-	Beach Management Unit
CIDP	-	County integrated Development Plan
DEA	-	Data Envelopment Approach
ESP	-	Economic Stimulus Program
EU	-	European Union
FAO	-	Food and Agriculture Organization
GDP	-	Gross Domestic Product
GM	-	Gross Margins
KCSAP	-	Kenya Climate Smart Agriculture Project
KMFRI	-	Kenya Marine and Fisheries Research institute
LM	-	Low midland Agro-ecological zone
LVFO	-	Lake Victoria Fisheries Organization
MUERC	-	Maseno University Ethical Review Committee
NACOSTI	-	National Commission for Science, Technology and Innovation
NMK	-	Njaa Marufuku Kenya
SDG	-	Sustainable Development Goals
SFA/ SFPF	-	Stochastic Frontier Approach/ Stochastic Frontier Production Function
SLI	-	Sustainable Livelihood Index
TE	-	Technical Efficiency
UM	-	Upper Midland Agro-ecological zone
WKCDD/FMP	-	Western Kenya Community Driven Development and Flood Mitigation program

OPERATIONAL DEFINITION OF TERMS

Aquaculture: Is the rearing of aquatic animals or cultivation of aquatic plants for food. In this study aquaculture refers to rearing of fish.

Blue Economy: According to the World Bank, the blue economy is the "sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems. It is an emerging concept which encourages better stewardship of our ocean, seas, lakes or 'blue' resources.

Cage Fish Farmer: Refers to a person who rears/ grows fish in cages.

Cage fish farming: Is growing fish in net enclosures suspended in existing water bodies such as lakes or ponds at high density in low volume (LVHD) or low density in high volume (HVLD) cages while maintaining free water exchange between the enclosure and the water body.

Economic Performance: Implies how successful a business is in producing benefits for its owners through product innovation and efficient use of resources. Technical efficiency has been used as a proxy of economic performance in this study.

Fish cage technology: is an aquaculture production system where fish are cultured in floating enclosed cages (see pictures in Appendix C).

Fish Cage: This is an enclosed floating net /pen that confines fish in an existing water resource.

Fish stakeholders: A stakeholder is one who has a stake in something. In this study, Fish stakeholders are therefore people who are involved in cage fish farming indirectly. These include, fishermen, fish traders and, consumers, as well as of fish artisans who provide equipment for fishing/fish farming, among others. This study focused on fishermen, fish traders, artisans and consumers.

Fisher fork: Refers to a person who catches fish for a living.

Livelihood capitals: refer to the vital resource bases of communities and different categories of households. Also known as livelihood assets.

Livelihood: A livelihood comprises people, their capabilities, and their means of living including food, income, and assets. This study was focused on their enhancement and seek to generate information aimed at improving the capitals and their contribution to living standards of the communities in Siaya County.

Riparian Counties: Used in this study to mean the Counties in the western region of Kenya that are bordering Lake Victoria.

Social welfare: Social welfare refers to the wellbeing of people in a society, either as individuals or as a group of people. This study was focused on how cage-fish farming, as an empowerment intervention, has contributed to the prosperity and standards of living of the communities along the lake region. This study finding have been used to recommend the right interventions that enable the communities to increase incomes through profitable cage-fish farming and thus enhance the standards of living of the communities leading to economic development.

Technical Efficiency: Is defined as the capacity of a firm to produce maximum level of possible output from the given set of inputs.

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CHAPTER ONE
INTRODUCTION

1.1 Background Information

Fisheries and aquaculture sectors significantly contribute to human livelihoods through supply of protein (fish), source of income, and employment, all which contribute to reducing poverty levels in developing countries(Kumar *et al.*, 2009). Statistics indicate that over 59.5 million people derive their livelihoods from fisheries and aquaculture either on a permanent, or casual basis(FAO, 2018, FAO, 2020). Notably, the recent increase in world population has increased the annual per capita fish consumption worldwide, a clear indicator that global demand for fish food will continue to increase(FAO, 2020). Moreover, a rapid increase in world fisheries and aquaculture has increased the total production of fish from both inland and marine, from 170.9 Million tonnes to 179 Million tonnes in 2016and 2018, respectively, consequently increasing the global fish production and per capita consumption(FAO, 2020).

Kenya harnesses both inland and marine capture fisheries where Lake Victoria produces over 90% of inland capture(FAO, 2016)and plays a critical role in fisheries production, affirming its role as a key livelihood source to the surrounding communities. The Fisheries and aquaculture sector has been reported to have contributed about 0.8% to the Country's Gross Domestic Product (GDP) and supporting over 500,000 people direct and over two million people indirectly through employment opportunities(KEMFRI, 2017). Despite the livelihood importance of aquaculture, production systems in the country are predominantly semi-intensive in earthen and lined ponds, which are characterized by low production per unit area and competition for land with human settlement/other sectors.

Kenya's capture fisheries have been on a declining trend as a result of overfishing, water pollution, and climate change-related factors (Ogello, 2013), leading to a low fish per capita

consumption of about 4.0kg/person/year (Njagi, 2020; Obiero*et al*., 2019) against global per capita consumption of 20.2kg/person/year (FAO, 2022)amidst increasing demand for fish protein (Ogello & Munguti, 2016). To counter the reduced supply, there has been a shift towards natural water bodies for aquaculture leading to demand for innovation of high productivity culture units such as cages and recirculating systems to aid in increased production. Moreover, fisher forks' livelihoods have been affected hence a need for an alternative solution. Aquaculture offers the best alternative for replenishing sources of fish stocks, improving the livelihoods of fisher forks, as well as enhancing food security and economic growth through its value chain linkages (Munguti *et al*., 2014).

Aquaculture has great potential for generating a wide range of benefits and significantly contributing to the Kenya's GDP and rural development. However, the sector faces several challenges. These include, low productivity of the fish culture systems, poor quality and limited supply of fingerlings, scarcity of quality feeds, high market competition, post-harvest losses, low-value addition and limited information on the economic performance of various fish farming culture systems (Munguti *et al*., 2014).

There has been a robust adoption of the cage technology in the Lake Victoria Basin and the uptake of intensive cage culture is expected to significantly contribute to increased fish productivity and economic development (Ogello & Munguti, 2016).In addition, cage culture has been embedded as one of the approaches required to steer the Blue Economy. However, varied challenges still exist that need to be addressed in order to unlock the bottlenecks in commercial cage farming such as lack of knowledge among farmers and investors due to limited documentation, high cost of input capitals, environmental concerns among others(FAO, 2004; KEMFRI, 2017).

Cage-fish farming is a technique where fish culturing is done in existing water resources where fish are enclosed in a sizeable cage that allows water to pass through freely (Salton, 2016). The origin of cage farming can be traced to Asia where cages were used as holding ground forfish, however, commercial cage-fish farming started in Norway in 1970s under development of Salmon farming (Tacon & Halwart, 2007).

In Kenya, cage-fish farming was initially practised by Dominion Farm Limited in Siaya County in 2005, and the European Union conducted trials in Kisumu. The cage technology has been widely adopted in the Lake Victoria Basin, and recent studies show an increase in the uptake of cage (3696 cages) culture along the five riparian counties of Lake Victoria (Ombwa *et al*., 2018; Orina *et al*., 2018). The cage culture system has various advantages, including free exchange of water and removal of wastes from the cages, reduced effects of drought concerning water availability, high productivity, flexible and ease of harvesting and monitoring, anticipated high profitability, and reduced the pressure on land due to the fact that it uses the existing water bodies such as lakes, tanks, dams, ponds, and Oceans. However, cages pose challenges to the environment of the lake and affect both the fish and other lake users. For instance, unconsumed or waste fish feeds from the cages have been reported to cause eutrophication of the lake, which negatively affects fish life (Njiru *et al*., 2019); while haphazard installation of the cage units hinders navigation by the fishermen.

Cage fish-farming along the riparian Counties of Lake Victoria has recorded low production about 21,000 MT against an estimated carrying capacity of 109,226 MT thus accounting for approximately 19% of potential cage fish production (KMFRI-ABDP-CAGES, 2022).Siaya County is one of the five riparian Counties in Lake Victoria Basin that has witnessed a high increase in cage installations since the year 2016 (Orina et al., 2018a). Despite this increase,

cage production has only contributed 27% to the County's 141.4MTaquaculture production levels in the county in 2017(Siaya County, 2018; Siaya, 2020). This is an indication of low fish production volumes from the cages. It is assumed that the low fish volumes from cages could be due to technical inefficiencies affecting cage performance and thus this study sought to establish the level of technical efficiency and factors that influence technical efficiency. Cage-fish farming technology is intended to revolutionize aquaculture in Lake Basin region and result in a wide range of socio-economic benefits that include access to nutritious food and economic empowerment of the fisher folks, but the extent to which these benefits are being realized has minimally been documented. There is limited documentation (Anjejo, 2017; Apine *et al*., 2019; Mensah *et al*., 2018) on effect of cage-fish farming especially on changes on livelihood capitals. Cage-fish farming has also created real and perceived concerns(Degefu *et al*., 2011; Egessa *et al*., 2018; Kaggwa *et al*., 2011; Ogello *et al*., 2013) regarding its effects on the environment, on capture fisheries, on health and socio-economic empowerment of lake communities. Perceptions on cage farming has minimally been documented in Ghana on Lake Volta (Mensah *et al*., 2018). However, there is scanty information on the perceptions of the communities regarding the cage culture enterprise around Lake Victoria.

1.2 Statement of the Problem

To achieve the goals of Kenya's Vision 2030 and the Blue economy blueprint, the Kenya Government intends to transform aquaculture as a profitable enterprise for economic growth. This revolution can be achieved by ensuring reduction in output variations, enhanced efficient input use and use of appropriate technological production systems. Cage-fish farming has been identified as an essential approach to increasing productivity and improving livelihood. Farmers have thus embraced the use of cage technology for fish farming. Cage-fish farming requires

economic considerations, including economic returns and efficiency. Output growth is determined by both technological innovations and the efficiency with which available technologies are used (Bravo-Ureta *et al.*,1993). Despite the increasing adoption levels and government efforts to invest in aquaculture through various programmes, cage-fish culture faces challenges in yield gap between the farmers' actual production levels (21,000MT) and the maximum attainable output of 109,226MT (KMFRI-ABDP-CAGES, 2022), thereby signalling presence of production inefficiencies occasioned by lack of economic information on cage performance by farmers and investors, high input production costs, environmental concerns among others (FAO, 2004; KEMFRI, 2017) which necessitates improvement of technical efficiency in order to maximize utilization of available scarce resources. Efficient use of inputs is critical for sustainable aquaculture productivity, increased profitability, and improved livelihoods. From the reviewed literature, Kenya still lags behind in terms of aquaculture efficiency at between 47% to 55% for pond production against the global range of TE between 53% to 99% in Nigeria, 84% in Ghana, 79% in Malaysia and 77% in Bangladesh. Moreover, studies done in Kenya focussed on the pond production and not cage production although their operations differ from each other. This study sought to determine the technical efficiency and the factors that influence technical production efficiency of cage-fish farming in Siaya County.

Moreover, despite cage-fish farming having been documented as profitable (Musa *et al.*, 2021), there is scanty information(Anjejo, 2017; Apine *et al.*, 2019; Mensah *et al.*, 2018) on its effects on changes on livelihood capitals. Studies undertaken on perceptions have been on the general aquaculture and not on specific culture systems (Bacher *et al.*, 2016). There is dearth information on the perceptions of the communities regarding the cage culture enterprise around Lake Victoria.

Due to low cage output and minimal documentation of the effects and perceptions of cage fish farming on livelihoods and adoption, this study was formulated to assess the technical efficiencies, determine factors influencing technical efficiency in Siaya County, evaluate the effects of cage fish farming on livelihoods capitals and assess perceptions on adoption of cage fish farming.

1.3 Objectives

1.3.1 General Objective

To evaluate the economic performance and effects of cage-fish farming on the livelihoods in Siaya County, Kenya.

1.3.2 Specific Objectives

i. To assessthe level of technical efficiency among cage-fish farmers in Siaya County.
ii. To determine the factors influencing technical efficiency amongcage-fish farmers in Siaya County.
iii. To evaluate the effects of cage-fish farming on livelihoods of farming communities in Siaya County.
iv. To assess the perceptions of fish stakeholders on cage-fish farming in Siaya County.

1.4 Research Questions

This study targeted at answering the following research questions:

i. What is the level of technical efficiency among cage fish farmers in Siaya County?
ii. What factors that influence technical production efficiency among cage-fish farmers in Siaya County?
iii. What are the effects of cage-fish farming on the livelihoods of the farming communities in Siaya County?

iv. What are the perceptions of fish stakeholders on cage-fish farming in Siaya County?

1.5 Justification of the Study

Enshrined in Sustainable Development Goals (SDG) 1, 2, 8, and 14 and Kenya's Vision 2030 is a pursuit for economic growth, increased productivity and production through diversification and building resilience to economic, social, and environmental shocks and disasters. Fish farming creates a widespread of social-economic benefits that includes access to nutritious food and economic empowerment of the fisher folks. Aquaculture contributes to food security and livelihoods (Ogello & Munguti, 2016) and adoption of technological production becoming critical. Cage-fish farming has been anchored in the Blue Economy blueprint as an important approach to increased productivity and improved livelihoods. Cage-fish farming has been viewed as a game changer in the Lake Victoria basin and has demonstrated to be profitable (Datta *et al*., 2014; Musa *et al.*, 2021). However, there is still low output from the cages from the utilization of the available technologies and inputs. Knowledge on the technical efficiency is important in determining areas of improvement to enhance maximum utilization of the scarce production resources. Understanding TE and factors influencing TE will enable the investors to improve productivity, increase profitability and thus improve livelihoods. Moreover, robust development of cage-fish farming is envisioned to have some impacts on the environment and other fish stakeholders (Njiru *et al*., 2019). There is no documentation on how the stakeholders perceive the effects of the enterprise in the region. It is therefore important to understand these perceptions so as to enhance the development of the enterprise. Siaya County formed a very reliable site for this study due to its robustness in cage development amongst the other riparian counties (KMFRI, 2017;Orina*et al.*, 2018) and is ideal for generalization of the findings. It has

the highest number of cages installed in the lake yet still suffers high poverty levels(KNBS, 2020). This study aims to find out the contribution of cage-fish farming on livelihoods.

This study form important ingredient in development of aquaculture production hence if economic indicators are not understood may lead to barring new potential investors in to cage culture as well as hinder existing cage farmers from accessing finances from financial institutions. This will therefore cause slow growth of the sector.

1.6 Significance of the Study

Siaya County envisages to fully exploit the blue economy and therefore this study supports the aquaculture policy formulation that is required to achieve her dream. This study forms important ingredient in development of aquaculture production hence understanding production efficiency is an important ingredient. The study sought to add to the knowledge bank of research as educational material for students, researchers, and practitioners interested in aquaculture, sustainable development, and rural livelihoods and fosters continuous learning and innovation in the field. The study on the economic performance of Cage-fish farming provides relevant information on the factors that constraint the efficiency utilization of production inputs in cage-fish farming enterprise. Specifically, the findings are expected to provide appropriate assessment of efficiency of cage enterprises and the viability of aquaculture projects thus improving competitiveness. Investment in competitive aquaculture enterprises will significantly increase fish supply and increase per capita fish consumption in the country as well as improve the nutrition and incomes of the local communities. This study will also raise stakeholder awareness about the economic and social dimensions of cage fish farming leading to greater community engagement, support for sustainable practices, and advocacy for responsible policies. The study also provides relevant information that is useful to policymakers and is expected to guide the formulation of regulations on cage enterprise in the lake region, and ensure increased

productivity without compromising the livelihoods. This study did not only seek to establish the efficiency and factors influencing the economic performance of cage culture systems in Siaya County but also determined the effects of cage-fish farming on livelihoods and understanding the people's perception towards the enterprise.

1.7 Scope of the Study

The study was conducted in Siaya County, specifically in Rarieda and Bondosub-counties, due to its robust development in cage-fish farming among the five riparian counties as well as having the largest area along the lakeshore of Lake Victoria. The study assumed the willingness of respondents to participate in the research and volunteer accurate information required to achieve the set objectives. The focus was only on cage farmers and fish stakeholders for datasets required in this study and addressed the technical efficiency (TE) and factors influencing TE as well as effects of cage-fish farming on livelihood capitals and perceptions of the fish stakeholders towards the enterprise. The TE of cage farming was- considered over one production cycle (6-8 months).

1.8 Limitations of the Study

The researcher faced some limitations, especially during data collection. These included limited/poor records from respondents, which would compromise accuracy of the data collected. The researcher relied on spoken responses from sampled respondents by allowing them to consult their household members for clarity so as to increase the reliability of the data collected. Since the researcher anticipated low number of respondents willing to participate in the research, more respondents were sampled to take care of the missing data. For language barrier limitation, the researcher read and translated the questions to the respondents in the most understandable language. Cage ownership was not considered in this study thus could have influence on the productivity of the cages. This study sampled the manager of the group cages as the farmer.

1.9 Assumptions of the Study

This study was conducted under the following assumptions: Fish reared in the cages is same species of Tilapia (*Oreochromisniloticus*). This study also presumed that the respondents would give the right information.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter reviews previously published literature and highlights on aquaculture development in Kenya, fish farming systems, technical efficiency concept, measurements of technical efficiency and effects of fish farming on livelihoods and livelihood capitals. The chapter also highlights the theoretical framework, empirical studies and the conceptual framework that the study was based on.

2.2 Global view of Aquaculture

Sustainable fisheries and Aquaculture has become a global agenda. Global fish production is estimated at 179 million tonnes in 2018 with a value of USD 401 billion of which aquaculture contributed 82 million tonnes valued at USD 250 billion and thus contributed to increased fish food and non food uses (maily fish meal and fish oil)(FAO, 2020). The contribution of world aquaculture 46% to global fish production in 2018, an increase from 25.7% in 2000. As a result aquaculture accounted for 52% of fish for human consumption (FAO, 2020). The leading aquaculture producers include China, Asia, Africa, America and Ocienia (FAO, 2018, FAO, 2020).

Aquaculture contributes to employment through engaging livelihoods both directly and indirectly (85% in Asia, 10% in Africa and 4% in Latin America and Caribean) with Aquaculture having the highest aquaculture engagement of 96%, followed by Latin America and the Caribbean, and Africa (FAO, 2018).

Cage aquaculture started in Asia where cages were used temporarily as holding ground as well as transportation of fish. Commercially, cages were pioneered by Norway in 1970. (Tacon & Halwart, 2007). In response to SDG 14 of conserving and sustainably using the oceans, seas and

marine resources for sustainable development, cage fish farming has been adopted as a key approach to blue economy and has rapidly grown in fresh waters.

2.3 Aquaculture Development in Kenya

In Kenya, fish farming era from 1900s, when spot fishing was introduced. Between 1921 -1948, static water pond culture was introduced (Anjejo, 2017; Maina *et al.*, 2014). The Fisheries sector in Kenya has undergone an evolution since the 1900s due to government interventions and support programs. For example, the economic stimulus program led to a nationwide mass campaign of fish farming resulted into increase in fish pond establishment hence increased farmed fish production. The sector plays a key role in providing direct and indirect employment opportunities thus contribute to the GDP as well as being a key pillar to the Blue economy concept. FAO estimates that fisheries contribute 0.5% of the GDP through fish export earnings and employment creation (FAO, 2016).

The Government of Kenya has made fisheries development a national development agenda. This is enshrined in the National Nutrition Action plan (2014-2017) and the Country's blueprint Vision 2030 which recognizes the contributions of the fisheries sector on the economic growth. The sector contributes to the economic benefits through employment creation and industrialization by propelling the emergence of industrial and small-scale businesses. There is great potential for commercialization of the aquaculture industry under the Blue Economy Concept which offers huge opportunities and potential (Munguti *et al.*, 2014). The approaches entrenched in the Blue Economy include Cage Culture, Recirculating Systems (RAS), aquaponics/ greenhouses, breeding and restocking of important indigenous species, and live fish markets (KEMFRI, 2017).Aquaculture remains a viable option to improve fish production in the country, provides the best opportunity to bridge the accelerating gap of farmed fish supply of

18,545 MT(KNBS,2020) vis-a-vis farmed fish demand150,000 MT(Obiero, Cai, et al., 2019)amidst the increasing population and decline in capture fisheries. This calls for more innovative technologies to stimulate food production.

2.4 Fish Production Systems in Kenya

Kenya's aquaculture systems are predominately earthen and lined ponds characterized by low production of between 3 to 6 kg/m^2/year and cage farming with production potential between 60 to100kg/m^3/year (FAO, 2013). Aquaculture is practiced under three production systems, namely extensive, semi-intensive and intensive systems (Table 2.1). An integrated system is also currently emerging where fish is grown in rice fields or poultry is reared over the pond. The extensive system involves minimal utilization of the inputs and is mostly in earthen ponds where fish is left to fend for itself from the natural organic matter and physical conditions of the water. This system is characterized by a low production level. A Semi-intensive system forms 70% of the aquaculture production in Kenya. The system is characterized by fertilization of the holding units and additional use of exogenous feeds to enhance productivity while the intensive system is characterized by complementing or substituting the natural productivity with exogenous feeds, aeration, and mechanical and bio filtration.

Table 2.1: Fish Production Systems in Kenya and their management practices

	Extensive	**Semi-Intensive**	**Intensive**
Culture Unit	Earthen/liner ponds Floating cages	Earthen/liner ponds Floating cages	Raceway Culture / recirculating systems, Tanks, Floating Cages,
Fish *Spp*	*Oreochromisniloticus* (Nile Tilapia), *Clariasgariepinus* (Cat Fish)	Nile Tilapia	Rainbow trout
Level of management		Ponds are fertilized by chemical and organic fertilizers Exogenous feeds used to supplement pond productivity	Exogenous feeds and aeration used to supplement pond productivity Both mechanical and bio filtration is necessary
Production levels	500-1500kg/ha/yr.	1000-2500kg/ha/yr.	10000-80000kg/ha/yr.

Source: FAO, 2013

Appropriate and most efficient production systems are essential for successful aquaculture development. The systems that increase productivity and maximize returns on investments are critical for commercialization. The selection of the aquaculture system to be adopted depends on factors such as goals of the development, target beneficiaries, the marketability of culture species, technological requirements and accessibility of production inputs coupled with the support facilities and services, investment requirements and environmental concerns (Soderberg, 2017).The fisheries activities in Siaya County are in two folds; capture fisheries dominant in Bondo and Rarieda sub-counties from Lake Victoria, and fish culture in all sub-counties (Department of Fisheries, 2018). Aquaculture is limited to the culture of two fish species (Nile tilapia, 72.9%, and African Catfish, 27.1%), (Siaya County, 2018) and largely from earthen fish ponds. Fish farming in cages in Lake Victoria is relatively a new practice in the county and has seen a significant boost in the county's Tilapia fish production from 2016. Currently, investors are venturing into cage farming as an alternate way for increased fish production and sustainable

livelihoods. For the investors to reap the benefits of the business there is a need to understand sound cage management principles including socio-economic insights necessary for achieving competitiveness (Aura *et al*., 2017)The profitability of commercial fish farming operations is of paramount importance to all farmers and investors.

Cage commercialization is transitioning subsistence fish farmers to market-oriented farming intending to make profits thus socio-economic insights are key to increase competitiveness. However, cage installation is done without the knowledge of the gains anticipated from the investment. All this is happening against a background of limited documented information on the economic performance of cage-fish farming (Munguti *et al*., 2014). Cage-fish farming has increased business opportunities among community members thus increased incomes amongst the communities (Anjejo, 2017). Increased production from cages has reduced the energy and hustle of the traders and thus changed the perception of sex for fish analogy through improved social behaviour along the lake. Barriers to women working in the lake has been reduced through introduction of cages since women can now own cages within the lake waters. (Kruijssen *et al*., 2018)

2.5 Technical efficiency

Technical efficiency (TE) is the capability of a farm to produce the maximum output from a given set of inputs while considering the underlying production function. TE can be measured by using two approaches: the input-oriented approach which seeks to answer the question 'by how much can a number of inputs be proportionally decreased without altering the amount of output produced' or by the output-oriented approach that seeks to answer the question 'by how much can the amount of output be proportionally increased without changing the amounts of inputs used' (Farrell, 1957).

2.6 Measurements of Technical Efficiency

Since the actual production function is never certain in practice, (Farrell, 1957) suggested that technical efficiency can be estimated from a sample data using either a parametric function such as the Cobb-Douglas form or by a non-parametric piece-wise linear technology.

2.6.1 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) model was formulated by (Charnes *et. al*., 1978) to incorporate multiple inputs and outputs simultaneously on the work of Farrel (1957). DEA is a deterministic method used in measuring Technical Efficiency that assumes all deviations from optimal output levels are caused by inefficiencies. According to Coelli *et al*., (2005), DEA uses linear programming methods and creates a deterministic frontier, and thereafter efficiency scores are calculated in comparison to the frontier. Data envelopment Analysis method does not impose functional forms on the production frontier, unlike the parametric stochastic frontiers. The method also differs from the parametric methods, as it does not make measurement assumptions. Despite the limitations of the non-parametric, DEA method, the approach has an advantage as it allows for the provision of information on input and output shadow prices of decision making units. DEA has potential to handle multiple outputs and inputs, unlike SFA. However, DEA models are not capable of testing hypothesis due to its deterministic form.

2.6.2 Stochastic Frontier Approach (SFA)

Stochastic Frontier Analysis (SFA) is a method of economic modelling that has its origin in the stochastic production frontier models simultaneously introduced by Aigner *et al* (1977). SFA separates the error term from the estimation of production function into inefficiency effects and random variations due to statistical noises unlike DEA, it allows for hypotheses testing regarding the production structure and the degree of inefficiency (Coelli *et al*., 2005). The most common model specifications of SFA are Cobb-Douglas and trans logarithm (Degla, 2015).

The DEA and SFA differ in assumptions of the distribution of the error term that represents inefficiency and also differ in the way that the functional form is applied on the data, for instance, the parametric approach uses econometric approaches to impose functional and distributional forms on the error term while the non-parametric approach does not (Hyuha *et al*., 2007). According to (Anwar, 2016), non-parametric models, Data Envelopment Analysis (DEA), have shortfalls in that they do not account for the possible effect of measurement errors in the data like the stochastic frontier models (SFA) do and this may lead to misleading results since they do not allow for random error.

In this study, SFA was used instead of DEA for measuring the technical efficiencies of the selected cage farmers, because it has the advantage of dealing with stochastic noise, allowing for statistical tests of hypothesis concerning production structure and degree of inefficiency. The Cobb Douglas specification was used because it is self-dual and has been proven useful by many empirical studies related to agriculture in developing countries. Translog specification is faced with issues of collinearity due to increased numbers of variables as a result of multiplication of production factors.

The Cobb-Douglas production function used for obtaining technical efficiency estimates was specified as follows;

$y_i = f(X_i;\ \beta).TE_i$ Equation 1

Where; y_i – is the observed scalar output of the farmer

X_i – is the vector of N inputs used by the farmer i

f (x_i; β) – is the production frontier

β – is a vector of technology parameters to be estimated

TE_i – the efficiency defined as the ratio of observed output to maximum feasible output.

TE_i = 1 shows that the i^{th} farm obtains the maximum feasible output, while TE_i< 1 provides a measure of the shortfall of the observed output from maximum feasible output. A stochastic component that describes random shocks affecting the production process was added. These shocks are not directly attributed to the farmer or the underlying technology, since sources of these shocks maybe weather changes and economic adversities. Each farmer is facing a different shock, but it is assumed the shocks are random and they are described by a common distribution. These effects were denoted with. exp $\{V_i\}$. the stochastic production frontier as follows:

$y_i = (X_i;\ \beta).TE\ .exp\{V_i\}$Equation 2

It was assumed that $TE_i$is also a stochastic variable, with a specific distribution function, common to all farmers and was written as an exponential, $TE_i = \exp\{-U_i\}$, where $U_i \geq 0$, since we require $TE_i \leq 1$.

Thus: $y_i = (X_i;\ \beta).TE\ .exp\{V_i\}\ .exp\{U_i\}$Equation 3

It's also assumed that f (X_i; β) takes the log-linear Cobb-Douglas form

Thus; $L_nY_i = \beta_0 + \sum \beta_n L_n X_{ni} + V_i - U_i$ Equation 4

Where:

V_i is the "noise" component, two-sided normally distributed variable and U_i is the non-negative inefficiency component, together they constitute a compound error term with a specific distribution to be determined.

2.7 Empirical Studies Review of Technical Efficiency

2.7.1 Empirical Studies Review of Technical Efficiency

Efficiency studies in Aquaculture are scarce in Kenya in comparison to other crop based enterprises. This study borrows from studies conducted in mainly Asia and Africa. This section reviews studies done in aquaculture with view of the variables applied in fish farming efficiency

studies, technical efficiency, methodologies used and factors that affect efficiency. Most studies done globally have used SFA and used Cobb-Douglas production function (Iliyasu *et al*., 2016; Aktar *et a*l., 2018; An, 2012; Antwi, 2020; Ekunwe & Emokaro, 2009; Ikpoza *et al*., 2021; Ogundari & Aklnbogun, 2010; Olayiwola, 2013; Onumah *etal*., 2010).

Onumah *etal*., 2010 examined the technical efficiency and its determinants of fish farms in Ghana and employed the stochastic frontier function using a cross-sectional data of 150 farmers. The author used the output of fish harvested in kilogrammes, while the input variables were labour in man-days, cost of fish feed, quantity of fingerlings in kilogrammes, total area of ponds in hectares, and other costs that comprised intermediate inputs such as chemicals, fertilizer, fuel, electricity, farm rent, maintenance cost and depreciation cost. The farm specific characteristics that were used as the inefficiency determinant variables by the authors were age; education; pond type (earthen or concrete); gender of the decision maker; culture system (monoculture or poly-culture); farm ownership (individual or group), extension services, location and region, which were used to capture regional influence on technical efficiency of production. The technical efficiency of the fish farms was found to range from 47% to 99%, with 86% of the farms operating at 0.71 index and above. The mean technical efficiency levels were estimated at 0.84. There was no regional effect on the technical efficiency of fish production.

The technical efficiency estimation and investigation of determinants of inefficiencies of cage fish farming in Peninsular, Malaysia (Iliyasu *et al*., 2016) revealed an estimated mean technical efficiency score of 0.79, which implied that the sampled fish farmers operated below the production frontier and thus, room for improvement. The authors sampled 198 cage fish farmers and recorded an estimated TE scores range of 0.11 to 0.93 with an estimated average TE score of 0.79. The authors used a stochastic frontier production function and used number of fingerlings

stocked, Labour in hours (total family and hired labour), total feed used in kilogrammes and other costs. For inefficient model, variables used included; age in years, experience in years, education level, farm status (owned or otherwise), number of species, extension visits, workshops attended and disease outbreaks.

The size of the farm, productivity and efficiency had direct relationship according to (Aktar *et al*., 2018) as they explored the relationships among Pangas fish farms in Bangladesh. The author used Stochastic frontier production function to estimates the level of technical efficiency while polynomial regression was employed to show the relationship among farm size productivity and efficiency in Pangas fish farming. From a sample of 125 farmers, the results indicated larger farms being more productive and technically efficient than the smaller farms, and the more productive farms were found to be more efficient. The data that were collected were categorized as small, medium and large and used in the analysis. The production function was explained by number of fingerlings, feeds in kilograms, salt in kilograms, lime in kilograms, human labour in man-days, pond size as proxy for farm size (small, medium or large), and other costs while the inefficient function was explained by age in years, education as years of schooling, experience in years, number of days of training and number of members earning. The results showed a range of technical efficiency of 0.77 with a range of 0.34 and 0.99.

Technical efficiency studies in Nigeria employed stochastic production frontier based on Cobb-Douglass production function (Ekunwe & Emokaro, 2009; Ikpoza *et al*., 2021; Olayiwola, 2013) and observed a mean technical efficiency of 0.85, 0.53 and 0.99 respectively. They used feeds, fingerlings, labour and pond size in their production function except Ukemwe & Emokaro who did not use pond size. Inefficiency determination variables included gender, age, education, experience, extension services and household size.

Nduku, 2015, evaluated fish farming under Economic Stimulus Programme (ESP) in Kenya. In her study she focused on whether the ESP program was able to achieve its goal and assessed the efficiciency of the counties in their implementation. The study employed SFA. The study recorded a technical efficiency of 65%. This results revicewed how efficient the counties were in utilizing the allocated resources in fish production under the ESP programme.

In the study by Munyua (2012) titled 'Two Essays on Technical Efficiency of Aquaculture Production in Kenya: Parametric and Non-Parametric Methodological Approaches' sought to assess the impacts of aquaculture promotion activities in Kenya through the parametric stochastic frontier analysis (SFA) and the non-parametric, Data Envelopment Analysis (DEA) techniques. Data on Tilapia fish production and other relevant farm specific information came from Aquaculture Collaborative Research Support Program survey conducted in 2011.The first study used SFA to assess the level and determinants of technical efficiency for a sample of tilapia fish farmers in Kenya in a one-stage procedure and averaged Technical Efficiency at 0.47. The second study applied output-based DEA to derive technical efficiency measures for tilapia fish farmers in Kenya and derived Technical efficiency at 0.55. The study also identified farm specific and socio-economic factors that are correlated with the technical efficiency through a post-estimation analysis estimation of those efficiency scores through Analysis of Variance (ANOVA), Ordinary Least Squares (OLS) and two-limit Tobit (2LT) models in second-stage estimation. The study majored on pond fish farmers only thus a gap exists for technical efficiency of cage farmers since management practices are not similar.

2.7.2 Critique and research gaps

From previous studies, evaluation and estimations of technical efficiencies has largely employed parametric approach; the stochastic frontier, which is considered more appropriate than the DEA

due to its ability to cope with severe measurement errors, and its ability to make statistical inferences regarding the factors that contribute to inefficiencies especially in Agriculture, since agricultural data are likely to be heavily influenced by measurement errors and the effects of weather conditions, diseases, among other. None of these studies were carried out in the study area and thus gives room for the study in order to allow for comparisons of TE and its influencing factors across the borders.

Munyua (2012) used DEA which resulted into 55% TE while SFA resulted into 47% TE. The two methods differed in the results and focused on pond production while Nduku (2015) focused on the impact of Government interventions through ESP in the counties. None of these studies was done on cage fish farming. This therefore creates a gap to study TE of cage fish family because the operational activities for pond and cage culture are not comparable.

Thus, this study borrowed from the literature and employed SFA based on Cobb-Douglas Production Function for estimation of Technical Efficiency (TE) and Censored Tobit model to determine the factors influencing TE.

2.8 Effects of Cage Fish Farming on local Livelihoods

A livelihood consists of capabilities, assets, and activities required for means of living and is sustainable when it can cope with or recover from stress and shocks.(Chambers & Conway, 1992). Lake Victoria fisheries have over the years provided diverse livelihoods to the farming communities and the country. The country has endeavoured to develop the livelihoods of her people and engaged in various programs and projects through development partners. Most of the interventions promoted in aquaculture by the Government and development partners have been aligned to economic empowerment such as Economic stimulus programme (ESP), Agriculture Sector Development Support programme (ASDSP), Njaa Marufuku Kenya (NMK), and Kenya

Climate Smart Agriculture Project (KCSAP) among others. However, incomes alone are not a sufficient reflection of the sustainability of the poor who receive the assistance of the Government in form of entrepreneurial projects (Samsudin, 2014).

2.8.1 Livelihood effects of cage-fish farming

Effects of the introduction of fish cages are viewed by different studies to be both negative and positive. Three categories of effects reviewed are socio-economic effects, human and environmental effects.

2.8.1.1 Socio-Economic Effects of Cage-Fish Farming on Livelihoods

Cage culture rapid growth in Siaya County among the riparian counties anticipates to increase job opportunities, enhance food security and increase incomes for all fisher forks in the value chain. The fisheries sector creates employment for thousands of Kenyans through fishing, boat making, repair of fishing equipment, fish processing, and other ancillary activities(CIDP, 2018). The communities in the lake basin depend on the lake for employment creation, generation of income, source of foreign exchange through fish exports, transportation, and enhanced nutrition and therefore improves the welfare of rural households and healthy animal protein (Ogello & Munguti, 2016; El-Sayed & El-Sayed, 2020).Aquaculture contributes to the livelihoods of the poor and thus leads to rural development (Edwards, 2000). According to Anjejo (2017), there has been an increase in new opportunities of livelihoods such as employment, retail businesses, net making, sinkers and jerrican (floaters) business in the lake region due to the introduction of cage-fish farming and this has led to improved wellbeing of the local communities as a result of improved incomes. Anjejo considered only fishermen, traders and cage workers and artisan. No data was collected on cage farmers. He also used descriptive statistics and frequencies were used to make inferences. His study used livelihood outcomes as the dependent variables and cage intervention as the independent variable. (Mensah *et al*., 2018) employed descriptive statistics

and found out that cage-fish farming has impacts on livelihoods positively through supply of food, income, employment and trade.

This study defers with Anjejo's and Mensah's studies in that, it's focused on cage farmers to evaluate the changes in livelihood capitals as a measure of changes in livelihoods and considered fish stakeholders' (fishermen, traders, artisans and consumers) perceptions on effects of cage fish farming on the livelihoods. Anjejo's study was only carried out on one beach but this study collected data from 13 beaches while Mensah's study was not carried out in the study area.

2.8.1.2 Human effects of cage-fish farming on livelihoods

These include mainly food supply, food and nutrition security**.** Fish diets provide food energy, proteins including amino acids, and essential body nutrients such as fatty acids (Kawarazuka&Béné, 2011). Aquaculture has increased fish supply (Metian, 2013) through technology adoption. The adoption of Cage-fish farming has increased access to fish stocks due to reliability in production and hence reliable supply of fish in the market. However, access to fish food remains critical for food security and the linkages between fish livelihoods and nutrition. Cage culture has increased access to fish by the traders hence making fish readily available in the market.

2.8.1.3 Environmental Effects of Cage-Fish Farming on Livelihoods

Several researchers have identified eutrophication as a key effect on the fish health and water quality of Lake Victoria (Degefu *et al*., 2011; Kaggwa *et al.,* 2011; Egessa *et al*., 2018.). Moreover, the conflict between fish cage farmers and fishermen has been reported thus resource conflicts have become inevitable with the lake users (Ogello *et al*., 2013). On the contrary, (Mensah *et al*., 2018)resulted in indifference of the attitudes of the respondents on issues of environment and thus concluded that farmers dealt with the environment as they ought to. From

the literature review, effect of livelihoods as a result of environmental effect of cage fish farming has not been explored. This study sought to establish the perceptions of the stakeholders' environmental effects cage farming affects their livelihoods.

2.8.2 Livelihood capitals

According to sustainable livelihood approach, five livelihood capitals are considered as physical capital, financial capital, human capital, social capital and natural capital. Physical capital indicates manmade assets and other forms of physical or hard capital making up the built environment. It comprises the basic infrastructure and producer goods needed to support livelihoods. Physical capital is generated from an economic production process that contributes to livelihoods. This can be measured by indicators like farm machinery, irrigation facilities and markets (Baffoe & Matsuda, 2018; Boateng, 2013). Financial capital are monetary resources measured by savings, credit and remittances (Baffoe & Matsuda, 2018; Donohue & Biggs, 2015; Erenstein *et al*., 2010). Social capital is the network of relationships that allow its members to exchange and access various assets available in its industrial network (Dewantoro & Ellitan, 2022). Human capital entails the human resource capability and potential. Human capital includes the parameters such as education level of farmers, training undergone, labour availability, health and experience of the farmers. Human capital enables people to pursue different livelihood strategies and achieve their livelihood objectives. At household level human capital is the number and quality of labour available and this varies according to household size, skill levels, leadership potential, health status and number of meals in a day. Mainly indicators include education, labour availability, the health and skills of the labour force used in production (Chen *et al.,* 2013).Natural resources are mainly environmental resources indicators such as access to land, water and forest resources (Baffoe & Matsuda, 2018) and farm land (Boateng, 2013). This study considered access to lake water and road as natural resources.

2.9 Perceptions on Effects of Cage-Fish Farming

The increasing demand for fish protein amidst diminishing capture supply has led to a rapid increase in the expansion of aquaculture and more so adoption of cage culture technology in the Lake Victoria. This rapid growth of intensive farming has heightened different perceptions raising questions about its environmental and the potential economic or social effects on local communities (Bacher *et al*., 2016). Cage-fish farming is carried out in public water body that is also a social good used for other activities such as transport, fishing, water extraction for domestic, industrial and agriculture hence social conflicts. Fishermen hold that their space has been reduced and thus reduced catches (Bacher *et al*., 2016). Feeds from cages, uneaten feeds, faecal and other wastes affect the water quality (Njiru *et al*., 2019). This study was seeking to explore the perceptions of the fish stakeholders on the effects of cage farming in relation to health, environment and socio economics benefits.

2.10 Theoretical Framework Review

2.10.1 Production Theory

Production economics theory using Cobb-Douglas was adopted for this study. The model displays the relationship between factors inputs and factors output.

The basic form of the model is:

$Y(L,K) = AK^{\alpha}L^{\beta}$ Equation 5

Where: Y- is the total productivity

L- is the labour input

K- is the capital input

A-total factor of productivity

α and β- output elasticities of capital and labour respectively

The total factor productivity measures the change in outputs resulting from the change in inputs. Usually, the change in output factor productivity is attributed to improvements in efficiency or technology. The output elasticity is the change in output that results from a change in either labour or physical capital. Return to scale is the term used to refer to the measure of the change in output resulting from a change in input (Cobb-douglas, 1928) that is referred to as either increasing, constant and diminishing returns to scale. The theory is related to the study where by factors affecting technical efficiency in turn affect cage production.

2.10.2 Sustainable Livelihood Approach

Sustainability implies a sense of longevity as well as resilience to the turbulence of politics, economic systems, and environmental change. Depletion of capture fish stocks worldwide has necessitated the development of sustainable aquaculture to sustain fish production and meet the demand. A livelihood is a set of people, their capabilities, and their means of living including food, income, and assets. A livelihood is considered sustainable if it can improve assets that livelihoods depend on both economically, environmentally and socially and has net benefits to other livelihoods, cope with and recover from stress and shocks, (Chambers &Conway, 1992; Morse *et al.*, 2013). Assets are information of resources, stores, access, and claims. They are then assessed in terms of their susceptibility to shocks and the institutional context within which they exist, to enhance the livelihood strategies.

When assessing levels of livelihoods, several measurements and indicators can be used to evaluate various aspects of people's well-being and quality of life. These can be through Livelihood Security Index (LCI) which uses social indicators for assessing the quality of life, coupled with meeting the basic needs of human beings by measuring progress at the family and community level through identifying the constraints to peoples‟ well-being as well as their assets

and opportunities (Lindenberg, 2002). Other indices that can be used include Livelihood Index, which was developed based on macro level data to evaluate the developmental process of the country by regions(Rai *et al*., 2008), Livelihood Vulnerability Index (LVI) that includes vulnerability indicators in developing livelihood index (Hahn *et al*., 2009). LVI is used to estimate climate change vulnerability based on eight domains namely sociodemographic, livelihoods, social networks, health, food and water security, natural disasters and climate variability.

Sustainable Living Index (SLI) developed by (Kamaruddin & Samsudin, 2014) captures broadly all livelihood elements focussed on formation of micro index that base on the livelihood assets possessed by every household. The Sustainable Livelihood concept includes livelihood asset, livelihood strategy, livelihood outcome, vulnerability context, and institutional involvement thus parameters that represent all indicators in the sectors are included. The Sustainable Livelihood Approach offers an integrated, multidimensional, and rational approach to poverty eradication and thus enhances understanding of livelihoods. The sustainable livelihoods approach improves understanding of the livelihoods of the poor as it organizes the factors that constrain or enhance livelihood opportunities, and shows how they relate. This study aimed to find out the opportunities that cage-fish farming has on livelihoods of every household in terms of economic empowerment through profits gained from the enterprise and relate it to livelihood outcomes. SLI therefore was the ideal methodology.

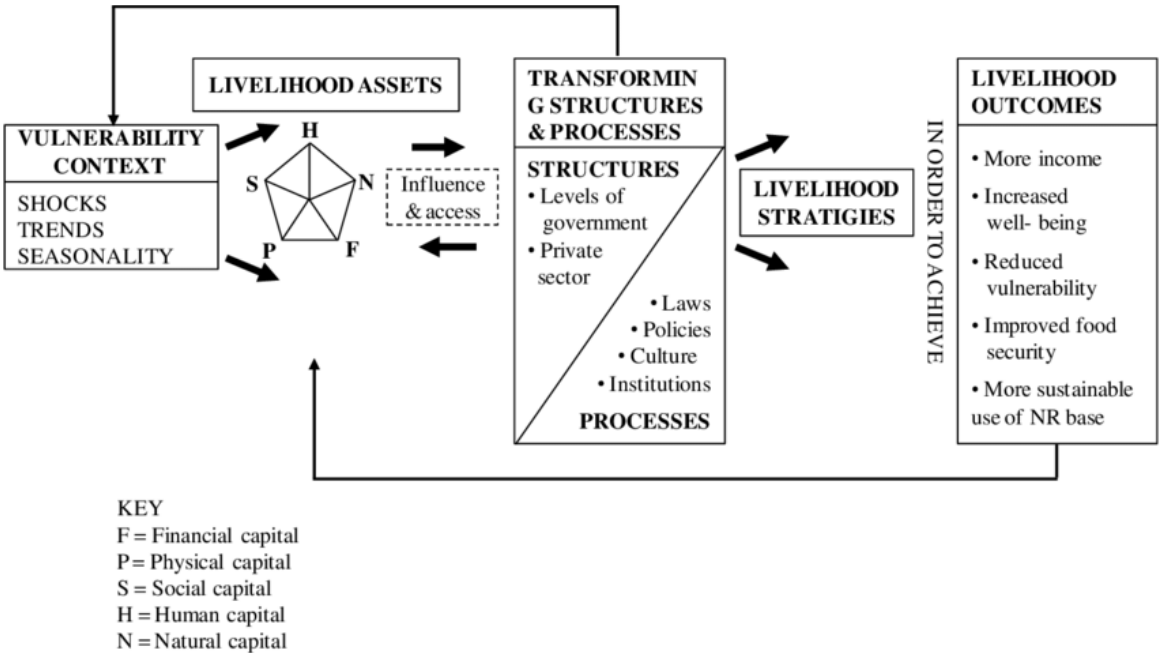

Figure 2.1: DFID Sustainable Livelihood Framework

2.11 Conceptual Framework

In this study, the dependent variable was technical efficiency and the independent variables were socio-economic factors. Social-economic factors of the farmers such as level of education, gender, age, feeds, labour, cage size, rate of fingerlings, and farming experience have effects on technical efficiency. Independent variables include both production factors and farm and farmer characteristics variables that affect the dependent variable (technical efficiency) and that forms the objective one of this study. Technical production efficiency affects the cage production thus affects livelihood outcomes such as income, social wellbeing, wealth, job creation, reduced vulnerability and improved food and nutrition security that has an effect on the livelihood assets. However, for livelihoods to be improved, adoption and management of livelihood strategy is dependent on the technical production efficiency and perception of the beneficiaries on the effects of the livelihood strategy on them. In this study, cage-fish farming is the livelihood strategy that was studied and it involved study of management of it by focusing on efficiency and the factors that influence the efficiency in terms of production. The study also focused on the

effects created by cage-fish farming on livelihoods assets and sought to assess the perceptions of the beneficiaries on the effects this farming has caused in order to influence its adoption.

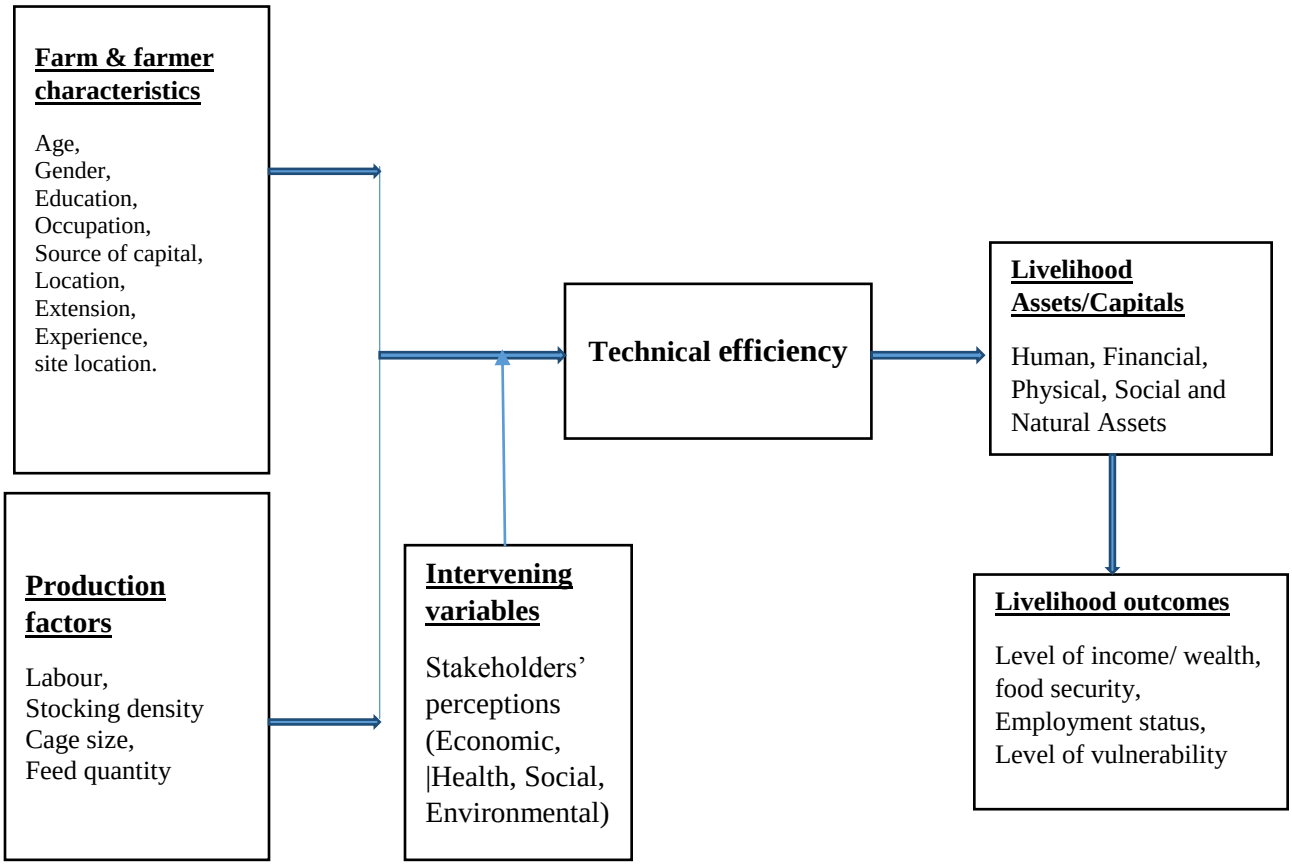

Figure 2.2: Conceptual Framework showing relationship between variables

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

The study describes the study area, research design and sampling procedure, research instruments, data collection, data analysis techniques and ethical consideration.

3.2 Study Area

This study was conducted in Siaya County which is one of the six Counties in the Nyanza region. The County has an area of approximately 2,530km² with approximately 1,005 km^2 water surface that forms part of Lake Victoria (County Government of Siaya, 2018).The county boundaries stretch from Busia County to the North West, Vihiga and Kakamega counties to the North East, Kisumu County to the South East, and Homa Bay County across the Winam Gulf to the South. The county is found between latitude 0º26´ South 0º18´ North and longitude 33º58´ and 34º33´ East with a spreads of five agro-ecological zones (LM1 to LM 5; Table 3.1). The County is drier in the Southern part which receive rainfall range between 800 - 1,600mm and is wetter towards the higher altitudes in the Northern part which receive rainfall range of between 800 - 2,000mm.The rainfall pattern is bimodal experiencing long rain season between March and June while short rain season is received between September and December.

Table 3.1: Agro-Ecological Zones in Siaya County

AEZ	Areas Covered
LM1 and LM2	Gem, Ugunja, Ugenya, and upper parts of Boro
LM3	Lower parts of Boro in Alego Usonga, Sakwa and Asembo
LM4 and LM5	Uyoma and Yimbo

Siaya County is characterized by high poverty levels estimated at 47.56% with a population of 993,183 persons (471,669 males, 521,496 females) (KPHC 2019, VOL.1). The County depends on Agriculture as the main source of income. Agriculture plays a critical role in ensuring the

County remains food sufficient and food secure. Specifically, this sector generates about 60% of household income and creates almost 61% of all employment opportunities. Most households in Siaya County depend on crops (Maize, Beans, Cassava, Sweet Potatoes, and Sorghum), livestock (Poultry, Zebu cattle and cross breeds, sheep, and goats),and fishing activities from Lake Victoria, Lake Kanyaboli, and Aquaculture for their livelihoods (MoALF, 2016). Apiculture is being popularized since investment and operation costs are low.

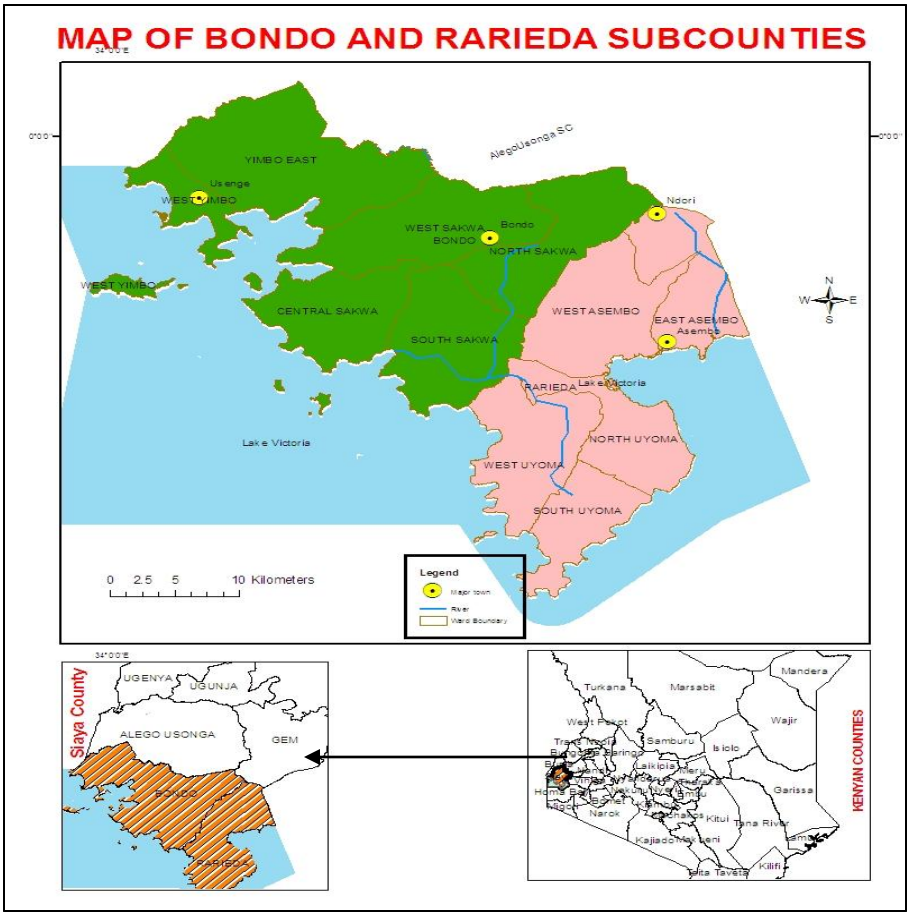

Figure 3.1: Map of Study Area in Siaya County

3.3 Research Design and Sampling Procedure

The study target edcage-fish farmers and fish stakeholders in Siaya County, and employed a descriptive survey design to collect a wide range of data sets though field survey that was conducted. A multistage sampling technique was used, firstly, purposive sampling was used to

select Siaya County as the study area from among the five riparian counties, followed by two sub-counties (Bondo and Rarieda) (figure 3.1) purposefully chosen for their geographical proximity to Lake Victoria. Secondly, the study limited its sampling to beaches where cage-fish farming is practiced. After that, a simple random sampling method was employed in selection of respondents from the target population within the beaches. Primary data was collected by means of a structured questionnaire for one production cycle through a field survey. Two sample sizes were used during the evaluation of the research objectives. 10% of each sample size was used for pretesting the data collection tools to determine the reliability.

First sample size

This sample size targeted only cage-fish farmers. The target population is only cage-fish farmers in Siaya County with a total of 1062 cage farmers from 19 beaches (Department of Fisheries, Siaya County, 2020). Sample size was determined according to Yamane (1967:886) formula(Israel, 1992).

Sample size = $\boldsymbol{n = \frac{N}{1+N(e2)}}$ Equation 6

Where: **n** is the sample size,

N is the population size and

e is the level of precision.

The survey sample size of 291 cage farmers was calculated as $\frac{1062}{1+1062\,(0.05*0.05)}$ata precision level of 5% which represents the sampling error that estimates where true value of the population lies.

Second sample size

For the second sample since the population was unknown, the researcher used random sampling to sample out fish stakeholders from the population and exclude cage-fish farmers from the sample. The population was clustered into four major categories of fish stakeholders that is

fishermen, fish traders, consumers and artisans. The researcher adopted the minimum sample size determination method called n-omega or Multistage Non-finite Population (MNP) and used a minimum recommended sample size of 30 (Louangrath, 2014)per sub group for the two sub counties to form a sample size of 240 for the four sub groups. The sample size was then apportioned (Table 3) based on the numbers on the beaches as 40% fish traders, 30% fishermen, 15% consumers and 15% artisans.

Table 3.2: Sample size apportionment

Category	Artisans	Fishermen	Fish Traders	Consumers
Percentage apportioned	15% (n=36)	30% (n=72)	40% (n=96)	15%(n=36)

The study targeted 240 fish stakeholders, however, there were declines and missing data which affected the numbers of fish stakeholders interviewed and 217 fish stakeholders have been used for analysis in the study.

3.4 Research Instruments

Data was collected through a structured questionnaire administered through field surveys (Appendix A). Data was collected by research assistants using Open Data Kit (Kobo Toolbox) to ensure the accuracy of data entry. Questionnaires were administered to cage farmers, fish traders, Consumers, fishermen, and artisans.

3.5 Data Collection

Primary data was collected through field survey using a structured questionnaire that was pretested at Kamenga Beach and the final version programmed in the Kobo Toolbox server (Open Data Kit) to enable mobile data collection and entry using tablets and smart phones into a database that was downloaded for analysis. Kobo Toolbox was developed by Harvard Humanitarian Initiative as a suite of tools for field data collection. It is open-source free software

that is easy to create forms and allows online and offline submissions hence offer the best option for collecting data in the field. The survey team used Kobo Collect v1.29.3 on their digital devices to collect and submit the data to the Kobo Toolbox server. The questionnaires were administered to two categories: cage farmers and fish stakeholders (Fishermen, traders, consumers and artisans). The data collected included bio data of respondents such gender, age, education level, occupation among others, the inputs used in production such as feeds quantities used, fingerlings, labour and sizes of cages.

Data collected on effects of livelihoods included respondents being asked questions to determine their perception on the trends of capitals' growth since the inception of cage-fish farming. Indicators such as trends of household health status, trend in household education levels for human capital, trends in quality and quantity of physical assets, trends in the socialization of the respondents in groups associations, participation in social activities, participation in decision making process, access to social capital and trend in growth of social capital. Financial capital was considered in relation to income/ revenue from cage-fish farming, saving trends, financial resource growth trends and level of control of the financial resources while natural capital was indicative from the trends of growth in terms of quality and quantity, access to natural resources such as the lake and descriptive of the nature of the natural resources.

This study considered possession of durable assets such as cages, improved housing, boat, household assets among others as the physical household capital. The components under study for social capital were one's status in community, involvement in decision making process, access to social capital through association or group membership and the trend of social capital since start of cage-fish farming. Natural capital parameters in the study included the trend of household/community Natural Capital (quality and quantity), access to community natural

capital and description of road network. Data on attitudes towards various perception statements were also collected from fish stakeholders who responded based on their agreement to each statement on a five Likert scale.

3.6 Validity and reliability of data and data collection tools

3.6.1 Pilot Study

Pre-test was conducted at Kamenga beach in West Sakwa ward. A sample of 30 cage farmers corresponding to approximately 10% of the study sample was interviewed randomly. Kamenga beach was selected for pilot study due to its central location within Bondo and Rarieda Sub Counties. STATA was used for data analysis.

3.6.2 Validity

The researcher tested the research tools (questionnaires) before the real research through pilot study process. Consultation was done with the supervisors and officers in the Directorate of Fisheries on whether the instruments were valid for data collection. Additional input was included and ambiguous questions deleted from the questionnaire as per their guidance and results of the pilot study. The findings obtained in the pre-test were not used in the final report as they were specifically for the purpose of testing the research instruments.

3.6.3 Reliability

The study tools were measured for their reliability to ensure consistency of the tool to measure the same way whenever it is used with the identical subject under the similar condition. The data from the pilot study was analysed to test for reliability. An R2 of 0.59 or more assured the reliability of the instruments in test-retest.

3.7 Data Analysis

3.7.1 Evaluation of technical efficiency of cage fish farmers

The Cobb-Douglas stochastic frontier model with distributional assumptions was chosen to assess the technical efficiency of cage fish farmers since, besides its generalization form, it is a simple tool that can be handled easily, even for multiple inputs (Bhanumurthy, 2002). The empirical version of the stochastic frontier model (Berger & Humphrey, 1997) with the specification of Cobb-Douglas functional form was expressed with the decomposed errors.

The frontier production function;

$$\ln Y_i = \beta_o + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + (V_i - U_i) \quad \text{Equation 7}$$

Where;

Y_i – is the cage productivity of i^{th} farm in Kgs per M^3

i – is the i^{th} farm, (i =1, 2....292)

β – Unknown coefficients of the independent variables to be estimated

X_i – the independent variables (X_1=labour, X_2=stocking density X_3= cage size, X_4=feeds)

U_i – cage farmer specific TE

V_i – statistical disturbance term.

Using the exponential form of the disturbance term in STATA version 13 (2013), the maximum likelihood estimates of the parameters in the stochastic frontier production were obtained.

3.7.2 Evaluation of factors influencing the technical efficiency of cage fish farmers

Since efficiency is not binary but rather bounded between zero and one, the Tobit model was used to regress the efficiency estimates obtained on some farm-specific attributes.

The Tobit model was as follows;

$$U_i = \beta_o + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 X_{8i} + \beta_9 X_{9i} + \beta_{10} X_{10i} + \varepsilon_i \quad \text{Equation 8}$$

Where;

U_i– farm-specific TE of the i^{th} cage farmer (ranges 0 to 1)

X_i – farm-specific attributes

ε- Independently distributed error term assumed to be normally distributed with a mean of zero and a constant variance.

Table 3.3: Description of the variables in the SFPF and Tobit model

Variable	Description	Unit	Priori expectation
Dependent Variable			
Cage productivity (Y)	Total quantity of fish produced per metre cubic	Kg/M^3	
Independent variables			
Labour (X_1)	Total number of family and hired labour used	Man-days	+
Stocking Density(X_2)	Fingerlings stocked in the cage per cubic metre	Number of Fingerlings/M^3	+
Cage Size(X_3)	Total volume under production	M^3	+
Feeds(X_4)	Total quantity of feeds used	Kilograms	+
Factors influencing Technical efficiency			
Dependent Variable			
TE	Technical efficiency score		
Independent variables			
Age (X_1)	Represents age category of cage fish farmer (1=18-35yrs)	Dummy	+
Gender (X_2)	Represent the sex of the cage farmer (1=Male)	Dummy	+
Marital status (X_3)	Marital status (1= Married)	Dummy	-
Level of Education (X_4)	Level of education of cage farmer (1= Secondary)	Dummy	+
Occupation (X_5)	The main occupation of the cage farmer (1= Fishing)	Dummy	+/-
Source of Capital(X_6)	The main sources of capital of the cage farmer (1=Grants)	Dummy	+/-
Location(X_7)	Geographical location (1= Central Yimbo)	Dummy	+/-
Extension services(X_8)	Number of Extension visits	Number	+
Farming Experience(X_9)	Years the farmer spent in cage fish farming	Years	+
Beach(X_{10})	Site along the lake where cage is located		+/-

3.7.3 The Effects of Cage-Fish Farming on the Livelihoods of Communities in Siaya County

The study endeavoured to evaluate the socio-economic effects created by cage-fish farming in the study area. The Sustainable Livelihood index (SLI) was constructed to evaluate the changes in livelihood capitals. Five capital frameworks of sustainable livelihoods were adopted(Morse *et al.,* 2013) and categorized as human capital, physical capital, natural capital, financial capital, and social capital. Sustainable livelihoods are linked to the enhancement of these capitals. A sustainable livelihood index was constructed from the aggregation of individual indices of the capital categories. A balanced weighted average approach(Hahn *et al*., 2009) was used where each indicator contributed equally to the index.

Each category index was calculated by the formula

$$Mi = \frac{\sum_{i=1}^{n} indicator \quad i}{n} \qquad \text{Equation 9}$$

Where:

M_i = Capital category index(Human Capital-HC, Physical capital- PHC, Natural Capital-NC, Financial Capital- FC and Social Capital – SOC)

n = Number of indicators in each category

The aggregate Sustainable Livelihood Index (SLI) was then computed from each capital using the formula:

$$SLI = \frac{\sum_{i=1}^{n} Mi}{n} \qquad \text{Equation 10}$$

Where:

SLI = Sustainable Livelihood index

n= the number of capital categories

3.7.4 Assessment of the Perceptions of Fish Stakeholders on Cage-Fish Farming in Siaya County

To achieve this objective, Principal Component Analysis (PCA) was used to estimate the opinions and attitudes of the respondents on the extent they agree or disagree on statements related to perception indicators. Principal Component Analysis is a multivariate statistical technique used to analyse data by extracting information from data tables as a new set of orthogonal variables called Principle Components with the aim of extracting and compressing the size of data set by keeping only important information(Abdi& Williams, 2010). The importance of the component is obtained by Eigen values associated with each component. The larger the eigen value the more the variable contributes to the component. The loading factors indicates the correlations between variables and components hence determines which variable is factored in which component.

3.8 Ethical Considerations

The research proposal and the data collection tools were submitted to Maseno University Ethical Review Committee (MUERC) and National Commission for Science, Technology and Innovation (NACOSTI) (appendix D and appendix E respectively) for ethical review and were approved and thus relevant permits granted. The study was undertaken as per the ethical guidelines regarding respondents' privacy, confidentiality, anonymity and no risk of harm to any participant. Also, their freedom and willingness to participate in the study was respected. All the respondents willingly and voluntarily participated in the survey by signing consent form (appendix B) without disclosing their names. There after the study objectives were read to each one of them and the use for information for the academic purposes explained. The data collected through the Kobo Collect was submitted to the researchers' cloud server which is protected by a password and once submitted to the server by the research assistants, it was disabled from their

gadgets hence the information could not be shared elsewhere. Information collected has been used for the study purposes and has not been disclosed to users not involved in the study. Findings from the study shall be disseminated through publication of the aggregated research findings and participation in conferences with the same subject matter. The participants in the research will benefit from the recommendations that being made through adoption of the technologies recommended and through policy formulation.

CHAPTER FOUR
RESULTS

4.1 Introduction

This chapter consists of five major sections. The first section entails discussion of the descriptive results comprising of socio-economic characteristics of cage fish farmers and fish stakeholders. The sections two to section five entails description of empirical results from the stochastic frontier analysis, the Tobit model, the Sustainable livelihood index, and the Principal Component analysis.

4.2 Socio-Economic and Demographic Characteristics of Cage-Fish Farmers and Fish Stakeholders in Siaya County

4.2.1 Socio-Economic and Demographic Characteristics of Cage-Fish Farmers in Siaya County

In the survey, a total of 292cage-fish farmers were interviewed. Among them, 19.18% and 80.82% were from Rarieda and Bondo Sub-Counties respectively. The socioeconomic characteristics of cage-fish farmers are shown in Table 5. Most cage farmers (47.26%) were between 18 and 35 years, and the remainder were between 36 and 50 years (43.49%). Notably, 2.05% of farmers were over 60 years while 7.19% were between the ages of 51 and 60. The results indicate that majority of those involved in cage farming are of productive age. Most cage farmers (86.99%) were male, with females accounting for 13.01%. Most of the cage farmers (88.36%) were married and 8.22% were single while those widowed and divorced were few at 3.08% and 0.34% of total respondents respectively.

The education level of respondents was categorized into five categories: no formal education, primary, secondary, technical, and tertiary. Table 4.1 indicate that most cage farmers (44.52%) had secondary education, and 35.62% had primary education. Most of the respondents had a formal education; those with no formal education were 1.37%. The respondents' main

occupation (51.68%) was cage-fish farming, being the main economic activity. However, capture fishing (22.15%) continues to support the livelihoods of fishermen in the study area. Other occupations included being employed (10.07%), small businesses (9.93%), crop farming (6.08%) and business consultant at less than 0.34%.

Table 4.1: Socio-Economic Characteristics of Cage-Fish Farmers in Siaya County

Variable	Description	Frequency	Percentage	Cumulative
Sub County	Rarieda	56	19.18	19.18
	Bondo	236	80.82	100
Age of respondent	18 - 35 years	138	47.26	47.26
	36- 50 years	127	43.49	90.75
	51-60 years	21	7.19	97.95
	Above 60	6	2.05	100
Gender	Male	254	86.99	86.99
	Female	38	13.01	100
Marital status	Single	24	8.22	96.58
	Married	258	88.36	88.36
	Widowed	9	3.08	99.66
	Divorced	1	0.34	100
Educational level	No formal education	4	1.37	55.82
	Primary	104	35.62	91.44
	Secondary	130	44.52	44.52
	Technical	29	9.93	54.45
	Tertiary	25	8.56	100
Occupation of the respondent	Fishing	64	22.15	22.15
	Business consultant	1	0.34	22
	Cage farming	154	51.68	74.16
	Crop farming	18	6.04	80.2
	Employed	30	10.07	90.27
	Small business	29	9.73	100

Source: Field Survey October 2021

The study was undertaken on 11 beaches in four wards within the study area. Majority of the cages are located in Uwaria, Luanda Ko' Otieno and Anyanga beaches (Figure 4.1).

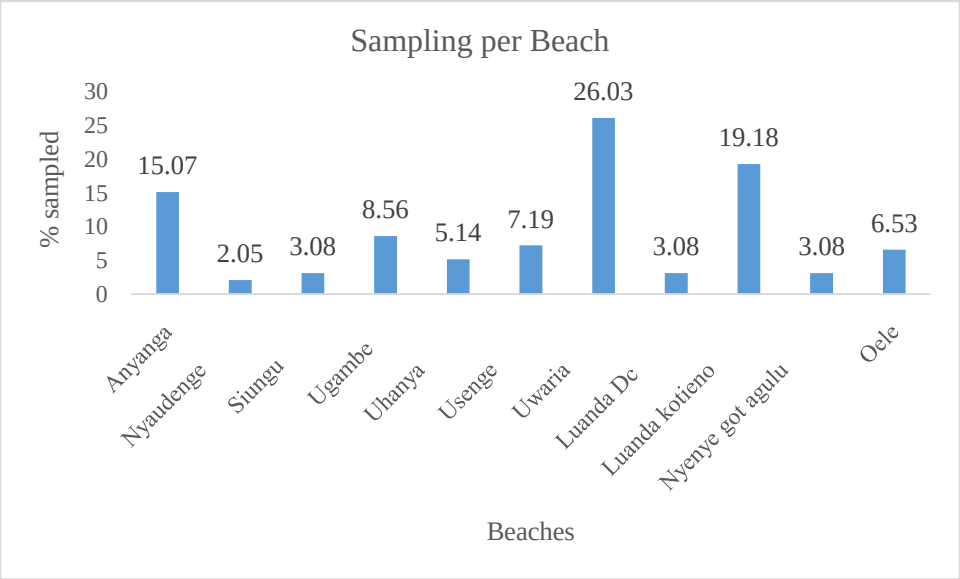

Figure 4.1: Sampling along the beaches in the study area

The survey revealed that the main sources of capital for starting cage-fish farming were from Savings (61.64%), loans from welfare associations (19.18%) and family contributions (9.58%) (Figure 4.2). Bank loan and grants had minimal recording 6.51% and 3.08% respectively.

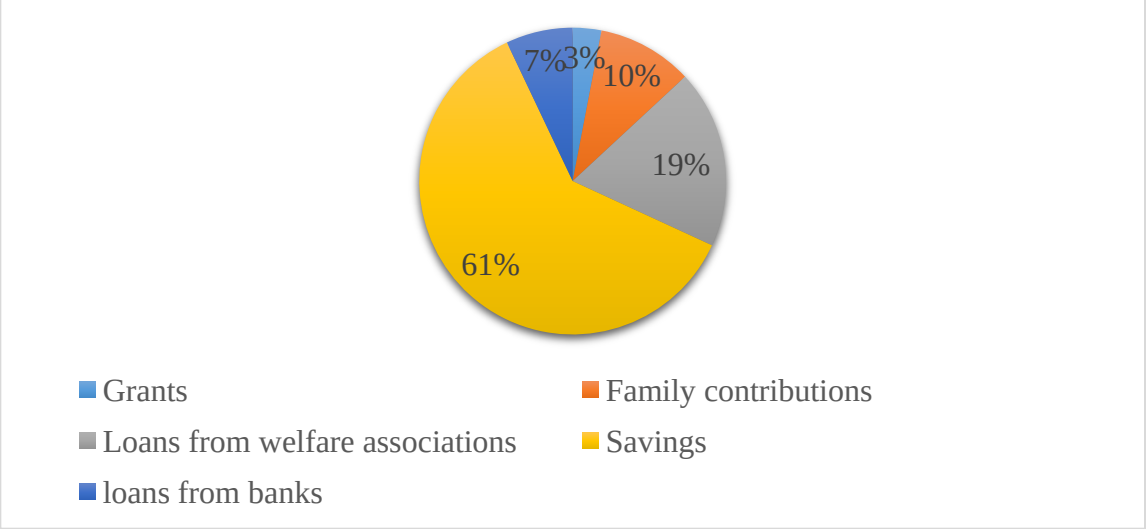

Figure 4.2: Sources of Capital for Cage- Fish Farming in Siaya County

High profits anticipated from cage farming was the major motivating factor for engaging in cage-fish farming (39.73%), followed by ready market for the fish (24.66%), low lake catches (17.47%) and availability of lake resource (10.96%). Other motivating factors to venture into cage-fish farming included demand for family needs, peer pressure and less labour which represented 3.42%, 3.08% and 0.68% of the respondents, respectively (Figure 4.3).

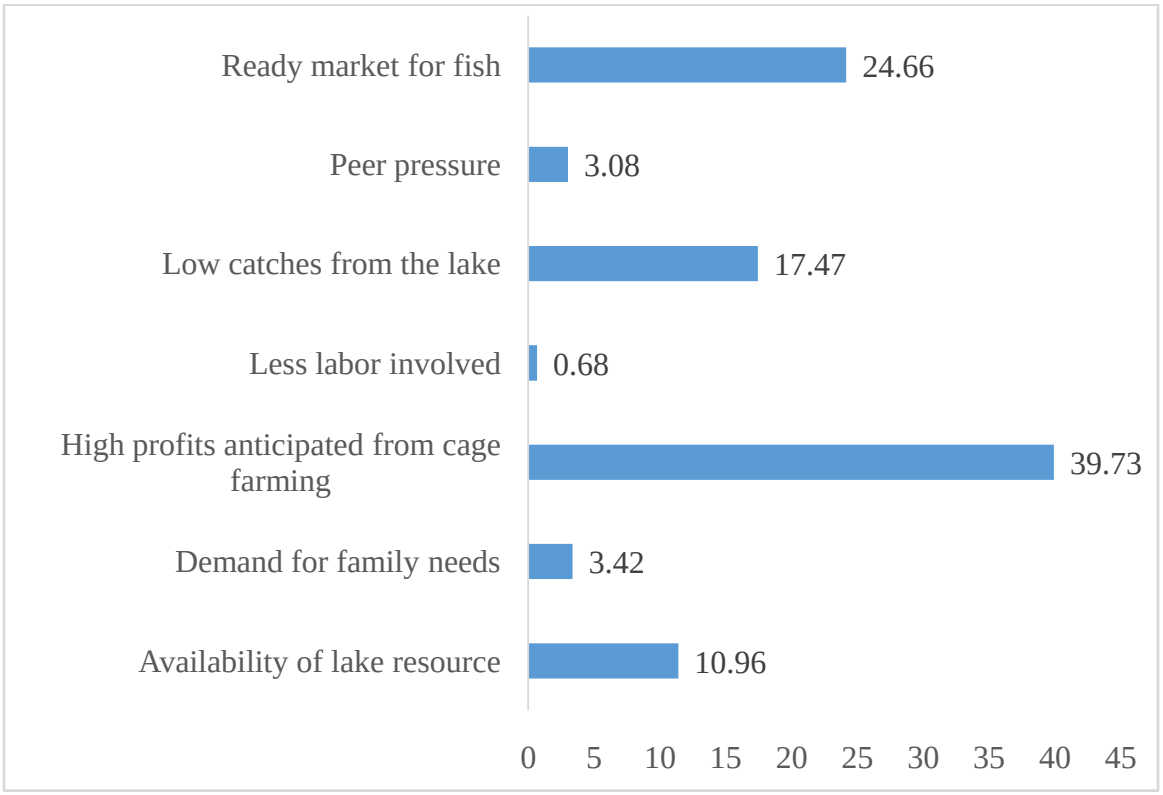

Figure 4.3: Motivating Factors for Cage-Fish Farming in Siaya County

4.2.2 Socio-Economic and Demographic Characteristics of Fish Stakeholders in Siaya County

The study sampled a total of 217 fish stakeholders were interviewed during the field survey (28.58% Rarieda and 71.42% in Bondo). The socio-economic characteristics of fish stakeholders are presented on Tables 6. Fish stakeholders interviewed from the study area comprised majorly

of fish traders (41.01%) and fishermen/Crew (31.80%). The other categories interviewed included Artisans (15.21%), and Consumers (11.98%).

Most of the fish stakeholders 65.44% were male while 34.56% were female. The results showed that majority of fish stakeholders were aged between 18-35 years who comprised 49.31% of the sample, 43.79% were aged between 36-50 years with only 1.84% aged above 60 years. Education level was categorized into four categories from no formal education, primary, secondary, and technical/tertiary levels. The fish stakeholders' in the study shows that majority (52.53%) had acquired primary education and (32.26%) had secondary education while 6.45% had no education as shown in Table 4.2.

Table 4.2: Demographic Characteristics of Fish Stakeholders in Siaya County

Variable	Description	Artisans (n=33)	Consumers (n=26)	Fishermen (n=69)	Fish Traders (n= 89)	Fish stakeholders (n=217)
		Percentage (%)	Percentage (%)	Percentage (%)	Percentage (%)	Percentage (%)
Respondent's Gender	Female	9.09	42.31	0	68.54	34.56
	Male	90.91	57.69	100	31.46	65.44
Respondent's Age	18- 35 years	45.45	65.38	56.52	40.45	49.31
	36-50 years	39.39	26.92	36.23	56.18	43.78
	51-60 years	9.09	3.85	5.8	3.37	5.07
	>60 years	6.06	3.85	1.45	0	1.84
Respondent's Education level	No formal education	6.06	7.69	5.8	6.74	6.45
	Primary	54.55	38.46	49.28	58.43	52.53
	Secondary	36.36	30.77	37.68	26.97	32.26
	Technical/Tertiary	3.03	23.08	7.25	7.87	8.76

Source: Field Survey October 2021

4.3 Technical efficiency of Cage Fish Farming

4.3.1 Stochastic Frontier results

This study adopted the second step of Cobb Douglas of using logariths to fit the data. In Table 7, the sum of the partial elasticity in the estimated model was 0.17 which is a sum of all the coefficients of variables used in the model (Labour, cage size, feeds and stocking density) implies on average, the production frontier exhibited decreasing returns to scale. In other words, if all the inputs are increased by 1%, output of fish per metre cube will increase on average by 0.17%. The study results indicated the highest output elasticity for cage size under production (0.15) followed by stocking density (0.12). Both cage size under production and stocking density variable were positively related to cage fish production and their higher elasticities implied that their contribution to cage productivity was dominant. A one percent increase in the cage size under production and stocking density, ceteris paribus, lead to a 0.15% and 0.12% increase in technical efficiency respectively whereas a 1% increase in labour leads to decreased technical efficiency by 0.20%. The positive coefficients of stocking density, quantity of feeds and cage size implies that the farmers are technically efficient with the use of these production factors while the negative coefficient of labboursuggests that labor input beyond a certain level may not contribute positively to technical efficiency. Farmers can therefore improve labor efficiency by employing mechanism such as collaborating and using same labour resource.

Table 4.3: Maximum likelihood estimates of the SFP function results

lnprodM[3]	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Lnlabour	-0.21	0.08	-2.59	0.01***	-0.36	-0.05
Lnstocking density	0.13	0.09	1.41	0.16	-0.05	0.31
lncagesize	0.15	0.02	7.60	0.00***	0.11	0.19
lnfeeds	0.09	0.02	5.82	0.00***	0.07	0.13
_cons	2.78	0.50	5.60	0.00***	1.81	3.75
Total elasticity	0.18					
/lnsig2v	-3.35	0.39	-8.69	0.00	-4.10	-2.59
/lnsig2u	-0.10	0.17	-5.75	0.00	-1.34	-0.66
sigma_v	0.19	0.04			0.13	0.27
sigma_u	0.61	0.05			0.51	0.72
sigma2	0.40	0.05			0.30	0.51
lambda	3.23	0.08			3.08	3.40

Log likelihood = -141.78, Likelihood-ratio test of sigma_u=0: chibar^2(01) = 18.87;Prob>=chibar^2 = 0.000

***Significant at 1%** Significant at 5% and * Significant at 10%, Source: Field Survey Data, 2021

4.3.2 Distribution of Efficiency Scores

The results of the Stochastic Frontier Model (Table 8) showed the aggregate maximum and minimum technical efficiencies for farmers to be 0.9317 and 0.1736 respectively. This implies that, the best practicing farmers had a technical efficiency of 93.17% whereas farmers with the worst practicing had a technical efficiency of 17.36% with an average technical efficiency of 65.06%. The aggregate means technical efficiency of 0.6506 implies that averagely, cage farmers were able to obtain 65.06% of optimal output from the given mix of production inputs and production technology they have. The results also indicate that the cage fish farmers were producing fish below their respective frontier levels. This implies that there is an opportunity for increasing technical efficiency by 34.94 % in the short-run under the existing production technology. Thus there is great potential to cage production by improving technical efficiency of the farmers, which will yield to improved yields and income, with a resultant impact on poverty reduction and wealth creation in the study area.

Table 4.4: General summary of TE and Summary by Categories

VARIABLE		MEAN TE	Max. TE	Min. TE	Dev.
TE		0.65	0.93	0.17	0.76
AGE	18- 35 years	0.69	0.93	0.25	0.68
	36- 50 years	0.67	0.92	0.30	0.62
	51- 60 years	0.54	0.90	0.17	0.73
	Above 60	0.43	0.82	0.19	0.63
GENDER	Male	0.65	0.93	0.17	0.76
	Female	0.62	0.91	0.19	0.72
LOCATION (GEOGRAPHICAL)	Yimbo East	0.60	0.87	0.26	0.62
	South uyoma	0.68	0.91	0.25	0.66
	West yimbo	0.66	0.93	0.19	0.74
	Central yimbo	0.65	0.91	0.17	0.73
BEACHES	Anyanga	0.65	0.89	0.29	0.60
	Nyaudenge	0.57	0.85	0.26	0.59
	Siungu	0.77	0.93	0.46	0.47
	Ugambe	0.62	0.88	0.27	0.61
	Uhanya	0.71	0.92	0.37	0.54
	Usenge	0.57	0.86	0.19	0.68
	Uwaria	0.65	0.91	0.17	0.73
	Luanda dc	0.62	0.87	0.43	0.44
	Luanda kotieno	0.68	0.91	0.25	0.66
	Nyenye got agulu	0.80	0.93	0.59	0.35
	Oele	0.58	0.87	0.34	0.55
SOURCE OF CAPITAL	Grants	0.73	0.86	0.38	0.48
	Family contributions	0.64	0.87	0.37	0.50
	Loans from welfare associations	0.67	0.93	0.26	0.67
	Savings	0.64	0.92	0.17	0.74
	Loans from banks	0.66	0.90	0.34	0.57
EDUCATION	No formal education	0.57	0.72	0.33	0.39
	Primary	0.66	0.92	0.27	0.64
	Secondary	0.65	0.93	0.17	0.76
	Tertiary	0.64	0.90	0.19	0.71
	Technical	0.66	0.90	0.24	0.65

From the study, analysis of technical efficiency by category revealed that TE decreases with increase in age, 69.11% for 18-35 years and 42.90% above 60 years. Gender depicted an average of 65.46% TE male farmers while female farmers showed TE of 62.32%. This demonstrates that

women have equivalent ability to achieving TE. Administrative location yields a decrease in TE if cage farmers move to Yimbo East. This could have occasioned by accessibility of factors of production, whereas movement from beach to beach has no pattern in terms of TE. Source of income determines the fast access to inputs and thus timeliness in supply of the inputs is critical. This study results shows that reliance on family contribution leads to low TE. This is so because one may fail to get required funds on time.

Education level results showed that TE is experienced by farmers with no formal education. The results indicate that technical skills and hands on skills through formal education. Farmers with technical or primary education resulted into a higher TE than those with secondary and tertiary education. Table 4.5 shows frequency distribution of individuals' technical efficiency estimates which indicate that the highest percentage of technical efficiency fall between 0.89 <1 while the least percentage fall between 0.9 and 1.0. This implies that technical efficiency is clustered around the lower production function and the technical distribution indicating that most of the cage farmers are lesser technical efficiency.

Table 4.5: Frequency Distribution of Technical Efficiency Estimates

Class	Frequency	Percent	Cumulative
0.1-0.29	10	3.42	3.42
0.3-0.59	98	33.56	36.99
0.6-0.89	175	59.93	96.92
0.9-1	9	3.08	100
Total	**292**	**100**	

4.4 Factors influencing technical efficiency

Appropriate recommendations for relevant policy review and implementation, necessitate identification of the sources of variations in technical efficiencies among cage fish farmers. As it follows from SFA, the efficiency scores fall between 0 and 1, hence making the dependent variables (technical efficiency scores from SFA model) a limited dependent variable. In this

respect, censored regression model (the Tobit model) was applied as the most appropriate analytical model. Selected farm and farmer characteristics were regressed against the TE scores of each farmer using the Tobit model. The results describe the influence of the selected variables and their direction of influence on TE as presented in (Table 4.6).

Table 4.6: Factors affecting technical efficiency in cage fish production

TE	Coef.	Std. Err	T	p>I t I	[95% conf. Interval]	
Age (18-35yrs)						
36 – 50 years	-0.02	0.02	-1.11	0.27	-0.07	0.02
51– 59 years	-0.17	0.03	-5.17	0.00***	-0.23	-0.10
Above 60 years	-0.29	0.05	-5.99	0.00***	-0.39	-0.20
Location (Central Yimbo)						
Yimbo East	-0.06	0.03	-1.96	0.05**	-0.12	0.00
South Uyoma	0.05	0.03	1.65	0.10	-0.01	0.12
West Yimbo	0.03	0.03	0.93	0.35	-0.03	0.10
Beach	0.01	0.00	2.02	0.05**	0.00	0.01
Gender (Male)	-0.01	0.02	-0.33	0.74	-0.03	0.02
Marital status (Married)						
Single	-0.01	0.04	-0.31	0.76	-0.08	0.06
Widowed	0.02	0.06	0.37	0.71	-0.09	0.13
Divorced	-0.13	0.16	-0.89	0.37	-0.47	0.18
Education (secondary)						
Technical	0.06	0.03	1.60	0.11*	-0.01	0.12
No formal education	-0.022	0.08	-0.26	0.79	-0.19	0.14
Primary	0.05	0.02	2.17	0.03**	0.01	0.09
Tertiary	0.05	0.04	1.33	0.19	-0.03	0.13
Occupation (Fishing)						
Business consultant	-0.05	0.17	-0.27	0.79	-0.38	0.29
Cage farming	-0.00	0.03	-0.01	0.99	-0.06	0.06
Crop farming	-0.05	0.05	-1.13	0.26	-0.14	0.04
Employed	-0.04	0.05	-0.91	0.36	-0.13	0.05
Small business	-0.03	0.04	-0.86	0.39	-0.11	0.05
Source of capital (Grants)						
Family contribution	-0.16	0.06	-2.46	0.01***	-0.28	-0.03
Loans from welfare associations	-0.11	0.06	-1.79	0.08*	-0.23	0.01
Savings	-0.14	0.06	-2.38	0.02***	-0.25	-0.02
Loans from banks	-0.13	0.07	-1.86	0.06*	-0.26	0.01
Extension	0.04	0.02	1.72	0.09*	-0.01	0.08
Experience	0.00	0.01	0.77	0.44	-0.01	0.02
_cons	0.67	0.09	7.38	0.00***	0.49	0.85
/sigma	0.16	0.01			0.15	0.17

*** Significant at 1% ** Significant at 5% and * Significant at 10%; Prob> chi2 =0.000, Loglikelihood =121.26; Source: Field Data, 2021

The age of cage fish farmers was dummied and had a negative influence on the technical efficiency of cage fish farmers and was significant at 1% level with a coefficient of -0.1660 and -0.2926 for 51-60 years and above 60 years respectively. This shows that as the cage fish farmers grow old, their level of technical efficiency decreases by 16.60% and 28.26% respectively. This can be attributed to the fact that old farmers are theoretically rigid to technology advancements and thus have tendencies to revert to traditional production methods.

The geographic location of the cage farmers was found to have minimal influence on the technical efficiency of the farmers. However, with dummying the variable it was established that there was only a significant negative influence (-0.0650). If farmers changed their production location to Yimbo East from Central Yimbo, TE would decrease by 6.5% and was significant at 5%. This change could be attributed to water levels as one moves toward the Winam Gulf affecting water levels as well as production support facilities such as Agro shops and market since Yimbo East has less of these facilities compared to Central Yimbo. Additionally, this study results established that the beach where the cages were installed had a positive influence on the technical efficiency of the cage farmers, significant at 5%. The results revealed that movement form one beach to another for cage production increased TE by 0.71%. These influence could be due to the quality and depths of water in these beaches, activities such as businesses along the beaches which may affect access to feeds and other services.

The education level of the farmer had a positive influence on the technical efficiency in cage fish farming with significance level at 5%. However, by dummying the variable with secondary education as the reference, the results show that decrease in level of education increases TE by 4.91% if the farmer has primary education and 5.58% for technical level. Moreover, where the farmer had no formal education, TE reduced by 2.22%. The results indicate that an increase in

level of education increases technical efficiency since the well-educated farmer will perform better with modern production practices than the less educated one since education improves the skill and entrepreneurial ability of the farmer in organization of inputs for the maximum efficiency.

The source of capital employed in cage fish farming was found to have a negative influence on the technical efficiency of the farmers. The results revealed that those farmers whose sources of capital were family contributions and savings significantly reduced TE by 15.61% and 13.52% respectively. The results showed that loans from welfare associations or banks had significantly reduced technical efficiency by 10.86% and 12.70% but had higher TE than those who relied on family contributions or savings. Low TE for farmers who fully rely on one source of income can be attributed to limited source of capital which limits access to essential.

4.5 Effect of Cage-Fish Farming on Livelihoods

Evaluation of effects of cage-fish farming on livelihoods was done by deriving a sustainable livelihood index through balanced weighted average approach as. From the datasets of cage farmers, means from indicators under each of the five livelihood capitals were calculated. A weighted average for each livelihood capital was computed for analysis (Table 4.7). Each indicator was assigned equal weight. The survey results showed that there was higher increase in financial capital recording the highest average mean of2.95, followed by physical capital with average mean of 2.94, human capital at 2.94, Social Capital at 2.67 and natural capital recording the lowest mean of 2.42 (Table 4.7). Road network was considered as a resource under natural capital and scored a mean of 2.1.

Table 4.7: Livelihood Capitals Trend Analysis

	Variable	Frequencies			mean	Average mean
	Variable Score	**1**	**2**	**3**		
	Human Capital					
1	Respondents' health trend	1	20	275	2.93	2.94
2	HH. health trend	1	19	276	2.93	
3	Respondent's education trend	1	10	285	2.96	
4	HH. education trend	1	11	284	2.96	
	Physical Capital					
1	Trend of the quality of your physical capital	3	8	285	2.95	2.94
2	Trend of the quantity of your physical capital	3	11	282	2.94	
3	Ownership or control over your physical capital		19	277	2.94	
	Financial Capital					
1	Trend of annual income from cage-fish farming	1	9	286	2.96	2.95
2	Trend of annual cash/savings	1	5	259	2.97	
3	Trend of financial capital over the years of cage-fish farming	3	8	285	2.95	
4	Control over financial resources in household		23	273	2.92	
	Social Capital					
1	Status in community	8	37	251	2.82	2.67
2	Household wealth status	2	135	156	2.54	
3	Involvement in decision making process in the household	7	60	229	2.75	
4	Access to social capital since you started cage6-fish farming	10	175	111	2.34	
5	Trend of your social capital since your started cage-fish farm	6	11	279	2.92	
	Natural Capital					
1	Trend of household/community Natural Capital (quality and quantity)	5	12	279	2.93	2.42
2	Access the community natural capital	21	179	96	2.25	
3	Description of the natural resource e.g. road network to your community	56	156	84	2.09	

*variable score: Increasing/ more readily available [3], Stagnant/readily [2], Decreasing/ less readily available [1]

Assessment of sustainability scores revealed that the highest proportion was on human capital (3.00)while the lowest was recorded on natural capital (Figure 4.4).

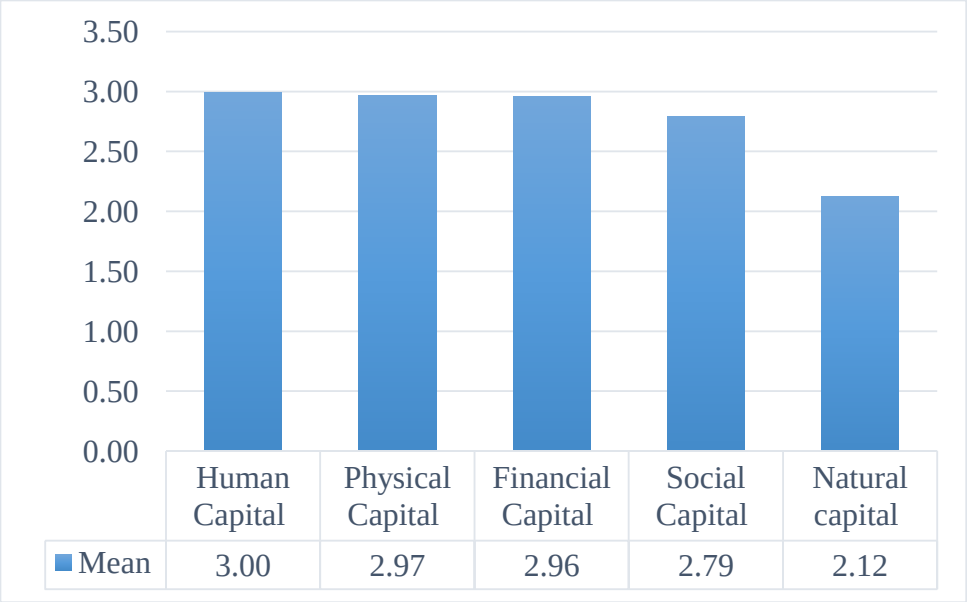

Figure 4.4: Capital Sustainability Scores

Livelihood index was developed from the average mean of each category and a sustainable livelihood index constructed from the aggregation of individual indices of the capital categories (Table 4.8). The results showed that the Livelihood indices of the individual categories ranged between 44.90% to 73.73%. Physical capital recorded highest percentage of 73.73% while social capital recorded the least percentage of 44.90%. The low social capital is attributed to lack of social networks such as marketing associations for cage farmers. However, the observed improvement of 44.90% has been realized in social capital through cage farmers' involvement in decision making activities at household level as well as community level through their engagement in BMU activities.

Table 4.8: Livelihood Capitals Indices

Category	Average Mean	Livelihood Index (%)
Physical Capital	2.9493	73.73
Financial Capital	2.9548	59.10
Natural Capital	2.3488	58.72
Human Capital	2.9257	48.76
Social Capital	2.6942	44.90
Sustainable Livelihood Index	**2.77456**	**57.04**

ASustainable Livelihood Index (SLI) of 57.04% was derived an indication that 57.04% of the changes in livelihoods of communities in the region are attributed to cage-fish farming (Table 4.8). Sustainable livelihood index is constructed on a scale of 0 to 100%. Therefore, a SLI of 50% and above is considered high and thus an indicator for livelihood improvement.

4.6 Fish Stakeholder perceptions regarding Cage-Fish farming

The attitudes of various fish stakeholders regarding cage-fish farming were assessed based on 22 different perceptions statements from economic, social, environmental and health categories. The results are outlined in table 4.8. The average response score indicated that the respondents fully agreed (3.84 - 4.35) that cage-fish farming had increased incomes, made fish readily available to market, brought many job/employment opportunities and thus enhanced community economic benefits, improved nutrition and livelihoods. They therefore advocated for increased number of cages in the lake. Some respondents partially agreed with the fact that cage-fish farming has improved security and enhanced development of good road network at the beaches. They also agreed that fish from cages is more expensive than from the wild catches. However, they demonstrated that there is no effect on navigation in the lake and no conflict with the lake users. Some respondents disagreed that Cage-fish farming has caused pollution of the lake hence affecting wild fish catches, feed and wastes from cages kill the wild fishes and reduce catches and cage materials used are affecting human health through caged fish consumed. They thus did not agree with the perception of reducing cages from the lake.

Table 4.9: Descriptive statistics of Cage-Fish Farming Perceptions

	Perception statements	Mean	Std. Dev.
1	Cage fish farming has increased income from fish	4.35	0.76
2	Cage fish farming has made fish more readily available in the market	4.19	0.85
3	Fish cage has improved security in the beaches	3.45	1.13
4	Fish cages have brought many job opportunities	4.21	0.86
5	Fish from cages is more expensive than from the wild catches	3.03	1.22
6	Fish cages has not brought any conflict with the lake users	3.27	1.19
7	Fish cage farming has created a lot of businesses opportunities in the region	4.17	0.81
8	Fish cages have improved the livelihoods of the of all the fisher forks in the area	3.76	0.85
9	There are economic benefits of being a cage farmer	4.01	0.77
10	Cage farming has created employment to the local communities	4.29	0.72
11	Cage farmers and fishermen conflict has affected the access to natural lake resources	2.08	1.09
12	Cage farming, fishing and crop irrigation farming can co-exist in the area	3.84	0.79
13	There is need to reduce the number of cages in the lake	1.76	1.09
14	There is need to increase the number of cages in the lake	4.16	0.99
15	Cage farming has enhanced development of good road network to the beaches	3.17	1.11
16	Cages installed in the lake have no effect on navigation in the lake	3.26	1.04
17	Cage farming has caused pollution of the lake hence affecting fish catches	2.03	0.99
18	Materials used to fabricate the cages affect the wild fish hence reduce catches	2.12	1.09
19	Feed wastes from cages help the wild fish to grow big	3.83	1.15
20	Feed and wastes from cages kill the wild fishes and reduce catches	1.89	1.00
21	Cage materials used are affecting human health through cage fish consumed	2.19	0.97
22	Cage farming has made fish readily accessible in the lake thus improved nutrition	4.22	0.85

1= Strongly disagree, 2= Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree

The stakeholder perceptions were assessed into four categories namely; economic, health, Social and environmental perceptions. The study employed Principal Component analysis (PCA) to assess the importance of these perceptions on cage-fish farming. The perception elements were

loaded into PCA and Table 4.9 shows component factor loadings results. A scree plot analysis of the components indicated that only 5 components had significant contribution (Appendix G) since they recorded high Eigen values of between 1.17 to 6.72 above the recommended value of 1. The percentage contribution of these components to the total variance was 61% (Table 4.10). The table shows the reliability scores represented by Cronbach's Alpha for the various key perception considerations of the various fish farming stakeholders. Cronbach's alpha is a measure of internal consistency and reliability for a scale or a set of related items in a questionnaire or survey. This was used in this study to measure the reliability of the correlation of stakeholders' perceptions in explaining the components. The components were named based on the correlated perceptions retained within the component. The component of economic and health perceptions include perceptions retained in component that consists of both economic and health related correlations, Social component retained correlations in the social perceptions whereas economic component only retained the perceptions that only relate to economic perceptions and environmental components retained correlated perceptions on the environmement. Elements in component one and five had Cronbach alpha values of 0.81 while component three had a value of 0.58 and could thus be considered reliable descriptors of the of economic, health, social and environmental perceptions.

Table 4.10: Component Loadings of Fish Stakeholders' Perceptions

	Perception statements	Components				
		1.	2.	3	4	5
	Economic and health perceptions					
1	Cage fish farming has made fish more readily available in the market	0.2973				
2	Cage farming has created employment to the local communities	0.2845				
3	Fish cage farming has created a lot of businesses opportunities in the region	0.2834				
4	Cage farming has made fish readily accessible in the lake thus improved nutrition	0.2493				
5	There are economic benefits of being a cage farmer	0.2277				
6	There is need to increase the number of cages in the lake	0.2255				
7	Feed wastes from cages help the wild fish to grow big	0.2113				
	Socio-economic perceptions					
8	Fish cages have improved the livelihoods of the of all the fisher forks in the area		0.3724			
9	Cage farmers and fishermen conflict has affected the access to natural lake resources		0.3241			
10	Fish from cages is more expensive than from the wild catches		0.3237			
11	Fish cages have brought many job opportunities		0.3185			
	Social perceptions					
12	Fish cages has not brought any conflict with the lake users			0.5233		
13	Cages installed in the lake have no effect on navigation in the lake			0.5042		
14	Fish cage has improved security in the beaches			0.4601		
	Economic perceptions					
15	There is need to reduce the number of cages in the lake				0.3877	
16	Cage fish farming has increased income from fish				0.2620	
	Environmental perceptions					
17	Cage materials used are affecting human health through cage fish consumed					0.3276
18	Materials used to fabricate the cages affect the wild fish hence reduce catches					0.3019
19	Cage farming has caused pollution of the lake hence affecting fish catches					0.2853
20	Cage farming, fishing and crop irrigation farming can co-exist in the area					0.2490
21	Feed and wastes from cages kill the wild fishes and reduce catches					0.2416

Economic and health perceptions formed the first component and was made up of perception statements that are related to both economic and health effects of fish-cage farming. The component had the highest Eigen value (6.72) and explained 31 percent of the total variance. The Cronbach's alpha of this component was 0.81 thus verified that the perception statements forming the component sufficiently explains the cluster. There were minimal differences between the loading factors of the independent variables (range 0.2973 to 0.2113) this indicates a close correlation of the variables in question.

Social perceptionsformed the third component cluster with Eigen value 1.76, Cronbach Alpha 0.58 (after removal of the 15th statement on improvement of road network, this raised the value from 0.49) and the factor loadings ranged (0.5233 to 0.4601), this component contributes to 08% of the total variance. This cluster brought together the perceived effects of fish cage farming on the social wellbeing. It is perceived that the installation of the fish cages in the lake has not affected navigation in the lake nor brought about any conflict with the lake users rather, it has improved security in the beaches since the stakeholders gave neutral responses.

Environmental perceptions, as the last component with Eigen value 1.17, Cronbach Alpha 0.81 and the factor loadings ranged (0.3276 to 0.2416), contributed to 05% of the total variance. This cluster brought together the perceived effects of fish cage farming on the environment. The respondents perceive that the cage materials used, feed and wastes from cages are affecting human health and the wild fish by causing pollution of the lake which leads to death of the wild fishes which in the long-run result to reduced fish catches. On the positive it was perceived that cage farming, fishing and crop irrigation farming can co-exist in the area.

Therefore, based on the Cronbach alpha (Table 4.11), the economic, health, social and environmental perceptions of cage-fish farming were the most important considerations by fish stakeholders in their engagement in cage-fish farming.

Table 4.11: Principal Component Analysis Model summary

Components	**Eigenvalue**	**Cronbach alpha**	**% of variance explained**	**Cumulative % of variance explained**
1. Economic and health perceptions	6.72	0.81	31	31
2. Socio-economic perceptions	2.38	0.39	11	41
3. Social perceptions	1.76	0.58	08	49
4. Economic perceptions	1.41	0.39	06	56
5. Environmental perceptions	1.17	0.81	05	61
Total	**13.44**	**2.98**	**61**	

CHAPTER FIVE
DISCUSSION

5.1 Introduction

Aquaculture has rapidly grown since 1970s and is considered a very important rural development and livelihood strategy due to the vital role it plays through its contribution to livelihoods and economy at large. However, low catches from the lake and low productivity from ponds have necessitated innovation of new culture systems to curb on the diminishing supply amidst increasing demand. The cage culture system, which has begun to significantly expand, focuses on increasing productivity. Moreover, cage-fish farming has bloomed in the Lake Victoria region and its effect on livelihood critical to understand and thus the aim of this study was to evaluate the effects of cage-fish farming on the livelihood capitals and also evaluate the perceived attitudes towards cage-fish farming. This study focused on the descriptive analysis of cage farmers and fish stakeholders, evaluating technical efficiency and the factors influencing technical efficiency, livelihood capitals and the perceived perceptions of respondents towards cage-fish farming.

5.2 Descriptive Analysis

The study findings (Table 4.1) revealed a higher percentage of respondents between 18 and 50 years, with the highest age percentage being 18- 35 for both cage-fish farmers and fish stakeholders. Due to high unemployment rates in Kenya, estimated at over 40%, young people are shifting their productive energy to aquaculture activities. Moreover, young people are quick adopters than old people and thus transitioning from the capture fishing to cage-fish farming technology is easier.

According to this study, the male gender dominated cage-fish farming enterprise, with the majority being married and having secondary education. Gender participation in aquaculture has

remained disproportionately male. As a result, the study confirms other global research on male dominance in aquaculture, with women having little involvement in production (Edet *et al*., 2013; Maina *et al.*, 2014; Aura *et al*., 2018; Kruijssen *et al*., 2018). This male dominance in fisheries and aquaculture activities may be due to existing social norms and nature of the business that allow men to perform fishing activities. However, the introduction of cage culture technology has increased female gender participation in fish production.

Majority of the cage farmers had secondary level education (Table 5)while the fish stakeholders had primary education (Table 6). However, there was presence of technical and tertiary education levels. The minimal percentage of non-formal education (1.3 % for cage farmers and 6.4% for fish stakeholders) implies that they could have acquired skills through other forms of education such as peer learning, on job training and extension(Ike & Chuks-Okonta, 2014).

5.3 Technical Efficiency of Cage-Fish Farming

Productivity and efficiency studies facilitate the assessment of the efficiency and effectiveness of production input use, and to measure efficiency and output levels against an optimum production frontier (Antwi, 2020). The production function pre-supposes technical efficiency, whereby maximum output is obtained from a given level of input combination. Values of output elasticities estimated for feeds, cage size inputs are significantly positive, stocking density is positive but not significant whereas labour is negative and significant (Table 4.3).

Feeds was positive and significant at 1% which implies that an increase in feeds by a kilogram would yield an increase in fish productivity by 0.09%. Fish feed plays a critical role in economic performance of cage production. Increase in feed quantity increases productivity as demonstrated by studies done in Ghana and Nigeria (Antwi e*t al*., 2017; Oluwasola & Ige, 2015). Increase in production area (cage size) has a positive correlation with productivity due to economies of scale

as a result of increased efficiency of factors of production. The small cage sizes are more preferred in the study area since they are easy to carry out operations, however, larger cage sizes are more productive and less damaged by currents and deemed efficient (Ombwa *et al*., 2018;Aktar *et al*., 2018). Labour as a key input was negative and significant at 1% implying that increase in one man-day would result in lower output. This therefore means that labour is not efficiently used as a result of family labour not being efficiently used or diversion of resources in the household due to large household (Ikpoza *et al*., 2021) and should be checked to ensure improvement in technical efficiency. This study results indicate that feed and cage size have a positive contribution to cage farms in the study area thus being efficiently utilized while labour has negative contribution due to either much labour being used that is not necessary.

The study also documents that cage farms exhibit decreasing return to scale. The technical efficiency shows the ability of farmers to derive maximum output from the inputs used in production. Mean technical efficiency of the sampled households is estimated to be 0.6506, indicating that the farmers produced 65.06% of potential (stochastic) frontier output thus implying that the realized output can be increased by 34.94% without additional inputs and technology in the short run in the study area. A range of technical efficiency is observed across the sampled cage farmers where the spread is large. The best cage farmer had a Technical Efficiency of 93.17%, while the worst cage farmer had a technical efficiency of 17.36% with majority (96.9%) of the farmers operating below 89% TE. This study results shows an increase in TE as compared TE of aquaculture production in Kenya as evaluated by (Munyua, 2012). However, the study results collaborates with other studies globally that farmers operate below the potential TE due to inefficiencies (Ekunwe & Emokaro, 2009; Onumah *et al*., 2010; Munyua, 2012; Olayiwola, 2013; Ikpoza *et al*., 2021).

5.4 Factors Influencing Technical Efficiency of Cage-Fish farming

Documented profitability of the cage culture has attracted a lot of investment in the cage culture system along the lake region(Musa *et al*., 2021). However, farmers face challenges in management of their farms and this could be attributed to directly or indirectly technical inefficiencies. This study revealed that technical efficiency of cage farmers was influenced by several socio-economic factors namely farmers' age, cage sitting/location, education level, and source of capital (Table 4.6).

Age of the cage farmers had a negative influence on technical efficiency indicating that technical efficiency reduced with increase in age. This is in conformity with the assumption that younger people have quick ability to adopt to new technologies than the farmers who are advanced in age. The results of this study also conforms to other studies that show that younger age are less likely to be inefficient in fish farming (Onumah *et al*., 2010; Munyua, 2012; Olayiwola, 2013) since older farmers are conservative thus not technically efficient due to their unwillingness to adopt new technology.

Cage site location represented by the beach had significant influence on technical positively. This is as a result of cage siting, an important factor since it affects cage construction and durability, operation costs, growth and survival rates of fish in the cages (Aura *et al.*, 2021; Orina *et al*., 2018). Most of cages within Siaya County are located in less than 4M depth due to ease in accessibility and close supervision yet depth is an important parameter to site suitability (Aura *et al*., 2021). Location of cages determines the water circulation within deep waters allowing water mixing, making feeds available to the fish and ensuring enough dissolved oxygen (DO) for fish growth. Despite delineation of suitable cage sites based on depth, DO, fishing, breeding grounds and water hyacinth among other factors(Orina *et al.*, 2018), some farmers on some beaches are

still practicing cage-fish farming without being cognisant of these factors on those beaches. This practice affects the economy of the cage-farmers by reducing efficiency hence profits in the long run. Geographical location had minimal influence, however, the results showed that movement from Central Yimbo to Yimbo East led to reduced TE. This could be triggered by the presence of production support facilities such as nearness to the market and existence to agrovets for supply of fish inputs that are available in Central Yimbo and lacking in Yimbo East thus limiting accessibility by farmers in Yimbo East.

Education is a measure of progressive attitude of farmers towards production techniques. This supports the idea that education increases the ability to perceive, interpret and respond to new technology and thereby enhances the farmer's ability to make prudent use of the available inputs. This study revealed that increase in education increases technical efficiency. This conforms to several studies that demonstrated education being a factor that affects productivity since it gives farmers opportunity to understand improved technologies designed to increase farm output and ensures efficiency (Iliyasu *et al.*, 2016; Aigner *et al.*, 1977; Aktar *et al.*, 2018; Antwi, 2020; Iliyasu *et al.*, 2016; Munyua, 2012; Olayiwola, 2013).

Capital plays a facilitative role in production through enhancing other factors of production. Capital is used to purchase productivity input such as fish feeds, payment of labour, purchase of culture unit and fingerlings. The source of capital was found to significantly influence technical efficiency. It had a negative coefficient thus affect TE negatively. Dependency on savings only as source of capital lead to lower TE as well as those farmers whose sources of capital were family contributions. Those whose source of capital for operating cage farming were loans from welfare associations or banks and grants had significantly higher technical efficiency. According to (Olayiwola, 2013), increase in sources of capital of fishery farmers increased TE. The results

of this study showed that the main source of capital for starting cage-fish farming was savings. However, liquidity constraints are not sufficiently met through one source of capital. This could be an indication that the amount of money received from these sources individually is not adequate for the running of the enterprise and thus need for a combination of the sources so as to increase capital based for purchase of production inputs. Availability of capital leads to adoption of technologies (Aswathy and Joseph, 2020).

5.5 Evaluation the Effect of Cage-Fish Farming on Livelihoods

Livelihood capitals play a critical role in rural development and agricultural production in rural areas and enhances capacity for self-development. These capitals require enhancement through implementation of developed strategies in order to support sustainable livelihoods. Cage-fish farming was identified as an economic strategy for improving livelihood capitals that in turn allows self-development of individuals and thus enriching their status and level of wealth. The main five categories of capitals considered are human capital, financial capital, physical capital, natural capital and social capital(Carney, 1999;Lasse, 2001).

Assets are a more reliable indicator of long-run economic wellbeing of households and individuals and provides a wider picture of the welfare of households/ individuals (KNBS, 2020). Ownership of these assets/ capitals implies wellbeing of the households. The more the assets one possesses, the better off the household or individual is. Studies have shown that escape from poverty is largely dependent on the type of assets in possession (Baffoe & Matsuda, 2018). Livelihoods of the farming communities in the study area have improved as a result of cage fish farming area (Table 4.8).

Physical capital gained the highest percentage index of 73.73, an indication that cage-fish farming has improved the physical capital a great deal. From the respondents, 70% indicated that

they had improved their housing, acquired modern utensils, electronics such as television, radios, smartphones among others. They also indicated having bought farm machinery as well as installed water harvesting structures like poly tanks and drums besides owning fish cages. Physical capital in this study was found to be the most endowed due to improvement in physical assets in possession as a result of engagement in an economic livelihood strategy. This was also observed in India where fish farming households were able to accumulate durable assets (Pandit *et al*., 2021) and improved livelihoods in Bangladesh (Ali *et al*., 2010)Physical capital has a potential for sustainability of livelihoods since with ready physical assets in possession such as cages, improved housing and household assets, one can be able to reinvest in the enterprise and thus make more impact on wellbeing in the society.

Financial Capital index denotes the financial resources that people use to achieve livelihood objectives (Lasse, 2001). The financial capital index was recorded at 59.10%, an indication that cage farming has a positive effect on the financial resources held by the respondents which is used to enhance the physical, human and natural capital. Key variable that were examined included annual income, cash/savings, access to credit and control over the financial resources. This study results shows that majority of the cage farmers used their savings to do cage farming with a few getting access to loans either through welfare associations or banks. Access to financial resources such as credit helps farmers to acquire or afford the factors of production and is regarded as one of the key elements in improving agricultural productivity (Immanuel, 2019). However, fish farmers are disadvantaged in acquiring credit due to the poor financial records as well as lack of fish farming loan products. This thus leads to low financial capital index meaning that lack of working capital affects entrepreneurial activities leading to financial portfolio being low *(*Kabir *et al*., 2012). Financial capital facilitates interaction with the other forms of capitals

thus ensuring adaptive capabilities to livelihood threats and vulnerabilities (Azad, 2022). The higher the incomes one has the more willing they become to pay for services (Cheng *et al*., 2022). Individuals are only willing to pay for the improvement of their livelihoods with increased incomes due to increased purchasing power. Low incomes deter one from enhancing their livelihoods thus increased household incomes were found to have contributed to the improved living status of the farmers through increased asset base (Faruque, 2007). High incomes enhances financial capitals and thus shapes the adaptive capabilities of the households to shocks and vulnerabilities to livelihoods. This study revealed that cage farming has improved financial assets by of 59.10%. Studies in Bangladesh and India also revealed that fish farmers increased their incomes (Ali *et al*., 2010; Pandit *et al*., 2021; Rajib *et al*., 2020).

Access to natural capital may lead to improvement of other livelihood assets such as financial capital. The main natural resources considered during the study were the lake resource and road network. An index of 58.72 percentage implies that there are no restrictions on access to the natural resource in the community and thus one can easily utilize the resource to leverage the other livelihood capitals. Accessibility to natural lake resources and its utilization has shown an improvement in livelihoods of the farming communities (Gurung *et a*l., 2005).

Human capital includes the parameters namely education level of farmers, training undergone, labour availability, health facilities and experience of the farmers. Literature measures human capital using indicators like education, literacy, labour availability and skills and health status(Baffoe & Matsuda, 2018;Chen, *et al.*, 2013). Human capital enables people to pursue different livelihood strategies and achieve their livelihood objectives. The key indicators for this study comprised of health status and education level trends. Over 80% of the respondents had formal education with only 1.3% having no formal education. A human capital index of 48.76%

was derived. Higher level of human capital increases human capability to exploit other sources of capital (Apine *et al.,* 2019). However, the low index of human capital derived in this study despite higher percentage of formal education could imply migration of the human capital to other sectors after development. Moreover, knowledge is not only formal but could as well include traditional form of gaining skills, this informal education levels were not considered in the study.

Social capital is enhanced as the number and intensity of social ties between a focal individual and other persons increase. Social capital plays a key role in development of agriculture specifically in collective action, group marketing as well as adoption of improved technologies. A social capital of 44.90% illustrated low involvement in communal activities by the fish cage farmers.

Social relations support success of an entrepreneur and can be a source of competitive advantage depending on their position in social hierarchy (Dewantoro & Ellitan, 2022). In this study parameters used included status within the community, decision making involvement, participation in community social activities, access to social networks as well as trends in growth of social capital. Social networks are a valuable resource since they create and facilitate economic opportunities (Gurung et al., 2005). Through associations and interactions with other entrepreneurs is an asset that people can use to expand their resource access. Fish marketing plays an important role in the rural livelihoods since it enhances aquaculture sector growth, well achieved with social ties being strong through group marketing as a result of collective bargain. Low social capital indicates that the farmers are not collectively working in groups and thus challenging in terms of bargaining power and market access. There is need to form association for cage farmers to advocate for collective action within the beach management units (BMUs)

and for enhancing market access in order to ensure proper returns are earned from cage-fish farming for improved livelihoods.

Livelihood outcomes

Improvement of livelihood capitals has not only contributed to livelihoods of cage farmers but also to the larger community by indirect employment creation through engagements of artisans in building and fabrication of cages, market provision for small traders of equipment and materials used in the construction and fabrication activities, trading among others (Anjejo, 2017). Asset levels of individuals determines their wellbeing in the society. Different assets combination are means for making a living but also gives meaning to the persons' world. Livelihood outcomes for cage-fish farming and other activities were positive and majority of the community members had averagely improved their standards of living through enhanced livelihood capitals. The study indicated that most of the farmers had improved their socio economic status through cage-fish farming. Majority of the indicators had high response with an average score of 3 which means that majority of livelihoods have averagely been improved since inception of cage-fish farming in the region.

Cage-fish farming has provided local opportunities for livelihood improvement thus sustainable development can be achieved through enhanced investment in the enterprise. This study has shade light on the livelihood improvement on cage farmers by 57.04% which agrees with the study by Pandit *et al*., 2021 that revealed that cage farming contributed improvement of livelihoods by 30%. This also collaborates with the study by Anjejo(2017) which indicates improvement in livelihoods of the fisher forks at Anyaga Beach.

5.6 Assessment of the Perceptions of Various Stakeholders on Cage-Fish Farming

Majority of the people in the study area perceived cage-fish farming as an endeavour that has influenced their livelihoods positively (Table 15). This is because majority of the people depend on the lake resource for cage farming, fishing, fish trading and artisanal work. The assessment of the people's attitudes towards economic, health, environmental and social development was encouraging. Cage fish farming has resulted in economic benefits and health improvement in the Lake Victoria. The results revealed that the standards of living have been improved through cage-fish farming by increasing availability of fish in the market thus enhancing accessibility to fish food for improved nutrition, creating employment and business opportunities. Despite the fact that fish contributes to food and nutrition security, consumption of the fish has been characterised by fish supply deficits leading to low per capita consumption (Obiero *et al*., 2019). Cage fish farming leading to increased production has made fish available thus improving nutrition. Cage fish farming has contributed to livelihoods through increasing incomes through the employment and business opportunities it creates (Anjejo, 2017; Mensah *et al*., 2018; Pandit *et al*., 2021). This study results therefore advocate for continuity of cage-fish farming as the respondents indicated the need to increase the number of cages in the lake.

Social perceptions considered in this study included stakeholders' conflict in lake resource use and security. Resource use conflict and insecurity was identified as challenges in sustainable cage fish farming in Lake Victoria (Orinda *et a*l., 2021) among fish cage farmers, transporters and fishermen thus resource conflicts have become inevitable with the lake users (Ogello *et al*., 2013). This study agrees with the results on perceived attitudes of existing conflict of fish cage farmers and fishermen being that Lake Victoria is a natural resource for all and there is risk for tragedy of the commons (Ogello *et al.*, 2013). One of the motivating factors of cage investment

is returns to scale and therefore to curb the challenge of insecurity, farmers have engaged the Beach Management Units at inception of the cage business and thus ensured 24-hour surveillance. They have also deployed security as part of investment cost for surety. This has thus improved security along the beaches. There is need for regulation ensure that cage farmers set up their businesses in delineated areas for cage production.

Environmental perceptions are a key considerations of fish stakeholders in regard to cage fish farming.The respondents perceived that the cage materials used, feed and wastes from cages are affecting human health and the wild fish by causing pollution of the lake which leads to death of the wild fishes which in the long-run result to reduced fish catches. Eutrophication has been of concern and was identified as a key effect on the fish health and water quality of Lake Victoria (Degefu *et al*., 2011; Egessa *et al*., 2018; Kaggwa *et al*., 2011). Despite the fact that recommendations have been made to use environmentally friendly galvanized metal and high density Poly Ethylene (HDPE) cages (Orina *et al*., 2018), they are expensive to adopt and thus farmers opt to use locally available materials to cut on costs (Charo-Karisa *et al*., 2009). This therefore highlights the need for review of the cage materials used, ensure availability and affordability of the recommended materials through subsidies on the materials as well as tailor-made credit products for cage farmers. Additionally, there is need to train cage farmers on economic utilization of fish feeds so as to reduce lake pollution. On the contrary, it was perceived that cage farming, fishing and crop irrigation farming can co-exist in the area. Perception analysis of the fish stakeholders thus indicate that economic, health, social and environmental benefits are the critical definers of adoption of cage-fish farming and thus advocate for the enterprise to be carried out in consideration of environmental issues for sustainability in order to sustain their livelihoods.

CHAPTER SIX
SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Introduction

This chapter comprises a summary of the research, conclusions, and draws recommendations for interventions from the research findings and areas of further research. All the conclusions are based on the findings for each objective while recommendations are derived from various gaps and weakness found from the research findings and are geared towards enhancement of cage-fish farming through improved efficiency for better livelihoods.

6.2 Summary

The purpose of this study was to evaluate the economic performance and effects of cage fish farming on the livelihoods in Siaya County, Kenya. Siaya County was chosen for the study for her robust cage development among the five riparian counties. The study was guided by four specific objectives namely: To assess the level of technical efficiency among cage-fish farmers, to determine the factors influencing technical efficiency among cage-fish farmers, to evaluate the effects of cage-fish farming on livelihoods of farming communities and to assess the perceptions of fish stakeholders on cage-fish farming in Siaya County. The study was conducted in Bondo and Rarieda Sub Counties due to their proximity to Lake Victoria. The study focused on cage farmers and fish stakeholder and thus sampled 292 cage fish farmers and 217 fish stakeholders on eleven beaches which practice cage fish farming selected through multistage sampling techniques. Stochastic frontier Approach was used to assess the levels of technical efficiencies, a tobit regression model to determine factors influencing technical efficiency, a sustainable livelihood index was constructed to evaluate the effects of cage fish farming on livelihoods of the farming community and Principle Component Analysis to assess the perceptions of fish stakeholders on cage fish farming.

Descriptive statistics showed that cage fish farmers age was between 18-35 years (47.26%), male gender dominance (86.99%) and married (88.36%). Majority of the cage farmers who were sampled had attained secondary level of education (44.52%) and main occupation was cage farming (51.68%) though some still engage in other occupations such as fishing (22.15%) and being employed (10.01%) among others. The main source of capital for starting cage farming was savings (61.64%) with a few getting loans from welfare association and others from banks, family contributions and grants. The major motivating factors for engaging in cage farming included anticipated profits, ready market and low catches from the lake. Majority of Fish stakeholders' sampled were male (65.44%) of age was between 18-35 years (49.31%) and had attained primary level of education (32.26%). The research found out that cage farmers are operating at a mean technical efficiency of 65.06% with the best performing farmer attaining a TE of 93% while the worse of farmer operating at 17% TE. This indicates that cage fish farmers have a potential of increasing their efficiency with the current inputs by 34.94%. The findings also demonstrate significant inputs in cage fish farming are feeds, size of the cages and labour ($P<0.01$). The study established that labour input is not being utilized efficiently and thus need to improve labour usage efficiency. Factors influencing technical efficiency include age of respondent negative and significant at 1%, source of capital, geographical location and beach where cages are cited ($P<0.05$) and education level. Cage fish farming has improved livelihoods in the study area through improvement of livelihood capitals. Physical capitals were highly enhanced through cage fish farming by 73.73% since the farming communities had accumulated physical assets followed by financial capital at 59.10% through increased income from cage farming. Access to lake resource and road network to the beaches supported the increase in natural capital (58.72%), human capital improved by 48.76%. However, social capital was the

had minimal improvement of 44.90% due to minimal social networks created. The findings show that economic, health, social and environmental perceived to be key considerations in cage fish farming adoption. Fish stakeholders advocate for cage fish farming because of the economic, health and social benefits they get. They however indicate that this should be done with environmentally friendly manner.

6.3 Conclusions

This study aimed to evaluate the economic performance and effects of cage-fishfarming on livelihoods of Lake Victoria communities in Siaya County. The study focused on determining technical efficiency and factors influencing technical efficiency, evaluated the effects of cage-fish farming on livelihood capitals and assessed the perceptions of the communities on cage-fish farming.

In determining the technical efficiency and factors influencing technical efficiency, the mean technical efficiency was found at 65% with labour input being inefficiently utilized. The technical inefficiency influencing factors are responsible in explaining the level and variations in the production of cage farms included age of respondent, education level, source of capital, and location of the cage (both administrative and beach). From these findings, the study provides evidence to increase cage fish production through improvement in technical efficiency through improvement of production technology and encouraging cage farmers' capacity building activities on efficient utilization of the production inputs especially labour, and exchange of ideas between the old and young farmers, experienced and less experienced ones.

The study results revealed an SLI of 57% which implies that, the changes in livelihoods of communities in the region were averagely attributed to cage-fish farming. Physical capitals were the most improved with social capital recording lowest improvement. In addition, fish

stakeholders perceived economic, health, social and environmental benefits of cage-fish farming as the most important considerations for their engagement. Besides the positive perceived perspectives on the cage-fish farming by stakeholders, they also observed that fish from the cages are more expensive and also alluded to conflict between cage farmers and fishermen hindering access to the natural resource. Based on these results, it is evident that cage-fish farming is a stable enterprise that impacts livelihoods in the lake region of Kenya. The high capital indices proved that cage-fish farming as a livelihood strategy has potential to improve the living standards of people in the region through increased economic benefits from the fish, creation of business and employment opportunities and enhanced availability of the fish leading to improved nutrition. Moreover, the community perceived the enterprise positively due to its positive economic benefits and health effects on the livelihoods.

6.4 Recommendation

For aquaculture to play a vital role in ensuring future fish availability for food security and livelihood improvement in the country, this sector has to develop and expand in an economically viable and sustainable manner. Amongst the many factors, increasing efficiency of resource use and productivity at the farm level is one of the prerequisites for sustainable aquaculture (Munyua, 2012). Kenya government continues to develop aquaculture production as farmers intensifying their efforts towards aquaculture, however, there is a likelihood of resource constraints due to competition due to rise in demand for limited resources use, thus become unfavourable to long-term economic viability and sustainability of the aquaculture production. Therefore, efforts should be made towards growth through improved technical efficiency by producing more by utilizing existing production inputs more efficiently. This study thus recommends the following:

i. There is a need for government ministries, departments and agencies, stakeholders, and financial institutions to come up with initiatives or formulate financial products for cage-fish farming investment to provide easy access to farming capital for this niche sector to stimulate fish cage development in the region.

ii. MOALF and development partners should prioritize capacity building of farmers through extension services to provide necessary skills in production for enhanced technical efficiency and cage performance.

iii. Furthermore, farmers should diversify their sources of income to raise multiple sources of capital to facilitate the adoption of larger cages and environmentally friendly cages (HDPE) as well as pool their resources to purchase larger cages.

iv. With respect to livelihood capitals, the farmers should be encouraged to form producer organizations or associations to enhance their social networks and increase their bargaining power in marketing their produce as well as purchasing inputs. This will enhance the social, physical and financial capitals.

v. Participatory resource use management is important to minimize on conflicts. This should be done through local community and relevant stakeholders engaging in dialogue and negotiations to develop mutually beneficial regulations and solutions in implementation of cage business.

vi. It is therefore important to address the efficient utilization of inputs and factors that influence technical efficiency for increased productivity thus increased incomes. Cage-fish farming should be encouraged by providing the necessary production skills for improved cage performance and enhance marketing for enhanced bargaining power.

These concerted efforts will pull potential investors and thus positive impact on the economy and livelihoods. Investment in cage-fish farming should thus be encouraged by all stakeholders.

6.5 Suggestions for Further Research

This study results showed that labour input was not technically efficient and thus a research could be carried out to determine the optimal labour requirements. The study covered evaluation of economic performance and effects of cage fish farming on livelihoods of communities in Siaya County, a similar study could be carried out in the other riparian counties to bring out the regional outlook. Other areas of further research include evaluation of allocative and economic efficiencies, and factors affecting allocative and economic efficiencies.

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APPENDICES

Appendix A: Research Data Collection Tools

1. CAGE-FISH FARMER QUESTIONNAIRE

ECONOMIC PERFORMANCE ANDEFFECTS OF CAGE-FISH FARMING ON LIVELIHOODS OF LAKE VICTORIA BASIN COMMUNITIES IN SIAYA COUNTY, KENYA.

Department of Agricultural Economics and Rural Development
Maseno University, P.O. Box, Private Bag Maseno, Kenya

Dear respondent,

Cage-fish farming has become an important innovation technology of fish production in order to supplement the diminishing capture fish. The technology has been wide spread and promoted by several organizations and the government in order to increase fish production levels. This study objective is to evaluate the economic performance and effects of cage-fish farming on livelihoods of L. Victoria basin communities in Siaya County. Your response to our questionnaire was be useful in this research and information obtained was not be shared with persons not involved in the study to enhance confidentiality. The results of the study were being strictly for academic purposes and provision of relevant information to policy makers.

In case of further queries about the research, please feel free to contact the researcher on Tel. 0721850080; email. tinamaemba@gmail.com

Oral Consent

Given the information provided to you about the aim of this research are you willing to participate in the rest of the interview? 1=YES [] 2=NO []

***(Enumerator:** If the response is NO, try to probe further to understand the concerns of the respondent. You may attempt to address their concerns then seek their oral consent once again. If the answer remains NO, end the interview and thank the respondent for their time)*

Date of interview ___/____/____

Name of Interviewer…….

Contact of interviewer …….

GENERAL INFORMATION

COUNTY……

SUB-COUNTY…….

LOCATION……

SUB-LOCATION……

VILLAGE……

BEACH ……

SECTION 1: CAGE FARMER BACKGROUND INFORMATION

Basic Information about the cage-fish farmer

1. Questionnaire number……
2. Age …….
3. Sex ……
4. Family size ……...
5. Marital status

   1= Married, 3= Single,

   2= Divorced, 4= widowed

6. Education level of respondent
   1= No formal education
   2= Primary
   3=Secondary
   4=Technical
   5= Tertiary
7. Primary Occupation of the respondent
   1= Employed,
   2= Crop Farming,
   3= Cage-fish Farming,
   4= Fishing,
   5= Small Business
   6= other -Specify)
8. What major economic activity do you engage in as your main source of livelihood?
   1= Employed,
   2= Crop Farming,
   3= Cage-fish Farming,
   4= Boat Fishing,
   5= Small Business
   6= other -Specify)
9. What are the others economic activities that you engaged in? ----------
10. How long have you practiced cage-fish farming? ----------
11. What was the source of capital for starting fish cage farming?
    1=savings
    2= Family contributions
    3= Grants
    4= Loan from welfare associations
    5= Loans from Banks
12. What motivated you to start cage-fish farming?
    1= Low catches from the lake
    2= High profits from cage farming
    3= Ready Market
    4= Less labour involved
    5= Peer pressure
    6= Other (Specify)

SECTION 2: CAGE-FISH PRODUCTION INFORMATION (Determining Productivity and profitability of fish cage and factors affecting productivity/profitability of cage-fish farming)

13. What is the size of your cage? (Tick one)
    1= 2x2x2 [],
    2= 3x3x5 [],
    3= 5x5x3[],
    4= 6x6x6 []

5= Other (Specify)

14. Type of cage
    1= Circular/Round
    2= Rectangular
    3= Semi circular
15. Do you own or rent the cages?
    1= Owned ----------
    2= Rented----------
16. How many cages are owned or rented?
    1= Owned ----------
    2= Rented----------
17. What is the cost of installing/renting one cage?
    1= Owned ----------
    2= Rented----------
18. How many cages are under fish production? …….
19. How many times do you stock your cages? (Tick one)
    (A) Once []
    (B) Twice []
    (C) Thrice []
    (D) None []
20. When did you stock the current cages in operation? ----------
21. What species did you stock? 1= Tilapia 2= Nile perch 3= Catfish
22. How many fingerlings did you stock in one cage in current stocking? ----------
    ---
23. Where do you source the fingerlings from? 1= Fish Hatchery 2= Fellow Farmers 3= Given by donor/ project 4= Fingerling Entrepreneur
24. What is the cost of one fingerling? ----------
25. What do you feed your fish on? 1= Commercial feed, 2= Homemade, 3= Combination of homemade and commercial

26. What are the types, costs and Sources of Fish Feeds you use?

Type of fish feed	Source of fish feed	Distance from farm to source of feeds (Km)	Time taken from farm to source of fish feeds	Amount (kg/ production season	Price/ unit	Frequency of Feeding (Number of feedings per day)	Duration fish is feed on that type of feed	Stock monitoring
Mash								
Floating pellets								
Other (specify)								

27. What is the cost of labour do you use per production cycle?

Activity	Time spend in	Amount paid	Source of labour	

	hours		1=Casual 2= Hired temporary 3= Hired Permanent 4= Family	
Stocking				
Feeding				
Security				
Harvesting				

28. What is the maturity age of your fish before you harvest? -1= six month 2= eight months 3= Other (Specify) –At what weight do you harvest your fish? 1= 200g 2= 500g 3= 800g 4= 1kg 4= Other (specify)
29. How do you harvest your fish? 1= all at once 2= partially
30. How many times do you harvest your fish per cage? ----------
31. What is the production per cage? ----------(kg)
32. What was the total yield/ harvest you harvested in the last season? ---------- (kg)
33. How do you preserve your fish? 1= Cooling in ice 2= smoking 3= drying 4= frying 5= none
34. How much fish is consumed in your household (kg)? ----------
35. What is the price of selling kg of fish and amount sold?

Type of fish	Unit	Amount	farm- gate price/ kg (or per unit) KES	Market price/ kg (or per unit) KES

SECTION 3: FISH FARMING REVENUES AND EXPENSES

23. This section captures the revenues and expenses of production of fish May – December 2020

Item	Unit	Quantity	Price per unit	Amount
Fish sales				
Related fish product/by products sales				
Variable Costs				
Fingerlings				
Labour				
Feed				
Transportation costs				
Fixed Costs				
Cage Installation costs /Lease				
Boat				
Repairs & Management costs				

Security personnel				
Interests paid on loan				
Depreciation equipment				
Depreciation of cages				

SECTION 4: MARKET ACCESS

24. Where do you sell your fish?

Fish Market 1= retail market 2= wholesale traders 3= transporters 4= Farm gate	Distance to market (Km)	Time taken from farm to source of fish feeds	Cost paid (Ksh)

25. What is the nearest main market centre from the fish farm? ---------- Kilometres
26. What is the type of road from the cages to that market? Codes 1= Tarmac, 2= All season murram road, 3= Seasonal murram road, 4= Other (Specify) ----------
27. Describe the distance to the nearest collection or postharvest storage facility? --------- kilometres
28. How many kilometres to you cover from your cages to the most important town? --------- kilometres
29. How much does it cost on transport to the most important town? KES……

SECTION 5: ACCESS TO EXTENSION SERVICES

30. Did you receive any extension or advisory services on cage-fish farming in the last 12 months?
31. What was the source of the advisories/ extension services? 1= Government agents 2= Private extension agents 3= NGO 4= Cooperative society 5= Other (Specify) ----------
32. Distance to the nearest extension service provider related to fish farming? ----------
33. What mode of transport do you use to go to the extension service provider's office? ------
34. How much does it cost you to reach for the services? ----------
35. How many times have you gone to seek for extension services in a year? ----------
36. Have you been visited by an extension service provider in the last 12 months? 1=Yes, 2=No If yes how many times? ----------
37. What topic did the extension worker train on during the last visit?

SECTION 6: LIVELIHOOD CAPITAL STOCKS (To evaluate the effects of cage-fish farming on livelihoods)

This section was take stock of the five categories of capitals with reference to when the farmer started cage-fish farming.

A) Human Capital

38. Household/personnel human capital status

	Total Number	No. Adults	No. Children	Trend
No. of household members				
No. of household members chronically sick				
No. of household members occasionally sick				
No. of household members scarcely sick				
No. of dependents registered under the medical scheme e.g. NHIF				
How many meals does your household have in a day?				
Educational level of spouse/husband, if is not the respondent				
No. of children now at school				
No. of household members with basic education				
No. of household members with artisan or vocational skills				
No. of respondent current reproductive status (pregnant, lactating etc.)				

Education codes: 1= No formal education 2= Primary 3=Secondary 4=Technical 5= Tertiary
Codes for trend: Improving [1], Remain the same [2], Deteriorating [3]

39. Have you ever received training on your livelihood strategy? 1-yes 2= No. (if yes, mention source and kind of training) ----------
40. what has been the trend of your health over the past five years?
    Improving [1], Remain the same [2], Deteriorating [3]
41. what has been the trend of your household health over the past five years?
    Improving [1], Remain the same [2], Deteriorating [3]
42. what has been the trend of your education or skill level over the past five years?
    Improving [1], Remain the same [2] Deteriorating [3]
43. what has been the trend of education or skill level of your household members over the past five years? Improving [1], Remain the same [2] Deteriorating [3]
44. What level of control do you exert on your own labour and time? Full control [1], no control [2], partial control [3]
    If not "full control", who control your labour and time? Husband [1], parents [2], other family members [3] or others (specify) [4] .....
45. How do you finance improvement of your education level of your household?
    1=Income from Cage farming
    2= Income from other occupations

3= well wishers
4= Donation/ bursaries/ savings
5= Loans
6= Disposal of assets

46. How wasyour score the sustainable status of your human resource? From a scale of 1 to 5 (1; Not sustainable at all to 5; very high sustainable)

B) Physical Capital

47. What has been the trend of the quality of your physical capital over the past five years? Increasing [1], Stagnant [2], Decreasing [3]
48. What has been the trend of the quantity of your physical capital over the past five years? Increasing [1], Stagnant [2], Decreasing [3]
49. To what extent do you exert ownership or control over your physical capital? Full control [1], partial control [2] or No control [3].
50. How was your score the sustainable status of your physical capital? From a scale of 1 to 5 (1; Not sustainable at all, to 5; very high sustainable)
51. What has been the trend of your financial capital over the years you've practiced cage farming? Increasing [1], Stagnant [2], Decreasing [3]
52. What extent do you exert control over your financial resources? Full control [1], Partial control [2] or No control [3]
53. What household physical assets have you improved since you started cage-fish farming?
    Improved housing [1]
    Use of improved cook stove (Gas, electric, improved charcoal jiko) [2]
    Modern kitchen utensils [3]
    Electronics (TV, Radio, Smartphones etc.) [4]
    Farm machinery/ equipment [5]
    Installed water harvesting structures (Drum, Poly tank etc.) [6]

C) Financial Capitals

54. What is your annual revenue from cage farming (amount)? ----------
55. What is the trend of your annual income from cage-fish farming? Increasing [1], Stagnant [2], Decreasing [3]
56. Personal annual cash/saving (amount)
57. What is the trend of your annual cash/savings? Increasing [1], Stagnant [2], Decreasing [3]
58. Personal access to credit
59. Salary or pension or other emoluments
60. How was your score the sustainable status of your financial capital? From a scale of 1 to 5 (1; Not sustainable at all to 5; very high sustainable)

D) Social Capital

61. What is your status in community? 1= native 2= settler 3= non resident
62. Do you hold any leadership role in the community? 1= Yes 2= No
63. If yes, what level of leadership do you hold? 1= Teacher 2= Religious leader 3= Administrative leader 4= Social Worker 5= Political activist

64. Please rank household wealth status (1=Ultra poor, 2=Moderate poor, 3=Better off and 4=Rich)
65. Do you belong to any of the following (Tick one)?
    Fish Farmer Society YES [] NO []
    Fish Community based Organizations? YES [] NO []
    Other specify ----------
66. If yes, for how many years have you been a member? ----------
67. What are the benefits you get in the group? 1= Marketing 2= Social welfare 3= Training 4= Financial support
68. Do you participate in social activities in the Community? 1= Yes 2= No
69. Which social activities do you participate in? 1= funerals, 2=wedding, 3= dowry 4= religious activities
70. Type of relation to other members in the community
71. Level of acceptance in the community
72. Are you consulted in decision making process in the household? 1= Yes 2= No
73. How readily did you access social capital over the past year?
    More readily [1], readily [2] or less readily [3].
74. what has been the trend of your social capital over the past five years?
    Increasing [1], Stagnant [2], Decreasing [3]
75. How was your score the sustainable status of your social capital? (From a scale of 1 to 5) Not sustainable at all [1], somewhat sustainable [2], quite sustainable [3], highly sustainable [4] or very highly sustainable [5]

E) Natural Capitals

76. What has been the trend of household/community Natural Capital (quality and quantity) over the past five years? Increasing [1], Stagnant [2], Decreasing [3]
77. How readily do you access the community natural capital over the past five years? More readily [1], readily [2] or less readily [3]
78. How was your score the sustainable status of your Natural capital? From a scale of 1 to 5 (1; Not sustainable at all to 5; very high sustainable) G:
79. How would you describe the road network to your community? Good [1] or poor [2]

General observation

80. What changes has cage-fish farming brought into your household? (Select all that apply)
    1= Improved incomes
    2= Increased steady supply of fish
    3= improved road network
    4= Diversification of business opportunities
    5= reduced crimes
    6= Improved education
    7= improved standards of living (Housing, diet, wealth etc.)
81. List any key problems you face as a cage-fish farmer
    ----
82. Suggest solutions to the above problems……

The End

Thank you for your participation

2. NON FISH CAGE FARMERS QUESTIONNAIRE

ECONOMIC PERFORMANCE AND EFFECTS OF CAGE-FISH FARMING ON LIVELIHOODS OF LAKE VICTORIA BASIN COMMUNITIES IN SIAYA COUNTY, KENYA.

Department of Agricultural Economics and Rural Development
Maseno University, P.O. Box, Private Bag Maseno, Kenya

Dear respondent,

Cage-fish farming has become an important innovation system of fish production in order to supplement the diminishing capture fish. The technology has been wide spread and promoted by several organizations and the government in order to increase fish production levels. This study objective is to evaluate the economic performance and effects of cage-fish farming on livelihoods of L. Victoria basin communities in Siaya County. Your response to our questionnaire was be useful in this research and information obtained was be treated with confidentiality and the results of the study was being strictly for academic purposes and provision of relevant information to policy makers.

In case of further queries about the research, please feel free to contact the researcher on Tel. 0721850080; email. tinamaemba@gmail.com

Oral Consent

Given the information provided to you about the aim of this research are you willing to participate in the rest of the interview? 1=YES [] 2=NO []

***(Enumerator:** If the response is NO, try to probe further to understand the concerns of the respondent. You may attempt to address their concerns then seek their oral consent once again. If the answer remains NO, end the interview and thank the respondent for their time)*

General Information

Date of interview ----------

Name of enumerator ----------

Name of Beach ----------

1. Gender of respondent 1=Male 2= Female
2. Age of the respondent (Years) ----------
3. Education level of respondent
   1= No formal education
   2= Primary
   3=Secondary
   4=Technical
   5= Tertiary
4. What is your role in this business? 1= Owner 2= Hired manager 3 = others (specify)
5. Description of the Respondent

1=Fish Trader, 2= Fisherman 3= Crop/irrigation Farmer 4= Transporter/ traveller, 5= Artisan, 6= Other (specify)

Fish Traders' information

6. What are the fish and fish products you handle?

1 = Tilapia fresh fish 2= catfish 3= salted fish 4= smoked fish, 5= fish animal feed, 6= others (specify)

7. What is the source of the fish product? 1= fishermen 2= Cage farmers 3= broker 4=Farm gate 5=others (specify)
8. What are the unit of purchase: 1 = number of pieces 2= kilogram 3= Gorogoro, 4= others (specify)?
9. Transport mode 1=Bicycle 2= Public vehicle/Matatus 3= hired pick up 4= Motorcycle 5= pick up 6= others (specify)
10. To whom did you sell: 1= Retailer 2= Final consumer 3= Both consumer and retailer 4= processors 5= others (specify)
11. Scale of operation, frequency of trade and quantity criteria for fish
12. types of fish traders operate in this town or market? 1= Retailers [] 2= Wholesalers [] 3= others (specify) ----------
13. How frequently do you buy fish and/or fish product for sale? 1= daily [] 2= 2-3 time a week [] 3= Weekly [] 4= fortnight [] 5= monthly [] 6= others (specify)
14. What quantities of fish products do you usually buy per month?
15. What size/weight of fish do your customers want? 1= 200g [] 2= 500g [] 3= 1kg []
16. Are you able to supply the size or weight of fish demanded by your clients? 1=Yes [], 2= No []

If the answer to the question above is no, state the reasons why----------

17. In your own view, how would you rate the demand for fish products in this market? 1= high demand [] 2= average demand [] 3= low demand []
18. Is the supply of fish products adequate to meet the customer demand throughout the year? 1= Yes [] 2= No []
19. What percentage of your household income is derived from the fish business? ----------
20. Would you be willing to work with other chain actors to improve the fish trade? 1= Yes, 2= No

    If no, why? ----------

21. Do you belong to any association of businesses dealing in fish products? 1=yes 2=No

If yes, what is the name of the Association ----------

22. How do you benefit from the association? ----------

Fisherman Information

23. Has there been a shift in your economic/livelihood activity?
    Yes [1]
    No [2]
24. When did you change your occupation/livelihood activity?
    Less than 1 yr. [1]
    Between 1 and 3 years [2]
    Between 3 and 5yrs [3]
    Above 5 years [4]
25. What used to be your occupation/livelihood activity?
    Crop Farming [1]

Fish trading [2]
Food vendor [3]
Employed [4]
Artisan [5]
Fishing [6]
Others (specify)……

26. What is your current occupation/livelihood activity?
    Crop Farming [1]
    Fish trading [2]
    Food vendor [3]
    Employed [4]
    Artisan [5]
    Fishing [6]
    Others (specify)……
27. Are you satisfied with your current occupation/livelihood?
    Yes []
    No []
    Explain.....
28. What is the reason (cause) for the change in your previous occupation/livelihood? (In order of priority)
    1) .....
    2).....
    3).....

28. Do you have intention to change your current livelihood activity? Yes [1] No [2]
    Why? ……..
29. What livelihood venture do you intend to change to? .....
    Why? ……
30. Perception statements on fish cage farming in Siaya County

Perception Statement	**1 Strongly disagree**	**2 Disagree**	**3 Neutral**	**4 Agree**	**5 Strongly agree**
Socio Economic perceptions					
Cage-fish farming has increased income from fish					
Cage-fish farming has made fish more readily available in the market					
Fish cage has improved security in the beaches					
Fish cages have brought many job opportunities					
Fish from cages is more expensive than from the wild catches					
Fish cages has not brought any conflict with the lake users					
Fish cage farming has created a lot of businesses opportunities in the					

region					
Fish cages have improved the livelihoods of the of all the fisher forks in the area					
There are economic benefits of being a cage farmer					
Cage farming has created employment to the local communities					
Cage farmers and fishermen conflict has affected the access to natural lake resource in the area					
Cage farming, fishing and crop irrigation farming can co-exist in the area					
There is need to reduce the number of cages in the lake.					
There is need to increase the number of cages in the lake					
Cage farming has enhanced development of good road network to the beaches					
Environmental concern perception statements					
Cages installed in the lake have no effect on navigation in the lake					
Cage farming has caused pollution of the lake hence affecting fish catches					
Materials used to fabricate the cages affect the wild fish hence reduce catches					
Feed wastes from cages help the wild fish to grow big					
Feed and wastes from cages kill the wild fishes and reduce catches					
Health concern perceptions					
Cage materials used are affecting human health through cage-fish consumed					
Cage farming has made fish readily accessible in the lake thus improved nutrition					

In your view what can be done to improve your fish business? ----------

The end

Thank you for your participation

Appendix B: Consent Form

CONSENT FORM FOR PARTICIPANTS

MASENO UNIVERSITY SCHOOL OF AGRICULTURE, FOOD SECURITY AND ENVIRONMENTAL SCIENCES

Title of Research: ECONOMIC PERFORMANCE AND EFFECTS OF CAGE-FISH FARMING ON LIVELIHOODS OF LAKE VICTORIA BASIN COMMUNITIES IN SIAYA COUNTY, KENYA.

Principal Investigator:

Christine Namaemba MSC/AF/00054/2019 Tel: +254 721 850 080

Email: tinamaemba@gmail.commailto:mulupidennis@gmail.com

Co-investigators

1. Dr. Kenneth Sibiko (Ph.D.) Tel: +254 701 281 697
   Department of Agricultural Economics and Rural Development
   Maseno University
2. Dr. Erick Ogello (Ph.D.) Tel: +254 708 842 832
   Department of Fisheries and Natural Resources
   Maseno University

Dear respondent,

REF: CONSENT FORM FOR PARTICIPANTION

We request your participation in this study, to enable us to evaluate the economic performance and effects of fish cage farming on livelihood of Lake Victoria Basin communities. The study is being conducted in Siaya County. The County has 6 Sub-Counties but we only focus on Rarieda and Bondo since they represent Sub Counties with cage-fish farming enterprises. The study was focus on four objectives: to determine the productivity and factors affecting productivity of fish cage farming, to determine the profitability of fish cage farming and socio economic factors affecting profitability, to evaluate the effects of fish cage farming on livelihoods and to assess the perceptions of fish stakeholders on fish cage farming.

In this study, your participation was involve responding to a questionnaire. The study purpose of the study is for academics and therefore outermost confidentiality and protection of the information collected is guaranteed and was not be disclosed to any unauthorized persons or used for any other purpose. The study is not intended to cause any potential risk or harm to the participants and has no direct benefits to the participant.

The questionnaires are numbered so that the analysis is based on questionnaire numbers and no names of participants was being disclosed for the purpose of anonymity and privacy throughout the study. The information collected was not be linked to any individual, rather was be used

collectively. The information was being important in making decision on increasing fish cage productivity and profitability to the farmers and policy makers.

You have a right to decline from participation or terminate participation at any time and was involve no penalty. The results of the study were culminating into a thesis and be disseminated through a publication thereafter which was be available to public consumption.

Contact Information

Any concerns may be addressed to Christine Namaemba MSC/AF/00054/2019Tel: 0721850080; email: tinamaemba@gmail.com

For any questions pertaining to rights as a research participant, please contact: The Secretary, Maseno University Ethics Review Committee, Private Bag, Maseno; Telephone numbers: 057-51622, 0722203411, 0721543976; 0733230878; Email address: muercsecretariate@maseno.ac.ke; muerc-secretariate@gmail.com OR muerc-secretariate@maseno.ac.ke

Agreement

Given the information provided to you about the aim of this research are you willing to participate in the rest of the interview? 1=YES [] 2=NO []

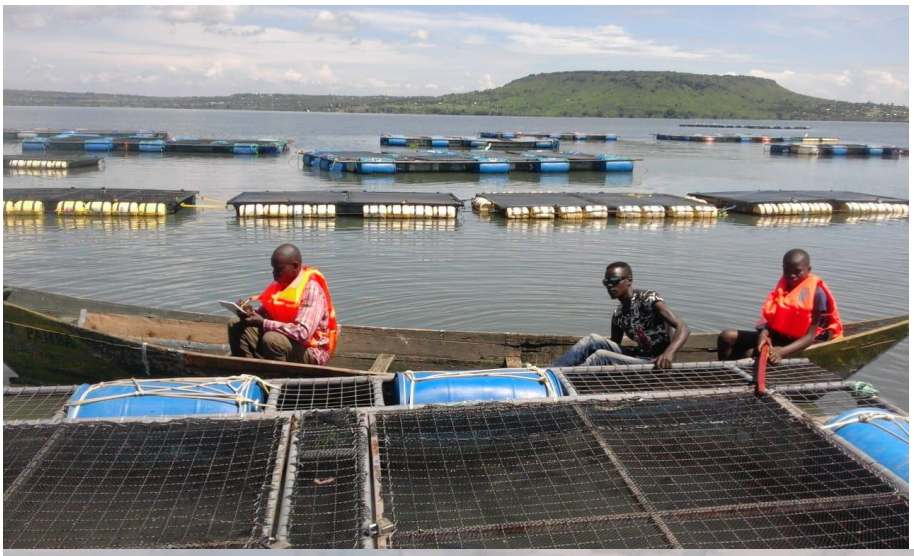
(If the answer is NO, end the interview and thank the respondent for their time. If the answer is YES, the respondent to sign the consent and be issued with a questionnaire for the study)

I have received this consent note to participate in a research titled: Economic performance and effects of cage-fish farming on livelihoods of Lake Victoria Basin communities in Siaya County, Kenya. All that is entailed in this research has been read and translated to me in Kiswahili and I totally understand my responsibility in this research. I consent to participate without any kind of inducement and I understand that I have a freedom of refusal or withdrawal from the participation at any time of my desire without any penalty.

Nimepokea fomu ya makubaliano ya kushiriki katika utafiti huu uliopewa mada: Economic performance and effects of cage-fish farming on livelihoods of Lake Victoria Basin communities in Siaya County, Kenya. Yale yote yaliyomo katika fomu hii ya makubaliano yamesomwa na kutafsiriwa kwa lugha ya Kiswahili na kufafanuliwa vilivyo na naelwa jukumu langu katika utafiti huu. Nimechukua msimamo kwamba nitashiriki bila kulazimishwa wala kuhongwa na naelewa kwamba naeza kata mkataba wangu wakuhusika wakati wowote bila hatua yeyote kuchukuliwa kwangu).

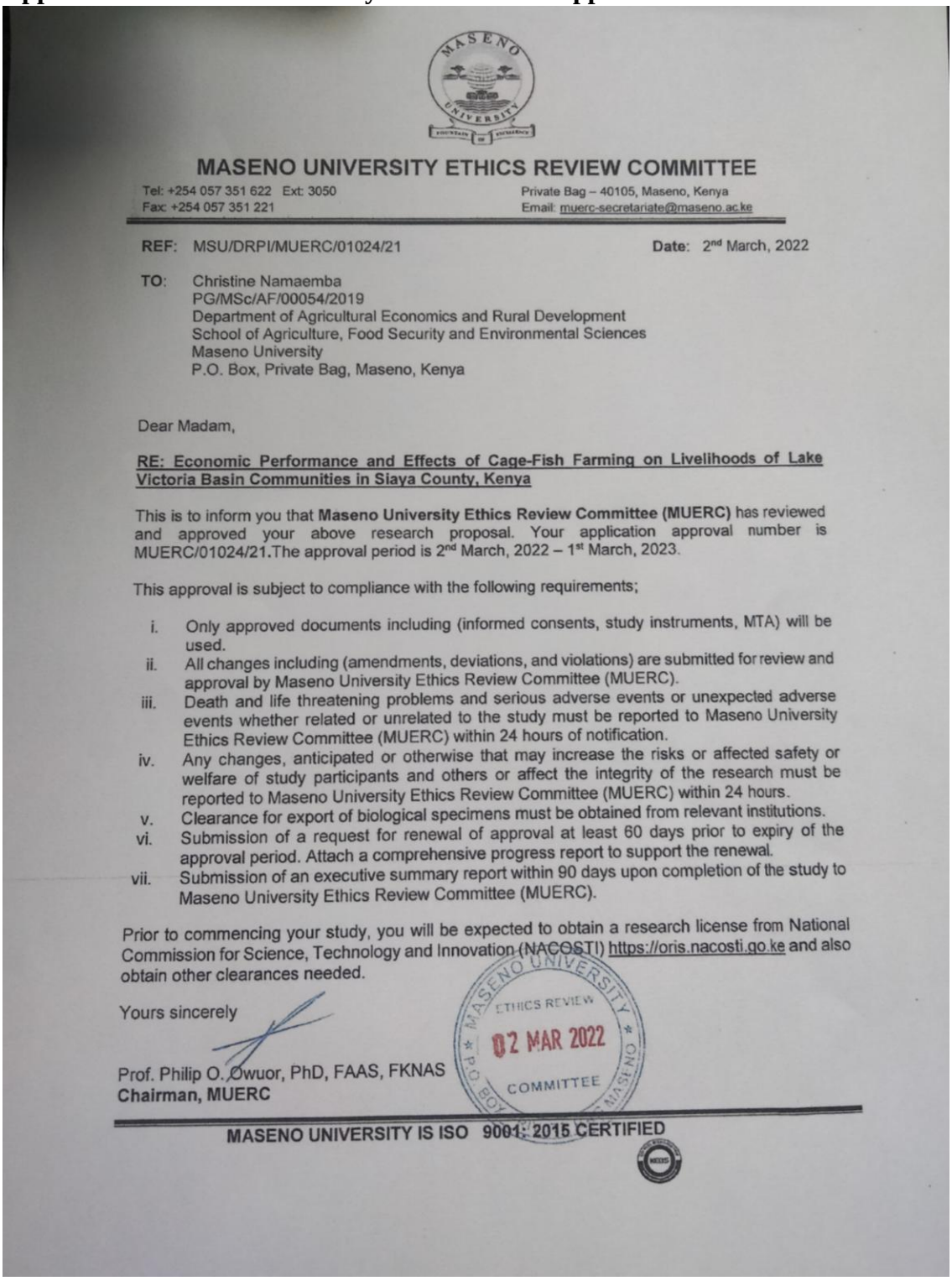
Signature of Participant…… Date…….

Appendix C: Pictorial presentation of fish cages



Source: Author 2019

Appendix D: Maseno University Ethics Review Approval



MASENO UNIVERSITY ETHICS REVIEW COMMITTEE

Tel: +254 057 351 622 Ext: 3050
Fax: +254 057 351 221

Private Bag – 40105, Maseno, Kenya
Email: muerc-secretariate@maseno.ac.ke

REF: MSU/DRPI/MUERC/01024/21 **Date:** 2nd March, 2022

TO: Christine Namaemba
PG/MSc/AF/00054/2019
Department of Agricultural Economics and Rural Development
School of Agriculture, Food Security and Environmental Sciences
Maseno University
P.O. Box, Private Bag, Maseno, Kenya

Dear Madam,

RE: Economic Performance and Effects of Cage-Fish Farming on Livelihoods of Lake Victoria Basin Communities in Siaya County, Kenya

This is to inform you that **Maseno University Ethics Review Committee (MUERC)** has reviewed and approved your above research proposal. Your application approval number is MUERC/01024/21.The approval period is 2nd March, 2022 – 1st March, 2023.

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by Maseno University Ethics Review Committee (MUERC).
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to Maseno University Ethics Review Committee (MUERC) within 24 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to Maseno University Ethics Review Committee (MUERC) within 24 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to Maseno University Ethics Review Committee (MUERC).

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

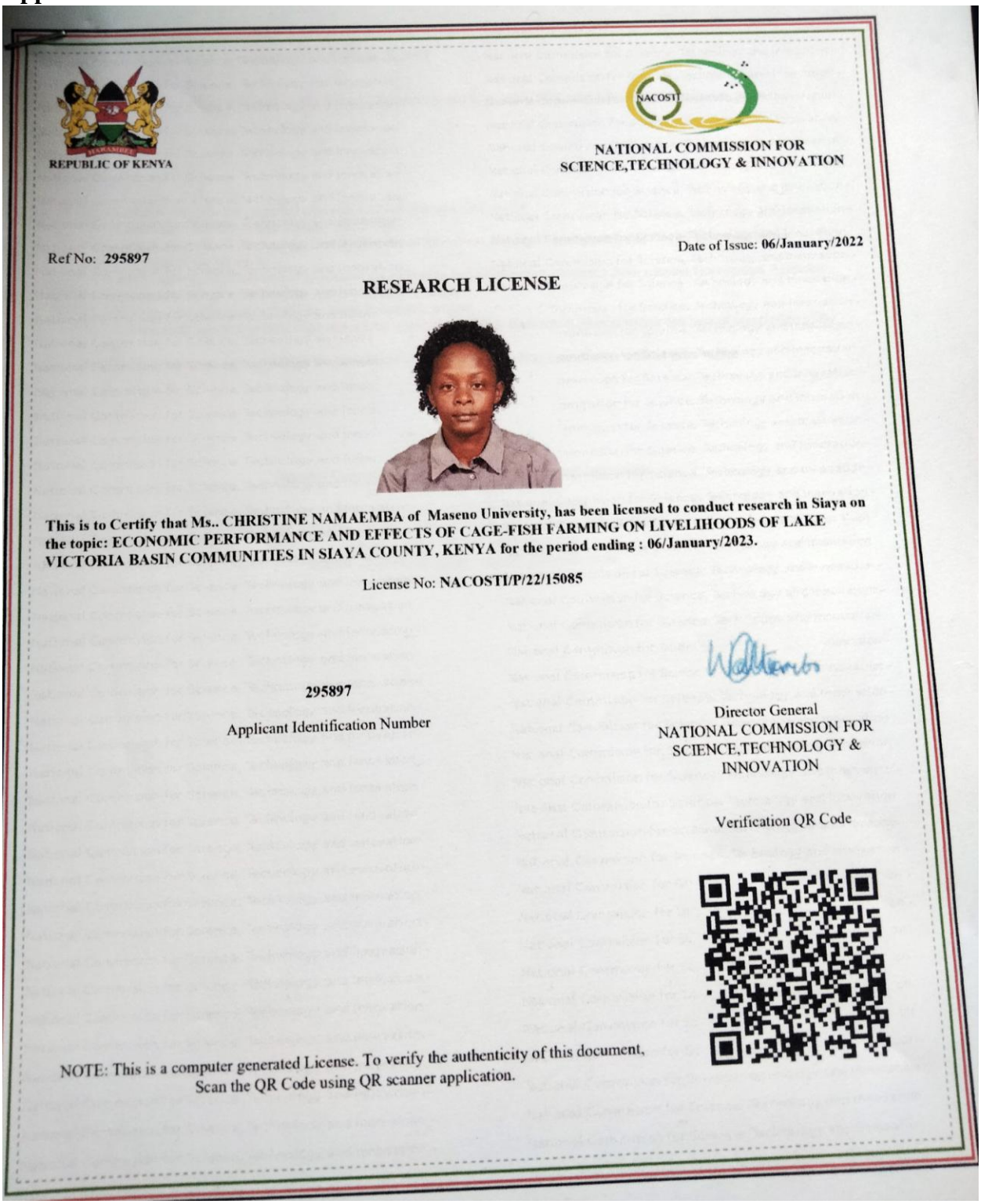
Yours sincerely

Prof. Philip O. Owuor, PhD, FAAS, FKNAS
Chairman, MUERC

MASENO UNIVERSITY ETHICS REVIEW COMMITTEE 02 MAR 2022

MASENO UNIVERSITY IS ISO 9001: 2015 CERTIFIED

Appendix E: NACOSTI Research license



REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **295897**

Date of Issue: **06/January/2022**

RESEARCH LICENSE

This is to Certify that Ms.. CHRISTINE NAMAEMBA of Maseno University, has been licensed to conduct research in Siaya on the topic: ECONOMIC PERFORMANCE AND EFFECTS OF CAGE-FISH FARMING ON LIVELIHOODS OF LAKE VICTORIA BASIN COMMUNITIES IN SIAYA COUNTY, KENYA for the period ending : 06/January/2023.

License No: **NACOSTI/P/22/15085**

295897

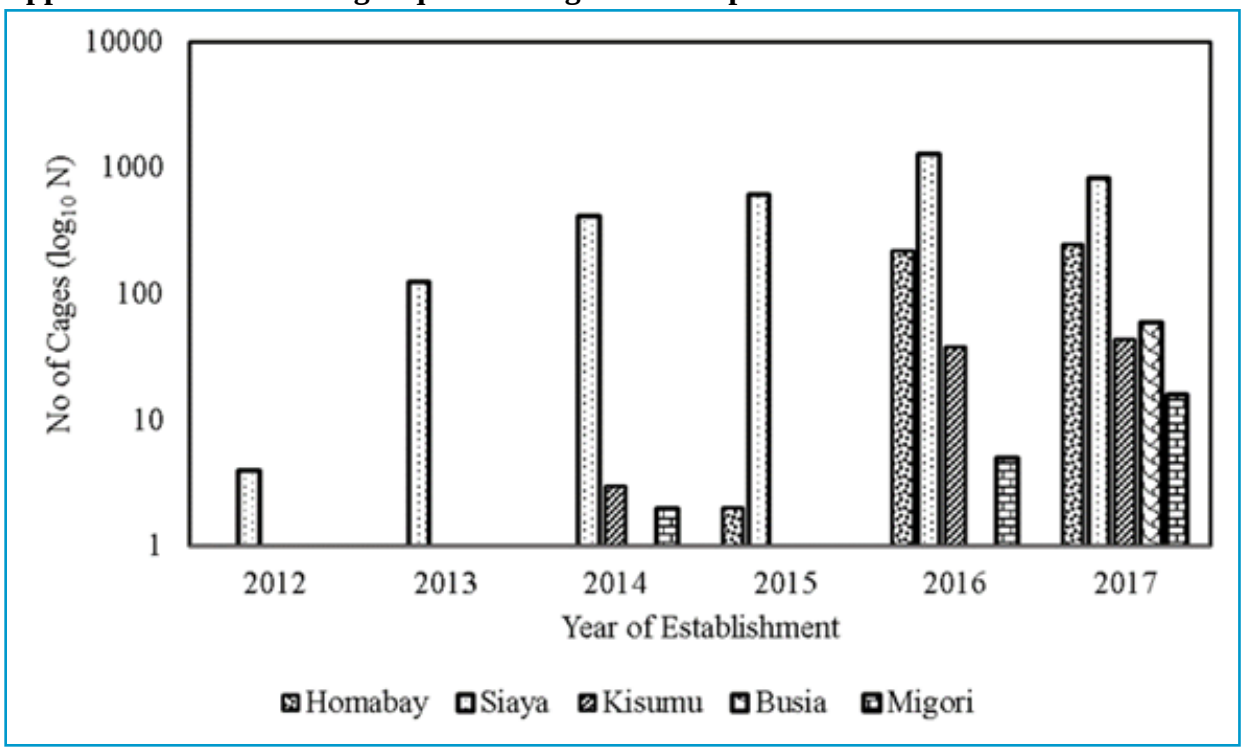
Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

Appendix F: Trends of cage aquaculture growth in riparian Counties in Lake Victoria



Source: KMFRI fact sheet No. KMF/RS/2018/ C1.8. i.

AppendixG: A scree plot of Eigenvalues of Principal Components used in Assessment of Fish Stakeholders Perceptions on Cage-fish Farming