FACTORS AFFECTING PRODUCTIVITY AND PROFITABILITY OF CAGE-FISH FARMING IN SIAYA COUNTY, KENYA

C. Namaemba[1#], K.W. Sibiko[1] and E.O., Ogello[2]

[1] Maseno University, Department of Agricultural Economics and Rural Development, P.O. Box Private Bag, Maseno, Kenya, [2] Maseno University, Department of Animal and Fisheries Science, P.O. Box Private Bag, Maseno, Kenya

ABSTRACT

Aquaculture is regarded as a critical rural development and livelihood strategy due to its vital role in livelihoods and the economy at large. However, declining capture fisheries from Lake Victoria and low pond productivity have necessitated the development of new culture systems to address the diminishing supply amidst increasing demand. The cage culture system has expanded rapidly and is projected to increase productivity significantly. However, investment in cage-fish farming is often made with little understanding of economic performance. This study aimed to determine the socioeconomic factors affecting the economic performance of cage-fish farming in Lake Victoria. A multistage sampling technique was adopted for the study through purposive sampling followed by simple random sampling to select 298 respondents. A structured questionnaire was used to collect primary data. The socioeconomic factors were determined using descriptive statistics and multiple linear regression. Results indicate that stocking density and fish weight at harvest improved cage productivity and profitability. In contrast, limited sources of capital decreased cage profitability and productivity ($P<0.01$) due to low operating capital. The size of the cage increased profitability but did not affect productivity. The marital status, and cage site location significantly affect productivity and profitability ($P<0.05$). This study recommends major interventions focused on improving cage design, stocking density, cage citing, technologies, and innovations in seed and feed production to increase productivity and, profitability. The government should also develop laws and regulations that ensure strict adherence to environmental performance in delineated sites for cage-fish farming.

Keywords: Cage-fish farming, socio-economic, productivity, profitability

[#]Corresponding author: tinamaemba@gmail.com

INTRODUCTION

Fisheries and aquaculture sectors contribute to human livelihoods by providing protein (fish), a source of income, and employment, all of which contribute to reducing poverty levels in developing countries (Kumar *et al*., 2018). The rise in world population has increased the annual per capita consumption of fish worldwide, a clear indicator that global demand for fish food will continue to rise (FAO, 2020).

Kenya's capture fisheries have been declining due to overfishing, water pollution, and climate change-related factors (Ogello *et al.*, 2013), leading to a decline in fish per capita consumption amidst increasing demand for fish protein (Ogello and Munguti, 2016). There has been a shift toward natural water bodies for aquaculture, resulting in an increased number of fish cages being installed in Lake Victoria as an alternative production technology in aquaculture to compensate for the reduced supply (Aura *et al.,* 2018).

Cage fish culture is a technology that keeps fish in an enclosed netting anchored in an existing water body. 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 culture along the five riparian Counties of Lake Victoria in Kenya (Ombwa *et al.*, 2018; Orina *et al*., 2018). The adoption of intensive cage culture is expected to significantly contribute to fish productivity and economic development (Ogello and Munguti, 2016). Cage culture has been incorporated into Blue Economy as one of the aquaculture development approaches (KEMFRI, 2017). Despite the increasing adoption levels, cage-fish culture faces several challenges to commercialize that need to be addressed in order to unlock the bottlenecks,

including lack of economic information on cage performance by farmers and investors, high input capital costs, environmental concerns among others (FAO, 2004; KEMFRI, 2017). The commercialization of cage-fish farming requires economic considerations, including economic returns and efficiency. Commercialization of cage-fish culture is gradually gaining popularity aimed to convert cage farmers from small-scale to large-scale market-oriented profit-making farming. Studies indicate that cage-fish farming has recorded higher profits than pond farming (Datta *et al*., 2014; Orina *et al*., 2018).

Siaya County is among the five riparian Counties along the Kenyan portion of Lake Victoria, which has experienced a rapid increase in cage installations (Orina *et al.*, 2018). Despite the increase, cage production only accounts for 27% of the County's fish production (Department of Fisheries, Siaya County, 2020). This indicates low cage output. Therefore, this study aimed to determine the socioeconomic factors affecting the productivity and profitability of cage culture in Siaya County, along Lake Victoria. Cage-fish farming technology is intended to revolutionize aquaculture in the Lake Victoria region and ensure economic empowerment. This study is necessary for recommending best practices, encouraging investors, and improving community livelihoods.

MATERIALS AND METHODS

Study area

This study was conducted in Siaya County (Figure 1) (0'26S:0'18N and 33'58:34º33E). The County has a land surface area of approximately 2,530 km² and a water surface area of 1,005 km² that is part of Lake Victoria (County Government of Siaya, 2018). It spreads over five agroecological zones (LM1 to LM 5). The County is drier in the southern part, and wetter in the northern part. The rainfall pattern is bimodal, with a long rain season from March to June and short rain season from September to December.

With a population of 993,183 persons (471,669 males, 521,496 females), Siaya County has a high poverty rate of 47.56% and food insecurity. Agriculture is the County's primary source of income. Agriculture is critical to ensuring the County's food sufficiency and security.

Sampling and data collection

The study targeted cage-fish farmers in Siaya County. A survey was conducted to collect a wide range of data sets. 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) 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 used to select respondents from the target population within the beaches. Primary data was collected using a structured questionnaire for one production cycle through a field survey. The sample size was determined according to Yamane (1967:86) formula (Israel, 1992).

$$n = \frac{N}{1+N(e2)}$$

Where n is the sample size, N is the population size, and e is the level of precision. The survey team collected data randomly and interviewed 298 cage farmers using the Open Data Kit (Kobo Toolbox) to ensure accuracy in data entry.

Data analysis

The study's data were analyzed using Stata version 13 for descriptive and inferential statistics. Descriptive statistics were used to tabulate the means, frequencies, and percentages to estimate production levels. The following equation measured cage-fish productivity.

$$Yp = \frac{Qy}{Ca}$$ ---------- Equation 1

Where: Yp denotes productivity (Kg/M³), Qy is the total output (yield) in Kilograms (Kg), and Ca is the volume of a cage in cubic metres (M³)

A budgetary technique was used to determine the gross margin using the following formula;

$$Gross\ margin = \pi i = PiQi - TCi$$

……Equation 2 (Oluwasola and Ige, 2015)

Where: π_i is the gross margin, P_i is the price of fish produced per kg, Q_i is the quantity of fish produced, and TC_i is the total variable cost of production.

The revenue items used in the calculations were the weight of fish harvested and the price per kg of fish, while the cost items included the cost of fingerlings,

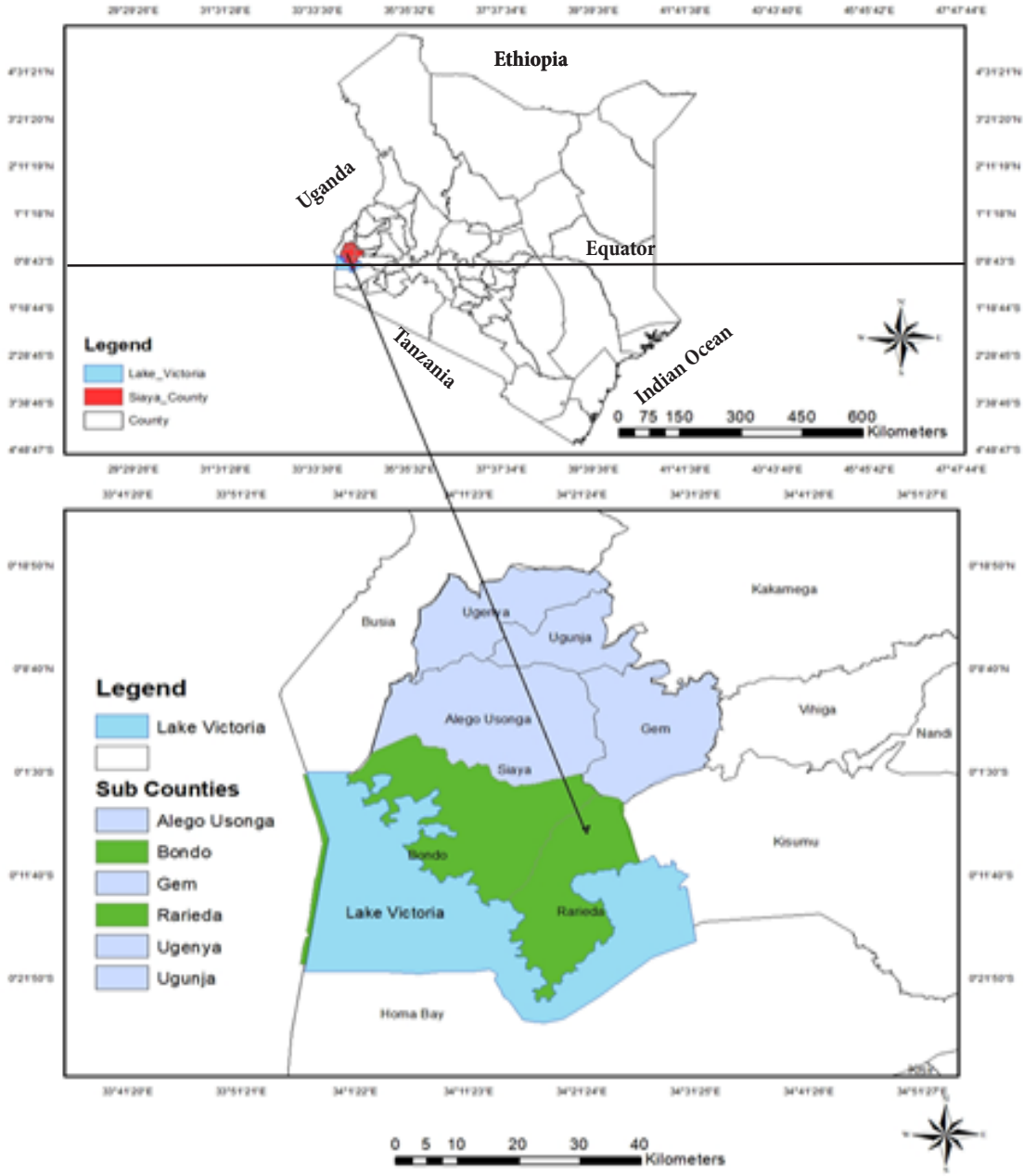

Figure 1. Map of study area in Siaya County

feed, labour, preservation, and marketing costs. The gross margin was used to analyze and evaluate the performance of cage culture units to establish their potential to generate income vis-à-vis the incurred costs. MS Excel computer application was used through enterprise budgeting to analyze the data collected to establish gross margin per unit (equation 3).

$$Profitability(Gross\ margin\ per\ m3) = \frac{Gross\ margin}{Total\ area\ under\ production} \quad \text{……..Equation 3}$$

Multiple linear regression was performed to determine the socioeconomic factors affecting productivity (equation 4) and profitability (equation 5) using STATA version 13 (2016). Primary independent variables included stocking density, the quantity of feed used, size of the cage under production, source of capital, the weight of fish at harvest, education level, occupation, marital status, a beach where cage-farming is practiced, age of respondent, gender of respondent, and extension services.

$$\boldsymbol{YP1 = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \beta 7X7 + \beta 8X8 + \beta 9X9 + \beta 10X10 + \beta 11X11 + \beta 12X12 + \varepsilon i}$$ -------- Equation 4

Where *YP_1 denotes productivity (KG/M^3), X_1 – Total Cage Size under Production, X_2 – Fingerlings stocking density, X_3 – Marital status, X_4 - Education, X_5 – Occupation, X_6 - Total feeds in Kgs, X_7 – Weight at harvest, X_8 – Source of capital, X_9 - Extension services (number of extension visits), X_{10} –Age of respondent, X_{11} – Beach where cage farming is practiced, X_{12} – Gender of the respondent, β_1, β_2... β_8 are parameters to be estimated, ε_i denotes the error term.*

$$\boldsymbol{YP2 = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \beta 7X7 + \beta 8X8 + \beta 9X9 + \beta 10X10 + \beta 11X11 + \beta 12X12 + \varepsilon i}$$ ---------Equation 5

Where; YP_2 denotes profitability (GM/M^3), X_1 – Total Cage Size under Production, X_2 – Fingerlings stocking density, X_3 – Marital status, X_4 - Education, X_5 – Occupation, X_6 - Total feeds in Kgs, X_7 – Weight at harvest, X_8 – Source of capital, X_9 - Extension services (number of extension visits), X_{10} –Age of respondent, X_{11} – Beach where cage farming is practised, X_{12} – Gender of the respondent, β_1, β_2... β_8 are parameters to be estimated, ε_i denotes the error term.

RESULTS

Demographic characteristics of cage-fish farmers

A total of 298 cage-fish farmers were interviewed during the field survey. Rarieda sub-county had 19.13% of the total farmers, while Bondo sub-county had 80.87%. The socioeconomic characteristics of cage-fish farmers are shown in Table I. Most cage farmers (86.91%) were male, with females accounting for 13.1%. Most cage farmers (47%) were between 18 and 35 years, and the remainder were between 36 and 50 years (44%). Notably, 2% of farmers were over 60 years while 7.4% were between the ages of 51 and 60. Most of those interviewed were involved in fishing activities.

The education level of respondents was categorized into five categories: no formal education, primary, secondary, technical, and tertiary. Table I indicate that most cage farmers (44.5%) had secondary education, and 35.2% had primary education. Most of the respondents had a formal education; those with no formal education were 1.3%. The respondents' main occupation (51.7%) was cage-fish farming, as the main economic activity. However, capture fishing (22.2%) continues to support the livelihoods of fishermen in the study areas. Other occupations included formal employment (10%), small businesses (9%) and trading (less than 1%). The survey revealed that the primary sources of capital for starting cage-fish farming (61%) were savings, 19% loans from welfare associations, and 10% from family contributions (Figure 2). Bank loans and grants were low at 7% and 3%, respectively. The expectation of high profits from cage farming was the primary motivating factor for engaging in cage-fish farming (39.9%), followed by a ready market for the fish (24.2%), low lake catches (17.5%), and availability of lake resources (11.4%). Other motivating factors for venturing into cage-fish farming included a desire to meet family needs, peer pressure, and less labour, which accounted for 3.4%, 3.0%, and 0.7% of the respondents, respectively (Figure 3).

TABLE I - SOCIOECONOMIC CHARACTERISTICS OF CAGE-FISH FARMERS IN SIAYA COUNTY

Variable	Description	BONDO		RARIEDA		CUMULATIVE	
		(n=241)	%	(n=57)	%	(n=298)	%
Respondent's Age	18 - 35 years	118	39.59	21	7.05	139	46.64
	36- 50 years	106	35.57	26	8.72	131	43.96
	51-60 years	13	4.30	8	2.68	22	7.38
	Above 60	4	1.34	2	0.67	6	2.01
Gender	Male	211	70.81	48	16.11	259	86.91
	Female	30	10.07	9	3.02	39	13.09
Marital status	Married	214	71.81	49	16.44	263	88.26
	Single	17	5.70	8	2.68	25	8.39
	Widowed	9	3.02	0	0	9	3.02
	Divorced	1	0.34	0	0	1	0.34
Educational level	No formal education	4	1.34	0	0	4	1.34
	Primary	90	30.20	15	5.03	105	35.23
	Secondary	104	34.90	30	10.07	134	44.97
	Technical	25	8.39	5	1.68	30	10.07
	Tertiary	18	6.04	7	2.35	25	8.39
Occupation	Fishing	60	20.13	6	2.01	66	22.15
	Business Consultant	1	0.34	0	0	1	0.34
	Cage farming	132	44.30	22	7.38	154	51.68
	Crop farming	12	4.03	6	2.01	18	6.04
	Employed	19	6.38	11	3.69	30	10.07
	Small business	26	8.72	3	1.01	29	9.73

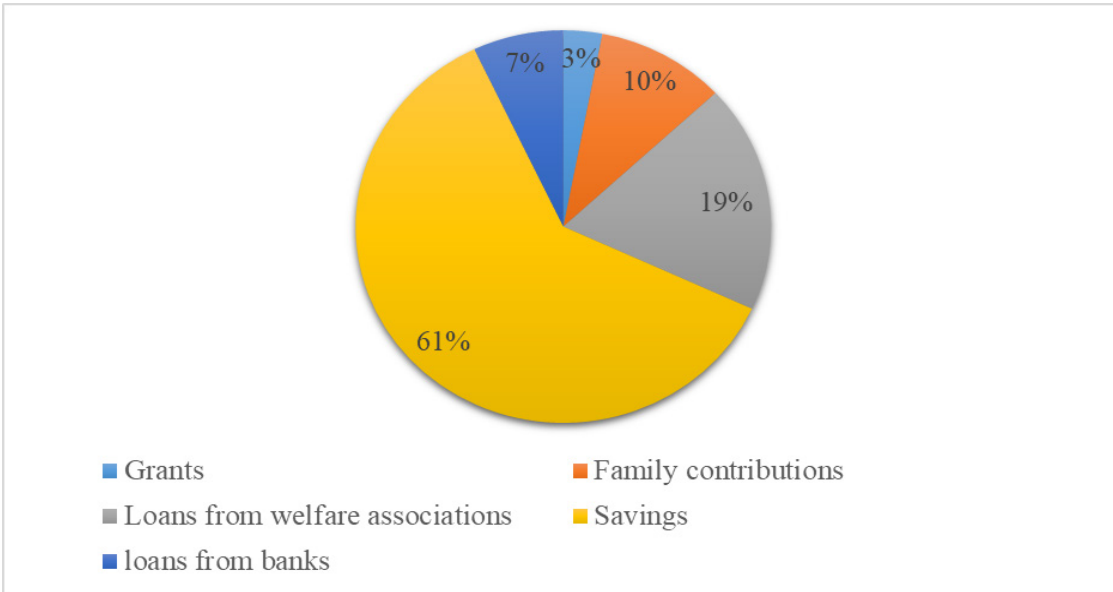

Figure 2. Sources of Capital for starting cage-fish farming

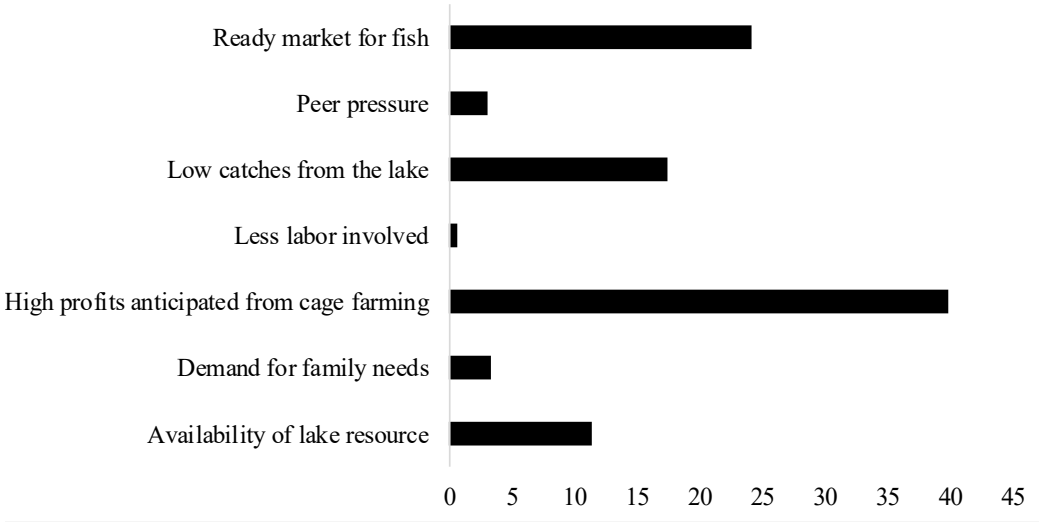

Figure 3. Motivating factors for cage-fish farming in Siaya County

Socio-Economic factors affecting cage productivity and profitability

The study examined the productivity and profitability of cage-fish farming in the area, using data collected from the farmers and targeting area under production, yield, and costs incurred at the end of the 2020/2021 production period. The study sought to determine the socioeconomic factors affecting productivity and profitability as cage performance measures. The data were analyzed through a multiple linear regression model, and the results are shown in Tables II and III. The regression coefficient (R^2) could explain the variations in response to variables by 59% and 33% for profitability, and productivity, respectively.

TABLE II - FACTORS AFFECTING PRODUCTIVITY OF CAGE-FISH FARMING IN SIAYA COUNTY

	Productivity (kg/m^3)			
Variable	Coefficient	Std. Err	t	P>|t|
Age of respondent (Yrs.)	0.79	2.39	0.33	0.74
Gender	2.59	2.32	1.12	0.27
Marital Status: Married	-24.00	26.26	-0.91	0.35
Marital Status: Single	-25.28	26.97	-0.94	0.35
Marital Status: Widowed	-41.92	27.14	-1.54	0.12
Education level	0.43	0.76	0.57	0.57
Occupation	0.40	0.99	0.4	0.69
Source of capital	-5.77	1.24	-4.67	0.00***
Weight at harvest (kg)	6.41	1.95	3.29	0.00***
Feeds (kg)	1.93	1.30	1.48	0.14
Cage size (M^3)	-1.22	1.49	-0.82	0.41
Cage site location: Siungu	29.56	9.86	3	0.00***
Cage site location: Uhanya	24.59	8.08	3.04	0.00***
Cage site location: Usenge	-14.78	7.22	-2.05	0.04**
Cage site location: Luanda Disi	-16.06	9.40	-1.71	0.09*
Cage site location: Nyenye Got Agulu	20.54	10.15	2.02	0.04**
Cage site location: Oele	-15.03	7.24	-2.07	0.04**
Stocking density (Fingerlings/m^3)	0.38	0.08	4.65	0.00***
Extension	-5.51	3.69	-1.49	0.14
Intercept	45.54	39.00	1.17	0.24
Productivity R^2 = 0.33	F= 5.57		P= 0.00	

Source: Field survey October 2021: (significance 10%, ** significance at 5%, and *** significance at 1%.). Cage site location and marital status were dummied to take care of variations.*

This study revealed that productivity and profitability are affected by several socioeconomic factors. The significant factors included stocking density, fish weight at harvest, the cage under production volume, the source of capital, marital status, and cage site location. The stocking density (P<0.01) and weight of fish at harvest (P<0.01) affected productivity and profitability positively, while the source of capital (P<0.01) affected the productivity and profitability negatively. Stocking density had a positive effect on both productivity and profitability. Stocking density determines the number of fish harvested at the end of the production cycle. A unit increase in stocking density would result in an increase in productivity of 0.4 kg/m^3, which translates to an increase in profitability by a margin of KES 98. The average weight (1% significance level) at which the fish was harvested was found to positively influence the productivity of cage farming by a margin of 6.4 kg /m^3. The more the weight of fish during harvesting, the more kilograms; hence, the high productivity index, measured as a ratio of kilograms harvested and the volume of the cage under production.

Cage size (at 10% level) significantly affected profitability positively but did not affect productivity. Increasing cage volumes under production are related to the economies of scale. An increase in one metre cubic of the cage under production results in a profitability increase by a margin of KES 952. However, if cage management remains unchanged from the past, the increase in volume does not affect productivity. The source of capital facilitates the other factors of production. This study discovered that, at the 1% level, the source of capital had a significant and negative impact on cage performance. The cage location site significantly affected productivity and profitability (P=0.00). This is indicative of other factors such as geographical positioning of the site, depth of siting, water quality, water waves, and proximity to the market, among other factors that influence fish growth; thus, productivity and profitability are affected. The marital status of the respondents was found to have a negative implication on profitability (P= 0.01). Married and widowed respondents had the most considerable negative influence, which could be attributed to resource allocation within the household. Married households have increased responsibilities due to procreation and association and thus may be affected by the challenge of distributing scarce resources. On the other hand, widowed households face limited resources due to the departure of one source, posing a distribution challenge. Depending on the family size, one may allocate fewer resources to cage-fish farming.

TABLE III - FACTORS AFFECTING PROFITABILITY OF CAGE-FISH FARMING IN SIAYA COUNTY

Variable	Coefficient	Std. Err	t	P>|t|
	Profitability (KES/m^3)			
Age or respondent (Yrs.)	285.52	830.95	0.34	0.73
Gender	-82.04	808.73	-0.1	0.92
Marital Status: Married	-22530.90	9145.69	-2.46	0.01**
Marital Status: Single	-21751.61	9391.26	-2.32	0.02**
Marital Status: Widowed	-25837.12	9449.78	-2.73	0.00***
Education level	317.69	265.24	1.2	0.23
Occupation	292.18	344.72	0.85	0.39
Source of Capital	-2103.83	430.51	-4.89	0.00***
Weight at Harvest (kg)	1031.35	677.75	1.52	0.13
Feeds in Kgs	162.66	452.74	0.36	0.72
Cage size in m^3	952.33	519.75	1.83	0.07*
Cage site location: Siungu	35347.45	3434.99	10.29	0.00***
Cage site location: Uhanya	5029.59	2814.10	1.79	0.08*
Cage site location: Nyenye Got Agulu	34540.82	3536.32	9.77	0.00***
Cage site location: Oele	-5454.74	2522.29	-2.16	0.03**
Stocking density (Fingerlings/m^3)	97.50	28.59	3.41	0.00***
Extension services	-1942.69	1285.46	-1.51	0.132
Intercept	29843.48	13583.13	2.2	0.03**
Profitability	R^2 = 0.59	F = 16.40		P= 0.000

Source: Field survey October 2021: (significance 10%, ** significance at 5%, and *** significance at 1%.). Cage site location and marital status were dummied to take care of variations.*

DISCUSSION

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 that allow men to perform fishing activities. However, the introduction of cage culture technology has increased female gender participation in fish production.

Kenyan laws prohibit the employment of minors under 18 years (Employment Act, 2016, Children's Act). As a result, the researcher administered the questionnaire to respondents over 18 years. The study findings revealed a higher percentage of respondents between 18 and 50 years, with the highest age percentage being 18- 35. Due to high unemployment rates in Kenya, estimated at over 40%, young people are shifting their productive energy to aquaculture activities.

The minimal non-literacy levels (1.3%) suggest cage farmers could have learned skills through other means, such as peer learning, on-the-job training, and extension services. Most of those interviewed were married. However, increased family size may have a negative impact on farm profitability because a large household consumes farm produce, resulting in low income.

Effect of Socioeconomic Factors on Cage Productivity and Profitability

Aquaculture productivity and profitability result from numerous factors that need to be understood. Profitability and productivity are key performance indicators affecting the adoption of new technologies in aquaculture (Kumar *et al*., 2018). The documented profitability of the cage culture has attracted significant investment in the cage culture system along the lake region (Musa *et al*., 2021). This study revealed that productivity and profitability are affected by several socioeconomic factors. Stocking density, fish weight at harvest, source of capital, and cage site location were significant factors affecting productivity. In contrast, stocking density, fish weight at harvest, the volume of the cage under production, source of capital, marital status, and cage site location were significant factors affecting cage-fish farming profitability.

The fingerling stocking density in cages affects Tilapia growth, efficiency, and production potential. Stocking density determines the size and weight of fish at harvest and, thus, the gross yield, which then determines the output per unit area and has a positive relationship with profits. In other words, higher productivity and income are associated with higher gross yields. These findings were consistent with previous studies on fish cage densities, indicating that growth yields were significantly increased with increasing stocking density (Ofori *et al*., 2009; Amos, 2013; Niazie *et al*., 2013; Nunoo and Asase, 2017). However, according to Niazie *et al*. (2013), stocking density is a crucial stressor to the growth rate of fish, causing the fish to use much energy for the homeostasis process.

When the price remains constant, it results in high profitability. On the other hand, cage size showed an increase in a unit of production, increasing the profitability of cage-fish farming. An increase in production area positively correlates with profitability due to increased efficiency of production factors based on economies of scale. The minimum cage size was 8 m^3 which farmers prefer because it makes monitoring and feeding easier. However, larger cage sizes are more productive and less damaged by currents (Ombwa *et al*., 2018).

Capital plays a facilitative role in production by enhancing other factors of production (Aswathy and Joseph, 2020). Capital is used to purchase productivity inputs such as fish feeds, payment of labour, and fingerlings. In this study, the source of capital was found to affect both productivity and profitability significantly. It had a negative coefficient, thus negatively affecting productivity and profitability. Changes in the source of capital, such as savings, grants, or access to credit, lead to low productivity and profitability. The present study's findings showed that savings were the primary source of capital for starting cage-fish farming. However, liquidity constraints are not sufficiently met through one source of capital. This probably indicates that the amount of money received from these sources is not adequate for the running of the enterprise and, thus need for a combination of the sources to increase capital based. Since capital availability leads to technology adoption

(Aswathy and Joseph, 2020), the inadequacy of capital leads to minimal adoption of technologies that improve productivity and profitability.

In this study, marital status had a significant negative effect on profitability. It is assumed that marital status ndicates that couples in the joint farming venture have a more significant influence on gross margin due to collaborative efforts and utilization of family labour, which lowers operational costs. Polygamy is common in Siaya County, resulting in increased responsibility for males, the dominant gender in cage fish farming (86%). Other forms of marital statuses, such as divorced or widowed, also affect resource allocation to cage-fish farming since the departure of one spouse means a reduction in resources. The location of the cage site had a significant effect on productivity and profitability. This is a result of a cage sitting, which is an important factor since it affects cage construction and durability, operation costs, and the growth and survival rates of fish in cages (Orina *et al*., 2018; Aura *et al.*, 2021). Most cages within Siaya County are located in less than 4 m depth due to ease of accessibility and close supervision, yet depth is an important parameter to site suitability (Aura *et al*., 2021).

CONCLUSION AND RECOMMENDATIONS

The socioeconomic factors which were found to influence productivity and profitability, by this study were the cage size, fingerling stocking densities, weight of fish at harvest, source of capital, respondents' marital status, and cage site location.

The stocking density and weight of fish at harvest positively impacted both productivity and profitability, while the source of capital negatively impacted both. The location of the cages influenced cage performance, either positively or negatively, depending on where the cages were placed. The respondents' marital status was found to have a negative impact on profitability, whereas cage size positively impacted profitability but was not significant on productivity.

Cage-fish farming should be encouraged by providing the necessary production skills for improved cage performance. There is a need for technology developers, such as the Kenya Marine and Fisheries Research Institute (KMFRI) and other research institutions, to develop interventions that ensure high fish weight is achieved in the shortest time possible. This can be realized by developing feeds with high conversion ratios and fast-growing Tilapia species. 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 and insurance to provide easy access to farming capital since the enterprise is profitable. Furthermore, farmers should diversify their sources of income to raise multiple sources of capital to facilitate the adoption of larger cages. Farmers should also pool their resources to purchase larger cages. The Kenyan Government should support fish hatcheries to produce quality fingerlings and subsidize the cost to increase accessibility and ensure farmers achieve appropriate stocking densities. The Government should also develop laws and regulations and strengthen enforcement to ensure that cages are installed only in designated areas for cage production. These coordinated efforts will attract potential investors, resulting in a positive impact on the economy and livelihoods.

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