Effect of Stocking Density on Growth Performance, and Survival of Nile Tilapia (*Oreochromis niloticus*) in Cage Culture System in Lake Victoria, Kenya

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Abstract

The Nile tilapia (Oreochromis niltoticus) constitutes an important animal protein source in the Great African Lakes population but wild supplies are rapidly declining. Cage aquaculture of O. niloticus is increasingly being applied in the lakes to bridge the fish supply-demand deficit. Despite the increasing use of fish cages in the Kadimu bay of Lake Victoria, Kenya, there are hardly any studies documenting acceptable stocking densities for sustainable production or research around cages necessary to inform policy on aquaculture production in the Lake. There is need to determine desirable stocking densities for the cages that provides optimal production and returns without compromising environmental quality of the waters. This study was conducted from February to September 2022 to determine the optimal stocking density and evaluate the influence of stocking density on growth performance and survival of O. niltoticus in floating cages at Kadimu Bay of Lake Victoria, Kenya. O. niloticus fingerlings with initial mean weight of 5.5 ± 1.72g, were stocked at densities of 50, 75, 100, 125 and 150 fish m^{-3} in $12m^3$ cages replicated three times per treatment. The fish were fed thrice per day with a commercially formulated diet and measured fortnightly for growth for a period of eight months. Growth performance was measured as mean weight gain (g) considering the difference between final mean weight of fish at the end of the experiment and the initial mean weight of fish before experimentation, while % survival was measured as the proportion of fish at the end of the experiment divided by the number of fish stocked multiply by 100. Results showed that fish stocked at lower densities D50 & D75 had the highest growth performance in terms of mean weight gain (545.0 ± 15.81 g and 527.4 ± 13.80 g, respectively). The least mean weight gain was observed at stocking densities of D125 & D150 (248.3 ± 10.64 g and 253.0 ± 10.04 g, respectively). The control treatment D100 which is the normal stocking density used by cage fish farmers, showed intermediate mean weight gain (348.2 ± 11.48 g) and was significantly lower ($p<0.05$) than the D50 and D75 treatments. The survival rate was highest (91% to 96%) for fish stocked at densities of D100 and D50 and lowest (79%, 84% and 85%) fish stocked at densities of D150, D75 and D125 respectively. Fish production (kg), was highest for fish stocked at D75 (32.9 ± 7.82 kg) and lowest for fish stocked at D125 (26.9 ± 5.78 kg). The specific growth rate (SGR, % per day) was lowest at D125 and D150 (1.6 ± 0.47 and 1.6 ± 0.30) respectively and highest at D50 and D75 (1.9 ± 0.23 and 1.9 ± 0.21), while feed conversion ratio (FCR) was lowest at D50 (1.2 ± 0.02) and highest at D150 (2.9 ± 2.01). Results of economic analysis showed the lowest Cost-benefit ratio in D50 (0.48) and highest ratio in D150 (1.16). In conclusion, stocking fish at density of D50 is more economically profitable than the other density treatments. Fish production was highest at D75 but the cost-

benefit ratio was best for fish stocked at D50, suggesting D50 to be the most suitable stocking density for cage fish farmers in the study area in sharp contrast to the current practice of stocking 100 fish per m^3. However, the cost-benefit analysis is based on a single production cycle and will need to be re-evaluated in subsequent production cycles. It is recommended for fish farmers to stock fish at a density of 50 fish m^{-3} in the study area as opposed to the current stocking of 100 fish m^{-3} for sustainable fish production.

Keywords: Cage aquaculture, economic analysis, condition factor, animal protein, weight gain, specific growth rate

INTRODUCTION

Cage fish farming is now a common practice in the Great African Lakes and Reservoirs (Opiyo *et al*., 2018) and is increasing rapidly on the Kenya side of Lake Victoria due to increasing demand for food fish and decreasing yield in capture fisheries (Aura et al., 2018). The Nile tilapia (*O. niloticus)* is a good candidate for cage aquaculture because of a number of reasons including (Pillay,1990); its omnivorous feeding habits, ability to survive in deteriorating water quality, ease of breeding under confined environmental conditions as well as under diverse types of aquatic ecosystems. However, even with a good aquaculture candidate, certain parameters like stocking density, water quality and feeding regime are important for optimal growth and yield (Mwainge et al., 2021; Nyakeya et al., 2022). Increasing stocking density may result in negative consequences such as, augmenting stress, disease prevalence and mortality, and even decreasing feed conversion ratio in farmed fish (Asase, 2013; Owuor et al., 2019; Oyier et al., 2021) thereby requiring optimal density determination. The optimal stocking density will, however, vary between species, environmental conditions and culture systems (Schmitton & Rosati, 1991; Ngodhe, 2021) with a bearing on the survival rate of fish (Asase, 2013).

Cage farming has the potential to bridge the gap between fish supply and demand deficit, enhance livelihoods, mitigate poverty and contribute to food and nutritional security of the local communities (Musinguzi et al., 2019). However, there is need for determination of optimal fish stocking densities in these lakes for both profitable investments and optimal feed application to avoid feed wastage that may result into ecosystem degradation (David et al., 2015; Musinguzi et al., 2019). Water quality control through prudent feed application and density regulation is critical in sustainable cage culture systems in order to avoid socio-cultural conflicts, reduce negative feedbacks such as eutrophication and diseases among other effects (David et al., 2015; Musinguzi et al., 2019; Mawundu et al., 2023). It is estimated that there are now about 4,400 cages on the Kenyan side of Lake Victoria (Aura et al., 2017; Orina et al., 2018). Despite the increasing use of fish cages in Lake Victoria, (Orina et al., 2018), there are hardly any studies on acceptable stocking densities for sustainable production or research around cages necessary to inform policy on aquaculture production in the lake (Aura et al., 2017). This study was therefore conducted to evaluate the effects of stocking density on growth and survival of *O. niloticus* in cage aquaculture on the Kenyan side of Lake Victoria. The results have potential application in policy development for managing cage fish production and aquaculture parks in Lake Victoria and for sustenance of livelihoods.

MATERIALS AND METHODS

Study Area

The study was done in Kadimu Bay (Figure 1), one of the bays in Lake Victoria (Kenya) that has active cage aquaculture. Lake Victoria is among Africa's Great Lakes, with surface area of about 59,947 km^2 (Stuart, 2016). It is the largest lake in Africa by surface area and the world's largest tropical lake and second largest fresh water lake globally (Prado *et al*., 1991). It has an average depth of 40 m with a catchment area covering 169,858 km^2 (Stuart *et al*., 2018). The lake is divided between three countries, Kenya (6 %), Uganda (45 %) and Tanzania (49 %). Kadimu Bay (Figure 1) is situated between latitude 0° 6' 0'' S and longitude 34° 6'0''E on the Kenyan side of the lake (Kottek *et al*., 2006). The depth range of the bay is between 3 to 12 m, about 947 km^2 in area, and spans a distance of 4.3 km (Calamari *et al*., 1995). The shallow and sheltered nature of the bay makes it popular for cage fish farming. Most of the sheltered bays in Lake Victoria have cage fish farming as an intensive production system (Opiyo *et al*., 2018). The cages in the lake range from smaller ones (2 x 2 x 2 m) to larger ones (10.5 x 5.0 x 2.5). The main cultured species in the cages is the Nile tilapia (*O. niloticus)*. The fish are fed with commercial feed pellets supplemented with farmer-formulated feeds comprising of fresh water shrimp (*Caridina nilotica*). There are over five fish cage sites at the Kadimu Bay of which this work was done at the Anyanga site (Figure 1) due to easy access and support from the cage owners.

Experimental Design

The study on growth and survival of the Nile tilapia was conducted in fifteen cages with dimensions of size 2 x 2 x 3 m (L * W * H 12m^3) fabricated with metal frames and synthetic nylon net (mesh size 1.2m) were installed in the Lake. Each cage was hanged to sinkers and plastic drums were used to keep the cages buoyant (see Figure 1b for cage layout in the experimental area). There were five density treatments at 50, 75, 100, 125 and 150 fish per m^3 hereinafter referred to as; D50, D75, D125, D150 and D100. The D100 treatment represents the common stocking density used by the farmers in the lake and was therefore considered a reference (Control) treatment. Treatments were replicated three times and fingerlings were assigned with random numbers in a completely randomized design procedure (Zar, 1999). The (*O. niloticus)* fingerlings were procured from the local JEWLET FISHERIES ENTERPRISE LTD and acclimatized in cages installed in the lake for two months (December, 2021 to January, 2022) before experimentation. After acclimatization, the fingerlings with mean (±SD) initial weight of 5.5 ± 1.72 g and mean (±SD) initial length of 6.8 ± 0.63 cm were transferred in the experimental cages using the completely randomized design approach in order to minimize experimenter induced biases. The fingerlings were consequently reared for a period of eight months (February to September, 2022). During rearing, a commercial feed (Skretting Nutra) with crude protein level of 44% and lipid of 6.27% was used to feed the fish. The fish were fed to satiation thrice a day at 9:30am, 12:30pm and 3:30pm up to a mean weight of 5.6 ± 1.76 g (Riche et al., 2004). Thereafter, a feed ratio of 5% of fish body weight was applied (Riche et al., 2004). Fish from the cages were sub-sampled fortnightly for weight and length measurements by taking about 15% of the fish in cages using a scoop net. Weight was measured with an electronic scale (6kg, 0.1g CGOLDENWALL high precision Digital Accurate Analytical) to the nearest 0.1 g and length with a measuring board to the nearest 0.01cm after gently blotting each sample fish with a wet towel. The fish were released back to the respective cages after measurements. At the end of the culture period, all the fish in each cage were weighed individually and the total number of fish surviving counted. During each fortnightly sampling, numbers of dead fish were noted, if any, and recorded.

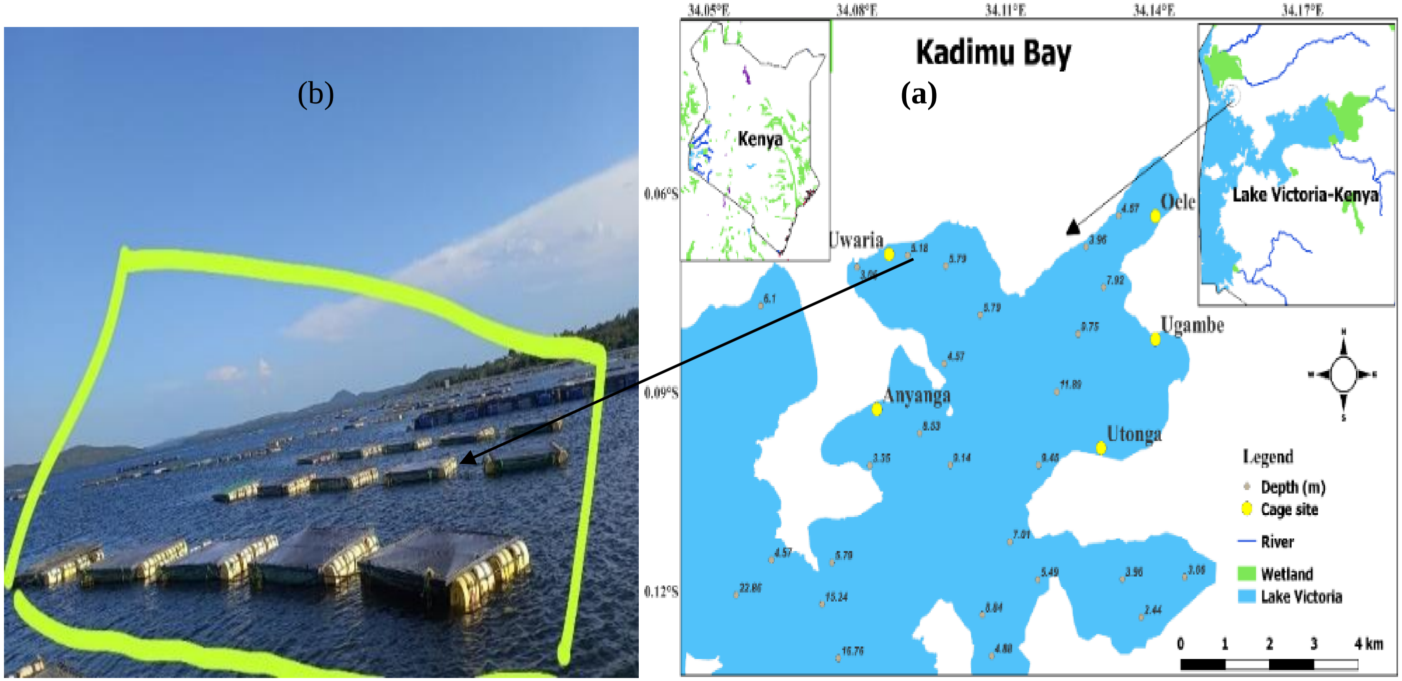

Figure 1: (a) Map of Kadimu Bay, Lake Victoria Kenya, showing the cage fish sites and (b) the layout of experimental cages at the Anyanga experimental site

Measurement of Environmental variables

Physico-chemical water quality parameters were recorded *in situ* fortnightly in the morning and evening to determine the influence of environmental variability on growth, if any. Temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), turbidity and electrical conductivity (EC), were measured *in situ* with a Hanna multiparameter probe (H9829). Water samples were collected bi-weekly for analysis of nutrients (nitrite, nitrate and ammonia). The samples were placed in a cooler box and transported to the laboratory for analysis of nitrite, nitrate and ammonia contents. The cadmium reduction procedure and the azo-dye complex technique (APHA, 2005) were used to estimate nitrate and nitrite concentrations, respectively, while the dichloroisocyanurate-salicylate procedure was used to estimate the ammonia concentration in the water samples (APHA, 2005).

Data treatment

The growth and survival rates were derived using the relationships below:

(a) Mean weight gain (g) = final mean weight (g) - initial mean weight (g)

(b) Average daily weight gain (g) = (final mean weight - initial mean weight)/culture period in days.

(c) Specific Growth Rate (% per day) = 100 × (ln W2-ln W1)/T2-T1
Where: W1= Initial mean body weight (g) at time T1 (days)
W2= Final mean body weight (g) at time T2 (days)

(d) Fish survival (%)= $\frac{\text{Number of survivor at the end of culture period}}{\text{Number of fish stocked}}$ x 100

(e) $\text{Feed conversion Ratio} = \frac{\text{weight of feed fed (kg)}}{\text{weight gain of fish (kg)}}$

(g) Fish production (kg) = Final mean weight * Number of fish in the cage.

The relative condition factor (Kn) of fish in each treatment were compared at the end of the culture period from the relationship:

$Kn = W/ a L^b$

Where, W is the observed weight (g), L is the observed length (cm), while a and b were derived from the length-weight relationship: $W = a L^b$

Economic Analysis

At the end of the experiment, an economic analysis was done to estimate the Cost-benefit ratio for different stocking densities on the basis of the Cost of fish production per kilogram (kg) of fish, computed from the product of the FCR and the cost of feed per kg, and the cost of fish per kg from the sale of fish for one production cycle.

(h) The Cost-benefit ratio was estimated as:

Benefit-cost ratio (BCR) = Cost of fish production per kg / Cost of fish sale per kg.

Statistical Analysis

The mean weights of the fish in each treatment were compared for significant differences at the end of the experiment using one-way analysis of variance (ANOVA) after log-transformation (log x+1) of data. The means of treatments with significant effect ($p < 0.05$) were then determined using the Tukey-Kramer multiple comparison *post hoc* test.

RESULTS

Water quality variables

Water quality variables did not differ significantly between the treatments ($p < 0.05$) (Table 1). However, mean (± SD) for pH ranged from a minimum of 7.6 ± 0.19 in treatment D125 to a maximum of 8.9 ± 0.13 in treatment D50. Dissolved Oxygen (DO) ranged from a minimum of 6.4 ± 0.38 mg/L in treatment D150 to a maximum of 7.5 ± 0.08 mg/L in treatment D75. Turbidity, a measure of sedimentation varied from a minimum of 2.2 ± 0.53fmu in treatment D50 to a maximum of 4.9 ± 0.36fmu in treatment D150 (Table 1). Conductivity varied from a minimum of 103.9 ± 6.09 µs/cm in treatment D50 to a maximum of 107.5 ± 5.91µs/cm in treatment D150, nitrates ranged from a minimum of 5.0 ± 2.44 mg/L in treatment D50 to a maximum of 7.8 ±2.71 mg/L in treatment D150, nitrites ranged from a minimum of 0.1 ± 2.02 mg/L in treatment D50 to a maximum of 0.3 ± 1.48 mg/L in treatment D150 and ammonia ranged from a minimum of 0.5 ± 0.37 mg/L in treatment D50 to a maximum of 0.6 ± 3.83 mg/L in treatment D150 (Table 1).

Table 1: Variation of water quality variables in the different density treatments in the cage culture of the Nile tilapia in Lake Victoria, Kenya (± represents SD of the mean)

	Stocking Density/ Treatments					ANOVA	
Parameters	D50	D75	D100	D125	D150	F	P
Temp. (°C)	26.5 ± 0.14	26.8 ± 0.12	27.5 ± 0.18	27.6 ± 0.18	27.7 ± 0.14	0.28	0.82
pH	8.9 ± 0.13	7.7 ± 0.25	8.1 ± 0.13	7.6 ± 0.19	8.0 ± 0.11	0.74	0.33
DO (mg/L)	7.3 ± 0.48	7.5 ± 0.08	7.2 ± 0.23	6.6 ± 0.56	6.4 ± 0.38	0.42	0.63
Turb. (fmu)	2.2 ± 0.53	2.9 ± 0.79	3.6 ± 0.83	3.7 ± 0.17	4.9 ± 0.36	0.25	0.84
Cond. (µs/cm)	103.9 ± 6.09	107.3±5.91	105.0 ± 6.29	107.3 ± 1.97	107.5±5.91	8.83	0.46
TDS(ppm)	62.0 ± 5.92	59.6 ± 1.60	65.9 ± 7.08	56.4 ± 1.85	67.5 ± 0.61	1.34	0.4
NO_3^-(mg/L)	5.0 ± 2.44	6.3 ± 3.82	6.6 ± 4.08	7.2 ± 4.34	7.8 ± 2.71	2.86	0.1
NO_2^-(mg/L)	0.1 ± 2.02	0.2 ± 2.04	0.2 ± 2.36	0.2 ± 1.29	0.3 ± 1.48	4.87	0.56
NH_3(mg/L)	0.5 ± 0.37	0.5 ± 0.90	0.5 ± 3.88	0.5 ± 3.84	0.6 ± 3.83	0.06	0.93

Growth and survival

The growth parameters (mean final weight (g), weight gain (g), average daily weight gain (g), specific growth rate (% per day), survival rate (%), feed conversion ratio and fish production (kg) of *O. niloticus* in varying density treatments are presented in Table 2. The mean (± SD) initial weight (5.5 ± 1.72 g) of the fingerlings did not vary among all treatments, while the final mean weight varied significantly among treatments. The final mean weight (g) after eight months of the experiment varied from a minimum of 253.8 ± 10.64 g in treatment D125 to a maximum of 550.5 ± 15.81 g in treatment D50. The mean initial length was uniform (6.8 ± 0.63cm) among all treatments, while the mean final length varied among treatments. The mean final length varied from a minimum of 17.9 ± 1.20 cm in treatment D150 to a maximum of 29.6 ± 3.59 cm in treatment D50. The mean weight gain (g) varied from a minimum of 248.3 ± 10.64 g in treatment D125 to a maximum of 545.0 ± 15.81 g in treatment D50. The average daily weight gain (g) ranged from a minimum of 1.0 ± 1.08 g in treatment D125 to a maximum of 2.3 ± 2.14 g in treatment D50. The specific growth rate (% per day) varied from a minimum of 1.6 ± 0.47% and 1.6 ± 0.30 in treatment D125 and D150 to a maximum of 1.9 ± 0.23 % and 1.9 ± 0.21 % in treatment D50 and D75 respectively. The survival rate at the end of the culture period was maximum (96%) for treatment D50 and minimum (79%) for treatment D150, while feed conversion ratio was minimum (1.2 ± 0.02) in treatment D50 and maximum (2.9 ± 2.01) in treatment D150. The fish production was highest in treatment D75 at 32.9 ± 7.82 kg and lowest in treatment D125 at 26.9 ± 5.78 kg (Table 2).

Table 2: Growth performance parameters and survival rate of the Nile tilapia (*Orechromis Niloticus)* in experimental cages under different density treatments in Lake Victoria, Kenya

Parameters	Stocking Densities/ Treatments				
	D50	**D75**	**D100**	**D125**	**D150**
Mean Initial Weight (g)	5.5 ± 1.72[a]	5.5 ± 1.72[a]	5.5 ± 1.72[a]	5.5 ± 1.72[a]	5.5 ± 1.72[a]
Mean final Weight (g)	550.5 ± 15.81[a]	532.9 ±13.80[a]	353.7 ± 11.48[b]	253.8 ± 10.64[c]	258.5 ± 10.04[c]
Mean Initial Length (cm)	6.8 ± 0.63[a]	6.8 ± 0.63[a]	6.8 ± 0.63[a]	6.8 ± 0.63[a]	6.8 ± 0.63[a]
Mean final Length (cm)	29.6 ± 3.59[a]	28.9 ± 2.36[a]	24.5± 2.95[b]	22.5 ± 3.16[c]	17.9 ± 1.20[b]
Mean weight gain (g)	545.0 ± 12.81[a]	527.4 ± 11.80[a]	348.2 ± 11.28[b]	248.3 ± 10.44[c]	253.0 ± 9.14[c]
Average daily weight gain (g)	2.3 ± 2.14	2.2 ± 2.13	1.5 ± 1.22	1.0 ± 1.08	1.1 ± 2.06
Specific Growth Rate (%)	1.9 ± 0.23[a]	1.9 ± 0.21[a]	1.7 ± 0.20[b]	1.6 ± 0.47[c]	1.6 ± 0.30[c]
Feed Conversion Ratio	1.3 ± 0.02[d]	1.3 ±1.02[c]	1.9 ± 2.01[b]	2.8 ± 1.33[a]	2.9 ±2.01[a]
Survival rate (%)	96	84	91	85	79
Fish production (kg/cage/240days)	27.2 ± 8.21	32.9 ± 7.82	28.3 ± 6.72	26.9 ± 5.78	31.3 ± 6.96

Condition factor, which define fish growth performance as influenced by the feed and the environment (a measure of wellbeing) was best in treatment D50 at 2.6 ± 2.83 and lowest in D150 at 1.8 ± 3.42 (Figure 2). The post hoc test reveals no significant difference between treatment D50 and D75, likewise between treatment D125 and D150 but there was significant difference between treatment D100 and the other treatments.

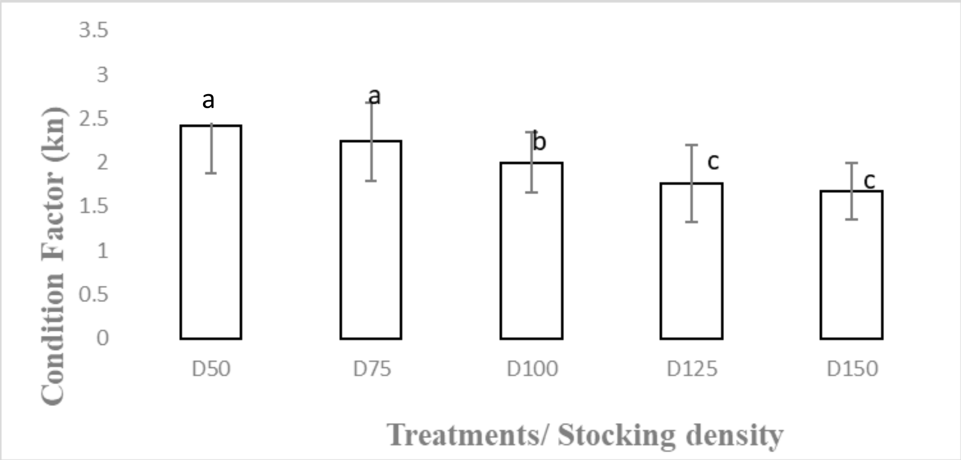

Figure 2: Variation of relative condition factor (kn) of fish cultured under different stocking densities in cages within Lake Victoria, Kenya. Error bars indicate SD, while similar letters indicate treatments with similar condition factor ($P < 0.05$).

The weight increment did not vary much among treatments for the first sixty (60) days but exhibited clear variations from the seventieth (70) day of the experiment and towards the end of the experiment (Figure 3). Weight increment was highest for treatment D50 being 400g at the end of experiment at day 240. Treatment D75 had the second-best weight increment at 320.78g at the end of the experiment. Treatments D100, D125 and D150 had mean weight increment values that were close and ranged from 200g to 250g at the end of the experiment (Figure 3).

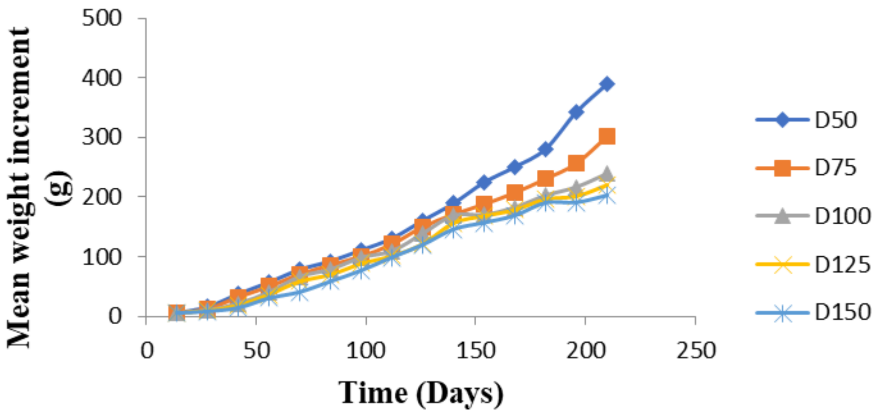

Figure 3: Variations in weight increment of cultured *O. niloticus* under different stocking densities in experimental cages in Lake Victoria, Kenya, for 240 days. D50-D150 indicate stocking densities

Economic Analysis

Considering the Cost-benefit analysis for one production cycle, the total cost of production for one kg of fish for treatment D50 was lower than the cost for the other treatments (D75, D100, D125 and D150) (Table 3). The total cost of production for one kg of fish increase with increasing stocking density, while the profit margins decreases with increasing stocking density (Table 3). The Cost-benefit ratio was least for D50 at 0.48 and highest for D150 at 1.16 (Table 3), implying D50 is more cost effective for the production of one kg of fish than the other treatments.

Table 3: Cost-benefit analysis of tilapia (*O. niloticus*) at different stocking densities from cage (12 m^3) after 240 days culture period at Anyanga cage site, Kadimu Bay, Lake Victoria, Kenya.

ECONOMIC ANALYSIS					
Parameters	D50	D75	D100	D125	D150
FCR	1.2	1.3	1.9	2.8	2.9
Cost of feed per kg (ksh)	120	120	120	120	120
Cost of fish production per kg (ksh)	144	156	228	336	348
Cost of fish sale per kg (ksh)	300	300	300	300	300
Profit margin per kg (ksh)	156	144	72	-36	-48
Cost-benefit ratio per kg of fish	0.48	0.52	0.76	1.12	1.16

DISCUSSION

In this study, the water quality variables were within suitable range for tilapia growth throughout the experimental period. The variation of water temperature (26.53 - 27.74°C) for example, was within recommended ranges for tilapia growth (Moniruzzaman et al., 2015). For optimum fish growth, dissolve oxygen levels should be higher than 5ppm for warm water fishes (Body, 1982; Lucas *et al.*, 2019). All the nutrients (Nitrates and nitrites) were within the recommended range for the growth of tilapia (Boyd 1982; Lucas et al., 2019) indicating that water quality in the experimental site did not confound the growth of the fish.

The influence of stocking density on the growth and survival of *O. niloticus* revealed that, growth performance as measured by weight gain was not significantly different between treatment D50 and D75 but significantly higher than treatment D125, D150 and D100.Treatments D125 and D150 showed no significant difference in growth. However, there was a significantly lower or higher growth in treatment D100 which was used as the control than the four other treatments D50, D75, D125 and D150. Even though there was no significant difference in terms of mean weight gain between treatment D50 and D75, fish production (kg) was highest in treatment D75 because of reduced crowding, compared to other treatments. These findings support the work of (Kawamoto, 1957; Haque et al., 1984) who observed that growth in fish is best at lower stocking densities. The reasons for the better growth performance in the lower treatment D50 can be associated with reduced competition for space, food, , and reduced crowding stress (Haque et al., 1984). The growth performance of *O. niloticus* will vary spatially and geographically in relation to differences in the environmental parameters that control growth, requiring determination of the optimum stocking densities in different aquatic ecosystems (Moniruzzaman et al., 2015). Variations in growth performance in relation to stocking densities have been reported by different studies (Sayeed et al., 2008; Asase, 2013) with consistent higher growth at lower densities but variable optimum densities for optimum returns.

Percentage survival rate for this study were 79%, 85%, 91%, 84% and 96% for D150, D125, D100, D75 and D50, respectively. These findings are comparable with the results from other tropical ecosystems where fish cage farming applied (Sayeed et al., 2008). The % survival decreased with increasing stocking density probably due to increasing competition for space and food among individual fish. The treatments with the best growth performance showed highest survival rates indicating the interaction between optimum growth and survival for viability of aquaculture facilities.

Condition factor provides knowledge on environmental suitability for growth and development of fish species (Lizama et al., 2002). It is also an important parameter in understanding feed intake for growth and development in fish (Kumolu-Johnson & Ndimele, 2010). Condition factor is influenced by both biotic and abiotic ecosystem variables and is used as a measure of ecosystem quality. In this study, the Condition factor for all the treatments range from 1.95 to 2.29 (Figure 2) suggesting that the fish were of good condition and reflecting the environmental quality standards of the culture environment (Irons et al., 2010).

Economic analysis on the cost of fish production per kg of fish showed an increase in the cost of production with increasing stocking densities of *O. niloticus* (Moniruzzaman et al., 2015). The Cost-benefit ratio was evaluated on the basis of cost of fish production per kg of fish (FCR* Cost of feed per kg (ksh)) and returns (Cost of fish per kg (ksh) from fish sales. From the analysis done on one production cycle, stocking at D50 provided the best production economic performance with the best Cost-benefit ratio of 0.48, while D150 provides the worst Cost-benefit ratio of 1.16, for one production cycle and are likely to increase in subsequent production cycles as a result of reduced cost of fish production per kg of fish. This finding is in agreement with the work of (Moniruzzaman et al., 2015).

CONCLUSION AND RECOMMENDATION

The result of this study indicated that, growth performance was highest at stocking densities of D50 and D75 fish m^{-3} for *O. niloticus*. Implying lower stocking densities of tilapia *O.niloticus* will exhibit better growth parameter performance and survival rate than higher stocking densities. Fish production, was highest at D75 but the benefit-cost ratio was highest for fish stocked at D50, suggesting D50 to be the most suitable stocking density for cage fish farmers in the study area. The study further reveals that, the water quality variables at the cage site are within acceptable limits for the culture of *O. niloticus.* It is recommended that, a careful decision on the trade-off between economic and production should be made to choose between D50 and D75. Maybe a density of 60 would be more appropriate.

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Conflict of Interest

None

Data Availabity Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request

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