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Effect of stocking density on growth performance, survival, production, and financial benefits of African sharptooth catfish (*Clarias gariepinus*) monoculture in earthen ponds

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ABSTRACT

The present on-farm study assessed the effect of different stocking densities on growth, production, and financial benefits of African sharptooth catfish (*Clarias gariepinus*) in earthen ponds for 180 days. Low stocking density (LSD), medium stocking density (MSD), and high stocking density (HSD) of 3, 6, and 9 fish m^{-2}, respectively, were tested. *C. gariepinus* stocked at LSD and MSD showed significantly higher weight gain, specific growth rate, and final mean weight than those cultured at HSD ($P < .05$). There was a significant linear relationship between the stocking density and the yields and financial variables ($P < .05$). Net fish yields were significantly higher for *C. gariepinus* reared at HSD and MSD than those stocked at LSD ($P < .05$). Similarly, *C. gariepinus* raised at MSD and HSD generated significantly more profit than those cultured at LSD ($P < .05$). Results demonstrated that farmers can achieve high net yield and financial benefits by stocking *C. gariepinus* at HSD of 9 fish m^{-2}.

KEYWORDS

African sharptooth catfish; financial benefits; growth; stocking density; yield

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Introduction

African sharptooth catfish, *Clarias gariepinus*, is one of the most important tropical freshwater fish species suitable for aquaculture (Dada and Wonah 2003), thanks to its desirable attributes such as fast growth, good feed conversion, resistance to disease, and ability to endure long drought and scarcity of food (Adewolu, Ikenweiwe, and Mulero 2010; De Graaf and Janssen 1996; Edward, Ladu, and Elihu 2010). Other aquaculture attributes of *C. gariepinus* include high fecundity rate, ability to tolerate environmental extremes and high stocking densities, high plasticity in its feeding habits (Bruton 1979 cited in Edward, Ladu, and Elihu 2010), as well as good market potential (Ali and Jauncey 2005).

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In Africa, *C. gariepinus* has replaced Nile tilapia (*Oreochromis niloticus*) as the most important fish species for aquaculture since 2004 (FAO 2012). *C. gariepinus* culture in many sub-Saharan African countries, including Tanzania, is performed for subsistence with little surplus production used to generate income (Omondi, Gichuri, and Veverica 2001). In Tanzania, *C. gariepinus* is commonly cultured in earthen polyculture ponds with *O. niloticus* (Shoko, Limbu, Mrosso, Mkensa et al. 2014b; Shoko, Matola et al. 2011b). However, most of the available research results on *C. gariepinus* culture have been obtained from experiments in tank culture systems (Almazán 2004; Appelbaum and Kamler 2000; Van De Nieuwegiessen et al. 2009). In indoor and outdoor tanks, water-quality parameters can easily be controlled and managed, as compared to earthern ponds (Keremah and Esquire 2014). Also, tanks require that water be frequently changed and aeration provided, and tanks exclude the existence of natural food organisms that form important food items in earthen ponds (Engle and Sapkota 2012). Furthermore, tanks lack adsorption effect of the soil that commonly occurs when *C. gariepinus* is cultured in ponds. Due to the nature of the two culture systems, tanks are mostly used for intensive production of *C. gariepinus* while earthen ponds are used for semi-intensive or extensive systems (Keremah and Esquire 2014). Because there are differences in conditions between pond and tank systems, the optimum production of *C. gariepinus* in developing countries would only be realized if a number of on-farm issues, such as the optimum stocking density in earthen ponds, are addressed (Edward, Ladu, and Elihu 2010; FAO 1995).

Financial analysis in fish farming is a relatively recent practice in Africa, with only a few studies reporting fiscal aspects (Kaliba et al. 2006; Omondi, Gichuri, and Veverica 2001; Shoko, Getabu, et al. 2011a; Shoko, Limbu, Mrosso, Mkenda, et al. 2014b; Wetengere 2009). However, financial analysis in aquaculture is important to evaluate the profitability of the culture system, to determine efficiency of resource allocation and management practices.

Monoculture of *C. gariepinus* is commonly practiced in other African countries such as Nigeria, where the culture technology for production of higher yield and optimum financial benefits are well established (Ayinla 2007; Nwachi and Toritseju 2013). There are no such studies that have assessed the financial benefits of *C. gariepinus* in monoculture at different stocking densities as high as nine fish m^{-2} in earthen ponds in rural fish farms in Tanzania. Therefore, the purpose of the present on-farm study was to assess the effect of three stocking densities of 3, 6, and 9 fish m^{-2} on growth, production, survival, and financial benefits of *C. gariepinus* monoculture in earthen ponds.

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Materials and methods

Description of the study site

This study was carried out from 1 April to 29 September 2010 (180 days in total) at Kimusi village (1°10" to 1°36" S; 34°08" to 35°01" E), Tarime District, Mara Region in the Lake Victoria basin, Tanzania. The district has bimodal rainfall that starts in September to December (light rainy season) and March to May (heavy rainy season). This site receives an average annual rainfall of 900 to 1,500 mm, and average annual temperature is between 14°C and 25°C (URT 1998). In the study site, *Oreochromis niloticus* is the most important cultured fish species. However, *Clarias gariepinus* is primarily caught in rivers and Lake Victoria at small size (fingerling stage) for use as food and as bait in Nile perch (*Lates niloticus*) fishery (Hecht 2013; Mkumbo and Mlaponi 2007).

Experimental design

This on-farm study was carried out in ponds owned and managed by a community of 15 different farmers to ensure that the results reflect the actual practice of fish farming in Tanzania. The ponds were located in the farmers' homesteads. In order to ascertain proper feeding regimes and sampling frequencies, scientists collaborated closely with farmers. Supervision was important so as to avoid variation caused by daily management regimes in different farmers' ponds.

The main source of water to the ponds was a permanent stream originating from the Mori River, one of the main rivers that supply water to Lake Victoria. Water levels in each pond were monitored weekly and maintained at the same level to avoid effect of water-level fluctuations. During weekly monitoring, about 30% of the water was exchanged to remove organic matter accumulated on the pond bottom in order to improve water-quality parameters. Before stocking, ponds were drained and limed with dolomite at a rate of 0.25 kg m^{-2} (Engle and Neira 2005) to regulate pond water pH and water chemistry in general (Shoko, Limbu, Mrosso, and Mgaya 2014a).

An incomplete factorial block experimental design was set up to test the effect of stocking density on growth, production, survival, and financial benefits of *C. gariepinus* in monoculture system. Nine ponds, each with an area of 150 m^2 and mean depth of 1.25 m, were stocked with *C. gariepinus* fingerlings of mean (± SE) initial weight of 5.23 ± 0.80, 5.17 ± 0.02, and 5.24 ± 0.06 g in triplicates at three different stocking densities of low (LSD; 3 fish m^{-2}), medium (MSD; 6 fish m^{-2}), and high (HSD; 9 fish m^{-2}), respectively. The ponds were randomly assigned different *C. gariepinus* stocking densities (treatments).

Fish were fed on a 297.50 g kg^{-1} crude protein diet made using locally available cotton seed cake 683.40 g kg^{-1} and maize bran 316.60 g kg^{-1} of dry

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Table 1. Composition of the diets fed to African sharptooth catfish (*Clarias gariepinus*) reared at different stocking densities in earthen ponds for 180 days.

Ingredients	Composition (g kg^{-1}) dry feed
Cotton seed cake meal	683.40
Maize bran meal	316.60
Total	1,000.00
Proximate composition of feed (dry matter basis)	
Dry matter	924.70
Crude protein	297.50
Crude fibre	136.70
Crude fat	109.60
Ash	68.10
Carbohydrate	388.10

feed (Table 1) for a period of 180 days. A sample of dry feed was analyzed for crude protein, crude fat (ether extract), crude fiber, ash, and total carbohydrate following the procedure detailed in the *Official Methods of Analysis of the Association of Official Analytical Chemists* (AOAC 1990). The ingredients were separately ground using a hammer mill with a screen size of 0.8 mm, weighed, and mixed in the required proportions to form a mash. The resulting mash was applied at a daily ration of 5% average body weight of *C. gariepinus*. The ration was divided into two portions and hand-fed twice a day, in the morning between 0900 and 1000 h and evening between 1500 and 1600 h. Pond fertilization with cattle manure was done at a rate of 10 kg 100 m^{-2} $week^{-1}$ (Isyagi 2005). The manure was applied by hand at the periphery of each pond. The dry cattle manure contained (g kg^{-1}) moisture 755.00, organic matter 222.00, total nitrogen (N) 9.20, total phosphorus (P_2O_5) 4.30, potassium 4.00 and calcium 5.50.

Data collection

Before stocking, 30 *C. gariepinus* were randomly sampled and their individual total weights (g) and lengths (cm) recorded to the nearest 0.01 g and 1 mm, using a sensitive weighing balance and a measuring ruler respectively. Before weighing, the specimens were blot dried to ensure accuracy (El-Naggar 2008). Thereafter fish sampling was conducted every 30 days, using a seine net (12.7 mm mesh size), and fish weights and lengths measured as before. Feeding was calculated and adjusted on a monthly basis, in accordance with the average weight of sampled fish.

Water-quality parameters were monitored to gain an insight into the prevailing environmental conditions in the fish ponds. Temperature, pH, and dissolved oxygen (DO) measurements were taken twice daily in the morning (0830 to 0900 h) and in the afternoon (1630 to 1700 h), using a multiprobe kit (model KTO, HQ, 40D PHC 101-LD 101–01 by Hach Company Ltd., USA). The results of the water-quality analysis showed that

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all parameters were within the acceptable range for the growth of *C. gariepinus* (Ibrahim and Naggar 2010). Dissolved oxygen ranged from 4.56 to 8.88 mg L^{-1}, temperature from 20.82°C to 25.91°C, and pH from 6.26 to 7.84.

At the end of the experiment, water was completely drained out of the ponds, and all fish from each pond were collected and counted. All fish harvested from each pond were then weighed for determination of gross fish yield (GFY). A random sample of 30 *C. gariepinus* was collected from each pond and measured individually to determine the final mean weight (FMW). The total mean weight gain (TWG) was calculated by subtracting the mean initial weight from the mean final weight. Mean weight gain (MWG) during intermediate sampling was calculated by subtracting the previous sampling mean initial weight from the current measured mean weight. Net fish yield (NFY), net annual yield (NAY), daily weight gain (DWG), specific growth rate (SGR), feed conversion ratio (FCR), percentage survival (%), and relative condition factor (K) were calculated using the following formulae:

$$NFY = \frac{W_h - W_s}{P} \tag{1}$$

where W_h = Total weight of fish harvested (kg), W_s = Total weight of fish stocked (kg), and P = Pond area (ha).

$$NAY = \frac{NAY \times 365}{t} \tag{2}$$

where t = Growth period (days).

$$DWG = \frac{Wf - Wi}{t} \tag{3}$$

where W_f = Final mean weight (g) and Wi = Initial mean weight (g).

$$SGR = \frac{ln\, W_f - ln\, W_i}{t} \times 100 \tag{4}$$

$$FCR = \frac{TFC}{TWG} \tag{5}$$

where TFC = Total feed consumed (dry) (kg) and TWG = Total weight gained by fish (wet) (kg).

$$Percentage\, survival = \frac{N_h}{N_s} \times 100 \tag{6}$$

where N_h = Total number of fish harvested and N_s = Total number of fingerlings stocked.

$$K = \frac{W}{L^3} \times 100 \tag{7}$$

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where W and L are final weight (g) and total length (cm), respectively.

Partial enterprise budgets were used to compare the relative profitability of *C. gariepinus* reared at different stocking densities under monoculture system. Costs were defined in terms of inputs categorized into variable costs (expenses that vary with the level of production) and fixed costs (costs that do not vary with the level of production). Variable costs included costs of inputs such as fingerlings, feeds, lime, casual labor, interest on operating costs, and transport costs, whereas fixed costs included fish pond construction and family labor costs. Fish were sold at a local market price of USD 2.54 kg^{-1}. The actual values of revenue generated by farmers after selling their fish were used in the analysis. All costs and revenues were converted to monetary values, and the net returns on investments were determined. The analysis was based on local market retail prices converted in US$ (US$1 = TZS 1,572.40 during the study period). Interest rate of 20% per annum was adopted from the local branch of the National Microfinance Bank (NMB) for the financial analysis.

Statistical analysis

Results are presented as means ± standard error (SE) and data were tested for homogeneity of variances using Levene's test. After confirming homogeneity of variances, one-way analysis of variance (ANOVA) was used to test if there were significant differences in FMW, MWG, DWG, SGR, percentage survival, NFY, and NAY among the three different stocking densities. When significant differences were detected, Tukey's multiple comparisons test was performed to compare the measured parameters among the three stocking densities. Percentage data were arcsine transformed prior to ANOVA and reversed afterward for reporting purposes (Zar 2010). ANOVA was also used in making financial comparisons among the three stocking densities. Multiple regression analysis was used to determine the relationship between measured parameters and stocking densities. All statistical analyses were performed using SPSS version 20 for Windows (Landau and Everit 2004). Significant differences were considered at the significance level of .05.

Results

The growth increments of *C. gariepinus* raised at the three stocking densities during the study are shown in Figure 1. The results showed a decreasing trend for mean weight gain, total mean weight, specific growth rate, and final weights as density increased (Table 2). *C. gariepinus* cultured at LSD attained higher mean weight than those cultured at HSD (P = .039). However, there

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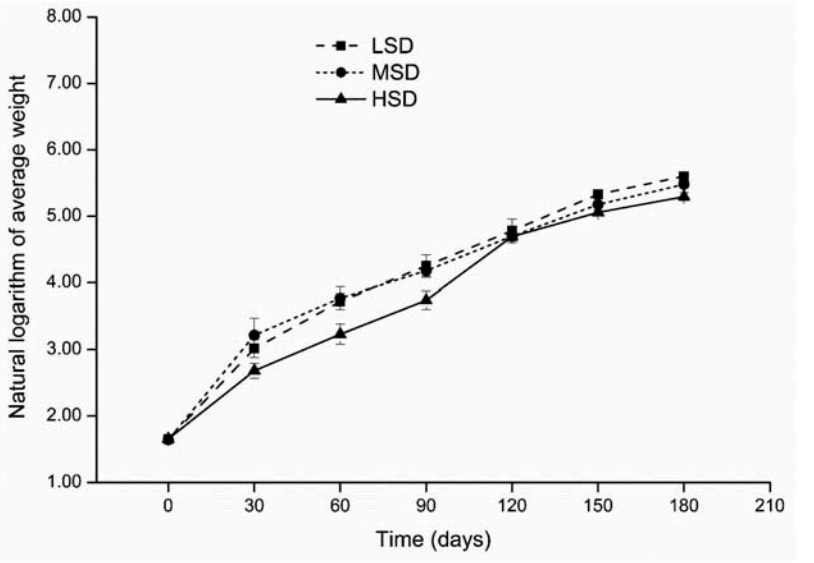


Figure 1. Change in natural logarithm of the mean weight (g) of African sharptooth catfish (*Clarias gariepinus*) cultured at low (LSD, 3 fish m^{-2}), medium (MSD, 6 fish m^{-2}), and high (HSD, 9 fish m^{-2}) stocking densities in earthen ponds for 180 days. (Error bars indicate ± SE).

Table 2. Growth and yield parameters of African sharptooth catfish (*Clarias gariepinus*) reared under low (LSD, 3 fish m^{-2}), medium (MSD, 6 fish m^{-2}), and high (HSD, 9 fish m^{-2}) stocking densities in earthen ponds for 180 days.[1]

Growth parameters[2]	LSD	MSD	HSD
Initial weight (g)	5.23 ± 0.80[a]	5.17 ± 0.02[a]	5.24 ± 0.06[a]
Final weight (g)	270.42 ± 2.16[a]	239.50 ± 4.95[a]	199.79 ± 11.82[b]
Daily weight gain (g day^{-1})	1.42 ± 0.13[a]	1.30 ± 0.10[a]	1.08 ± 0.11[a]
Mean weight gain (g)	44.20 ± 3.74[a]	39.05 ± 3.07[a,b]	32.43 ± 3.27[b]
Total weight gain (g)	265.19 ± 2.08[a]	234.32 ± 4.97[a]	194.55 ± 11.85[b]
Percentage survival (%)	98.83 ± 0.29[a]	97.58 ± 0.18[a]	95.42 ± 4.16[a]
SGR (% bw gain day^{-1})	2.19 ± 0.16[a]	1.73 ± 0.17[a,b]	1.63 ± 0.15[b]
FCR	2.37 ± 0.22[a]	2.80 ± 0.25[a]	2.73 ± 0.27[a]
K	1.15 ± 0.08[a]	1.03 ± 0.01[a]	1.00 ± 0.02[a]
Yield parameters			
GFY (kg ha^{-1})	8,014 ± 75[b]	14,022 ± 281[a]	17,175 ± 1,389[a]
NFY (kg ha^{-1})	7,857 ± 73[b]	13,712 ± 282[a]	16,702 ± 1,390[a]
NAY (kg ha^{-1} yr^{-1})	15,932 ± 148[b]	27,804 ± 572[a]	33,868 ± 2,818[a]

[1]Values in the same row with different superscripts (a and b) are statistically different ($p < .05$); values are mean ± SE for three replicates.

[2]SGR stands for specific growth rate, FCR for feed conversion ratio, K for relative condition factor, GFY for gross fish yield, NFY for net fish yield, and NAY for net annual yield.

was no significant difference in mean weight gain for *C. gariepinus* cultured at LSD and MSD ($P = .529$) and those stocked at MSD and HSD ($P = .349$). Specific growth rate of *C. gariepinus* was also affected significantly by stocking density ($F = 3.430$, $P = .035$). A similar trend to mean weight gain was shown in specific growth rate.

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The final weight of *C. gariepinus* decreased significantly as density increased (F = 22.265, P = .002). *C. gariepinus* cultured at HSD attained significantly lower final mean weight than those cultured at LSD (P = .001) and MSD (P = .022). *C. gariepinus* cultured at LSD had statistically similar final mean weights as those cultured at MSD (P = .061). The total mean weight gain decreased significantly at higher density (F = 22.191, P = .002; Table 2), with a trend similar to that of the final weight.

Daily weight gain (F = 0.733, P = .486), feed conversion ratio (F = 0.296, P = .745), and condition factor (F = 0.377, P = .687) were not significantly affected by the three different stocking densities tested (Table 2). Regression analysis showed that, only total weight gain and final mean weight decreased significantly with the increase in stocking density (Figure 2).

Percentage survival of *C. gariepinus* cultured at different stocking densities were generally high (95.42 ± 4.16% to 98.83 ± 0.29%), with no significant difference among different stocking densities (F = 0.512, P = 0.623; Table 2). There was no meaningful relationship between survival and stocking density (R^2 = −0.139; Figure 3). However, one replicate of the nine fish m^{-2} stocking density showed a lower survival than the two other replicates of the same treatment (Figure 3).

The fish yields were significantly different among the stocking densities for GFY (F = 32.250, P = .001), NFY (F = 30.133, P = .001), and NAY (F = 30.133, P = .001). *C. gariepinus* stocked at HSD and MSD attained significantly higher yields (GFY, NFY, and NAY) than those cultured at LSD with no significant

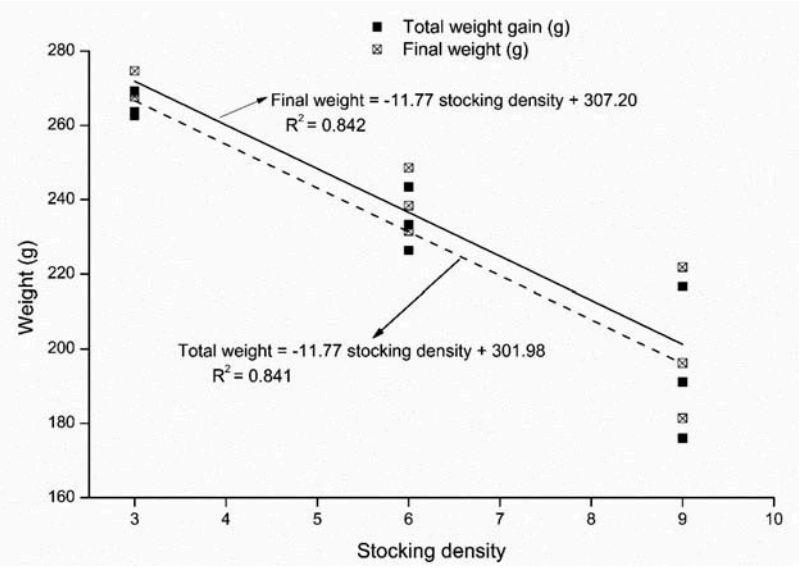


Figure 2. The relationship between stocking density (fish m^{-2}) and total weight gain (g) and final mean weight (g) of African sharptooth catfish (*Clarias gariepinus*) cultured in earthen ponds for 180 days.

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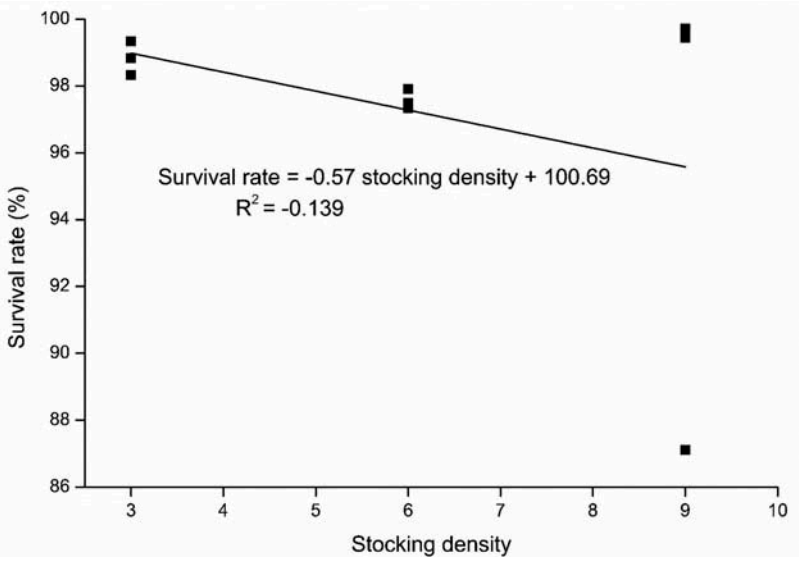


Figure 3. The relationship between stocking density (fish m^{-2}) and survival (%) of African sharptooth catfish (*Clarias gariepinus*) cultured in earthen ponds for 180 days.

difference in yields between MSD and HSD ($P < .05$; Table 2). Regression analysis results revealed that all the yields increased with an increase in stocking density (GFY, $R^2 = 0.887$; NFY, $R^2 = 0.879$; and NAY, $R^2 = 0.879$; Figure 4).

Results of partial enterprise budget analysis showed that all the experimental stocking densities produced positive net returns (Table 3). There was

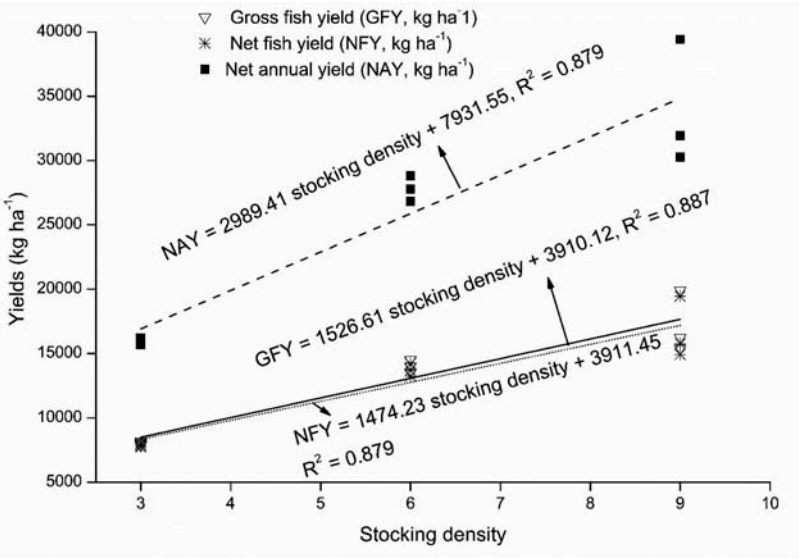


Figure 4. The relationship between stocking density (fish m^{-2}) and the yields of African sharptooth catfish (*Clarias gariepinus*) cultured in earthen ponds for 180 days.

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Table 3. Financial analysis of African sharptooth catfish (*Clarias gariepinus*) cultured at low (LSD, 3 fish m^{-2}), medium (MSD, 6 fish m^{-2}), and high (HSD, 9 fish m^{-2}) stocking densities in earthen ponds for 180 days (US$1 = TZS 1572.40).[1]

Item	Unit	LSD	MSD	HSD
Gross revenue	USD	399.73 ± 3.70[a]	697.61 ± 14.35[b]	849.77 ± 70.69[b]
Total variable cost	USD	243.82 ± 2.70[a]	446.31 ± 4.95[b]	442.37 ± 12.51[b]
Income above variable cost	USD	155.91 ± 5.87[a]	251.30 ± 17.93[a,b]	407.40 ± 78.55[b]
Total cost	USD	262.90 ± 2.70[a]	465.39 ± 4.95[b]	461.45 ± 12.51[b]
Net return	USD	136.83 ± 5.87[a]	232.22 ± 17.93[a,b]	388.32 ± 78.55[b]
Break-even yield	kg	103.35 ± 1.06[a]	180.45 ± 1.54[b]	181.39 ± 4.92[b]
Break-even price (Variable cost)	USD kg^{-1}	1.55 ± 0.03[a]	1.63 ± 0.05[a]	1.35 ± 0.13[a]
Break-even price (Total cost)	USD kg^{-1}	1.67 ± 0.03[a]	1.70 ± 0.05[a]	1.40 ± 0.14[a]

[1]Values in the same row with different superscripts (a and b) are statistically different ($p \leq .05$). Values are mean ± SE for three replicates; the analysis is based on pond area of 150 m^2.

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a significant difference in terms of income above variable cost ($F = 7.409$, $P = .024$) and net returns ($F = 7.409$, $P = .024$) among the stocking densities. The results of Tukey multiple comparisons test showed that *C. gariepinus* raised at MSD and HSD generated significantly more profit in terms of income above variable cost and net returns than those cultured at LSD ($P < .05$) with no significant difference in profits between MSD and HSD ($P > .05$; Table 3). Results further showed that there was no significant difference in the break-even price based on variable cost ($F = 3.182$, $P = .114$) and total cost ($F = 3.717$, $P = .089$) among different stocking densities (Table 3). Results of multiple regression analysis showed significant increase in gross revenue ($R^2 = 0.879$), total variable cost ($R^2 = 0.686$), income above variable cost ($R^2 = 0.655$), total cost ($R^2 = 0.686$), net return ($R^2 = 0.655$), and break-even yield ($R^2 = 0.713$) as the stoking density increased (Figure 5). However, both break-even prices (variable and total costs) did not significantly increase with an increase in stocking density ($R^2 = 0.352$ and $R^2 = 0.405$ respectively; Figure 5).

Discussion

The present study investigated the effect of stocking density on growth performance, survival, production, and financial benefits of *C. gariepinus* reared in earthen ponds. The results showed that mean weight gain, total mean weight, specific growth rate, and final weight of *C. gariepinus* were affected by stocking density. The present findings agree with previous results reported by Bok and Jongbloed (1984) and Hossain, Beveridge, and Haylor (1998) in the same species. In their findings, Bok and Jongbloed (1984) found an inverse relationship in individual growth rates and fish density in *C. gariepinus* stocked at 2.5, 5.0, and 12.5 fish m^{-2} in ponds. In another study by Micha (1975), as cited in De Graaf and Janssen (1996), testing the growth performance of *C. gariepinus*

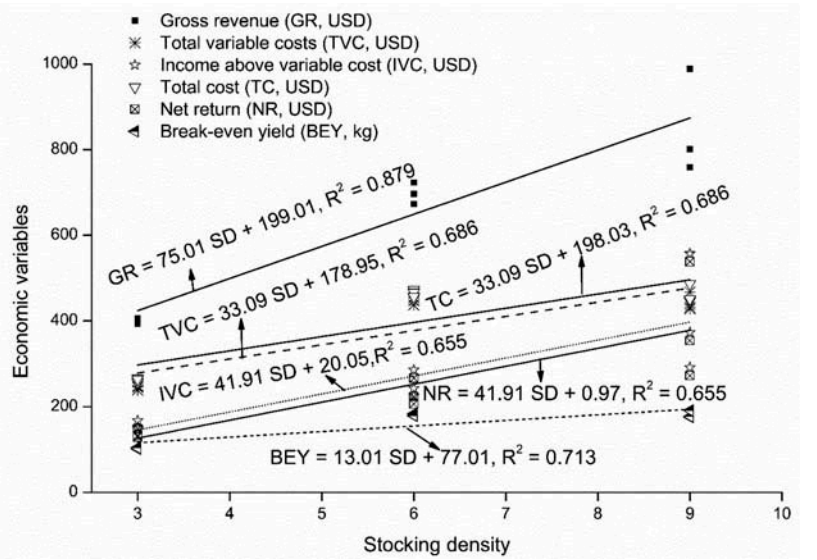


Figure 5. The relationship between stocking density (fish m^{-2}) and financial variables of African sharptooth catfish (*Clarias gariepinus*) cultured in earthen ponds for 180 days. SD means stocking density.

reared in earthen ponds at 2.0, 10.0, 20.0, and 60.0 fish m^{-2} found that, growth rate decreases with increasing stocking densities. Micha estimated an optimum stocking density of 2.0 to 10.0 fish m^{-2} for obtaining high growth rate of *C. gariepinus* in earthen ponds. However, due to its ability to tolerate high stocking densities (Bruton 1979, cited in Edward, Ladu, and Elihu 2010), the increase in number of fish as density increases overshadows the influence of growth on production and economics. Based on the findings of Micha and the results from the present study, it could be recommended to culture *C. gariepinus* in earthen ponds at 9 fish m^{-2} for optimum production and financial benefits.

Percentage survival of *C. gariepinus* in the present study was generally high (95.42% to 98.83%) with no significant difference among stocking densities. High percentage survival at higher stocking densities is attributed to air breathing and relatively high tolerance of *C. gariepinus* to poor water-quality conditions (Hecht et al. 1996, cited in Toko et al. 2007). *C. gariepinus* is known to survive under high stocking densities, especially with fully developed arborescent organs (aid in air breathing) (Adewolu, Adeniji, and Adejobi 2008; Lin and Diana 1995). The present findings suggest that farmers can culture *C. gariepinus* at a stocking density as high as 9 fish m^{-2} without affecting fish survival.

All the yield parameters of the study were significantly higher at 6 and 9 fish m^{-2} compared to 3 fish m^{-2}. Furthermore, the yield parameters were directly proportional to the increase in stocking density. Similar results on

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increase in production with increasing stocking density have previously been reported in *C. gariepinus* reared in earthern ponds (Bok and Jongbloed 1984; Shoko, Limbu, Mrosso, Mkenda et al. 2014b) and in cages (Hengsawat, Ward, and Jaruratjamorn 1997). The increase in yield as stocking density increases in the present study could be attributed to a combination of high survival and increasing stocking density (Hengsawat, Ward, and Jaruratjamorn 1997). Since the experimental stocking densities increased from 3 fish m^{-2} to 9 fish m^{-2}, the number of *C. gariepinus* was higher at the high initial stocking densities at the end of the study. Thus, the high number of *C. gariepinus* and high survival at higher initial stocking densities resulted in higher yields.

Results on financial analysis showed that positive net returns were realized in all stocking densities tested. Results further indicated that both the net profits (income above variable cost and net returns) were proportional to stocking density. These results are similar to those obtained in previous studies by Bok and Jongbloed (1984), Hengsawat, Ward, and Jaruratjamorn (1997), and Van De Nieuwegiessen et al. (2009). The positive net returns realized from the three stocking densities tested in the present study imply that farmers can make profit by stocking *C. gariepinus* at density as low as 3 fish m^{-2} (Engle 2012). However, farmers can obtain much more profit by increasing the stocking density of *C. gariepinus*. This is because financial production in cultured fish is based on yield, which is affected by survival of the cultured fish (Hengsawat, Ward, and Jaruratjamorn 1997). Because survival was the same in the present study, yield estimates were dependent on initial stocking density. Consequently, higher stocking densities of *C. gariepinus* (6 and 9 fish m^{-2}) showed significantly higher benefits than the lower stocking density (3 fish m^{-2}).

Moreover, the culture of *C. gariepinus* at the study area offers a sustainable means of financial production based on the break-even prices found. Break-even prices are important financial aspects to be considered in any enterprise because they indicate the profitability of the operation in the short and long term, provided the commodity price at the market is higher than the break-even prices obtained (Engle and Neira 2005). The fact that fish from the present study were sold at higher prices than the break-even prices in terms of variable and total cost indicates that the operation is profitable both in the short and long run (Engle 2012).

The results of the present study have shown that culturing *C. gariepinus* in earthen ponds at stocking densities of 6 to 9 fish m^{-2} leads to a higher production and profit than 3 fish m^{-2}. However, the lack of significant difference in income above variable cost and net return between medium and high stocking densities in the present study suggests that farmers can accrue higher profit by culturing *C. gariepinus* at an optimum stocking density of 9 fish m^{-2}.

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Conclusions

Based on findings from the present study, it is concluded that the stocking densities of 3 and 6 *C. gariepinus* m^{-2} allow the production of large-size individual fish. However, because of this fish's ability to tolerate high stocking densities, culturing *C. gariepinus* at 6 and 9 fish m^{-2} does not affect percentage survival and produces the highest net fish yields and financial returns. Therefore, it could be recommended that farmers stock their earthen ponds at the initial density of 9 *C. gariepinus* m^{-2}.

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