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Determination of optimum Nile tilapia *Oreochromis nilotica* (Linnaeus, 1758) (Cichliformes Cichlidae) fish stocking density in constructed ponds: a case of Chibero College, Zimbabwe

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ABSTRACT Fish growth performance is affected by stocking rate. Various fish stocking densities are given in literature. A study was carried out to determine the effects of different stocking densities on feed conversion efficiency (FCE), growth rate, pond water replenishment rate and survival rate of Nile tilapia fish, *Oreochromis nilotica* (Linnaeus, 1758) (Cichliformes Cichlidae). The study was carried out at Chibero College of Agriculture over a six-month period. In a Complete Randomized Design (CRD) fashion, 1000 uniform mono-sex fingerlings, with an average body weight of 5 g, were randomly assigned to the fish ponds at three different stocking rates: 8, 10 and 12 fish/m^2. Same feed quality (CP 45, 40, 36 & 32%) was used in the three ponds and adjusted for age and numbers in each pond. Water was checked using an elbow test and replenished once palm of the hand was not visible. One-way ANOVA in Genstat 18th edition was used to analyse growth rate data. Microsoft excel was used to plot graphs. Means were separated using Fischer's LSD at 5% significance level. The study revealed that differences in stocking densities have no significant effect on the survival rate, growth rate and feed conversion efficiency of Nile tilapia fish. However, water quality deteriorated at a faster rate in highly stocked pond. Researchers conclude that it is possible to use higher stocking densities provided feed quantity and water quality are closely monitored and adjusted accordingly. Therefore, we recommend fish farmers to take advantage of the merits brought about by higher stocking densities provided they properly monitor feed and water quality by use of such traditional methods as the elbow method.

KEY WORDS Feed conversion efficiency; growth rate; Nile tilapia; stocking density; survival rate.

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INTRODUCTION

Aquaculture is the breeding, rearing, and harvesting of fish, shellfish, algae, and other organisms in all types of water environments (FAO, 2022). With the overall increase in human population and the depletion of natural resources, fish contribute a significant amount of animal protein to diets. Aquaculture is rapidly expanding in both population and importance to human life (MAAIF, 2020).

Global tilapia production – Nile tilapia *Oreochromis nilotica* (Linnaeus, 1758) (Cichliformes Cichlidae) – exceeded 4.5 million metric tonnes in 2012 and is expected to reach 7.3 million metric tonnes by 2030 (The World Bank, 2013). The Asian region dominates the production of tilapia with around 3,000,000 metric tonnes of farmed tilapia (FAO, 2014). Growth in aquaculture production is required to meet the current per capita demand of 60,000 tonnes in Zimbabwe and to exceed the demand (Vinga, 2023). Fish culture under small scale operations have failed due to a myriad of factors including lack of knowledge regarding the management of fish in their growing environments. Currently, aquaculture production accounts for about 18,400 tonnes per annum of the total fish production in Zimbabwe. The largest industrial fish farm in Zimbabwe, Lake Harvest, produces 6,000 tonnes of fish annually in cages in Lake Kariba. Africa produced 1,177,435 metric tonnes of farmed fish in 2016. Egypt is the greatest producer, with an annual output of 940,000 tonnes, followed by Uganda, Nigeria and Ghana (Nicholson, 2018). The Nile tilapia was one of the first fish species to be cultivated in the globe and is a staple diet in many tropical and sub-tropical nations (Pompa & Masser, 1999).

After carp, Tilapias are the second-most significant fish species in the world for aquaculture, with an output of over 6 million tonnes in 2016 and a market value of 11.2 billion US$ (Prabu et al., 2019). This is due to their rapid growth rates, breeding abilities, ability to complete their life cycle in captivity, tolerance of environmental stress and strong market demand (MAAIF, 2020). The Nile tilapia culture in Zimbabwe dates back to the late 19th century, shortly after it was discovered that it performed better than carp in the tropical climate of Zimbabwe (Pompa & Masser, 1999). The local, regional and European markets all have a high level of acceptance for Nile tilapia. Additionally, the worldwide decline in capture fisheries increases the need for aquaculture expansion to close the supply-demand imbalance (Nandlal & Pickering, 2004; Bogmans & van Soest, 2021). If small-scale farmers were adequately informed about the proper tilapia fry stocking densities, which is one of an essential husbandry practice that can increase a culture system's production capacity and efficiency while also determining the economic viability of a production system in intensive aquaculture, they would be willing to embrace this new trend in aquaculture (Pompa & Masser, 1999).

Due to high input costs, Zimbabwe's small-scale fish producers frequently experience low yields that result in slim profit margins. The majority of farmers are using the range of 1 to 3 fingerlings per square metre (10,000–30,000 fish/ha) (Pompa & Masser, 1999; Chhorm & Webster, 2006) and 3 to 8 fingerlings/m^2 (30,000–80,000 fish/ha) or below (Bhujel, 2013). This setback is partially caused by a lack of understanding regarding the optimal density of fry stocking in nursery ponds to enhance output; as a result, the current study was set up with various stocking densities over a six-month period.

Currently, most fish farms use a stocking density of 4 000 fry/m^3 (Islam, 2007). Proper stocking densities will result in faster growth rate of fish thus more weight at harvest (Ronald et al., 2014). Reduced growth rate will result in use of more feed among other resources which will cause the profit margins to shrink. Good water quality and correct stocking density are important for the healthy development of the fish. Proper stocking density have benefits which include easy to manage water quality, dissolved oxygen, pH levels and ammonia levels. Therefore, it was intended for this research to provide knowledge on the optimal Nile tilapia fish stocking density that would maximize sustainability.

MATERIAL AND METHODS

Study area

The study was undertaken at Chibero College of Agriculture situated in Chegutu district, Mashonaland west province of Zimbabwe. Chibero College is located 70 km south west of Harare being 3035" east and 1806" south. The average summer temperatures ranges from 24–28 degrees Celsius and average winter temperatures range from 15 to 18 degrees Celsius. Summer temperature ranges are favourable for fish production. This results in fish production only done in summer as in winter temperatures will be low and this discourages production in winter if the ponds are not under greenhouse. Chibero College of Agriculture falls under natural region IIb which receives an annual rainfall ranging from 700 to 1050 mm (Chibero college meteorological department, 2023). Soils are clay loam soils with good drainage coupled with a gentle slope. The farmers surrounding this project site are mainly into small scale mixed farming and few are into commercial crops and livestock production.

Experimental design

Males of Nile tilapia fry were stocked in a completely randomized design (CRD) with three treatments (varied stocking levels) replicated twice. Mono sex refers to the culturing of either all male or all female fish (Ventura, 2018) employing the technique of sex reversal. Sex reversal was done using synthetic hormones in the fingerlings' early life. Ponds were divided into three treatments viz.:

Treatment A (T_1) (Pond A) with 8 fingerlings per square metre, resulting in a total of 1,500 fingerlings in this pond.

Treatment B (T_2) (Pond B) with 10 fingerlings per square metre, resulting in a total of 1,850 fingerlings in this pond.

Treatment C (T_3) (Pond C) with 12 fingerlings per square metres, resulting in a total of 2,250 fingerlings in this pond.

The size of each pond was 283.5 m^3.

Fingerlings collection and stocking

Fingerlings were purchased from a registered trader in the fingerling fish sector. Sex-reversed fingerlings were employed in all treatments. Each fry weighed 5 g on average. Throughout the trial period, the ponds were kept clean and using proper husbandry methods.

Figure 1. Feeding fish on pond shallow ends: Chibero College of Agriculture, Chegutu district, Mashonaland west province of Zimbabwe.

Fish pond design and management

The fish ponds were all rectangular in shape, measuring 18 metres long by 10.5 metres wide by 1.5 metres high for a total volume of 283.5 m^3. To get rid of parasites, germs, and other undesirable creatures before the experiment started, the ponds were drained and allowed to sun dry for two weeks. To encourage plankton growth and the necessary water quality, inorganic fertilizers at a rate of 4 kgs of ammonium nitrate and 1–2 kgs of phosphorus per hectare were administered. During the first two months after stocking, when the fish were still young (10–50 g), fertilization of the ponds was done on a weekly basis to encourage plankton growth. Constructed ponds were used which had a dam liner underneath. An improved aerator system was mounted at the pond site to improve dissolved oxygen.

Management of fish in ponds

Feed management. A formulated feed supplied was used, feeding was done in the morning at 9:30 and in the afternoon at 14:30 everyday. The feeding times were maintained from fingerlings to adult stages. Feeding was done when the water was warm and fingerlings will be moving about, checking for mortalities and other ill health was also done at that time. The feeding regime is shown in Table 1.

Feed crude protein (45%) was the highest for the starter and it declines as the fish grows with grower having 32% CP.

Feed was put on the same position on shallow ends (Fig. 1) of the ponds as a way to monitor and check fish behaviour.

Water management. When water starts to turn green it means there will be excess nutrients in the water from the feed promoting excess plankton growth. This can be tested so that you know if it is still good for fish survival through the use of the Elbow test for checking water quality in a pond (Chibero College of Agriculture, 2020).

Product	Size of pellets	Crude protein (%)	Fish size (grams)	Duration of using feed (weeks)
Starter 2	Medium crumble	45	1-5	3
Starter 3	Large crumble	45	5-15	3
Juvenile 1	Small pellets	40	15-50	4
Juvenile 2	Medium pellet	36	50-100	4
Grower	Large pellet	32	100-300	10

Table 1. Feeding regime for Nile tilapia fish in Chibero College of Agriculture, Chegutu district, Mashonaland west province of Zimbabwe.

- Dip your hand into the water to elbow level.
- If you just barely see your palm it should be green in colour showing enough nutrients for fish.
- If pond water is too clear there are not enough nutrients in pond. One can clearly see the palm of her hand in water from the elbow level. Rectify by adding fertilizer to the pond to supply nutrients which promote plankton growth.
- When pond water is grey and bubbly, the pond is over fertilized and oxygen will be escaping the pond hence the bubbles. The palm of the hand cannot be seen at elbow level. This can be rectified by adding more water to the pond.

Measurements. Data on growth rate was gathered monthly to evaluate the effects of stocking density, and daily survival rates were assessed by looking for dead floating fish in the water. In order to reduce handling stress, weight increase was assessed once a month using a spring balancing scale. To calculate feed conversion efficiency (FCE) at the conclusion of the trial, feed quantity was recorded.

Sampling. Experimental fish samples were taken at random intervals every 30 days using a seine net (2 m height, 10 m length, mesh A7) to evaluate the fish's ability to grow. To determine the mean weight, 5% of the fish from each pond were sampled.

Data analysis. One-way ANOVA in Genstat 18th edition was used to analyse growth rate data. Microsoft excel was used to plot graphs. Means were separated at 5% significance level using Fischer's LSD.

RESULTS AND DISCUSSIONS

Growth rate of Nile tilapia under different stocking densities

The growth rate values of Nile tilapia monosex were observed to average 127, 89 and 80 grams in T_A, T_B and T_C, respectively (Table 2).

According to the study, there were no appreciable impacts of stocking density at a 5% significant level on the growth rate of Nile tilapia fish. The findings are at odds with those of Ronald et al. (2014), who found that stocking density had a substantial impact on the growth rate of fish. The extent of stocking rates utilized in the two researches, as

Treatment	Treatment Mean
TA	127
TB	89
TC	80
Grand mean	99
CV %	74.6
LSD	82.7
p	0.464

Table 2. Growth rate results of Nile tilapia fish.
Key: TA = 8 fish/m^2; TB = 10 fish/m^2; TC = 12 fish/m^2.

well as the differing environmental conditions or locales, may be the cause of discrepancies in the results. As we increased the stocking density of monosex tilapia, the specific growth rate values were noted to be 3.36, 3.30, and 3.17. The growth rate (size as indicated by weight) was observed to gradually increase with the reduction in stocking density, even if the growth was statistically the same. This recent finding is consistent with research by Islam (2007), Begum (2009), and Rahim (2010), which found that particular growth rates were highest at the lowest stocking densities. Hossain (2007) attained a specific growth rate that was in the 3.14 to 3.32 percent range.

Growth performance of the fish over time is plotted in Fig. 2.

Although treatment A, with less fish per area, had slightly higher growth rates, the differences were not statistically significant. Therefore, farmers can take advantage of using higher stocking densities on limited land.

Feed Conversion Efficiency for Nile tilapia fish on different stocking densities

The average values of Feed Conversion Efficiency of monosex Nile tilapia were observed to be 1.28, 2.17 and 2.47 in T_A, T_B and T_C, respectively (Table 3).

Hossain (2007) and Rahim (2010) found a greater feed conversion efficiency (FCE) in higher stocking density and a lower FCE in lower stocking density, in contrast to the findings of this study. According to research by Hossain (2007) and Rahim (2010), monosex tilapia had a lower Feed Conversion Ratio (FCR) in ponds with low stocking densities (150 fish per decimal) and a higher FCR (1.59) in ponds with high stocking densities (250 fish per decimal). A higher FCE in lowly stocked ponds was found in the current study, and this was attributable to less resource competition in the surrounding environment.

Effect of different stocking densities on frequency of fish pond water replenishment

The elbow test was used to continually maintain the water exchange level in the ponds at 15% of pond capacity and the pea green color of the water. A sign that the water quality is poor is when one is unable to see the palm of his hand after dipping it up to the elbow. To increase the ponds' ability to

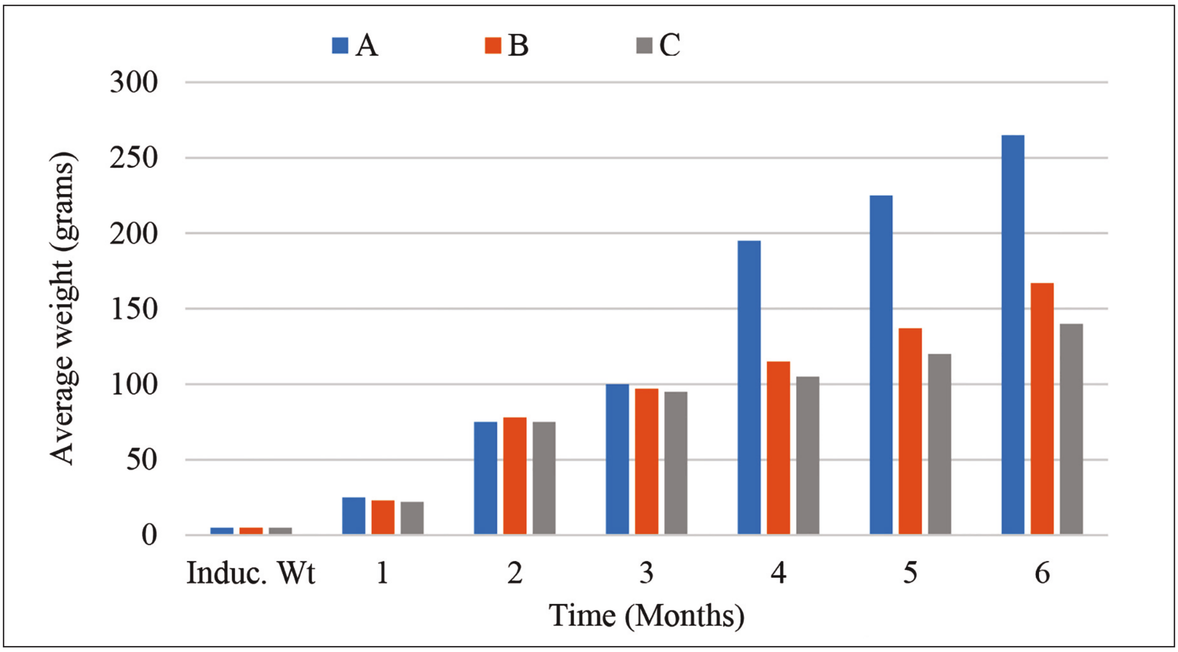

Figure 2. Monthly average growth rate of Nile tilapia fish at different stocking densities in Chibero College of Agriculture, Chegutu district, Mashonaland west province of Zimbabwe.

Group	Amount of feed consumed (kg)	Weight (kg)	Feed Conversion Efficiency (FCE)
Treatment A	500	390	1.28
Treatment B	650	299.25	2.17
Treatment C	750	303.75	2.47

Table 3. Feed Conversion Efficiency per each treatment in Chibero College of Agriculture, Chegutu district, Mashonaland west province of Zimbabwe. Key: Treatment A = 8 fish/m^2; Treatment B = 10 fish/m^2; Treatment C = 12 fish/m^2.

Treatment	Frequency
TA	4
TB	7
TC	13

Table 4. Water replenishment over a period of six months. Notes: Treatment A (TA) = 8 fish/m^2; Treatment B (TB) = 10 fish/m^2; Treatment C (TC) = 12 fish/m^2.

hold oxygen, an aerator was utilized. According to the study, water replacement frequency needs to be raised for larger stocking densities. Treatment T_A has the lowest replenishment rate due to its lowest stocking density (Table 4).

Current study results are in line with Chhorm & Webster (2006) findings who revealed that stocking density has an effect on water replenishment rate of fish.

The Nile tilapia survival rate at various stocking densities

Treatment A (T_A) recorded the best survivability (96%) and T_C had the lowest survivability (63 percent). High competition for food and space among the fish as well as variances in pond climatic circumstances were thought to be the causes of the variation in survivorship. Rahman (2000) noted a more-or-less comparable survivability and recorded a survival rate range of 94 to 96 percent in semi-intensive tilapia growth. In terms of survival, the highly stocked pond (12 fingerlings per square meter) had a higher (63 percent) mortality (Fig. 3).

At 5% significant level, the research reviews that different stocking densities have no significant effect on Nile tilapia survival rate. Mensah et al. (2013) cements the findings in the current study as he avers that stocking density has no effect on mortality when fish are reared in different stocking density compared to when raised in constructed ponds. During the sex reversal treatment in the study, testosterone treatments had no discernible influence on the growth and survival of *O. niloticus* fry. It was discovered that treating fry at a higher stocking density had a substantial impact on their growth, feed conversion, and yield, but not on their survival. Although there was no significant difference in the profit index between the treatment groups, the trial's cost-effective treatment with high survival and strong growth was low stocking density (Mensah et al., 2013). The findings of this study show that increasing stocking density in Nile tilapia fry leads to homogeneous growth and that survival rate is only considerably impacted by stocking density at the extremes (Ronald et al., 2014). During the sex reversal treatment in their study, Mensah et al. (2013) observed that testosterone treatments had no discernible influence on the growth and survival of Nile tilapia fry. It was discovered that treating fry at a higher stocking density had a substantial impact on their growth, feed conversion, and yield, but not on their survival (Mensah et al., 2013). The findings of this study show that increasing stocking density in Nile tilapia fry leads to homogeneous growth and that survival rate is only considerably impacted by stocking density at the extremes (Ronald et al., 2014).

CONCLUSIONS

This study shows that if water quality is appro-

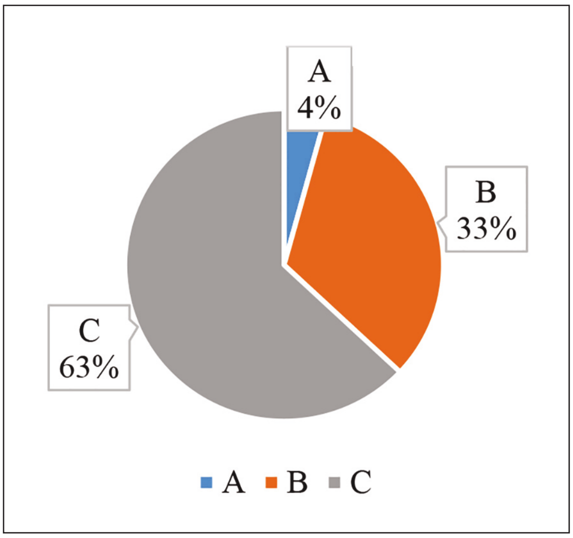

Figure 3. Share of mortality rate during the trial period. Notes: A = 8 fish/m^2; B = 10 fish/m^2; C = 12 fish/m^2. Mortality is expressed as a proportion of total deaths in all ponds under the trial.

priately changed based on the elbow test results as a strategy to maintain the water environment quality, increasing stocking density in Nile tilapia fish has no effect on Feed Conversion Efficiency and growth rate. According to the study, raising the stocking density of treated fry to 12 fry/m^2 had no appreciable impact on survival. There was no discernible change in growth rate, feed conversion efficiency, or mortality across different Nile tilapia stocking densities at the 5% level of significance.

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