

Investigation of the impact of stocking density on the production of *Oreochromis niloticus* fry in hapas

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Abstract

The aim of this study was to determine the stocking density that maximizes the commercial production of *O. niloticus* fry in hapas at Lake Harvest Aquaculture. The study was conducted over a period of nine weeks. Three stocking densities of 4500 (A), 8000 (B) and 11500 (C) fry/hapa with four replicates each were used in the study. The stocking density of 4500 was used as the control. Fry were fed with a mixture of fry meal (40% Crude Protein) and crumbles (30% Crude Protein) in a ratio of 1:2 respectively using the Lake Harvest Aquaculture Feed Chart. Weekly random fry sampling was done, with a sampling intensity of 60 % for all replicates to determine average body weight per treatment. The average body weight was used to determine fry growth, feed conversion ratio and the computation of fry survival rates after the final harvest. Data was tested for normality using the Kolmogorov – Smirnov ($p < 0.05$). A one way analysis of variance was computed for all variables at 5 % level of significance. Stocking density had no significant influence on fry growth ($p = 0.603$), fry survival, ($p = 0.774$) and feed conversion ratio ($p = 0.304$). Since the stocking densities used in this study did not influence fry growth, survival and feed conversion ratio, we conclude that the current stocking density at the farm was low and rather conservative. Consequently, we recommend that Lake Harvest Aquaculture use a stocking density of 575 fry/m³ in order to increase fry production. For a more convincing validation of this study, it would be necessary to conduct a replica of this study with much higher stocking densities for the optimization of fry production at Lake Harvest.

Key words: *Oreochromis niloticus*, Fry, Feed conversion ratio, Hapa, Stocking density

Introduction

The culture of Nile tilapia (*Oreochromis niloticus*) can be traced to ancient Egyptian times as depicted by bas-relief from Egyptian tombs dating back over 4000 years ago, which showed the fish being held in ornamental ponds (Beveridge *et. al.*, 2002). Nevertheless, significant worldwide distribution of tilapia, primarily *Oreochromis mossambicus* occurred during the 1940s and 1950s, whilst distribution of the more desirable *O. niloticus*

occurred during the 1960s up to the 1980s (Little *et. al.*, 1993). Since the introduction of *O. niloticus* in local systems in the 1980's the species has been intentionally introduced into many farm dams and subsequently found its way into the various lakes and rivers of Zimbabwe (El- Sayed, 2007). In the culture of *O. Niloticus*, true hapa culture, in which fish or other organisms are held for long periods of time whilst they increase weight, is of comparatively recent origin and seems to have developed independently in a number of countries,

mostly in South East Asia (Bentsen *et al.*, 2001; Hossain *et al.*, 2004). Hapa systems are more advantageous over the traditional pond systems in that they improve feeding effectiveness since feed can easily be spread by hand in the hapa (Bentsen *et al.*, 2001). In some instances, hapas have recorded better feed conversion ratios and survival rates as they also offer a shield to fry against reptilian predation, (Dionisio *et al.*, 1997). The system offers an enormous opportunity for close monitoring of fry or fish condition and enhances the harvesting of fry and fingerlings as compared to the pond system in which 30 % of fish stocked may die during harvesting (Hossain *et al.*, 2004).

However, optimum stocking density of *O. niloticus* fish has attracted interest from researchers around the globe (Khattab *et al.*, 2000; Jamu, 2003; Chowdhury *et al.*, 2004). This is partly because of environmental conditions that differ from place to place and partly because *O. niloticus* has proved to be resilient to the effects of high stocking densities (Dionisio, 2001). Three main factors are postulated to affect the choice of a stocking density namely, water quality (oxygen availability), feed availability and objectives of the farmer. Target size at harvest and desirable biomass at harvest can also affect the choice of stocking density on a unit area (Watanabe, 2000). The need to maintain high productivity while maintaining water quality has also led many researchers into stocking density studies (Dionisio, 2001). Ever since the establishment of Lake Harvest, survival rates of fry in fry holding ponds are too low averaging 54%.

To ensure that the production chain at the farm is not disrupted, surplus fry should be produced during the summer season to cater for the winter months when no breeding takes place. One way of achieving this management objective is by recuperating fry survivals during the breeding season. Consequently, this establishment has necessitated the introduction of the hapa system to curb this draw back to fry production at the farm. However, no stocking densities optimum for fry production in hapa systems at the farm and prevailing environmental conditions have been established. Consequently, the study aimed at determining the stocking density that optimises the commercial production of *O. niloticus* fry in hapas at Bakerton farm.

Methods

Study area

Lake Kariba is located in Mashonaland West province of Zimbabwe, on the north eastern border with Zambia. The latitudinal positions are 16° 30' - 17° 00'S and 20° 00' - 29° 40'E. The altitude of Kariba is about 540m above sea level. The climate is generally tropical with three distinguishable seasons: a hot rainy season from late November to March, a cool dry season from May to August and a very hot dry season from September to early November. Annual rainfalls range from 400 mm to about 700 mm. Winter temperatures rarely go below 13 °C; daytime temperatures are at about 40°C during the hot months (Timberlake, 2000). Notorious fish predators include the African fish Eagle (*Haliastur vocifer*), the crocodile (*Crocodylus niloticus*) and the monitor lizard (*Varanus niloticus*) (Timberlake, 2000).

Experimental Animals and Stocking Density

Three stocking densities were chosen for comparison during the nine-week experimental period, A= 4500 fry/hapa i.e. 225 fry/m³, B= 8000 fry/ hapa i.e. 400 fry/m³ and C= 11500 fry/hapa i.e. 575 fry/m³.

Since Lake Harvest fish are not fed on natural feed, the feed supply model was not used in the study. Consequently, stocking density A was used as the study control since this was the one in use prior to the study. Hapas were pegged in six rows and each was composed of two hapas making a total of twelve hapas. An inter row and in row spacing of 2.5m was used. Hapas were then labeled one to twelve using metal tags. Letters A (4500 fry/hapa), B (8000 fry/hapa) and C (11500 fry/hapa) representing three stocking densities, with four replicates per treatment, were randomly assigned to the hapas.

Harvesting Fry for Stocking

Fry were initially starved for 24 hours prior to harvest, as a way of reducing stress during harvesting. Fry harvesting from tanks to the hapas was conducted early in the morning to reduce heat stress.

The volumetric method was used to obtain the ABW of the fry (Hopkins, 2002; Chowdhury *et. al.*, 2004; Hossain *et. al.*, 2004):

$$ABW = (Y - X)/N \dots\dots\dots (1)$$

Where, ABW = average body weight of fry, Y = final volume of water with fry, X = initial volume of water without fry, N = number of fry scooped into the measuring cylinder.

Feeding Fry

Fry were starved for two days before feeding commenced. During the first week, fry were fed on fry meal while in the second week; fry were fed a mixture of fry meal (40% Crude Protein) and crumbles (30% Crude Protein) in a ratio of 1:2 respectively. This was done to cushion the protein content of feed since crumbles have lower protein content than that recommended at this stage (Ferdouse *et. al.*, 2001). It was also done to cater for smaller fry that had not grown enough to feed on crumbles (Ferdouse *et. al.*, 2001).

From the third week until the termination of the experiment, 30% crude protein crumbles were fed following the feed rate and growth chart at the farm. Feeding regimes were conducted four times a day owing to the prevailing weather conditions (Kimball, 2001). Replications of each stocking density were assumed to have the same biomass, thus the same feed rate was applied throughout the experimental period. Survival rate was also assumed to be 100% as per the initial stocking numbers, thus biomass was calculated in accordance with the number stocked (Ferdouse *et. al.*, 2001). Daily Feeding Rate (DFR), the amount of feed to be fed on a daily basis (Kimball, 2001) was calculated using the following model:

$$DFR = \text{Hapa Biomass} * \text{Feed Rate} \dots\dots\dots (2)$$

Where Hapa Biomass = ABW * number of fry stocked

Feed Rate: 15 % of ABW for week 1 and week 2.
10 % of ABW for week 3 to week 9.

Specific Growth Rate, Feed Conversion Ratio and Survival Rate

The first samples were taken after seven days of stocking. Fry were randomly sampled from the hapas at 60% sampling intensity per hapa (Dey, 2003), on a weekly basis for eight weeks. The ABW of the fry was obtained from the samples and used to obtain the FCR and fry growth rate (Dey, 2003).

The specific growth rate (SGR), feed conversion ratio (FCR) and survival rate of fry were determined according to (Dey, 2003):

$$SGR = (ln W_{ik} - ln W_{ip}) * 100 \% / (T) \dots\dots\dots (3)$$

Where, W_{ik} = final mean individual fish mass, W_{ip} = initial mean individual fish mass, T = number of days elapsed.

$$FCR = P / (W_k - W_p) \dots\dots\dots (4)$$

Where, P = amount of feed fed (kg), W_k = final biomass of fish (kg), W_p = initial biomass of fish (kg).

Survival rate of stocked fry was obtained after harvesting all the hapas at the end of the experiment. The number of harvested fish was obtained by dividing the total hapa biomass by the ABW of fry. This was done for all the replications of each stocking density. The survival rate was obtained by the formula:

$$\text{Survival Rate} = (N_x / N_y) * 100 \% \dots\dots\dots (5)$$

Where, N_x = number of fish harvested, N_y = number of initially stocked

Data Analysis

Variables were tested for normality using the Kolmogorov – Smirnov test (Zar, 1999). Survival rates could not satisfy the normality assumptions and were Arcsine transformed. One-way analysis of variance was then employed to determine if there were any significant differences in the growth rate, FCR and survival rates of fry in the three stocking densities at 5 % level of significance. Post hoc analysis of the data was conducted through the least significant differences. All tests were conducted using the Statistical Package for Social Scientists (SPSS) version 15.0.

Results

Fry Growth

Results obtained from the study showed that there was no significant difference ($p = 0.603$) in the fry growth rate at different stocking densities, indicating that stocking density had no effect on fry growth. The average fry mass over the nine week period is shown in table 1 below.

Stocking density (fry/m ³)	N	Initial fry weight (mean ± SE)	Final fry weight (mean ± SE)	Mean daily gain (g/day)
225	32	0.160 ± 0.017	4.767 ± 0.033	0.0731
400	32	0.160 ± 0.017	4.833 ± 0.067	0.0742
575	32	0.160 ± 0.017	4.533 ± 0.031	0.0720

Table 1: Average fry weight per stocking density over the experimental period

The average body mass of fry in the three stocking densities over the nine week experimental period

is illustrated in Figure 1 below.

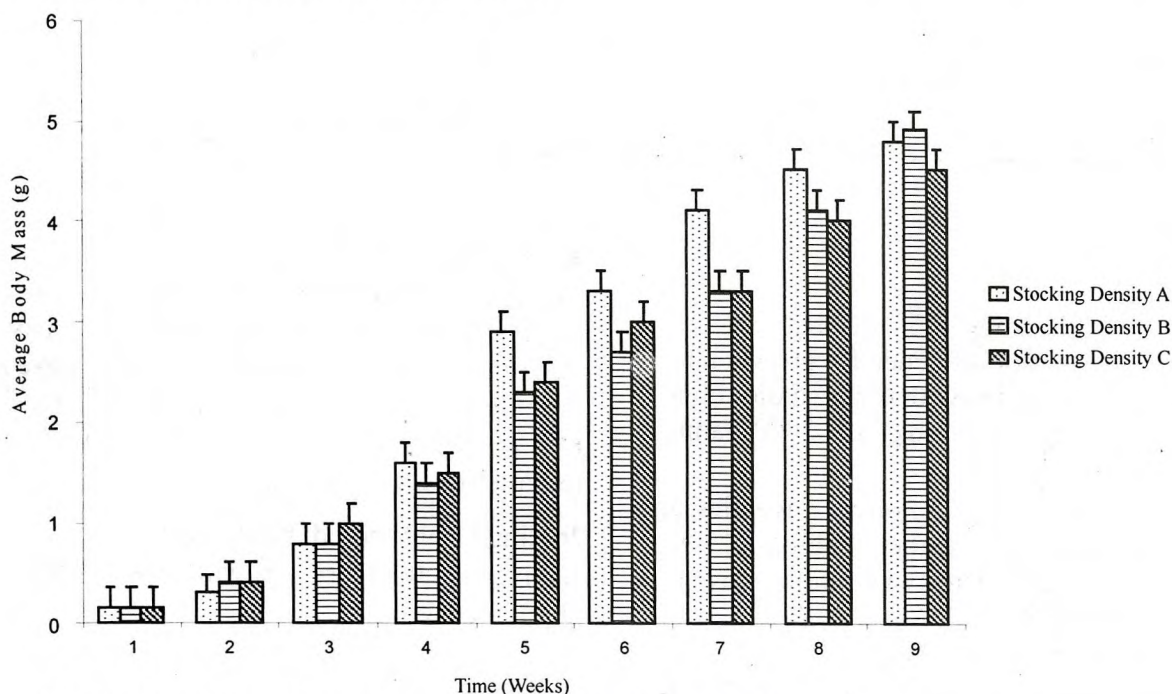


Figure 1 Average fry body mass over the experimental period

Survival Rates

The average survival rates for the three stocking densities over the nine week experimental period are shown in Table 2 below.

Table 2: Mean survival rate for the three stocking densities over the experimental period.

Stocking Density	N	Mean Survival ± Std Error
A	4	64.2025 ± 3.1273
B	4	66.9525 ± 3.7353
C	4	64.1900 ± 2.6261

There were no significant differences ($p = 0.774$) in the survival rates of fry for the three stocking densities over the nine week period.

Feed Conversion Ratio

The feed conversion ratios of the fry at different stocking densities were not significantly different ($p = 0.304$) over the entire experimental period.

The average FCR values for the three stocking densities for the nine week period are shown in Table 3 below.

Table 3: Mean FCR values for the three stocking densities for the experimental period

Stocking Density	N	Mean FCR ± Std Error
A	4	2.7000 ± 0.3749
B	4	2.2500 ± 0.0289
C	4	2.6000 ± 0.4082

Discussion

Growth Rate

The findings of this study indicate that stocking density in hapas does not influence fry growth rate. This establishment concurs with other studies done using the same species (Khatab *et. al.*, 2000; Jamu, 2003; Hussain, 2004).

In a separate study with *O. niloticus* juveniles at three differing stocking densities, Jobling (1999) established that stocking density variations may not affect the growth of the fish. Khatab (2001) also concluded that stocking density does not affect fry growth after a study with six significantly differing stocking densities.

Although stocking density contributes to the accumulation of metabolites of decomposing faecal wastes, *O. niloticus* fry seem to be more resilient to the poor water quality conditions that may arise (Khatab, 2001). Furthermore, fry have been observed to move in schools and may suggest that *O. niloticus* fry are more adaptable to overcrowding (Khatab *et. al.*, 2000; Jamu, 2003; Hussain, 2004).

Jobling (1999) noted that stocking density is much likely to affect fry growth when feed is not supplemented.

The use of a complete commercial diet at the farm ensured that feed was in *ad libitum* and as such stocking density did not influence fry growth rate. This concurs with the findings of Hussain (2004) who established that when a complete commercial diet is provided, stocking density has minimum effect on growth. The high water flow rate system ensured a continuous dilution and removal of faecal waste thus minimising the effect of toxicity and anorexic conditions. As such, high stocking densities would have minimum effect on the growth rate of the fry as observed by Jamu (2003). Moreover, the fact that *O. niloticus* fish are tolerant to conditions of poor oxygen enables them to thrive even under conditions of high stocking densities maintaining their growth rates as a result (Khatab *et al.*, 2000; Khatab, 2001; Hossain *et al.*, 2004).

However, Jensen, (2000) recognised a decline in growth of fry stocked at 2000 fry/m³, 4000 fry/m³, and 5000 fry/m³. Thus, as stocking density per cubic meter increases, a decline in growth has been recognised by other researchers (Tacon, 1997; Watanabe, 1999; Watanabe, 2000; Varandaraj, 2001). This could be attributed to an increase in competition for feed resources and space. However, even though Jensen (2000) observed a decline in growth rate at 500 fry/m³, a maximum stocking density of 575 fry/m³ of the current study did not alter growth rate in any way.

This variation may be attributed to the environmental conditions as well as husbandry differences of these studies. Nevertheless, Watanabe (2000) argue that when stocking densities seem to have no effect on fry growth, it may be an indication that absolute carrying capacity might not have been reached or exceeded. As such, ability of *O. niloticus* to grow at high densities has led researchers to insufficiently conclude that growth of *O. niloticus* is not affected by stocking density (Shackel *et al.*, 2004).

Such sedations may only obstruct a theoretical aquaculturist in his or her quest for true understanding of tilapia aquaculture.

Survival Rate

The findings of this study revealed that there was no significant difference in the survival rates of fry stocked at three different densities. This is in agreement with results obtained by Pardon (2001) illustrating that survival of *O. niloticus* is hardly affected by the effects of high stocking densities. However, it has been noted that starvation, poor fry handling, avian and reptilian predation (McAndrew *et al.*, 2004) and cannibalism (Pardon, 2001) may result in fry mortality thereby reducing the survival rates of stocked fry. On the contrary, it has been observed that *O. niloticus* may attain a survival rate of 96-98 % in properly managed systems (Pardon, 2001; McAndrew *et al.*, 2004). Thus the high survival rates as well as insignificant differences across the stocking densities may be attributed to the use of predator nets as well as continuous monitoring of the hapas at the farm.

Feed Conversion Ratio

Siddiqui *et al.*, (2000) observed no differences in the FCR of *O. niloticus* reared in brackish water fed on a 34% protein diet at stocking densities of 1632 and 426 fry/m³. This corresponds to the findings of this study where a diet with similar protein content was used. Similarly, Watanabe *et al.*, (2000) established that, the FCR of Florida *O. niloticus* fed on 32% protein level did not differ at densities ranging from 100 - 300 fry/m³. Nevertheless, it must be noted that FCR was generally poor among the three stocking densities as compared to the findings of Maharathi (2002).

However, this is in contrast to Jobling (2004) who established a high FCR of 1.3 in fingerlings fed with a diet containing 40 % crude protein reared in lagoon nets.

More so, other variables such as temperature, dissolved oxygen and pH may have significantly impacted feeding response and consequently attributed as poor feed conversion ratio (Kimball, 2001; Hopkins, 2002; Jobling, 2004).

Conclusions

According to the findings of this study, we conclude that stocking density has no influence on the growth rate, survival and feed conversion ratio of *O. niloticus* fry when raised in hapas. Consequently, we recommend a stocking rate of 575 fry/m³ rather than the current of 225 fry/m³. However, the current study did not surpass the optimum stocking density as in other studies which makes it difficult to recommend an optimum fry stocking density in hapa systems. As such, a further study to establish the optimum stocking density in hapas for fry production at Lake Harvest Aquaculture is highly recommended.

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