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The Effects of Stocking Density on the Growth and Survival of Nile Tilapia (*Oreochromis niloticus*) Fry at Son Fish Farm, Uganda

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Abstract

Besides affecting land usability that subsequently impacting on profitability of an aquaculture venture, stocking density is believed to affect growth rate and survival of fish species stocked. In this study, Nile tilapia fry were randomly stocked at densities 1000, 1330, 2000, 2670, 4000 and 5330 fry/m^3 for an experimental period of 23 days. All fish were fed a commercial feed (45% protein) at levels of 20, 18 and 15% body weight in week one, two and three. The impact of stocking density on standard length, body weight, survival, growth homogeneity, specific growth rate and feed conversion ratios was determined on samples taken weekly for the experimental. A negative correlation between stocking density and growth rate was recorded. Survival was lowest with high stocking densities, 87% at 4000 fry/m^3 and 82.9 at 5330 fry/m^3.Results demonstrate that increasing the stocking density of Nile tilapia fry beyond 2670 fry/m^3 significantly affects survival and growth of fry (ANOVA).

Keywords: Fish farm; Nile tilapia

Introduction

Background

Tilapias are the world's second most important fish species for aquaculture after the carp and this is due to their high growth rates, being prolific breeders, completing their life cycle in captivity, tolerance to environmental stress and high market demand [1]. Nile tilapia culture in Uganda traces way back in the late 1940's just after it had proved to do better than the carp in Uganda according to experiments that were carried out at the by then Kajjansi Experimental Station [2] The culture of Tilapia expanded exponentially until a more recent overtake by the catfish making Tilapia now, Uganda's second most cultured fish species. Nile tilapia is widely accepted on the Ugandan local market, regional markets and is also exported to the European market. Furthermore, the declining capture fisheries worldwide, (Gabriel et al., 2007 drives an increased need for aquaculture expansion in order to bridge the gap between production and demand. For Uganda, this new wave of aquaculture would be fully endowed by small scale farmers if they had adequate knowledge on the appropriate Nile tilapia fry stocking densities as it is believed to be a critical husbandry practice that can boost the production capacity and efficiency of a culture system [3] in addition to determining the economic viability of production system in intensive aquaculture [4]. Stocking densities of Nile tilapia fry normally range from 3000 to 4000 fry/m^3. However a stocking density as high as 20,000 fry/m^3 is also practical given good water quality [5]. SON Fish Farm is currently using a stocking density of 4000 fry/m^3 in 2x1x1 meter hapas and most fish farms in Uganda don't deviate much from this density. However, the basis of this stocking density is not justified and the definite best stocking density is not known. It is on the basis of this knowledge gap that the current study was proposed.

Problem statement

Fish farmers in Uganda in the grow-out sector often face low yield that culminates in low profit margins given input costs. This setback, to some extent stems from lack of sufficient knowledge on the best practice of fry stocking densities in hapas or nursery ponds that would maximize production. For this reason, a study was proposed to address the concern in a local setting that could be representative of various potential fish farm sites in central Uganda.

Justification

The research was envisaged to give knowledge on appropriate stocking density of tilapia fry that would maximize production and profitability of grow-out aquaculture enterprises.

Objectives of the study

Major objective: To establish the most appropriate stocking densities for Nile tilapia fry in hapas set in earthen ponds.

Specific objectives: To investigate the effects of stocking density on feed conversion ratios (FCR) of Nile tilapia stocked in hapas in earthen ponds.

- To determine the effect of stocking density on growth homogeneity of Nile tilapia fry in hapas in earthen ponds.
- To compare the growth (daily weight gain (DWG) and specific growth rate (SGR) rate) at different stocking densities.
- To determine the survival rate of Nile tilapia fry at various stocking densities.

Hypotheses

H_o: Stocking density does not affect feed conversion ratios in Tilapias

H_o: Stocking density does not affect growth homogeneity of Nile tilapia fry.

H_o: Stocking density does not affect growth of Nile tilapia fry.

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H_o: Survival rate of Nile tilapia fry is independent of stocking density.

Methods and Materials

Study site

The research was carried out at Source of the Nile (SON) fish farm, a mono-sex tilapia culture fish farm located in Bugungu, Njeru sub county in Buikwe district. One of the primary nursing ponds at this farm (G ponds) were used for the experiment (Figure 1).

Research design

The case study involved stocking Nile tilapia fry at different stocking densities and maintaining uniform management practices for a period of four weeks. Data was collected weekly to assess impact of stocking density on survival and growth of fry.

Experimental design

Two replicates were used for each treatment and these were fed on 20%, 18% and 15% body weight in week 1,2 and three respectively. This was done using a 45% crude protein feed.

Specific methods

Harvested fry of mean length 12.4 ± 0.16 mm and mean weight of 0.03 ± 0.0016g originating from the same brood were randomly selected and stocked in hapas in various stocking densities that is;1000fry/m^3, 1330 fry/m^3, 2000fry/m^3, 2670fry/m^3, 4000fry/m^3 and 5330 fry/m^3, respectively . Fish were fed manually with 20%, 18%, and 15% of body weight daily for the first week, second week and for the rest of the experiment duration, respectively. Aquatro feeds (45% crude protein) obtained from Livestock Feeds Limited (LFL) in Mauritius were used for three weeks with a feeding frequency of eight rounds per day. Every after one week, measurements were carried out on fish fry between 09:00 -11:30 am depending on the weather of the day and finally at the time of grading. Standard length and body weight were taken to the nearest millimeter and nearest 0.01g, respectively using calibrated graph paper and a mini digital pocket gram scale. The fish were removed from the hapas between the 24th and 25th day and graded. To determine survival at grading time, number of fish in the hapa was established and computed against the number at stocking.

Growth performance analysis: Fish Growth Performance was evaluated basing on Specific Growth Rate (SGR), Food conversion Ratio (FCR), Survival Rate (SR) and Daily Weight Gain (DWG) using the formulae below:

$$\text{SGR (\% per day)} = \frac{(Logn\,Wf - LongnWs)}{T} \times 100$$

Where: Wf = Final weight of fish; Ws = Weight of fish at Start; T = Duration of nursing

$$\text{FCR} = \frac{amount\ of\ dry\ food\ int\,age(g)}{Fresh\ weight\ gain\ in\ fish}$$

$$\text{SR -Survival rate (\%)} = \frac{Final\ harvested\ amount}{Stocked\ amount} \times 100$$

$$\text{DWG –Daily Weight Gain} = \frac{Fresh\ weight\ gain\ in\ fish\,(g)}{Duration\ of\ nursing}$$

Statistical analysis

Data collected from the experiment was analyzed using one-way ANOVA and when ANOVA indicated that there was a statistical difference between the stockings densities means, Tukeys Tests were used to compare these means. The software of statistics calculations and model was SPSS statistics version 20 and all statistical tests considered significant at (P < 0.05).

Results

Length and weight

The mean length at the beginning of the experiment and at week one sampling were not significant for all the stocking densities (P =1.0 and 0.192, respectively). At sampling two (week two) there was a significance difference in the mean length of all the three samples (P < 0.0001). Tukeys test indicated a significance between the highest density of 5330fry/m^{3}and rest of the densities (P<0.0001) but no difference between densities 2000, 2670 and 4000 fry/m^{3}and 1330 fry/m^3 (P = 0.331, 0.955 and 0.978, respectively). By week three, fry stocked at 1000 m^3 exhibited the highest final mean length (27.471 +/- 0.331) while fry stocked at 5330 m^3 recorded the lowest (22.804 +/- 0.222). By the end of the experiment, the mean length of the six stocking densities was significantly different (P<0.0001).

The relationships between stocking density and mean length at week one, two and three samplings are shown in Figure 2.

All the stocking densities showed a gradual increase in weight with density of 1000 fry/m^3 having the greatest gain from 0.03 g average body weight at stocking to 0.43 ± 0.057 whilst 5330 fry/m^3 registered the lowest from 0.03 average body weight at stocking to 0.24 ± 0.042g by grading time (Figure 3).

Figure 1: An Aerial view of Son fish farm showing the G ponds (primary nursing ponds).

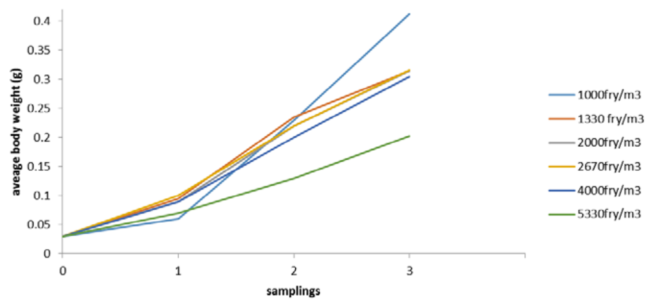

Figure 2: The relationship between mean standard length and stocking density of fry at for the three samplings.

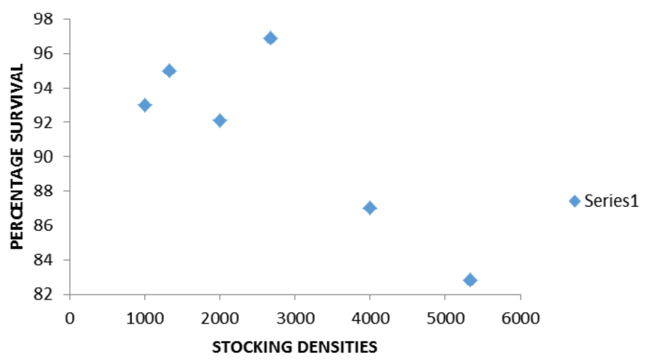

Figure 3: Relationship between average body weight and time samplings.

Survival rate

From the experiment, the results were divided into two groups depending on the percentage survival. The first group had stocking densities 2670,1330,1000, and 2000 fry/m³ in order of decreasing survival but all having high survivals of above 90%. The second group had densities 4000 and 5330 fry/m³ and these had less than than 90% as far as survival is concerned (Table 1).

There existed a high negative correlation between survival and stocking density (P= -0.835) (Figure 4).

		1ST SAMLING ON 15/6/12				
1000	**1330**	**2000**	**2670**	**4000**	**5330**	**STOCKING 6/6/12**
17	18	17	20	16	16	11
19	16	17	19	13	14	12
14	15	16	18	16	12	11
18	13	19	14	20	12	12
16	17	18	20	15	15	11
15	17	16	16	14	14	12
20	12	15	15	13	15	13
15	18	20	17	15	16	13
18	18	20	14	16	17	13
14	15	20	19	20	15	14
16	16	15	20	16	18	13
13	17	16	15	15	20	11
16	16	19	14	20	22	13
16	19	19	16	18	18	13
15	19	14	18	13	15	12
19	18	19	16	19	20	10
18	16	20	17	14	18	11
14	15	13	14	14	15	11
17	19	15	15	14	16	14
14	14	14	14	17	14	15
14	12	14	19	20	19	13
20	20	18	18	16	15	11
15	17	20	16	19	16	12
15	16	13	16	13	16	11
14	15	15	16	15	13	13
14	19	14	17	15	13	12
13	17	14	17	14	14	12
14	18	18	18	16	18	13
18	16	20	15	14	12	12
15	23	15	19	18	18	13
14	15	14	18	19	15	12
14	20	15	14	14	17	15
10	12	13	15	17	18	11
19	16	15	16	17	17	13
17	17	14	17	16	19	14
14	16	15	14	16	17	11
16	17	18	16	13	16	13
16	15	16	14	16	16	13
19	16	19	20	20	12	14
20	18	15	16	17	12	13
17	16	15	20	15	13	14
15	17	20	21	15	14	13
17	14	19	15	16	16	11
19	15	19	14	15	17	11
18	19	18	16	14	16	12
17	18	14	15	12	14	12
21	16	20	19	13	18	12
20	12	17	16	15	14	13
17	17	14	17	16	19	14
19	20	14	17	15	13	12
		2nd SAMPLING ON 23/6/12				
1000	1330	2000	2670	4000	5330	
20	17	20	16	20	19	
24	22	21	20	23	19	
25	20	20	19	20	18	
26	22	23	19	20	17	
23	22	24	20	22	17	
22	22	22	22	22	21	
20	20	24	18	21	21	
27	23	21	20	20	17	
24	23	18	19	19	18	
30	17	20	24	21	21	
23	20	24	25	20	19	
23	19	20	25	23	18	
24	24	23	19	23	17	
28	23	24	25	20	14	
22	22	23	19	24	18	
23	17	23	25	22	18	
24	20	20	25	20	16	
20	19	24	20	21	20	
22	24	22	20	20	18	
19	23	22	24	26	16	
21	22	25	22	21	18	
22	17	20	23	20	20	
18	20	24	20	23	21	
26	20	24	22	24	22	
20	25	23	22	22	15	
22	23	20	18	22	16	
22	18	22	21	21	16	
26	22	22	22	20	16	
22	19	25	20	20	20	
22	20	20	25	23	15	
20	17	19	19	20	21	
22	17	20	20	20	17	
26	25	24	17	22	17	
18	20	20	19	22	19	
21	20	23	18	22	18	
20	22	21	24	22	17	
22	25	20	20	24	16	
26	25	23	22	20	21	
18	23	21	19	16	16	

21	18	24	20	20	20	
27	23	26	19	26	21	
24	21	25	14	20	16	
23	20	20	21	22	22	
22	24	20	24	21	16	
26	21	24	19	20	22	
18	21	24	19	26	20	
21	24	23	22	21	22	
20	24	20	24	20	20	
22	21	22	19	23	21	
26	21	22	19	24	16	
18	24	22	22	23	22	
		3rd SAMPLING ON 29/6/12				
1000	1330	2000	2670	4000	5330	
30	25	25	20	26	26	
26	25	27	25	28	21	
34	26	27	23	28	22	
25	26	26	25	26	23	
31	27	26	23	19	21	
25	31	25	23	26	22	
26	26	29	23	22	22	
29	27	29	28	22	22	
22	27	26	30	27	22	
30	26	29	23	28	21	
26	25	24	26	24	23	
20	26	25	25	25	21	
29	26	25	25	27	23	
31	28	26	26	27	23	
26	24	26	26	25	22	
31	30	26	27	24	21	
29	25	20	25	24	25	
28	26	30	23	24	24	
28	25	27	29	28	22	
28	23	30	24	25	24	
32	26	28	26	25	23	
26	28	22	22	26	25	
22	29	25	23	24	26	
29	23	28	21	24	22	
20	26	25	26	22	24	
28	30	27	24	24	25	
30	27	30	25	26	21	
32	31	27	21	26	24	
27	25	24	22	24	23	
25	25	26	23	24	21	
29	27	27	21	24	21	
31	27	19	23	24	22	
32	25	28	29	23	23	
25	27	24	22	24	26	
32	26	26	21	24	20	
36	27	24	24	24	25	
27	25	29	25	22	26	
27	23	25	24	24	23	
22	28	28	23	28	22	
30	29	24	24	26	22	
30	24	28	22	28	21	
30	25	26	27	22	23	
30	27	25	22	24	21	
22	26	27	23	25	22	
29	27	27	25	24	23	
20	25	26	28	24	24	
28	23	26	27	24	25	
30	28	25	25	28	21	
32	29	29	23	25	22	
27	24	29	25	25	23	
25	25	26	28	26	24	

Table 1: stocking and sampling length data for the six stocking densities.

Food conversion ratio, specific growth rate and daily weight gain

Results of food conversion ratio (FCR) specific growth rate (SGR) and daily weight gain (DWG) are shown in Table 2. There was a great significant difference in the food conversion ratios and specific growth rates of the six stocking densities (F = …..; P<0.0001). FCR was lowest at stocking density of 1000 fry/m^3 (1.63) while 5330 fry/m^3 had the highest FCR (2.22). The daily weight gain decreased with increasing stocking density with an anomaly existing between densities of 2670 and 4000 where by 2670 had a lower daily weight gain (0.0116 g/day) than 4000 (0.0121g/day) which was higher in density. Daily weight gain and specific growth rate both decreased with increasing stocking density with 5330 fry/m^3 having almost just half the daily weight gain as 1000fry/m^3, however in both cases there was an anomaly at a stocking density of 2670 fry/m^3 which had lower daily weight gain and specific growth rate than expected.

Linear regression showed a great correlation between food conversion rate and the growth rate using mean length. (R^2 =0.878) with food conversion able to explain up to 77% of the length (R^2=0.77). There existed a very good correlation as well between stocking density and growth rate using mean length (R=0.928 and R^2=0.86). This also happened between stocking density and feed utilization or conversion level. (R^2 =0.844 and R^2= 0.712)

However the effect of stocking density on growth could not be explained by the regression (ANOVA P=0.52) while the effect of stocking density on feed utilization level and that of feed utilization level on growth were significantly explained by the regressions (P=0.035 and 0.022 respectively).

Growth homogeneity

At stocking the fry sampled fell in three homogenous groups according to length in millimeters that is, 10-11mm with 13 fry, 12-13mm with 29 fry and 14-15mm with 8 fry hence there was some degree of homogeneity at stocking. This homogeneity was however not realized by the first sampling after one week (Table 3) as length ranged in up to 5 groups in all the six stocking densities. In the second and third week samplings, there was an observed trend of increasing homogeneity with increasing stocking density. Homogenous growth was observed in the high stocking densities with all the samples in the highest density (5330 fry/m^3) falling in just three groups and 36 out of the 50 sampled being below 24 mm.

STOCKING DENSITY(fry/m3	AVERAGE BODY WEIGHT(g)	TOTAL WEIGHT(g)	NUMBER OF SURVIVALS	PERCENTAGE SURVIVAL
1000	0.43	600	1395	93
1330	0.35	665	1900	95
2000	0.34	989	2762	92.1
2670	0.32	1240	3875	96.9
4000	0.308	1608	5220	87
5330	0.24	1589	6621	82.8

Table 2: Survival rates and significance levels for the stocking densities.

The number of fry in lower higher classes (longer fry) also decreases as the stocking density increases hence shorter fry produced (Tables 2,4,5,6).

Discussion

Stocking density and growth

The effect of population density is usually seen to be either density dependent or density independent. Wiener et al [6] suggested that stocking density that negatively affect fish growth are density dependent. In the current study, the first sampling showed no significant effect of stocking density on growth while the second and third showed a great significant effect of stocking density on growth. This can be explained by the fact that at appropriate stocking density before attainment of carrying capacity, the fish grow properly thus at this stage stocking density did not affect fish growth by sampling one. This can also be explained by the slow growth after immediate stocking of fry due to stress from the harvesting process thus no extreme utilization of resources in the hapa.

By the second sampling the highest stocking density (5330 fry/m^3) was significantly different from the rest of the stocking densities. This indicated that as early as two weeks it had reached its carrying capacity which is one of the reasons to explain reduced growth rate. In sampling three, there was no significance between density 4000 and 5330 fry/m^3 implying that in a time period of one week 4000 fry/m^3 had also increased in biomass to carrying capacity thus affecting growth. 2670 fry/m^3 density reported lower growth rates than 4000 fry/m^3 even though they did not differ significantly, this can be explained by the high survival rates of 96.9% as compared with 82% in 4000 fry/m^3 making them have insignificantly different number of fry. These results are in agreement with Yousif [7] and Breine et al. [8] who reported that it's a generally accepted principle that increasing stocking density adversely affects fish growth. High stocking densities are associated with stress, competition for food and living space, voluntary appetite suppression and more energy expenditure in antagonistic interactions [9,10]. According to Bacellos et al [11], stress leads to increased cortisol production by even resting plasma cortisol and these increases with increasing stocking density, he continues that higher cortisol concentrations are considered as chronicle response to social stress due to high stocking density and this impairs fish growth due to mobilization of dietary energy by physiological alterations caused by stress.

Survival rate

In this study, the high survival rates of tilapia fry at high stocking density (82.9% at 5330 fry/m^3) indicate amenability of tilapia to intensive culture [3]. However, this can also be attributed to favorable environmental conditions during the experiment. This is in agreement with El Sherif [11] who found out that survival of up to 100% could be linked to good environmental conditions. Lower survivals were realized when stocking density was higher than 2670 fry/m^3. This means that tilapia fry can survive at high densities of up to around 2670 fry/m^3 but at extremely high densities the survival rate is significantly affected, this can be due to stress, decreasing water quality due to increased biomass and other density dependent factors at this point not only affecting growth rate, but also cause increase mortality rates. Thus 4000 fry/m^3 and 5330 fry/m^3 are in agreement with Osofero [12] who found an inverse relationship between stocking density and survival while 1000,1330,2000 and 2670 fry/m^3 are in line with Alhassan [3] who realized no effect of stocking density on survival. The high stocking densities (4000 fry/m^3 and 5330 fry/m^3) are not in agreement with Alhassan [3] because he considered very low stocking densities (8, 10 and 12 fry/m^3) thus could not find the limit to the insignificant effect stocking density on survival as the current study did (Figure 5).

Growth homogeneity

Yousif [7] realized that as initial size was homogenous for all densities and ample daily feedings done, one would expect fish in each density to be slightly but not significantly different in final body sizes. In this study however although the initial size was homogenous stocking density had an effect on final size among individuals of initially the same size. The little or no homogeneity in first sampling occurring at high stocking density can be due to tilapia's aggressive behavior [4] where some fish maintain a domain position, grow faster while others in low dominance hierarchy end up being chronically stressed leading to appetite suppression, reduced food intake and low growth rates thus decreasing homogeneity in growth of fish from the same brood stock and feed on the same food under the same environment. In the second and third sampling growth homogeneity however increased with increased stocking density with 5330 fry/m^3 being the most homogeneous. This can be related to studies on Artic charr. According to Jobling 1985 [13], change in interspecies relationships that defend territories is reduced as stocking density increases to extreme in Artic charr, this could also explain findings that a positive relationship exists between stocking density and homogeneity in Artic Charr [14] and thus highest homogeneity at high tilapia stocking densities in this study. This is still in agreement with Kanawabe [15] who worked on Salmoids and found out that rearing them at high densities reduces territorial behavior and breaks the dominance hierarchy. This reduces the chronic stress by fish in low dominance hierarchy thus improving their growth; however the improved growth doesn't indicate that every individual is growing fast but rather increased growth of slow growers and reduced growth of fast growers due to reduced dominance over food.

Since Nile tilapias raised in tropics are generally fast growing with little slow growers, there is a general significant decrease in growth rate at high densities and high growth homogeneity. This finding is however not in agreement with the negative relationships found between

STOCKING DENSITY (Fry/M^3)	TOTAL WEIGHT STOCKED(G)	TOTAL WEIGHT HARVESTED (G)	TOTAL WEIGHT GAIN(G	TOTAL FEEDS GIVEN (G.)	FCR	SGR (%)	DWG(g/day
1000	45	599.85	555	906.5	1.63	4.4	0.0167
1330	60	665	605	1136.8	1.88	4.5	0.0133
2000	90	938.4	846.4	1622.4	1.92	4.4	0.0129
2670	120	1193.81	1073.81	2021.6	1.88	4.2	0.0116
4000	180	1827	1647	3140.4	1.91	4.3	0.0121
5330	240	1589.76	1349.76	2997.6	2.22	3.8	0.0088

Table 3: Food conversion ratio, specific growth rate and daily weight gain for the six stocking densities.

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	1000	1330	2000	2670	4000	5330
10- 13	1	4	0	0	1	5
13-14	13	3	13	9	14	11
15-16	13	18	14	18	21	16
17-18	12	16	8	12	6	12
19-20	10	8	15	10	8	5
21+	1	1	0	1	0	1

Table 4: Length frequency groups for week one sampling in millimeters.

	1000	1330	2000	2670	4000	5330
13- 19	4	8	1	6	1	28
19-20	8	13	15	23	19	10
21-22	16	13	11	9	17	12
23-24	10	12	19	6	10	0
25-26	8	4	4	6	3	0
27+	4	0	0	0	0	0

Table 5: Length frequency groups for week two sampling in millimeters.

	1000	1330	2000	2670	4000	5330
18- 24	4	7	3	22	7	36
24-25	2	22	14	15	26	10
26-27	18	12	19	8	10	4
28-29	18	6	11	4	7	0
30-31	7	2	3	1	0	0
32+	1	1	0	0	0	0

Table 6: Length frequency groups for week three sampling in millimeters.

stocking density and growth homogeneity in red tilapia (4,16). Joblings [16] realized that proper dominance hierarchies in Artic charr were established in three months so it can also be assumed that three weeks was not enough time for establishment of proper social interactions and dominance hierarchies in this study.

Food conversion ratio (FCR), specific growth rate (SGR) and daily weight gain (DWG)

Food conversion ratio increased with increasing stocking density thus as stocking densities increased the fry became less efficient in utilizing the food for somatic growth. This is attributed to increased stress due to decreasing water quality as stocking density is increased far beyond the carrying capacity [17]. This is in agreement with Guimareaes et al. [18], who found out that efficient utilization of diets may vary within a single species because of not only the particular strain of fish but also environmental factors. On the contrary, Osofero [12] reported no effect of stocking density on food conversion ratio which he attributed to using the same feed in the same environment. Hence in the current study the environment played a very great role in influencing the food conversion ratio through water quality.

Daily weight gain and specific growth rate generally decreased with increasing stocking density indicating the decreasing feed utilization ability as explained above. However the anomaly at 2670 fry/m^3 is attributed to the very high survival rate (Figure 4) which made the carrying capacity to be realized faster. This affected growth negatively thus lowering both the specific growth rate and daily weight gain.

Conclusions and Recommendations

Conclusion

- The results in this study demonstrate that increasing stocking density in Nile tilapia fry results into homogenous growth and survival rate is only significantly affected at extremes of stocking density.
- Feed conversion ratios, specific growth rates and daily weight gain are as well affected by stocking density in this study.
- Many individuals grow at less than their maximum potential rate at high stocking densities thus growth homogeneity
- Fish growth is plastic hence the proper growth rate lacking at some stocking densities can be regained in secondary nursing hapas by proper stocking and growth homogeneity at grading, but at the same time larval fish are very delicate hence need proper management and this is can be achieved when they are in one unit which calls for higher stocking density. Thus survival of fish is the most important factor in the primary nursing hapas since lost fish can't be regained in the following rearing stages and this rules of stocking densities of 4000 fry/m^3 and 5330 fry/m^3
- Further research is needed to understand how stocking density affects growth and survival in secondary nursing happas and other grow out stages that follow afterwards [19-25].

Recommendations

According to this study, it is recommended to have stocking densities not exceeding 2670 fry/m^3 in hapas placed in earthen but depending on one's required output and resources available to manage carrying capacity this can vary.

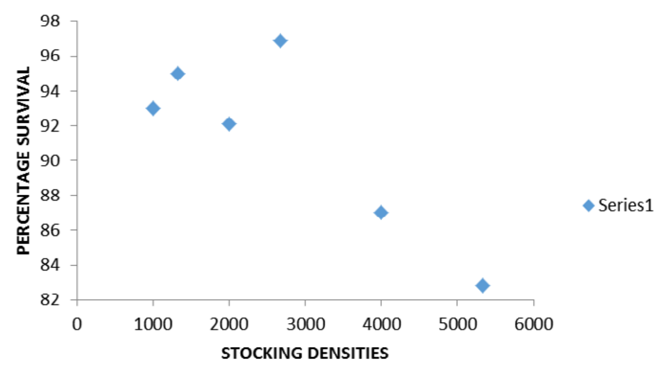

Figure 4: A correlation between survival and stocking density.

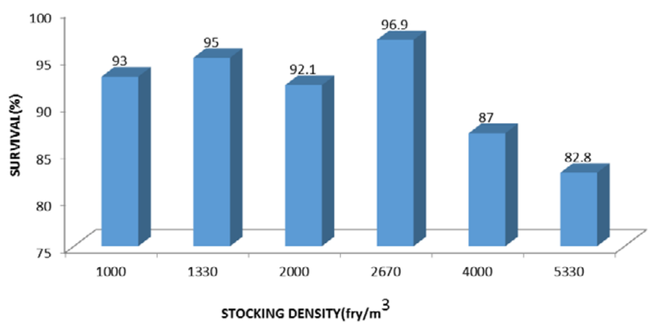

Figure 5: Survival rates for the six stocking densities at the end of the experiment.

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