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Growth performance of Monosex Nile Tilapia (*Oreochromis niloticus*) juveniles at different stocking densities in cages at Lake Bunyonyi in South Western Highland Agro-Ecological Zones (SWHAEZs)

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Abstract
Stocking density is among the critical factors affecting fish growth. Although cage culture is gravely being promoted by the government, information regarding the impact of stocking density on fish growth performance of juveniles in cages in Uganda is limited. This study examined the growth performance of Monosex Nile tilapia (*Oreochromis niloticus*) juveniles at various stocking densities in cages. The fish of mean wet weight and total length of 1.1±0.1g and 1.3±0.1cm respectively were transferred from nursing ponds in aerated containers to experimental cages at three stocking densities (1000, 1250 and 1500 juveniles/m3). The fish were fed on 45% crude protein formulated diet and total length and wet weight were determined weekly for eight weeks. During each sampling event, water quality parameters (temperature, dissolved oxygen and pH) were measured at the surface and 1.5-2.0 meter depth, before, within and after cages to assess the effect of cages on the water quality in and around the farming area. Results indicate that juveniles stocked at 1000/m^3 were significantly heavier and larger than those in higher stocking densities which, in turn were not different from each other. Better performance of fish at lower stocking density could be attributed to availability of space which reduces crowd-related stress, less competition for food and less loss of energy due to the antagonistic behavioral interactions, among others. Likewise, the survival rate was higher (74.0%) at 1000/m^3 stocking density than 69.8% at 1250/m^3 and 63.1% at 1500/m^3 because of reduced mortalities at lower densities. Further, the cage system appeared not to affect water quality parameters measured probably because of low production level and the high circulating nature of water around the farming area. The study demonstrates that increasing stocking density of Nile tilapia juveniles in cages reduces growth and survival rate, hence, growth and survival of *O. niloticus* juveniles in cages are density-dependent. Thus, culture of Monosex tilapia juveniles at a density of 1000 fish/m^3 cages can be considered ideal for augmented production of the fish under South Western Highland Agro-Ecological Zone's context. However further studies at increased feeding rates are recommended for improved survival and growth rates and thinning of juveniles to avoid wastage of resources.

Keywords: Aquaculture, cage culture, growth performance, condition factor, Nile tilapia, stocking density, survival rates

1. Introduction

The high population has increased demand for fish globally because of its (fish) nutritional benefits that are better known [1]. It is also well documented that most capture fisheries have been over exploited due to; overfishing, habitat degradation and pollution [2, 1]. Therefore to reduce the gap between demand and supply, growth of aquaculture is needed as an alternative to the dwindled capture fisheries [2]. This can be realized through full commercialization of the aquaculture sector that involves production of fish using more intensive and advanced systems like cage culture. Cage fish farming is found suitable to overcome the problem of land shortage, which is otherwise common with less intensive culture systems like pond culture. However, full commercialization of this enterprise has often failed due to inadequate knowledge regarding ideal stocking density of the fish [3].

In aquaculture, 'stocking density' refers to the concentration at which fish are initially stocked into a system. It is considered one of the important factors affecting fish growth performance [4]. Stocking density influences the amount of feed, the carrying capacity, enterprise profitability and above all growth rate of fish [5]. Many studies have been done on tilapia concerning stocking density in many production systems like pond culture [6, 7], tanks [8, 9], and cages [10, 3]. But information related to effect of stocking density on growth and survival of juvenile tilapia fishes is limited and sometimes inconsistent. Different studies show that there are significant effects of stocking density on larval survival, growth rates and feed utilization efficiency [10] and other studies report that stocking density does not affect body size and survival of the fingerlings [8]. Also, Osofero, *et al*. (2009) have reported that there were no significant differences in daily weight gain, specific growth rate, final weight, relative growth rate, feed conversion ratio (FCR), survival and protein efficiency ratio. Thus, the impact of stocking density of tilapia juveniles in cage needs to be addressed in a coherent manner.

Nile tilapia (*Oreochromis niloticus*) is a widely cultured species as it grows and reproduces in a wide range of environmental conditions and tolerates stress induced by handling [9].With its characteristics, *O. niloticus* can easily be cultured well in various aquaculture systems like cages, ponds, tanks, raceways. Recently, cage culture has been considered an efficient method for culturing Nile tilapia in various countries

There is a considerable increase in the range of production values of fish catch and thus tropical water bodies offer better opportunities for extensive and semi-intensive cage and pen culture [11]. Cage culture is an alternative means of aquaculture especially for land-less fish farmers. SWHAEZ is blessed with an abundance of scattered inland water mass comprising of minor lakes, streams and rivers [12] part of which lies in Kabale like Lake Bunyonyi and have the potential to serve in a versatile capacity. South Western Highland Agro-Ecological Zone’s domestic fish production is dominated by the small-scale artisanal farmers who could be encouraged to go into cage fish farming system utilizing the vast available scattered inland water bodies. Cage culturing makes it possible to grow fish in bodies of water where draining and seining would be difficult or impossible.

Tilapia cage culture is used mainly in two different forms; for rearing juveniles in juvenile cages and for rearing fish in grow out or production cages. The juveniles are stocked in juvenile cages mainly for acclimatization [13] and solving a problem of space competition [13]. Beyond the nursing period, the juveniles can be graded into different size groups and stocked in separate grow-out cages. It has been observed that the juveniles from the juvenile cages perform better in terms of growth and survival than those stocked directly into the grow-out cages [13]

Therefore, tilapia cage culture is a recent development in minor lakes of South Western Uganda and studies on fish nutrition, seed production, and good site selection among others have been done; but cage culture has often failed due to inadequate knowledge regarding ideal stocking density of juveniles. This has impacted on growth and survival of *Oreochromis niloticus* juveniles. In practice, the densities at which farmers keep their stocks are based on experience and handbooks used as a guide. The stocking densities in these handbooks are mainly copied from other regions with well-established facilities and sometimes from experimental stations.

Therefore, this study will generate important information which can and/or will be used to guide farmers interested and carrying out commercialized cage fish farming on Lake Bunyonyi and other minor lakes in South Western Highland Agro-Ecological Zones (SWHAEZ), on an appropriate stocking density of the juveniles in cages to better performance in terms of growth and survival rate. This will therefore lead to improvement in productivity and profitability of cage fish farming in SWHAEZ.

1.1 Objectives of the study
1. To determine the body (and weight) changes over the experimental period of the O. niloticus juveniles stocked at different densities in the cages
2. To determine the survival rate of O. niloticus juveniles at the different stocking densities
3. To monitor the water quality parameters (temperature, dissolved oxygen and pH) of the water before sampling, within cages and after sampling the cages.

2. Materials and Methods
2.1 Study site
The experimental study was conducted at the Kachwekano Zonal Agricultural and Development Institute (KaZARDI) cage site on Lake Bunyonyi for the months of May 2016 to July 2016. The site (0826703E, 9859382N) was located downstream of Bunyonyi Lake (Figure 1).

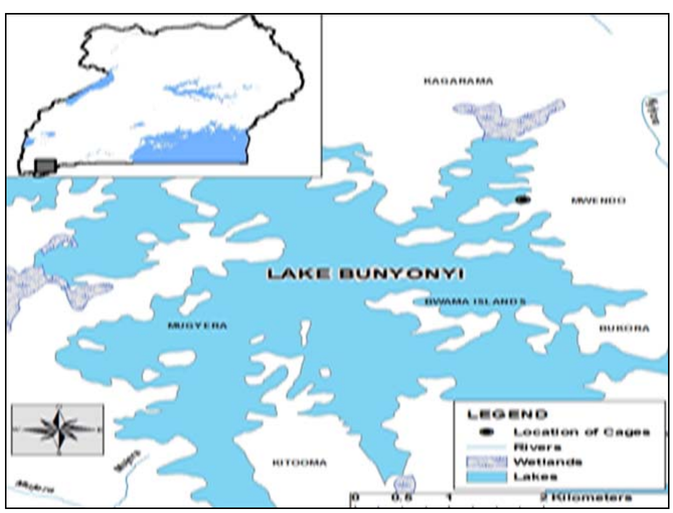

Fig 1: Location of the experimental site at Lake Bunyonyi

The site, 20.6 m from shore was well suited for cage culture of tilapia due to reasons such as a more stable water quality, high flow rate of the water in the cages (0.1 ms-1) and greater depth (10.5 m) between the cage floor and the bottom of the water (Figure 2).

Fig 2: Arrangement of cages across the water flow on Lake Bunyonyi

2.2 Experimental design

The study involved stocking six experimental cages with juvenile *O. niloticus* from the same pond at 1000, 1250 and 1500 juveniles/m3. The fish were first conditioned 24 hours prior to transfer from the pond. Each cage was 10m3 and separated from each other by one meter. All the juveniles were fed on a 45% crude protein Ugachick feed from Uganda throughout the experimental time. They were fed at 15% body weight for the first four weeks and 10% for the last four weeks.

2.3 Fish sampling and final harvest

Fish were sampled bi-weekly (between 07:00 and 10:00 hours GMT) during when the weights (Ohaus portable digital scale (model DIGI DS 671); ± 0.1 g), standard length (measuring board; ± 1.0 mm) and the number of fish were assessed for each treatment. Fifty live fish were randomly scooped out of each cage unit for their measurements and immediately returned to their respective cages. The survival rates were determined by establishing the total numbers of fish remaining after 8 weeks during grading. The total weight in grams and average body weight of the juveniles at grading was established for each stocking density. This helped in establishing the total number of juveniles at the termination of the study. The established numbers of juveniles at termination were converted to percentages as survival rates of the fingerlings per each stocking density in their respective replicates. The cage nets were inspected and cleaned during each sampling.

2.4 Specific method

The specific growth rate, condition factor, coefficient of variation in weight, net yield and survival rates were calculated for the determination of growth.

2.4.1 Specific growth rate, SGR

The specific growth rate for each treatment group was calculated as:

SGR = SGR = 100 × [(loge Wf − loge Wi)] t -1

Where, loge is natural log, Wf is the final mean wet weight (g), Wi is the initial mean wet weight and t is the time in days (Ricker, 1975).

2.4.2 Mean daily weight gain

This was calculated as ($Wf - Wi$) t-1 where Wf is the final mean weight at harvest (g), Wi is the initial mean weight at stocking and t is the time in days.

2.4.3 Condition Factor, K

The condition factor K was calculated as: K = BW / SL3, (Tesch, 1971).

Where, BW is body weight of fish (g) and SL is the standard length of fish (cm).

2.5 Determination of the water quality (Temperature, Dissolved oxygen and pH):

Water quality parameters (Temperature, dissolved oxygen and pH), were measured using a combined YSI meter, twice in a day on sampling days throughout the experimental period. First measurements were in the morning between 8:00-9:00am before sampling and in the afternoon between 4:00-5:00pm. The measurements were taken both at surface and between 1.5 and 2.0 meter depth. The measurements were taken at three different sites; before sampling, within cages and after sampling the cages.

2.6 Statistical analysis

One way ANOVA was used to analyze the effects of stocking density on the total length and wet weight of the juveniles throughout the experiment at the three stocking densities. A post hoc test using Turkey test was used to explore the differences between wet weight and total length of different densities. The survival rates are established using the following formula; SR -Survival rate (%) = Final number harvested/ Total number stocked x 100. Averages of the water quality parameters (Temperature, dissolved oxygen and pH) of the water within, before and after cages, both at surface and 1.5-2.0 meter depth were computed. The statistical package used was SPSS version 11.0.

3. Results

The study examined the growth performance of juvenile Nile tilapia fish stocked at three different densities (1000, 1250- and 1500fish/m3). During the study, 50 tilapia juveniles from each of the different densities were randomly scooped and measured weekly between 9:00-11:00 am for a period of eight weeks. During every sampling event, water quality parameters (temperature, dissolved oxygen and pH) were measured before sampling, within cages and after sampling cages at surface and 1.5-2.0 meter depth.

3.1 Weight and Length

Results for the mean weight and the growth patterns stocked at three different stocking densities are presented in table 1 and figure 3 respectively. Results for mean total length of juvenile Nile tilapia stocked at three densities from week one to the end of experiment (week eight) are shown in table 2. Initially, the mean weight and length of the juveniles were 1.1±0.14 g and 1.3±0.10 cm respectively. With regard to mean weight, results indicated that between weeks one to week three post-stocking, the juveniles at stocking density 1000/m3 were significantly heavier than those under stocking densities 1250 and 1500/m3 (ANOVA, F= 47.2, p = 0.0001), which were not different from each other (ANOVA, P = 0.062). Likewise, the mean total length of the fish under the stocking density of 1000fish/m3 were significantly higher than those of stocking densities 1250 and 1500 fish/m3 (ANOVA, F=206.1, p = 0.01). From week four to seven, there was a significant difference in weight among all the stocking densities, juveniles at stocking density 1000/m3 being the heaviest and those of 1500/m3 being the lightest (ANOVA, F= 352.8, p =0.026).

Table 1: The mean weight (g) of juveniles during different weeks of the experiment

	1000/m3	1250/m3	1500/m3
Duration	**Mean± SD (g)**	**Mean± SD (g)**	**Mean± SD (g)**
Week1	2.51±0.6	1.84±0.4	1.48±0.2
Week2	3.58±1.2	2.67±0.8	2.36±0.5
Week3	4.49±1.1	2.89±0.8	2.87±0.8
Week4	6.84±1.2	5.73±1.1	3.82±0.8
Week5	8.31±1.9	6.91±1.2	5.09±1.1
Week6	15.49±1.8	9.69±1.7	7.07±1.2
Week7	18.56±2.1	12.76±1.6	9.11±1.3
Week8	23.49±5.1	14.11±3.6	13.73±3.3

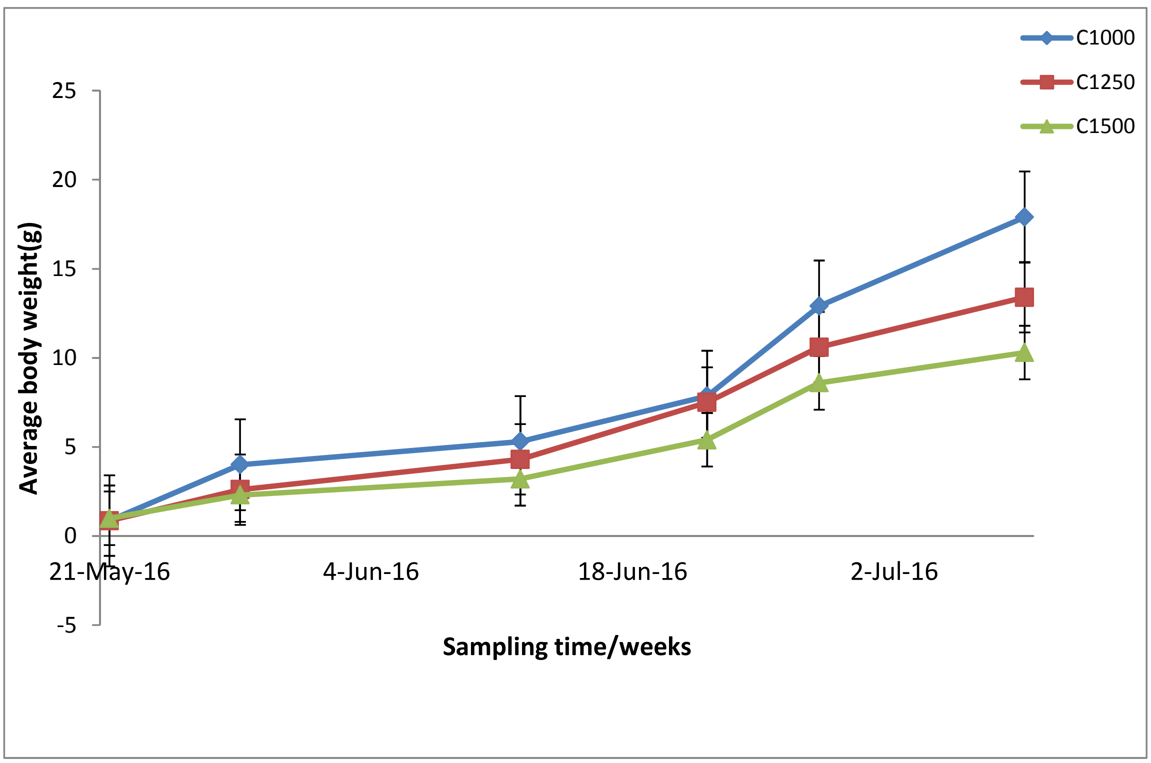

Fig 1: Growth performance of *Oreochromis niloticus* fingerlings stocked in cages at three stocking densities.

Likewise for length, where juveniles at 1000/m^3 recorded the highest mean total length from week four to week seven, while those at 1500/m^3 recorded the lowest mean total length (ANOVA, F = 1067.2, p = 0.026). At the end of the experiment (week 8), juveniles stocked at 1000/m3 were significantly heavier than those at 1250 and 1500/m3 (ANOVA, F = 82.5, p = 0.0001), which were not different from each other (ANOVA, p = 0.078). Similarly, the length of juveniles stocked at 1000/m3 was significantly higher than that of the higher stocking densities (ANOVA, F=179.1, p = 0.001) which were not different from each other (ANOVA, P = 0.08).

Table 2: The mean total length (cm) of juveniles during the experiment

	1000/m^3	1250/m^3	1500/m^3
Duration	**Mean± SD/cm**	**Mean± SD/cm**	**Mean± SD/cm**
Week1	1.51±0.2	1.47±0.2	1.38±0.2
Week2	2.36±0.7	1.86±0.5	1.38±0.1
Week3	3.54±0.8	1.72±0.3	1.49±0.3
Week4	5.16±0.9	3.09±0.6	1.86±0.3
Week5	5.96±1.2	4.51±6.1	2.53±0.6
Week6	9.91±2.4	4.89±0.6	3.37±0.5
Week7	13.52±1.6	5.70±0.7	4.22±0.4
Week8	13.88±1.9	9.17±1.0	8.87±1.0

3.2 survival rate
The study revealed that stocking juveniles at different densities affected survival rates. The highest survival rate of 74.0% was recorded in juveniles stocked at 1000/m3. The juveniles stocked at 1250/m3 had a survival rate of 69.8%, followed by 1500/m3with a survival rate of 63.1% (Figure 2).

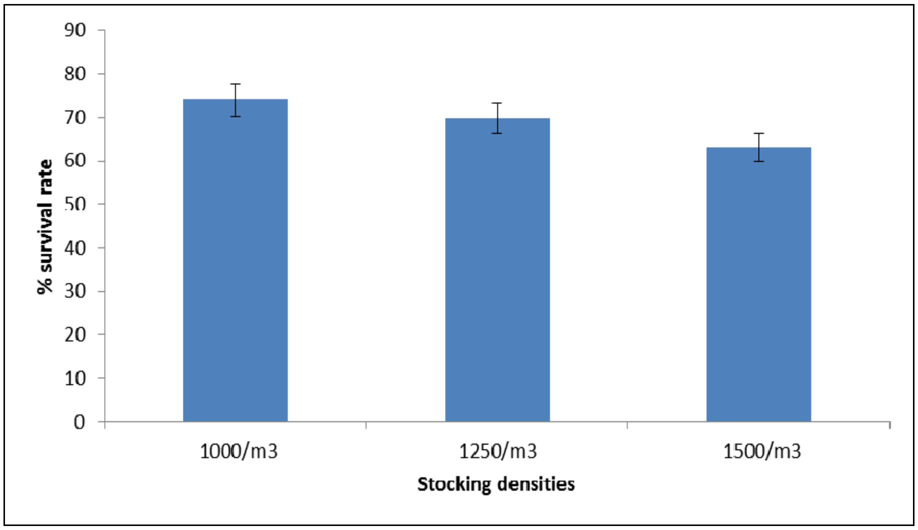

Fig 2: Trend in survival of caged *Oreochromis niloticus* fingerlings under three stocking densities.

3.3 Condition factor (K)
The condition factors, in cultured fish were significantly affected ($p < 0.05$) by stocking densities. The treatment with 1000 fingerlings/m3 had the best mean condition factor (1.89 ± 0.15) while the treatments with 1250 fingerlings/m3 and 1500 fingerlings/m3 showed similar ($p > 0.05$) mean condition factors of 1.67 ± 0.13 and 1.41 ± 0.13 respectively (Figure 3).

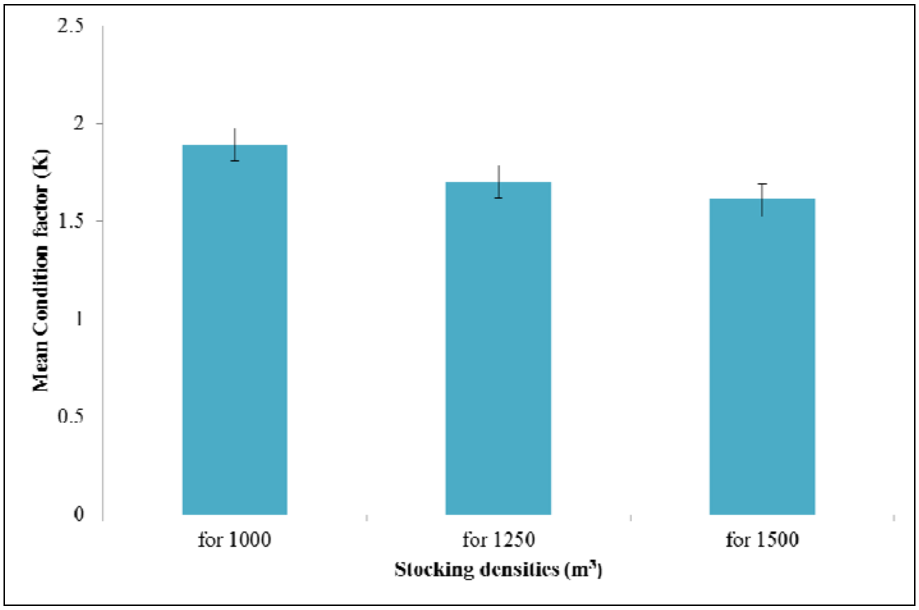

Fig 3: Mean condition factors of *Oreochromis niloticus* fingerlings stocked in cages at three densities.

3.4 Water quality parameters

3.4.1 Temperature

Average maximum and minimum temperature, during the study (Table 3) remained within the growth limits for Nile tilapia culture [14]. The temperature changes didn't present any significant effects on fish growth in the lake.

Table 3: Variation of water quality parameters at sampling sites (surface and 1.5-2.0 meter depth).

Parameter	Temperature(˚C) Mean± SD		DO (mg/l) Mean± SD		pH Mean± SD	
Site	Surface	1.5-2.0	Surface	1.5-2.0	Surface	1.5-2.0
Before	24.32±0.5	24.07±0.5	4.35±0.4	4.11±0.4	7.07±0.3	6.72±0.2
Cage	24.36±0.5	24.12±0.5	4.36±0.3	3.95±0.3	7.09±0.2	6.72±0.2
After	24.47±0.5	24.30±0.4	3.91±0.2	3.51±0.2	6.46±0.4	5.89±0.3

3.4.2 Dissolved oxygen

The average surface dissolved oxygen was 4.2±0.4mg/l; with average dissolved oxygen after cage being slightly lower than before and cage (Table 3). For 1.5-2.0 meter depth, the average dissolved oxygen was 3.9±0.4 mg/l. The average surface dissolved oxygen was higher than at
1.5-2.0 meter depth.

3.4.3 pH

The results for pH indicated an average surface pH of 6.9± 0.4. The average pH between 1.5 and
2.0 m was 6.5±0.5. After cage pH values showed to be lower than the other two sites (Table 3).

4. Discussions

Stocking density is an important factor affecting growth and survival of fish [17] and high stocking density has often shown results of reduced growth and survival rates [18]. However, information related to impact of stocking density on growth performance of monosex tilapia juveniles in cages in SWHAEZ is limited. This study therefore focused on examining the effect of stocking density on growth performance of Nile tilapia juveniles in cages on Lake Bunyonyi.

4.1 Effect of stocking density on the mean weight and length of the Nile tilapia fingerlings

The results of the study shows that growth performance was favorable in fish stocked at a lower stocking density as compared with those stocked at higher densities (Table 1 and 2). Generally juveniles at the lowest stocking density (1000/m3) were significantly heavier and larger compared to those at higher densities (1250 and 1500/m3). The findings of the present study are consistent with previous studies, though under different culture systems [17, 18, 7]. The lower growth performance of tilapia at higher stocking density could have been caused by voluntary appetite suppression, where fish voluntarily loses appetite even when food is readily available [19]. Apart from loss of appetite, competition for food could also be another cause of reduced growth in fish stocked at higher densities [20, 21]. The study was carried in an open water system and therefore fish could have supplemented their diets with naturally occurring phytoplankton and zooplanktons in the water. Hence, fish stocked at lower densities could easily access these food sources without stiff completion.

Furthermore, stress due to reduction in space availability was reported to be the primary factor for growth inhibition in juveniles stocked at high densities [22]. Tilapia is a territorial and aggressive fish [17] thus competition for spaces aggravates crowd- related stress, significantly affecting growth. In addition, there is diminishing social dominance [23], where fish fight for their social status in the growing environment, subsequently lowering growth performance. Furthermore at high stocking densities, more energy is expended on the intense antagonistic behavioral interaction between fish and this can significantly lower the growth performance of fish [19] Besides, behavioral aspects, water deterioration, due to low dissolved oxygen [20, 24], ammonia accumulation [21], among others can also affect growth of fish. However the present study shows water quality parameters which are still within the permissible ranges of Nile tilapia culture.

4.2 Effect of Stocking Density on Condition Factor of the Nile tilapia fingerlings

The fish from this study, although stocked initially at different densities exhibited less significant ($p > 0.05$) condition factor (K). However, the overall averages over the entire experimental period showed a significantly ($p < 0.05$) higher value (1.89) for the low density (1000 fish/m3) than the high densities (1500 fish/m3.)

The higher condition factor observed in the 1000 fish/m3 could as a result of the fish in this treatment utilizing their food for somatic growth as observed with their greatest weight gain. Feeding and food availability influences the physiological differences of fish because food reserves that accumulate through feeding increase the fish condition factor [25]. Hence the best condition in this treatment might have as well contributed to the significant improvement observed in the average daily weight gain and specific growth rates in the 1000 fish/m3.

4.3 Effect of stocking density on the survival rate of the Nile tilapia fingerlings

In the present study, stocking density showed to have an effect on fish survival, as fish at the lowest stocking density had higher survival compared to those at higher densities. Stocking density is highlighted as an area of particular concern in the welfare of intensively farmed fish. Stocking fish beyond an optimum level can cause a significant increase in fish mortality leading to reduced production. This is in contrast with a study by Yakubu, *et al.,* (2012), who indicated that stocking density does not affect the survival rate of *O. niloticus* in water flow through system. Yakubu, *et al.,* (2012) have stated that mortality of *O. niloticus* raised in water through system is not density dependent. The relatively high survival rates of the Nile tilapia juveniles indicate responsiveness of tilapia to intensive culture [17].

4.4 Effect of stocking density on water quality

Different water quality parameters including temperature, dissolved oxygen and pH are generally considered to have primary importance in fish culture [24]. The temperatures in all the different density cages were more or less stable during the culture. The results of the study indicate an optimum temperature for the growth of O. *niloticus (*Table 3). The optimum temperature for tilapia culture is reported to be 20-30 °C [24, 26]. The ideal dissolved oxygen level for tilapia culture is 4-5 mg/l [26] and the study showed higher dissolve oxygen values in the cages (Table 3), suggesting good environment for tilapia culture [26].

The lower oxygen levels after cages recorded during this study could be as a result of utilization of oxygen for respiration of fish within and around cages [27]. Meanwhile, the lower pH recorded after cages could be as a result of more carbon dioxide released after fish respiration [27], which reacts with water to form a weak carbonic acid, which lowers the pH.

5. Conclusion

The results of the study demonstrate that increasing stocking density in Nile tilapia juveniles in cages results into reduced growth and survival rate. This suggests that both growth and survival of *O. niloticus* juveniles in cages are density-dependent. Water quality parameters in the farming area on Lake Bunyonyi are still within permissible levels for growth of *O. niloticus in cages.*

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