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SHORT COMMUNICATION

Growth performance of male monosex and mixed sex Nile tilapia (*Oreochromis niloticus* L.) reared in cages, Lake Victoria, Kenya

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Abstract Growth performance of 17 alpha-methyl testosterone treated monosex and hormone untreated mixed sex tilapia was done for a period of 180 days in cages adjacent to Lwanda Disi beach, Lake Victoria, Kenya. Mixed sex Nile tilapia is known for frequent spawning in culture systems, resulting to fish with varied sizes and stunted growth. To attain male monosex fingerlings, the newly hatched fry were sex reversed by feeding them a diet laced with 17-alpha-methyl testosterone hormone for 21 days. Thereafter, the fry were fed 40% crude protein (CP) diet until stocking into cages. Mixed sex fry of same cohort were fed 40% crude protein starter diet until the time of stocking. A total of 6 cages (2×2×2 m) were randomly stocked with 1000 male monosex and mixed sex fingerlings. The individual mean (± SD) weight at stocking was 9.5 ± 0.06 g and 8.8 ± 0.08 for monosex and mixed sex, respectively. The experimental fish were fed starter diet 40% CP at 10% of body weight for the first two months. From the third month till the end of the experiment, the fish were fed 30% CP diet at 3% of body weight. Measurement of fish total length, body weight and selected water quality parameters was done once a month. There was a significantly higher ($P < 0.05$) mean body weight gain (BWG), specific growth rate (SGR) and condition factor (CF) for male monosex fish. Conversely, Feed conversion ratio (FCR) was significantly higher ($P < 0.05$) in mixed sex Nile tilapia. Survival rates (%) and water quality parameters did not differ between the groups. Though the mixed sex Nile tilapia did not reproduce in cages they performed poorly compared to male monosex.

Keywords Aquaculture . Fingerlings . Sex reversed

Introduction

Nile tilapia is one of the most popular freshwater fish species in global aquaculture and a source of animal protein and income around the world (Chakraborty et al. 2011). It is widely distributed in several countries of the world (Gómez-Márquez et al. 2015; Mahfujul et al. 2017). Nile tilapia possess various characteristics that make it suitable for aquaculture which include fast growth rates and high quality of fillets (Thongprajukaew et al. 2017); tolerance to environmental conditions and withstands stress induced by handling (Ogello et al. 2017); omnivorous feeding habits (Vasconcelos et al. 2018); resistance to disease, efficient feed conversion ratio (El-Sayed 2002) and good acceptance by consumers (Githukia et al. 2015). Global production of Nile tilapia has shown a continuous increase from 265.7 thousand tons in 2010 to 4325.4 in 2018. This contributed 8.3% of major fish species produced in 2018 (Food Agriculture Organization 2020).

Mixed Nile tilapia is known to over reproduce in culture systems, leading to stunted growth (Chakraborty et al. 2011) and small sizes at harvest, which become unmarketable (Githukia et al. 2015). To overcome

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this problem various methods have been employed to produce monosex male tilapia populations for culture. These include environmental manipulation (Wessels and Hörstgen-Schwark 2007), hand sexing (Fuentes-silva et al. 2013), interspecific hybridization and YY male genetic manipulation (Alcántar-Vázquez et al. 2014; Madalitso et al. 2020) and hormone feeding (Vinarukwong et al. 2018). Amongst these techniques, the use of 17 methyl testosterone (MT) hormone in sex reversal of Nile tilapia for commercial purposes is mostly preferred (Celik et al. 2011). MT is an artificially manufactured male reproductive hormone which mimics the one produced naturally. In order to produce male monosex populations, fish fry are treated with feed laced with MT hormone (Thongprajukaew et al. 2017). This method has a high success rate, easy to handle and cost effective (Haffray et al. 2009). With the mushrooming of cage investment in the Kenyan side of Lake Victoria (Orina et al. 2018), Nile tilapia being the only species cultured in cages, it was important to conduct this research. Growth experiments comparing performance of males only and mixed sex Nile tilapia populations, have been conducted in other culture systems. For example, a study compared YY, MT reversed and genetically improved farmed tilapia in cages suspended in ponds (Kamaruzzaman et al. 2009) while a similar study was conducted using hapas in earthen ponds (Githukia et al. 2015). Whereas male monosex and mixed sex were compared in different culture systems, Chakraborty et al. (2011) and Gómez-Márquez et al. (2015) did similar study in ponds. However, there is no information focusing on growth performance of sex reversed and mixed-sex Nile tilapia under cage culture, specifically from the Kenyan part of Lake Victoria. Therefore, the aim of the present study was to establish a sustainable method for the production of Nile tilapia by comparing the growth of monosex and mixed-sex tilapia in cages of Lake Victoria, Kenya.

Materials and methods

Study area

This study was done in cages at Lwanda Disi beach, Lake Victoria, Kenya (Altitude of 1,107m above sea level, Latitude 0° 4’17.72” S, Longitude 34°7’14.616 E) (Fig. 1). The fish fry were produced at Kenya Marine and Fisheries Research Institute (KMFRI), Sangoro Aquaculture Station (Altitude 1230 m above sea level, Latitude 0° 39′S, Longitude 37°12′E).

Experimental fish and feeding

Fertilized eggs were removed from the mouths of females and put under incubation in the hatchery. Sex reversal was done by feeding hatched fry to satiation, immediately after absorption of the yolk sac, with a diet laced with 60 mg 17 MT kg^{-1} for 21 days to satiation, immediately after absorption of the yolk sac in the hatchery (El-Greisy and El-Gamal 2012). The MT feed was prepared by dissolving 60 mg 17α- MT in a liter of ethanol. This solution was then mixed with one kilogram of finely ground 40% CP starter mash and left to dry under a shade for 24 hours before placing it in a refrigerator at 4 °C. On the other hand, mixed sex fingerlings were fed 40% CP hormone untreated starter diet to satiation and reared in the hatchery for 21 days. Experimental fingerlings were transported to the cages in polythene bags filled with water and oxygen.

A total of six cages (2×2×2 m) were each randomly stocked with 1000 fingerlings. Three of the cages were stocked with male monosex whereas the other three were stocked with mixed sex. The individual mean (± SD) weights at stocking were 9.5 ± 0.06g and 8.8 ± 0.08 g for monosex and mixed sex, respectively. The cages were made of galvanized metal with plastic barrels as floats. The mesh size of inner netting and outer netting was one inch and two inches, respectively. The nets were securely fixed to the cage platform using nylon twine. The experimental fish were fed starter mash 40% CP at 10% body weight for the first two months. In the third month till the end of the experiment, the fish were fed 30% CP commercial pellets, at 3% of their body weight. The daily feed rations for each cage were divided into two equal portions and were fed at 0900 hrs and 1600 hrs. Feeding rates were adjusted monthly, according to the body weight of the experimental fish.

Sampling, evaluation of growth performance and survival

Measurement of fish length, weight and selected water quality variables was done once a month for a

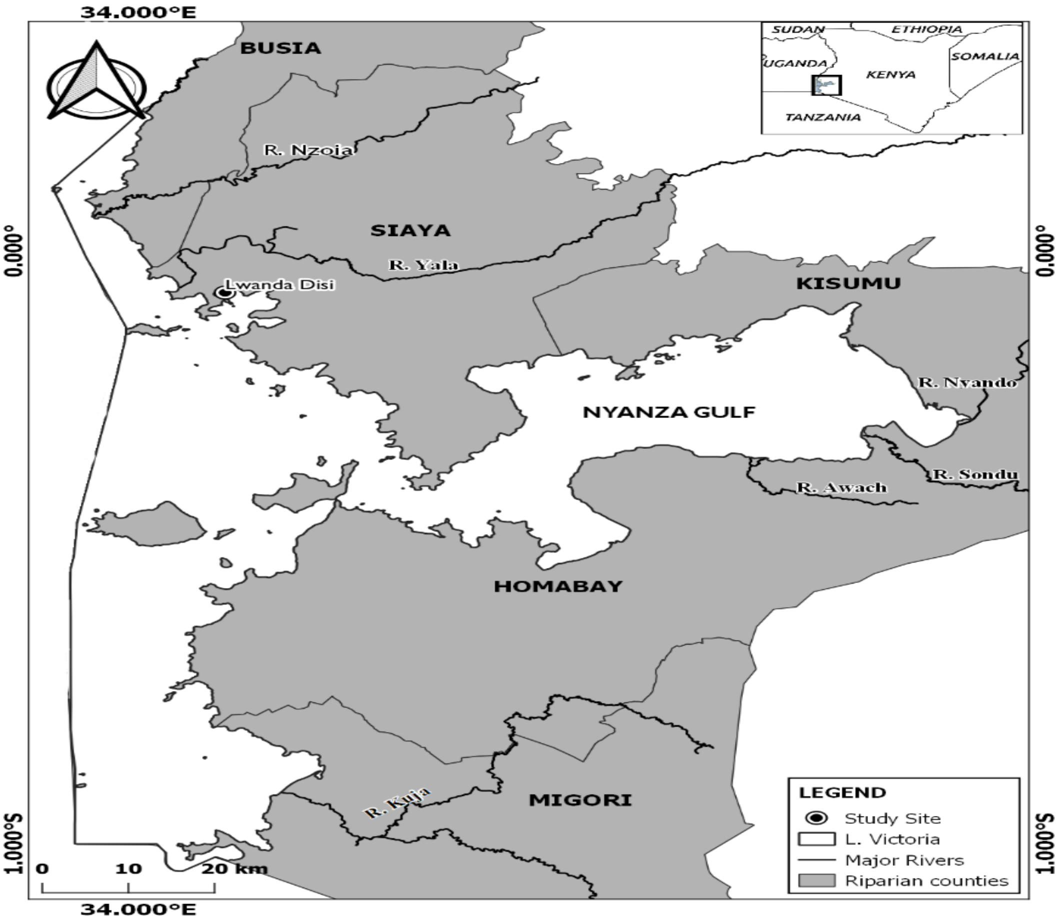

Fig. 1 A map showing the study site at Lwanda Disi, Lake Victoria, Kenya

period of 180 days. During each sampling, 30 fish were scooped randomly from each of the cages using 10mm mesh size scoop net. Fish were returned to their respective cages immediately after measurements were done. Fish wet body weight (g) and total lengths (cm) were measured using a digital balance (Metler Toledo AG204, Japan) and a fish measuring board respectively. Total harvest was done after 180 days of culture. The fish were counted and weighed individually to determine growth variables. The ratio of males to females in the treatment groups was determined at the end of the experiment. This is because it was not possible to confirm the sexes of very young fish at the time of stocking. Body weight gain (BWG), feed conversion ratio (FCR), condition factor (CF), specific growth rate (SGR), and survival rate (%) were calculated at the end of the experiment using the following formulae:

BWG = W_f - W_i where W_f and W_i are final and initial wet weight in grams, respectively.

FCR = Dry feed given/wet weight gain.

CF= body weight (g)/L^b ×100 where: L = total body length and b is the value obtained from the length weight equation.

SGR =100 [lnWt - lnW_0] / [t-t_0] where ln = natural logarithm; Wt is the mean weight at day t and W_0 is the mean weight at day t_0.

Survival rate (%) = N_o – Nt /N_o ×100 where t = time in days, N_o and N_t are fish number at time 0 and at time t respectively.

Water quality

Dissolved oxygen (DO), temperature, electrical conductivity, pH and total dissolved substances (TDS) were measured insitu, using a multiparameter meter (YSI pro, USA). The measurement was done by lowering the probe of the meter into the water at a depth of 10 cm from the water surface.

Table 1 Selected water quality parameters recorded in the cages during the rearing period (mean ± SE)

Parameter	Male monosex	Mixed sex
Temperature (°C)	26.49 ± 0.12[a]	26.41 ± 0.23[a]
pH	8.68 ± 0.10[a]	8.51 ± 0.11[a]
Conductivity (μS cm^{-1})	114.57 ± 0.82[a]	115.6 ± 1.02[a]
Dissolved oxygen (mgL^{-1})	6.37 ± 0.29[a]	6.31 ± 0.36[a]
TDS (mgL^{-1})	70.87 ± 0.30[a]	71.25 ± 0.41[a]

Means with the same letter in a row are not significant different (P > 0.05).

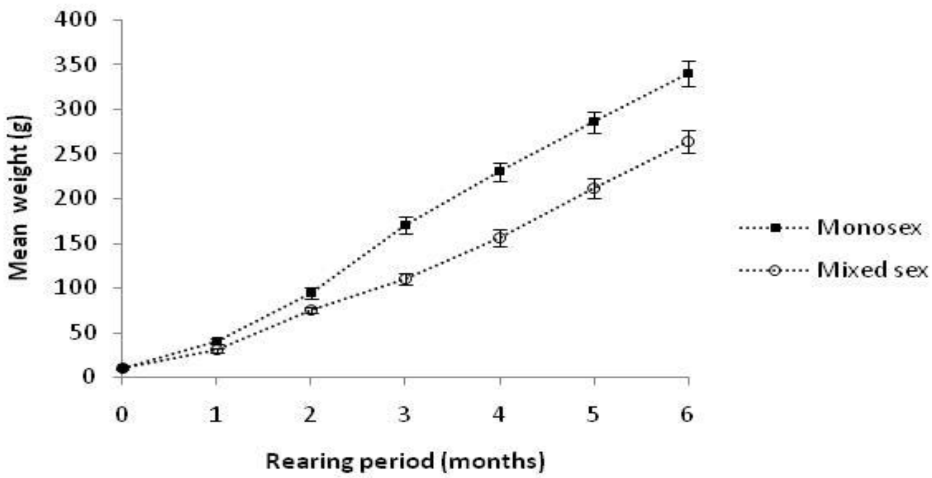

Fig. 2 Monthly mean weights (± SE) of male monosex and mixed sex Nile tilapia reared in cages for 180 days

Table 2 Growth performance of male monosex and mixed sex Nile tilapia reared in cages for 180 days (mean ± SE)

Growth variable	Male monosex	Mixed sex
Initial weight (g fish^{-1})	9.5 ± 0.18[a]	8.8 ± 0.23[a]
Final weight (g fish^{-1})	340.5 ± 1.34[a]	264.5 ± 1.45[b]
BWG (g fish^{-1})	331 ± 2.73[a]	255.7 ± 2.12[b]
FCR	1.4 ± 0.04[a]	1.8 ± 0.03[b]
CF	1.9 ± 0.02[a]	1.4 ± 0.06[b]
SGR (day^{-1})	1.98 ± 0.25[a]	1.49 ± 0.21[b]
Survival (%)	96 ± 2.4[a]	95 ± 2.1[a]

Means with the same letter in a row are not significantly different (P > 0.05).

Statistical analysis

Data was tested for normality using Shapiro – Wilk method and when conditions were met, data was subjected to statistical analysis. One-way ANOVA was used to compare variation between treatments. Statistical significance was set at P < 0.05. Statistical analyses were performed using R statistical software for Computing Platform © 2015 R Foundation.

Results

The summary of the selected water quality parameters is presented in Table 1. There were no significant differences in Temperature, pH, Conductivity, DO and TDS among the cages.

The growth performance curves for male monosex and mixed sex Nile tilapia is shown in Fig. 2. There was a significant difference in growth rate between male monosex and mixed sex Nile tilapia (P < 0.05).

A summary of growth performance parameters for male monosex and mixed sex Nile tilapia are presented in Table 2. At the end of 180 days of rearing, monosex group had 97% sex reversal success to all males while in the mixed sex group there were 52% females and 48% males. The final mean weight of male monosex was 340.5 ± 1.34 g while that of mixed sex was 264.5 ± 1.45 g showing a significant difference between the two groups ($P < 0.05$). The male monosex Nile tilapia had significantly lower FCR than mixed sex ($P < 0.05$). Similarly, the mean CF for male monosex was significantly higher than that of mixed sex group ($P < 0.05$). However, there was no significant difference in survival rates between the two groups ($P > 0.05$).

Discussion

All the selected water quality parameters in cages of both groups was found to be within the recommended ranges for growth of Nile tilapia (Boyd and Lichtkoppler 1979; Madalitso et al. 2020). Thus, any growth performance variations between male monosex and mixed sex Nile tilapia may have not been influenced by water quality conditions.

Better FCR in male monosex group indicates that they were efficient in utilization of feed provided by extracting nutrients from the feed and transforming it into flesh. However, FCR values of both groups were within suggested range of 1.4 to 2.5 (Alhassan et al. 2018) for tilapia cage aquaculture systems in Africa.

Condition factor is an indicator of the well being of a fish (Ridha 2011). The mean CF values of 1.9 ± 0.02 and 1.4 ± 0.06 for male monosex and mixed sex respectively were higher than those obtained in an earlier study where Nile tilapia was reared in ponds (Githukia et al. 2015). The higher CF in male monosex group may be attributed to the fact that male monosex Nile tilapia has a higher growth rate, with greater uniformity of size and good meat quality (Beardmore et al. 2001). However, in both groups the CF was above 1 indicating that the fish were in good health condition (Kembenya et al. 2014; Ogello et al. 2017).

Nile tilapia is known for its mouth brooding behavior but eggs or fry were not found in the mouths of the big sized females .The breeding cycle of mixed tilapia in cages is disrupted, permitting mixed sex populations to be reared without being sexually mature. This may occur due to the fact that cages lack nesting places to necessitate courting and ultimate spawning (Halwart and Tacon 2007). Even though mixed sex Nile tilapia did not reproduce in cages they performed poorly as compared to male monosex. This can be attributed to the fact that Nile tilapia exhibits sexual dimorphism in which males grow quicker and bigger than females (Kamaruzzaman et al. 2009). Therefore, the proportion of females in the mixed sex group might have probably contributed to lowering their overall growth performance. This is so because in females, there is a greater allocation of metabolic energy towards reproduction. While in males, the metabolic energy is channeled towards growth as they benefit from anabolism enhancing androgens (Tran-Duy et al. 2008). Better growth of male monosex Nile tilapia has been observed in different studies(Chakraborty et al. 2011; Githukia et al. 2015; Gómez-Márquez et al. 2015). Faster growth of monosex male tilapia has been linked to less energy spent in reproduction activities such as fighting to defend territories, preparation of egg nests and courtship (Mukti et al. 2020; Tran-Duy et al. 2008). In addition, the males have an aggressive feeding behavior (Fuentes-silva et al. 2013).

The high survival rate observed in fish from both groups can be attributed to favorable water quality conditions during the experimental period. Further, the survival rate of 96% among male monosex was in agreement with Fuentes-silva et al. (2013), who suggested that survival rates of all male Nile tilapia is over 96%. This indicates further that the use of hormone for sex reversal of tilapia does not reduce survival (Chakraborty et al. 2011).

Conclusion

The results of this study indicate a significantly high growth performance of male monosex tilapia compared to mixed sex Nile tilapia reared for a similar period under similar culture conditions. Therefore, culture of male monosex Nile tilapia shortens the grow-out period, thus reducing feeding and management costs.

Conflicts of interest The authors declare that they have no conflict of interest.

Authors' contribution EMK participated in conceptualizing, data collection and drafting the manuscript. RNO participated in experimental design and data collection. The two authors contributed to the submitted version.

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