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ORIGINAL RESEARCH ARTICLE

GROWTH PERFORMANCE, FECUNDITY AND SEXUAL GROWTH DIMORPHISM OF *Oreochromis esculentus* AND *Oreochromis niloticus* UNDER CAGE CULTURE IN KISII COUNTY, KENYA

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ABSTRACT
Oreochromis esculentus, a fish species relished by people around the Lake Victoria region is no longer abundant due to competitive exclusion by introduced fishes and fishing pressure. There is a need for its culture for production and determination of its growth performance in captivity. Little information is available on the growth of *O. esculentus* in captivity. This study aimed to evaluate growth performance, sexual growth dimorphism and fecundity of two species, the threatened *O. esculentus* and the traditionally cultured Oreochromis niloticus for recruitment of the former in aquaculture. Growth trials were undertaken at the Fish Multiplication Centre in Kisii County. Three treatments of *O. esculentus* (from Gesebei dam), *O. niloticus* (from County Fish Multiplication and Training Centre – CFMTC) and *O. niloticus* (from Kitaru dam) were replicated four times in cage culture. Each cage was stocked with 30 fingerlings, cultured for eight months and fed twice daily. Fish samples were collected biweekly for weight and length measurements. Eggs/ fry were retrieved from brooding females and relative fecundity was evaluated. Data was analyzed using the analysis of covariance. For asymptotic weight, *O. niloticus* (CFMTC) weighing 329.7±5.48 g outperformed *O. esculentus* (Gesebei) 317.7±5.48 g and *O. niloticus* (Kitaru) 258.8±5.48 g ($p < 0.05$). The *O. esculentus* had the highest asymptotic length of 30.5±0.29 cm, followed by *O. niloticus* (CFMTC) 28.5±0.29 cm and 26.5±0.29 cm for *O. niloticus* (Kitaru) ($p < 0.05$). There was no significant difference in growth performance between the males and the females of *O. esculentus* in terms of asymptotic length and weight. For relative fecundity, there was no significant difference with slopes for fecundity means at 95% confidence intervals, with *O. esculentus* (Gesebei) at -0.07543, *O. niloticus* (CFMTC) and *O. niloticus* (Kitaru dam) at -0.06036 and -0.12034, respectively. The study showed *O. esculentus* is suitable for aquaculture due to its performance in length and can be a conservation strategy.

Key words: Cage culture, fecundity, growth parameters, *O. esculentus, O. niloticus*, sexual growth dimorphism.

1.0 INTRODUCTION
The percentage of terrestrial key biodiversity areas covered by protected areas increased, from 16.5 per cent in 2000 to 19.3 per cent in 2015. Over the same period, the share of freshwater key biodiversity areas that were protected increased from 13.8 per cent to 16.6 per cent, and the share of mountain key biodiversity areas under protection grew from 18.1 per cent to 20.1 per cent (SDGs UN – DESA, 2015). The focus in Goal 15 of the SDGs was to halt biodiversity loss which came at a critical time since many species of amphibians, birds and mammals had slid towards extinction (SDGs UN – DESA 2015).

Bearing in mind the concerns of biodiversity loss cited in the MDG and the Sustainable Development Goals (UN, 2016) report, there was a need to investigate the conservation potentials of the critically endangered *Oreochromis esculentus* (Graham), found in Lake Victoria and its satellite lakes in Kenya, Tanzania, and Uganda especially L. Nabugabo, L. Kyoga and L. Kwania (Trewavas, 1983). Its natural habitats were swamps and freshwater lakes (Twongo *et al*., 2006) while its population status in Lake Victoria varied (Trewavas, 1983). After 1954 when Red belly Tilapia (*Tilapia zillii*) was introduced into the Lake, *O. niloticus* and Blue-spotted Tilapia (*Oreochromis leucostictus*) also appeared there, probably introduced incidentally with the Tilapia (Lowe – McConnell, 1956). It was later noted that *O. niloticus*, which became very successful, had displaced *O. esculentus* (Graham). According to Aloo (2003), the second half of the last century witnessed Lake Victoria's ecosystem undergo drastic ecological changes with the most notable being the decline in populations of many endemic Cichlid fishes. Furthermore, the Lake lost nearly 200 Haplochromines and one tilapiine, *O. esculentus* (Graham, 1928). Other than the introduction of *O. niloticus*, the predatory Nile perch, *L. niloticus* which was also introduced into the Lake resulted in the endemic populations becoming rare, declining by more than 80% in the last 20 years (Twongo *et al*., 2006).

Tilapia is one of the most important fish species cultured worldwide and males tend to grow faster than females (Lorenzen, 2000; Charo Karisa *et al*., 2006). Due to the higher growth rate in male tilapia, the adoption of various methods of manipulating the sex of offspring to male-only for culture is a common practice (Beardmore *et al*., 2001). Production of monosex populations is related to sexual growth dimorphism, with either males or females growing faster depending on a particular species (Martínez *et al*., 2014). Fecundity is also an important attribute in ichthyology as it is a determinant on fish production, fish stock recruitment and management (Qadri *et al*. 2015). Fecundity data and its relationship with other morphological characteristics for instance weight, size and age gives an index of density-dependent factors that affect the population size. *O. niloticus* is the most prominent species for culture. The males are reported to be 20 – 30% heavier in weight compared to females (Kohinoor *et al*., 2003).

The attribute of the faster growth rate of the male tilapia is what influences the uptake of monosex culture in holding units such as tanks and floating cages and also with the enhancement of stocking density in those and other holding units (Lind *et al*., 2015). However, certain reports indicate that monosex production utilizing male-only tilapia may not necessarily yield better results than a mixed-sex culture (Kamaruzzaman et al., 2009). It has also been reported that the cost implications and resources needed for the production of an all-male population may at a point in time be less lucrative than just going ahead with the production of a mixed-sex population (Lind *et al*., 2015). Hence the need for its culture for biomass production. Little information is available on growth parameters and sexual growth dimorphism of *O. esculentus* in captivity. Both the sexes of *O. esculentus* grew at the same rate and matured at the same size in any given environment (Lowe, 1955; 1956; Garrod, 1959). According to Cridland (1961) in over twenty – three months, the average growth of males of ten aquarium bred pairs was faster than that of females. As with other species, the size of the initial breeding is determined by the environment. Garrod (1959) reports that in aquaria this may occur at 10 cm and at an age of 5 months. In a pond at Korogwe, to which the species was introduced, Lowe (1955) found that both sexes had bred when they were less than seven months old and had reached a length of 16 – 19 cm Total Length (TL).

O. esculentus, an endemic fish species relished by the people around Lake Victoria region is no longer abundant due to competitive exclusion by introduced fishes and fishing pressure. Incidences of predation by the *L. niloticus* and out competition by the *O. niloticus* that occupied a similar ecological niche with *Singida tilapia* rendered it a critically endangered species (Twongo *et al*., 2006). In addition to the threat by the introduced species, fishing habits e.g. seining was a preferred harvest method that resulted in enhanced efficiency and capacity that led to overfishing of *O. esculentus* (Steeves, 2011). The overfishing led to the use of fishing gear with smaller mesh sizes as stocks dwindled with smaller and younger fish being caught and as a result, few adults were able to fill the population fissure (Steeves, 2011). *O. esculentus* is tolerant to low dissolved oxygen levels as they are known to cope in below one ppm range (Froese and Pauly 2017). This would be stressful to *O. niloticus*. It is also renowned for its palatable taste with relatively firm flesh that is suitable for sun drying (Mwanja and Kaufman, 1995).The objective of this study was to evaluate growth performance, sexual growth dimorphism and fecundity of two fish species, the *O. esculentus* and the traditionally cultured *O.niloticus* under cage culture.

2.0 MATERIALS AND METHODS

2.1 Study area

The study was carried out in fish ponds at the County fish farm (S 00°40.308' E034°46.482') in Kisii County. Kisii County is part of the catchment that drains towards Lake Victoria.

The Kisii region lies within the highlands west of the rift valley, 305.1 kilometres from Nairobi. Its elevations range from 1,250 m and 2,200 m above mean sea level. Kisii region has a highland equatorial climate resulting in a bimodal rainfall pattern with an average annual rainfall of 1,500 mm. The County is endowed with numerous springs, streams and rivers therefore water as a resource is abundant. The minimum temperatures range from 15° – 20°C and maximum of 21° and 30°C. The County has a high potential for agricultural development including aquaculture (County Integrated Development Plan, Kisii, 2018).

2.2 Fish species

Two fish species were used in this study, *Oreochromis esculentus* and *Oreochromis niloticus* Fingerlings of both *O. esculentus* and *O. niloticus* were the First Filial (F1) generation of broodstock sourced from Gesebei (S00°45.271' E035°01.431') and Kitaru (S00°36.984' E035°02.671') dams, respectively, in Borabu Sub County of Nyamira County. Fingerlings of *Oreochromis niloticus* were sourced from the broodstock at the County Fish Multiplication and Training Centre (CFMTC), Kisii County. The terms *O. esculentus* (Gesebei) and *O. niloticus* (CFMTC) and *O. niloticus* (Kitaru) is used here to refer to the fish species or treatments.

2.3 Research design

A randomized block design was used in this experiment. The study was replicated four (4) times. There were three (3) treatments: *O. esculentus* (Gesebei), *O. niloticus* (CFMTC) and *O. niloticus* (Kitaru). The experimental units were cages of 1 m^3 in size installed in a large concrete pond measuring 362 m^2 in surface area. The fingerlings were stocked in the twelve (12) 1 m^3 cages, four (4) cages each for *O. esculentus* (Gesebei), *O. niloticus* (CFMTC) and *O. niloticus* (Kitaru). A stocking density of 30 fingerlings per square metre was used. The fish feeds utilized were isonitrogenous diets with protein level of 28% crude a protein (CP). Fish were fed at 3% live body weight. Each ration was split into two equal parts and fed twice a day at 10.00 and 16.00 hrs.

2.4 Field procedures

Sampling was undertaken at a two-week interval for length and weight determinations. The study was conducted for eight (8) months. The weights of fish specimens was measured using an electronic weighing scale (Scout Pro SPU 601, USA) whereas their length was measured using a graduated measuring board. The relative fecundity of fish species was calculated from the count of the total number of eggs per gram of female according to Bagenal (1978). Sampling for fecundity commenced in late April when some fish presented with eggs/ fry in their buccal cavity. The number of eggs/fry were recorded alongside the fish specimen's total length and weight. Determination of the sexual growth dimorphism commenced when differentiation in male and female anatomy of fish species could be determined. During the biweekly sampling, sex, length and weight were recorded for each fish specimen. The following water quality parameters were also determined at the culture site: dissolved oxygen (DO), water temperature and pH. The dissolved oxygen in ppm was measured using a dissolved Hanna type oxygen meter (USA), while water temperature (^oC) was monitored using the thermometer reading on the DO meter. The pH was measured using a Hanna type pH meter (USA). The DO and water temperature were recorded thrice a day (8 am, noon and 5 pm). The pH was measured twice, at 8 am and 6 pm.

2.5 Data analysis

In determining the growth performance of the fish species, growth parameters (L_∞, W_∞ and K) were estimated based on the Von Bertalanffy growth formula (Prein *et al.*, 1993) expressed as follows:

$$L_t = L_\infty \left(1 - e\text{-}K^{(t-t_o)}\right)$$

Where, L_t = length (in cm) at time t (in years), L_∞ = asymptotic length or the maximum attainable length if the fish is allowed to grow, K yr-1 = instantaneous growth coefficient, t_o = age at which length equals zero or a scaling factor.

The Statgraphics Version 17.0 statistical package was used for the data analysis while Excel version 2010 was utilized to transform data to get the logs of length and weight for the three treatments. From the transformed data, the comparative slopes from the graphs for growth performance, sexual growth dimorphism within species and fecundity. W_∞ was derived from the exponential of the value of the intercept.

3.0 RESULTS

3.1 Water quality parameters

Figure 2 shows the water quality at the culture site from March to November 2015. There was no significant differences among the water quality parameters during the entire culture period. The dissolved oxygen ranged from 0.2 milligrammes per litre (mg/l) to 15.4 mg/l) while water pH of between 6.8 – 10.1; water temperature ranged from 2.4 ^oC to 29.5^oC. Ammonia ranged from 0.1 – 0.13 mg/ l.

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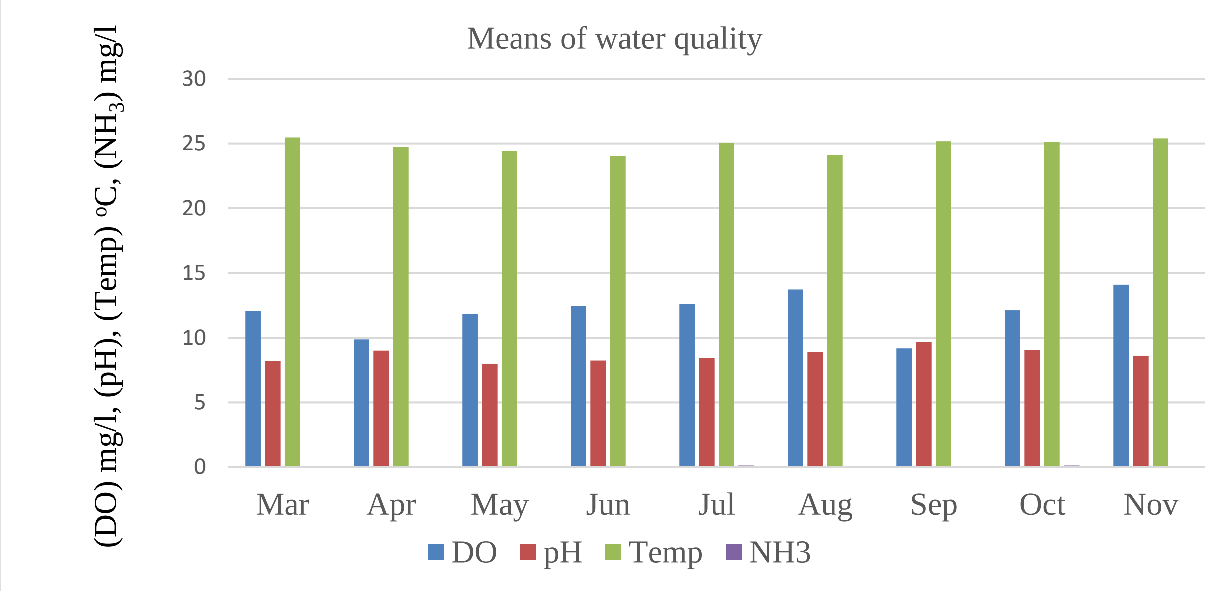

Figure 1. The average dissolved oxygen (DO in mg/l), ammonia (NH_3 in mg/l), water potential of Hydrogen (pH) and temperature (Temp in °C) at the culture site from March to November.

3.2 Growth parameters

The predicted maximum length (L∞) for the fish species were significantly different ($p < 0.05$), with the highest mean length of 30.5±0.29 cm obtained from *O. esculentus* (Gesebei) and lowest for *O. niloticus* (Kitaru) (Table 1). The mean length of *O. niloticus* (CFMTC) was 28.5±0.29 cm. The maximum weights (W∞) for *O. niloticus* (CFMTC) and *O. esculentus* (Gesebei) were significantly higher ($p < 0.05$) than that of *O. niloticus* (Kitaru). There was no significant difference in growth coefficient K in 365 days (Kyrs) and growth rates among the treatments (Table 1).

Table 1. The average asymptotic length L∞ (cm), asymptotic weight W∞ (g), growth coefficient K (years), growth rate (g/day) of two fish species under cage culture (mean ±SE, n =4).

Fish species	L∞ (cm)	W∞ (g)	Kyrs	Grate (g/day)
O. esculentus (Gesebei)	30.5±0.29^{c}	317.7±5.48^{b}	1.0±0.03^{a}	1.5±0.03^{a}
O. niloticus (CFMTC)	28.5±0.29^{b}	329.7±5.48^{b}	1.0±0.03^{a}	1.2±0.03^{a}
O. niloticus (Kitaru)	26.5±0.29^{a}	258.8±5.48^{a}	1.3±0.03^{a}	1.2±0.03^{a}

3.3 Sexual growth dimorphism

The results for sexual growth dimorphism of lengths and weights for males are presented in Figures 2 and 3, respectively. The asymptotic length (L_∞) (Figure 2) and asymptotic weight (W_∞) (Figure 3) of the male *O. niloticus* (CFMTC) were significantly higher than the *O. esculentus* (Gesebei) and *O. niloticus* (Kitaru) males ($p<0.05$).

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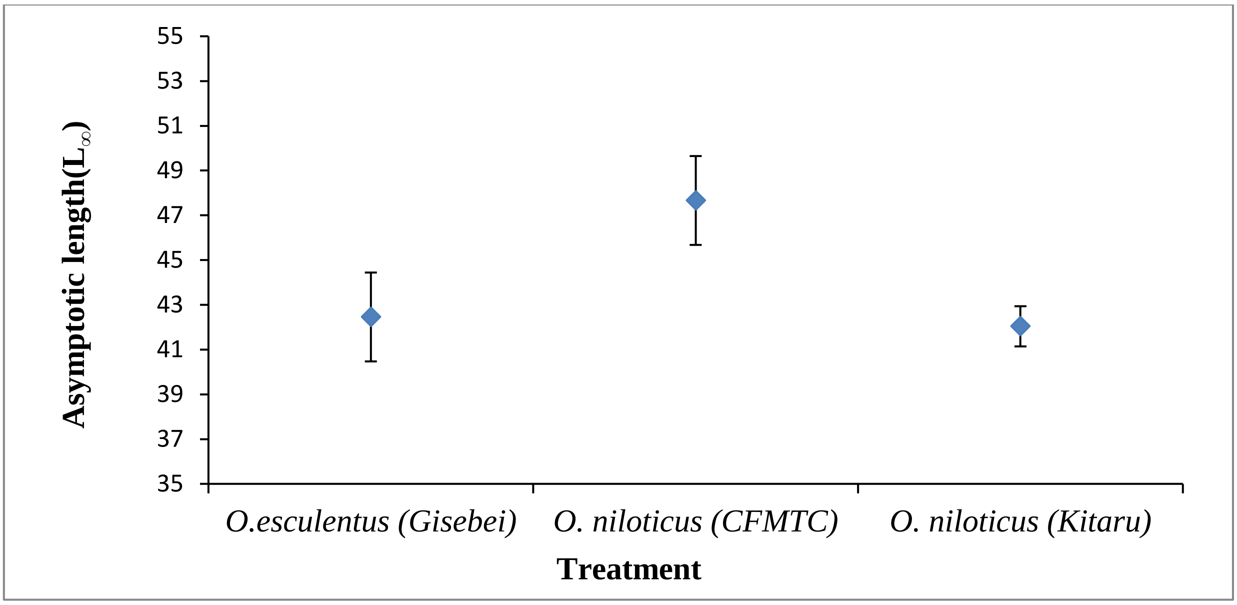

Figure 1. Asymptotic lengths (cm) for males among treatments under cage culture (mean ± 95% confidence intervals, n=4)

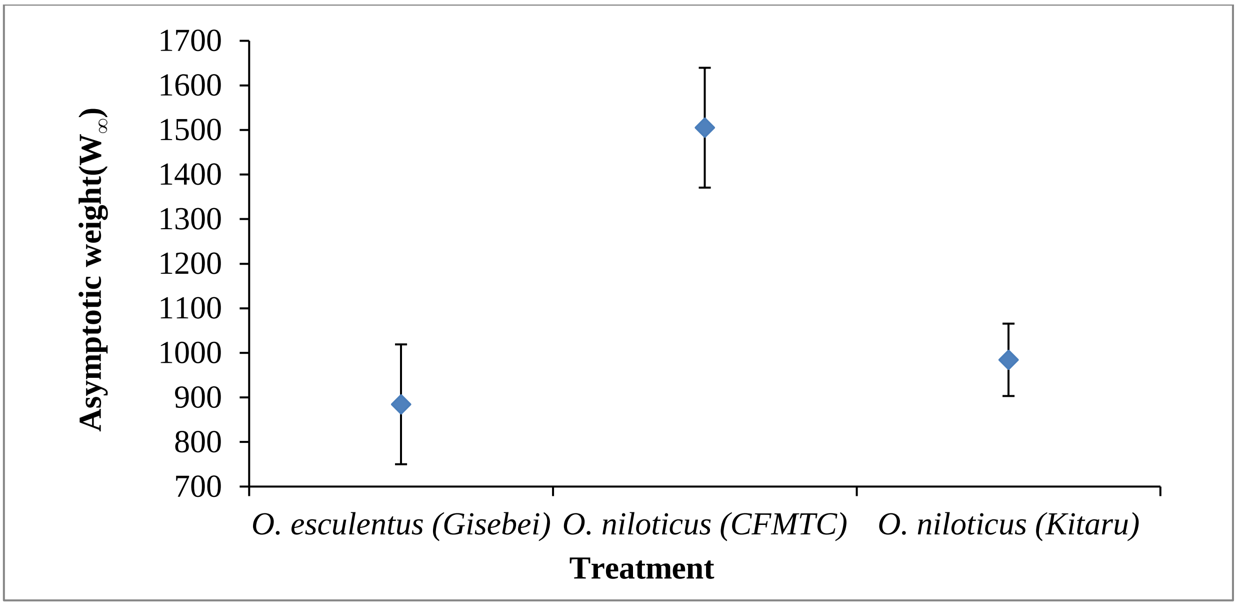

Figure 2. Asymptotic weights (g) for males among treatments under cage culture (mean ± 95% confidence intervals, n=4)

The sexual growth dimorphism of lengths and weights for females are presented in Figures 5 and 6, respectively. The *O. niloticus* (CFMTC) and *O. esculentus* (Gesebei) females recorded higher mean asymptotic lengths than the *O. niloticus* (Kitaru) females ($p<0.05$; Figure 5). The mean asymptotic weights of the treatments were significantly different, with female *O. niloticus* (CFMTC) having the highest value (1000 ± 110), female *O. niloticus* (Kitaru) the lowest (600 ±56), while female *O. esculentus* (Gesebei) was intermediate (800 ± 59).

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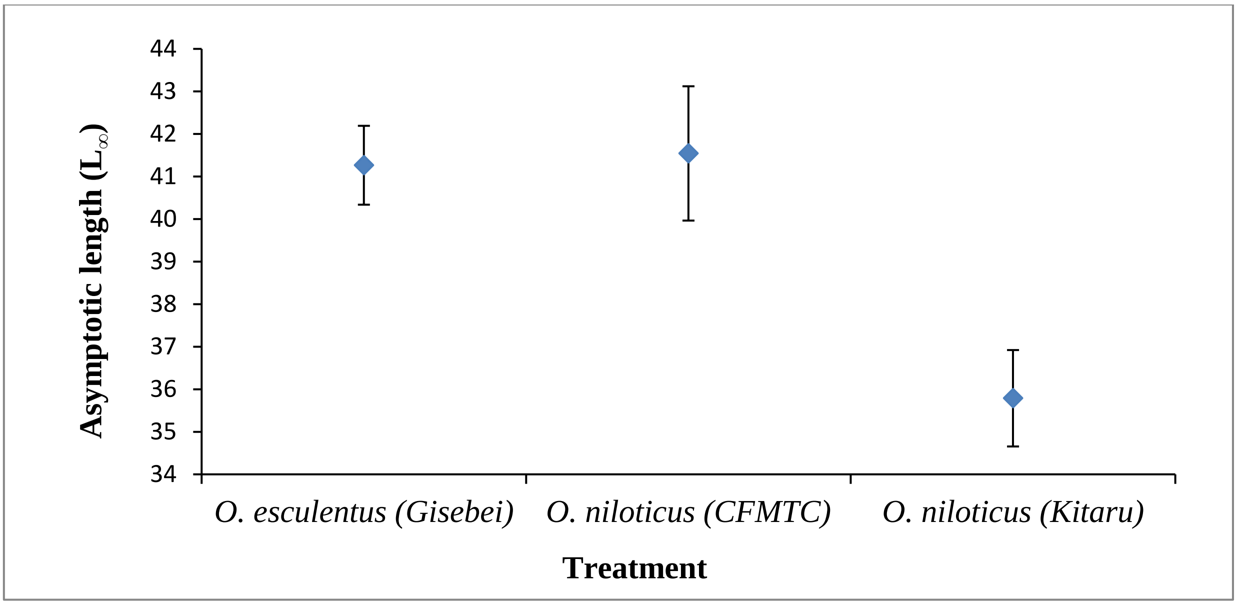

Figure 3. Asymptotic lengths (cm) for males among treatments under cage culture (mean ± 95% confidence intervals, n=4).

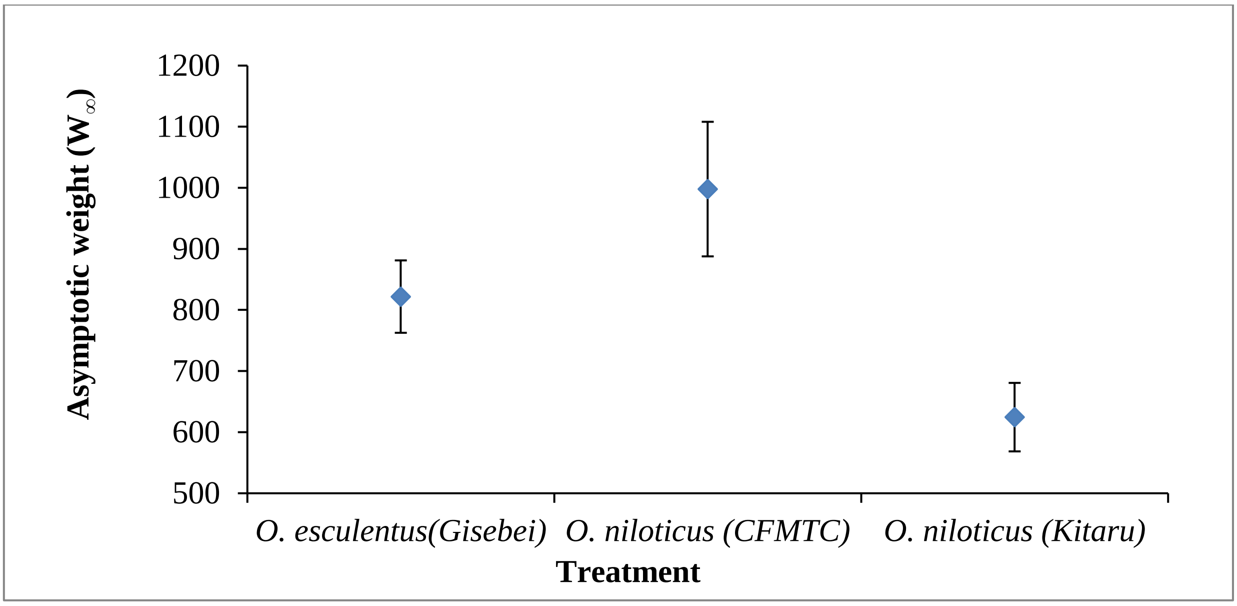

Figure 4. Asymptotic weights (g) for females among treatments under cage culture (mean ± 95% confidence intervals, n=4).

There was no significant difference in asymptotic length and weight between the males and the females of *O. esculentus* (Gisebei) (Figures 7 and 8).

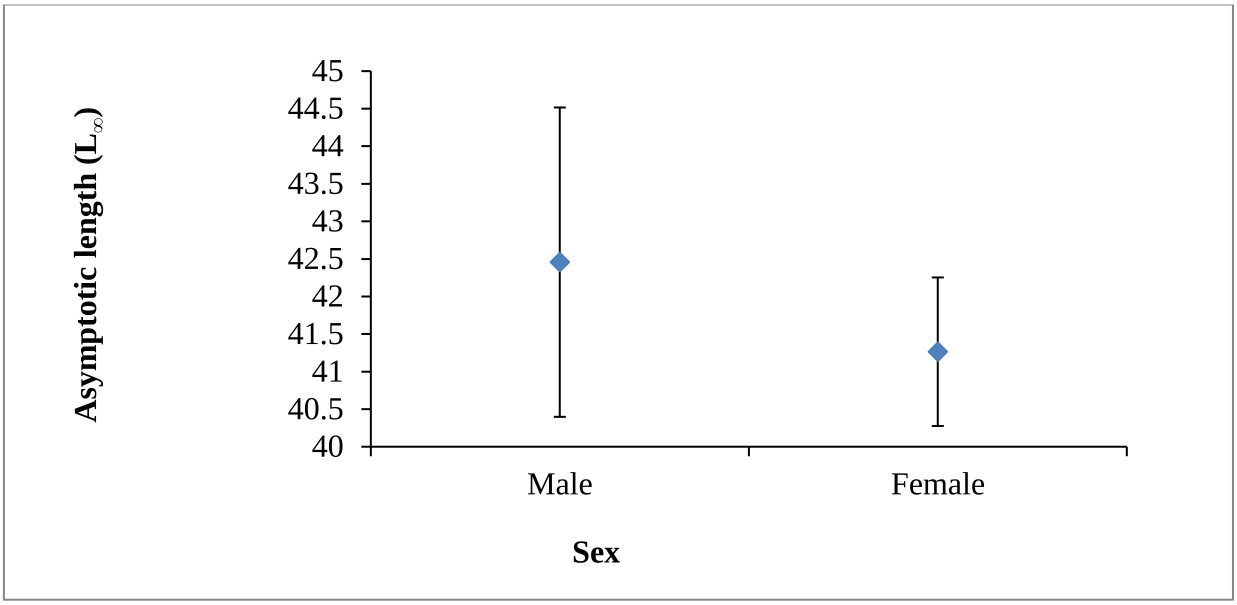

Figure 5. Asymptotic length (cm) for males and female of *O. esculentus* (Gesebei) under cage culture (mean ±95% confidence interval, n=4).

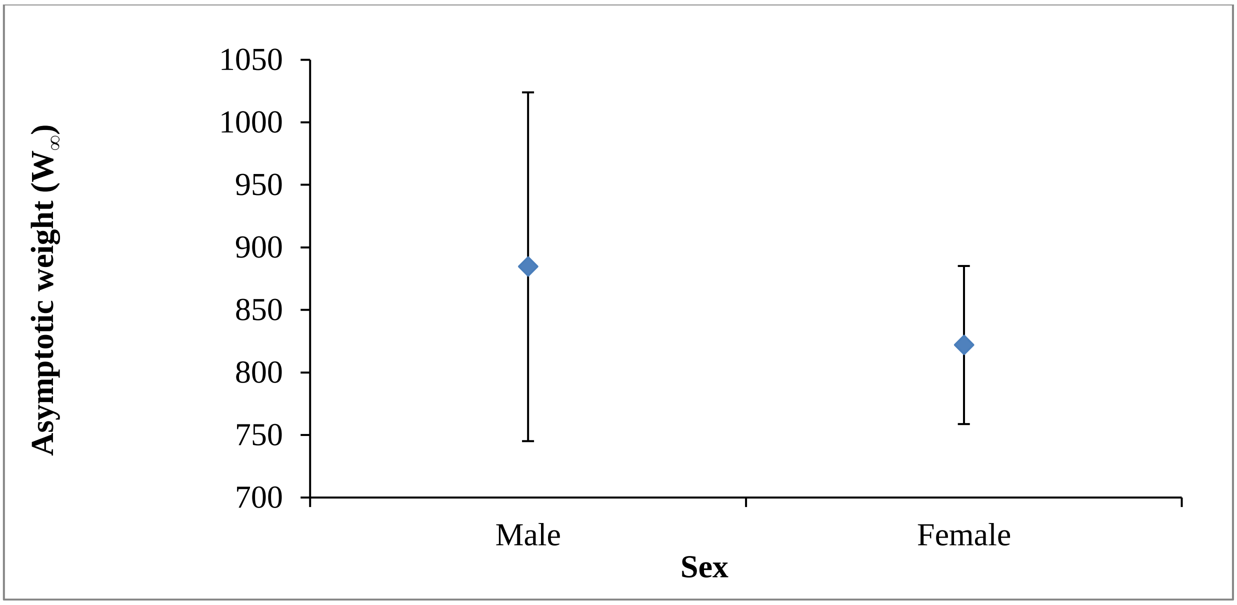

Figure 6. Asymptotic weight (g) for males and females of O. esculentus (Gesebei) under cage culture (mean ±95% confidence interval, n=4).

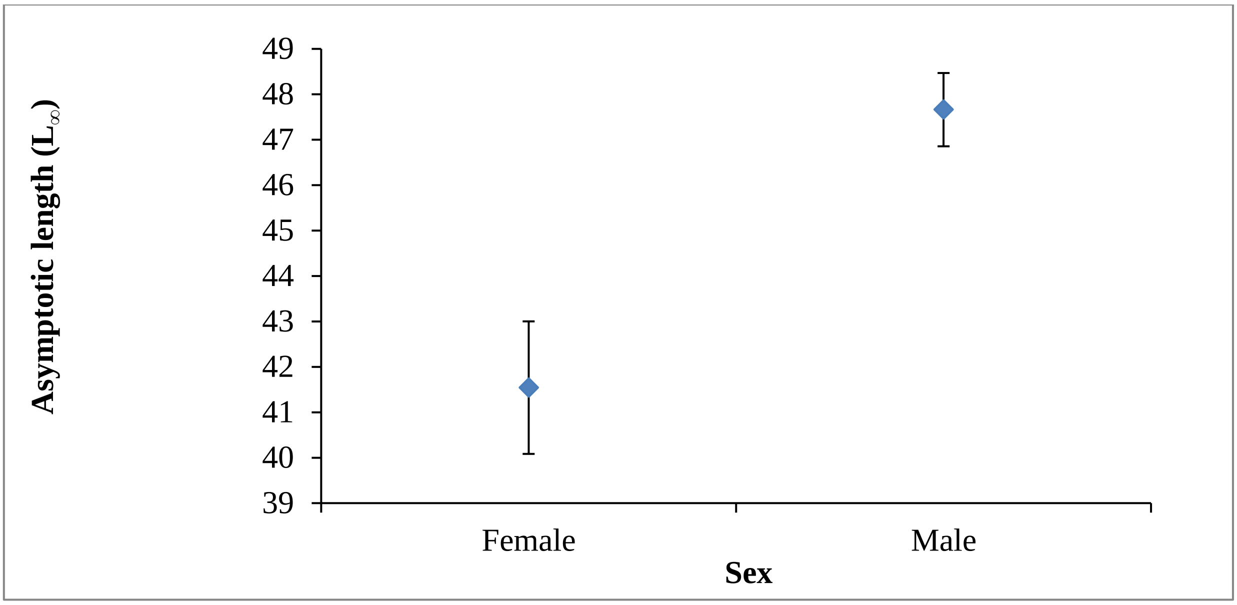

Figure 7. Asymptotic length (cm) for males and females of O. niloticus (CFMTC) under cage culture (mean ±95% confidence interval, n=4).

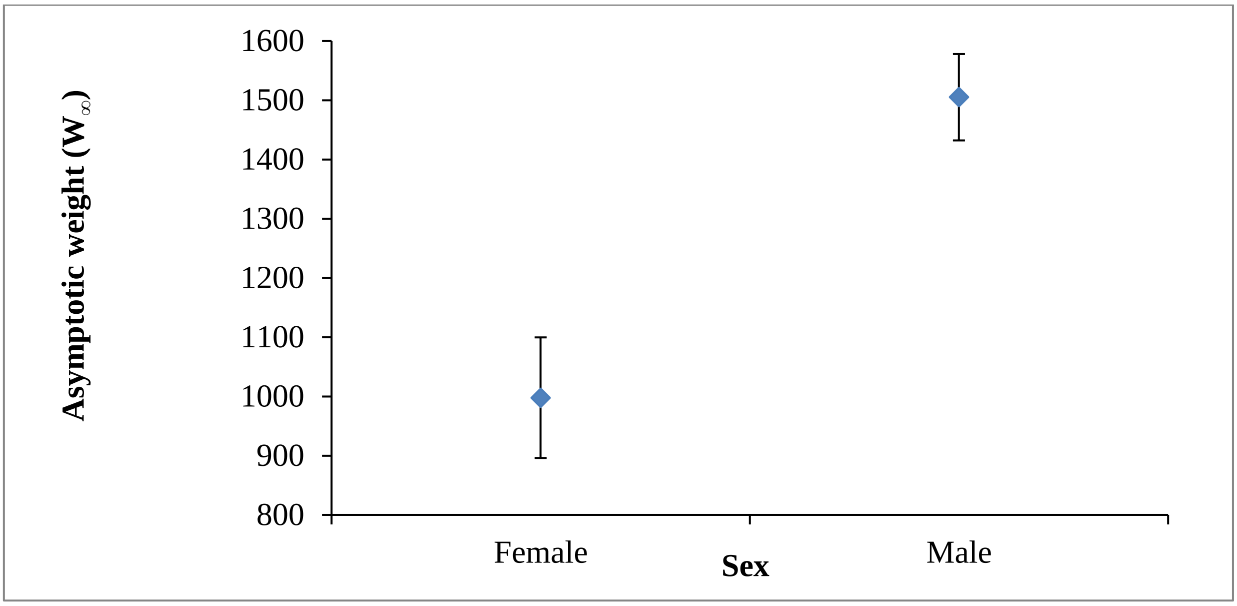

Figure 8. Asymptotic weight (g) for males and females of O. niloticus (CFMTC) under cage culture (mean ±95% confidence interval, n=4).

There was a significant difference in asymptotic lengths and weights between the males and the females of *O. niloticus* (CFMTC), with the males recording higher values than females (Figures 8 and 9). Similar observations were also obtained for the males and females in *O. niloticus* (Kitaru) (data not shown).

3.4 Relative fecundity

Figure 12 shows the slope of the mean fecundity among the three treatments: *O. niloticus* (CFMTC), *O. niloticus* (Kitaru) and *O. esculentus* (Gesebei). There was no significant difference in fecundity among the treatments ($p > 0.05$, Figure 11). In all instances, except in one of the cages, the fish caught with egg/ fry were observed in the month of April, 45 days from the onset of stocking. The cage was one of the replicates for *O. niloticus* (CFMTC) of which fry were retrieved in May and may indicate a delayed maturation for that group. The highest number of eggs counted was from a 19 g individual *O. esculentus* was 575. For relative fecundity, there was no significant difference with slopes for fecundity, with *O. esculentus* (Gesebei) at -0.07543, *O. niloticus* (CFMTC) and *O. niloticus* (Kitaru at -0.06036 and -0.12034, respectively.

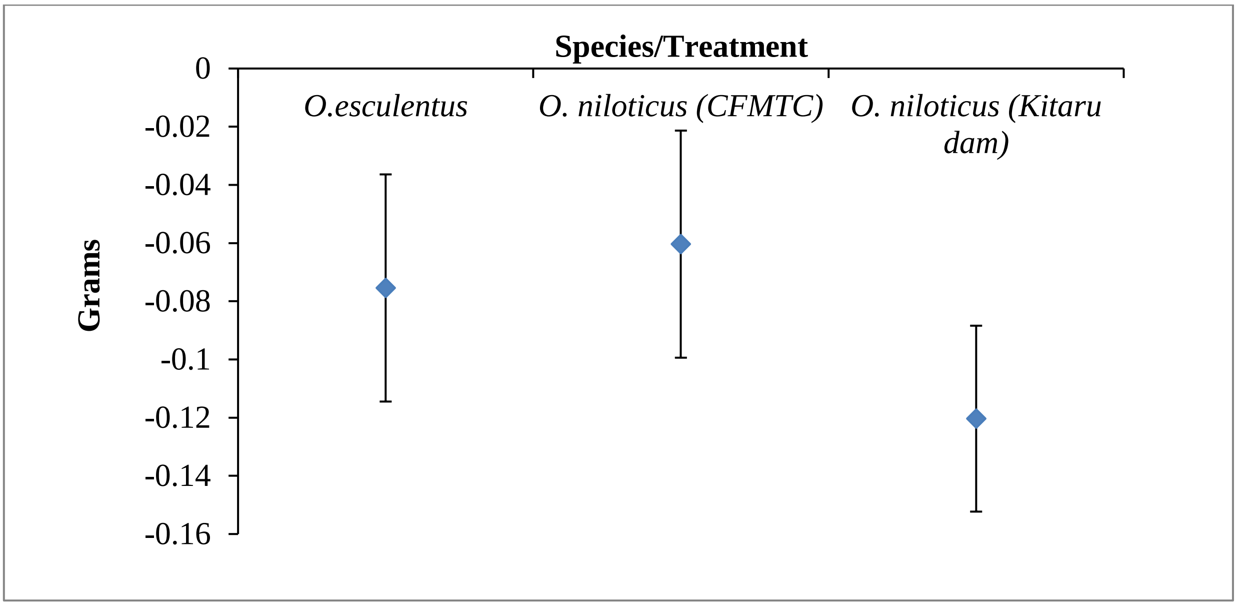

Figure 9. Average fecundity among species / treatments under cage culture (mean ±95% CI, n=4).

One of the intriguing observations in this study was the presence of fry in the buccal cavity, which was an indicator that fertilization of the eggs took place. It was noted that despite the fish being held in cages with netting mesh size of 2.54 cm, the brooding females were still able to collect the eggs in to their buccal cavities.

4.0 DISCUSSION

4.1 Growth parameters

Higher length and weight values were obtained for *Oreochromis. niloticus* than for *Oreochromis. esculentus*. The present study confirmed the superiority of *O. niloticus* over *O. esculentus* to growth parameters as observed by other studies (Yakubu, 2012; Munguti *et al*., 2014; Githukia *et al*., 2015). In tropical pond waters and under semi-intensive culture management, *O. niloticus* can grow up to 150 – 250 g in four to six months, 500 to 800 g in 10 to 12 months, and 2 – 3 kg in 2 years (Hussain, 2004). The success of *O. niloticus* in aquaculture is due to its high potential for growth and reproduction in a wide range of environmental conditions (Liti *et al*., 2005). The superior performance of the *O. niloticus*, may be attributable to its history of domestication, as the parent stock were brooders from the CFMTC. The growth of some species of fish have been markedly improved by selection programs that have given them some level of improvement in selected traits including growth and reproduction, which are considered to be the main indices of performance (Dos Santos *et al*., 2013). Therefore, such breeding practices could have been the contributing factor in the better performance of *O. niloticus*. Selective breeding is known to offer continued genetic gain, and these can be permanent and can be transmitted from one generation to the next (Ponzoni *et al*., 2007), hence a factor to be considered with respect to the *O. niloticus* from the CFMTC.

The *O. esculentus* fingerlings were the First filial (F1) generation of a broodstock sourced from Gesebei dam, whereas those of *O. niloticus* (Kitaru) were F1 generation of brooders sourced from Kitaru. The dams, which contained the *O. niloticus* and *O. esculentus* were constructed in colonial time and subsequently stocked for recreation purposes. It is possible that inbreeding occurred with the passing on of poor performance traits to the *O. esculentus* (Gesebei) and the *O. niloticus* (Kitaru) hence resulted inbreeding depression. The widespread introgression of genes from other less desirable feral tilapia species is a point of concern (Macaranas *et al*., 1986).
The growth performance of *O. esculentus* (Gesebei) was subordinate to *O. niloticus* (CFMTC) in weight with respect to growth performance and sexual growth dimorphism, except for length in which the former was better than the latter. In the present study, *O. esculentus* had a lower weight, with a slightly elongated and leaner stature comparative to the *O. niloticus* (CFMTC) and the *O. niloticus* (Kitaru). Trewavas (1983) made a similar observation, which the author attributed to the longer caudal peduncle of the *O. esculentus* relative to that of the O. niloticus. The longer length of *O. esculentus* does not translate to a significant increase in flesh and weight, attributes that are important in aquaculture. Despite the subordinate status of *O. esculentus* in terms of weight compared to *O. niloticus*, the former is famed for its superiority in palatability and highly valued by local fishermen, who refer to it as "ngege" (Steeves, 2011). *O. esculentus* is referred to as 'savoury cichlid' in the literature (IUCN, 2008) and could have an advantage if marketed as a high-value fish, putting it in league with species like the turbot in Europe and the Salmon where the approach have been seen and targets niche markets. The *O. niloticus* (Kitaru) performed the least compared to the other treatments.

4.2 Sexual growth dimorphism

The growth performance (in terms of length and weight) of male *O. niloticus* was better than *O. esculentus* and *O. niloticus* males. The female and male of the *O. esculentus* had similar growth performance in terms of both length and weight. The present observations are supported by Garrod (1959), who reported that in a given environment both sexes grow at the same rate and mature at the same size. Such an outcome would advocate for a mixed-sex culture regime and hence qualify *O. esculentus* as a suitable candidate for mixed-sex aquaculture or an all-male or all female culture regime. Hence, the extra cost of creating monosex populations by hormonal or other manipulation may not be required. An all-male or all-female culture regime for *O. esculentus* could also be considered.

The females and males of the *O. niloticus* (CFMTC) had distinct growth performance in terms of both length and weight, with the males performing better than females. This observation confirms the view that *O. niloticus* is the most prominent species for culture and that the males on average are superior to females in growth (Lorenzen, 2000). The males are reported to be 20 – 30% heavier in weight compared to females (Kohinoor *et al*., 2003). The results of these authors correspond with the outcome of the present study and validate the view that *O. niloticus* is best suited for all male monosex cultures. In many species including *O. niloticus*, the culture of monosex is very common (Lorenzen, 2000). Production of monosex populations is related to sexual growth dimorphism, with either males or females growing faster depending on a particular species

(Martínez *et al*., 2014). In tilapiines, male monosex culture takes precedence (Martínez *et al*., 2014). The female and male of *O. niloticus* (Kitaru) were also distinct in performance for both traits. This observation is in agreement with that of Lind *et al*. (2015) who demonstrated that the magnitude of sexual size dimorphism can vary substantially within and among tilapiines. *O. niloticus* (Kitaru) had distinct performance in both length and weight.

4.3 Relative fecundity

No significant differences were observed in the relative fecundity for the treatments. Relative fecundity has also been reported to decrease with the increase in female size (Siraj *et al*, 1983). The number of eggs produced by a female at a time varies with the strain, age and weight as well as the environmental factors prevailing at the time (Kohinoor et al., 2003). Available literature indicates that the *Oreochromis* genus lay their eggs in a depression mainly dug by the male and subsequently fertilized externally (Trewavas, 1983). The fact that there was no possibility of digging depressions in the cages raises the question about the value of the excavation of the basins. The observation of fry, in this case, may suggest several possible strategies applied in the breeding of mouthbrooders. The perception that by using cages fertilization of eggs is impracticable seems erroneous, as the females could still be able to collect the eggs into their buccal cavities.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The findings of the present study confirmed that *O. esculentus* could be a suitable choice for aquaculture though it is not superior to *O. niloticus* in terms of weight. The aspect of either gender of *O. esculentus* performing qualifies it as a species for mixed-sex culture. However, its presumed superiority in palatability would have to be assessed further as this would give it an added advantage over *O. niloticus*, where large sizes do not matter. Besides contribution to aquaculture, ensuring conservation of this endangered species is guaranteed through growth in captivity. The two test species were not distinct in their relative fecundity. It was intriguing that brooding females with fry indicated that the preparation of nests for spawning may not be mandatory. The availability of fry also indicated that there could be another strategy for breeding adaptability of *Oreochromis genus*. This strategy needs further research as it is an indicator that there is plasticity with respect to tilapiines in its breeding behaviour.

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