Growth performance and survival of monosex cultured *Heterobranchus longifilis* juveniles in concrete flow-through and stagnant water systems.

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Abstract: The growth performance and survival rate of monosex *Heterobranchus longifilis* juveniles were examined. A total of 144 *Heterobranchus longifilis* juveniles were stocked in eighteen (18) concrete tanks at stocking density of sixteen (16) fishes per tank of 2 by 2 metre square in flow-through and stagnant water systems triplicated for fifty six (56) days. Mixed sex tanks of *Heterobranchus longifilis* served as the control. The mean initial weight was taken as 1.22±0.00g while the highest mean final weights were 7.86±0.12^{a} g and 6.34±0.02^{c} g for monosex females and males in stagnant culture THFS and THMS. *Heterobranchus longifilis* also showed highest Specific growth rate of 3.80±0.03g in the female stagnant system THFS. Food conversion ratio and Feed conversion efficiency were highest in female flow-through tank THFF and stagnant tank THFS with values 4.09±0.00^{a} and 16.83±0.08^{a}. Performance Index showed *Heterobranchus longifilis* mixed sex performed better than the flow-through monosex culture of *Heterobranchus longifilis*. High survival rate 95.83±4.17% was seen in female stagnant tanks THFS. Lowest survival rates were recorded in the monosex flow-through and stagnant systems of *Heterobranchus longifilis*. Condition factor K was greater than 1 throughout the study for both species. Values were closely similar for the specie in monosex and mixed sex culture. Water quality parameters were at normal ranges for freshwater culture, throughout the study. It is recommended that concrete flow-through and stagnant systems be used for monosex and mixed sex culture of *Heterobranchus longifilis*.

Keywords: growth, survival, triplicates, monosex, *Heterobranchus longifilis*, flow-through, stagnant.

Introduction

The most cultured African catfish species in Africa, especially in Nigeria are *Clarias gariepinus (Burchell, 1822*; Engle and Valderrama, 2001); *Heterobranchus* species (Ellis *et al.,* 2002) and their hybrids. These species exhibit different feed utilization efficiencies, growth performance, and disease resistance, under different culture systems (Gamal *et al.*, 2008).

Scientific studies into the growth response and survival rate of *Heterobranchus longifilis* revealed that this specie exhibits fast growth and ability to withstand adverse condition in earthern ponds and concrete tanks (Viveen *et al.,* 1985). *Heterobranchus* species in addition to the above mentioned characteristics, has some advantages exhibits higher growth rate, feed conversion (Anibeze and Eze, 2000) and gives remarkable yield (Legendre, 1986). Growth tells of the manifestation of the net outcome of energy increases and losses within a framework of both biotic and abiotic conditions (Nwipie *et al.,* 2015). There is however, little information about the growth and survival of *Heterobranchus longifilis* under flow-through and stagnant concrete tank systems, in monosex culture. The ability to culture fish populations of a single sex is most succintly, a useful tool in preventing unwanted reproduction, enabling and affording aquaculturists the opportunity to select, culture fish of only the faster-growing sex

(Simco *et al*., 1989). This becomes an economic advantage to commercial fish producers (Simco *et al*., 1989; Goudie *et al*., 1993). Since the culture of *Heterobranchus longifilis* became more intensive, adequate feeding is required for maximum returns. For fish to grow well is clearly hinged on good nutrition especially when fish are kept in enclosures (Omoruwou and Edema, 2011). This in itself, is a challenge to the fish farmer because feed ingredients are expensive (Akinwande *et al.*, 2002; Dada and Akinwande, 2005).

Based on the many challenges faced by fish farmers, the statement of the problem for this study include the facts that flow-through systems require a good supply of quality water since the type of culture medium has significant impact on fish productivity (Ross and Waten, 1995). Without adequate and constantly available water, fish growth will be limited.

Again, fish stocks in stagnant systems allow for low stocking density, as high stocking density in stagnant systems will lead to losses of fish stocks (Ayinla, 2007) and sex-specific differences in growth become very significant; where one sex grows significantly faster than others (Chakraborty and Banerjee, 2012).

This study was therefore undertaken because there was the need for sustained fingerling production under other water conditions apart from the recirculatory system as documented by various authors (Ekelemu and Ogba, 2005); monosex culture fish stocks help prevent unwanted reproduction, allowing culturists to select and culture fish of only the faster growing sex (Simco *et al.*, 1989) and ultimately, effective management of fishery needs vital information regarding population parameters such as length-weight, age, growth, mortality of the exploited stock (FAO,2006).

Materials and methods

Study area

The study was carried out in the outdoor concrete tanks of the National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, Niger State. New Bussa is the headquarters of the Borgu Emirate and Borgu Local Government Area. New Bussa is located at 9°53′N 4°31′E coordinates (Wikipedia, 2016).

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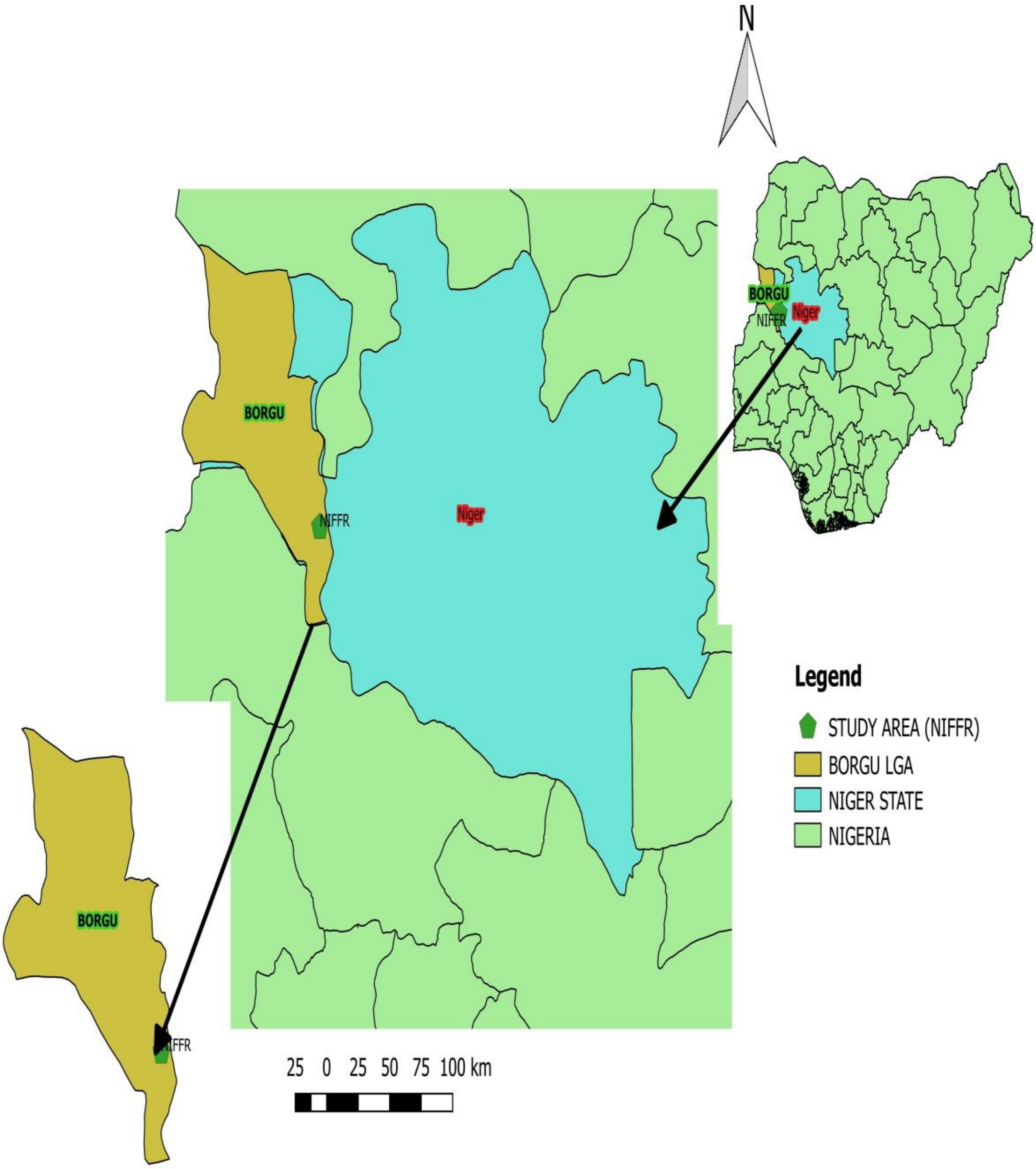

Source: NIFFR Archives, (2015)

Figure I: Map of Borgu Local Government Area with headquarters at New Bussa

Experimental procedure

Eighteen (18) tanks measuring 2m x 2m=4m^2 in dimension, used for this experiment had three treatments in triplicates for the concrete flow-through system and the stagnant systems. A mechanism was devised using a PVC pipe in the concrete flow-through system in such a way that water was constantly flowing into the tanks set aside for flow-through monosex culture of the species via an inlet, while water was at the same time flowing out via an outlet.

The PVC pipe was built into the tank (1.5 inch diameter) equal in length to the experimental water depth, fitted to each compartment to drain excess water, while leaving water at the required ¾ depth in the tank. Only the flow-through system was continuously aerated by opening up the inlet and outlet units so the same flow-rate of water which comes also flows out.

Growth calculations

Data collected were analysed and the following parameters were determined: Length L, Weight gain WG, Condition factor K, Specific growth rate SGR, Survival rate SR and Percentage (%) survival, Feed conversion rate FCR , Feed conversion efficiency FCE and Performance index PI (Davies *et al.*, 2013). Body weights were measured to the nearest 0.01g using a digital weighing scale (MODEL DT 302). The total length (TL), standard length (SL) were taken to the nearest 0.1cm using a measuring board. The length-weight relationship were estimated by using the equation provided by Fulton (1904) and adopted by Ricker (1973): $W=aL^b$, where W=weight of fish in grammes (g), L=total length of fish in centimetres (cm), a= regression coefficient or slope. The equation was linearized by a logarithmic transformation into: Log Weight =log a + b log.

The condition factor K was calculated using the means of the total length and weight of fish as provided by Pauly (1983) with the equation: $K = 100w/L^3$, where K =condition factor, W= mean body weight in grammes (g), L=mean total length in centimeters (cm). The linear relationship between the length and weight was also estimated by calculating the coefficient of determination (R^2). Growth parameters were as follows:

Survival Rate (SR) = number of fish stocked – number of mortalities (Paschal *et al.*, 2006).

Specific Growth Rate % day (SGR)

$$= \frac{\log_n \text{final weight} - \log_n \text{initial weight}}{\text{time (days)}} \times 100$$

(Benedict *et al.*, 2005).

FCR= Total weight of dry feed offered / Total weight gain (Sveier *et al*., 2000).

$$FCE = \frac{\text{Final weight by fish}}{\text{Weight of feed given}} \times 100$$

(TBoujard *et al.*, 2002).

Performance Index PI =

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Survival rate X Final mean weight (g) - Initial mean body weight(g) / Rearing duration in days

(Engle and Valderrama, 2001).

% Survival =

number of broodstock survivors at the end x 100
number of juveniles stocked at the beginning

(Coulibaly *et al.*, 2007).

Experimental design

The experimental design was a 2 X 2 X 3 factorial design.

Data analyses

Data collected were subjected to statistical analysis using analysis of variance (ANOVA). T-test was used to compare growth in the flow-through and stagnant water systems. Duncan Multiple Range Test (DMRT) was used for mean separation and the differences were determined at level of significance (P< 0.05) (Duncan, 1955). Data were furthermore subjected to analysis for regression.

Results

Growth performance

At the beginning of the experiment as seen on Table 1, *Heterobranchus longifilis* males, females and mixed sex had mean initial weights of 1.22±0.00 g. There was no significant difference (p>0.05) in mean initial weights (MIW) for *Heterobranchus longifilis* monosex and the mixed sex tanks species respectively.

Males and females in mixed sex culture of *Heterobranchus longifilis* for flow-through and stagnant systems THF, THS showed no significant difference (p>0.05) in mean final weights of 6.73 ± 0.14^{b}g and 7.30 ± 0.06^{b} g as seen on Table 1. Males and females of *Heterobranchus longifilis* cultured in flow-through systems THFF, THMF on the other hand, exhibited significant difference (p<0.05) in mean final weights of 5.83 ± 0.01^{d} g and 5.86 ± 0.06^{c} g in monosex culture; while the females in the stagnant system of this monosex culture THFS exhibited the highest mean final weight of 7.86 ± 0.12^{a} g recorded in the study. Males of this same specie in tanks THMS showed mean final weight of 6.84 ± 0.02^{c} g in the study.

Therefore, it is suggested that the mean final weight of male and female *Heterobranchus longifilis* in monosex culture, reared in flow-through and stagnant concrete systems were almost similar throughout this study. Percentage Weight Gain (%WG) for this study, as seen on Table 1 showed highest weight gain for *Heterobranchus longifilis* female and male in tanks THFS as

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40.00±0.85[a]%, and a higher weight gain for the mixed sex culture system in flow-through and stagnant systems respectively with %WG of 34.60±0.70[b] % and 35.25±0.25[b] %.

Closely followed with high weight gain values were the THMS and THMF tanks with values 27.40±0.73[c] %, 26.78±0.02[c] % also for *Heterobranchus longifilis* male and female in monosex stagnant and flow-through systems; while the *Heterobranchus longifilis* female in monosex THFF, showed the lowest weight gain value of 23.20±0.15[d] %, in the study. There was no significant difference (p>0.05) among the mixed sex treatments of *Heterobranchus longifilis* yet there was a significant difference (p<0.05) between the treatments in monosex culture. The Specific growth rate (SGR) per day as seen also on Table 1 showed highest growth rates per day for *Heterobranchus longifilis* female THFS in monosex, stagnant system with values 3.80±0.03[a] g per day.

Flow-through tanks of *Heterobranchus longifilis* male and female juveniles in monosex culture also showed high specific growth rate of 3.03±0.01[d] g and 3.22±0.02[c] g per day for THFF, THMF depicting a significant difference (p<0.05) between these treatments. The mixed sex flow-through and stagnant tanks THF, THS had higher specific growth rate values of 3.58±0.04[b] g and 3.61±0.01[b] g per day, showing no significant difference (p>0.05) among the treatments.

The Food Conversion Ratio (FCR) as seen on Table 1 from this study, showed that *Heterobranchus longifilis* females, males and mixed sex exhibited a more good food conversion with almost similar values. *Heterobranchus longifilis* females in flow-through system THFF showed the highest FCR in the study with 4.09±0.00[a]. The stagnant culture systems THFS, THMS showed food conversion ratio values of 4.07±0.00[c], 4.08±0.00[b]; indicating therefore, a significant difference (p<0.05) for food conversion ratio in *Heterobranchus longifilis* tanks between these treatments.

Feed Conversion Efficiency was highest in *Heterobranchus longifilis* female in monosex culture stagnant tanks THFS with value 16.83±0.08[a]. The mixed sex culture flow-through and stagnant tanks for *Heterobranchus longilis* THF, THM followed with higher feed conversion efficiency values of 16.30±0.12[b] and 16.37±0.04[b] showing a no significant difference (p>0.05) between THF, THM. Feed conversion efficiency in *Heterobranchus longifilis* flow-through tanks THFF, THMF showed high values of 14.60±0.04[d] and 15.24±0.08[c] indicating a significant difference (p<0.05) between THFF and THMF. Tank THMS showed higher FCE with value 15.35±0.04[c] depicting a significant difference (p<0.05) between THFS and THMS. Percentage survival (% survival) seen on Table 1, showed high survival rates of 95.83±4.17[a] %, 62.50±0.00[b] % as evidenced in THFS, THMS respectively for *Heterobranchus longifilis* females, males in stagnant systems of monosex culture during this study. The mixed sex of *Heterobranchus longifilis* THF, THS showed higher survival rates of 85.42±5.51[a] %, 83.33±8.33[a] % respectively, depicting no significant difference (p>0.05) between the treatments. % Survival for the flow-through systems holding *Heterobranchus longifilis* male and female in monosex culture during the study also showed 62.50±0.00[b] %, 68.75±3.61[b] % for THFF, THMF indicating also no significant difference (p>0.05) between the treatments. Performance Index (PI) showed a higher value of 7.12

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±0.53[c] and 7.08 ±0.69[b] in the mixed sex flow-through and stagnant system of THF, THS holding the female and male *Heterobranchus longifilis* in mixed sex culture. Treatment THFF holding the females of *Heterobranchus longifils* in flow-through system, monosex culture showed the lowest PI value in the study with 3.91±0.02[c]; while the highest PI value in the study was observed in THFS with 8.95±0.45[a]. Performance index values in the study for both *Clarias gariepinus* and *Heterobranchus longifilis* indicated no significant differences ($p>0.05$) between treatments throughout the study, except for THFS, THMS which showed a significant difference between their treatments.

Growth patterns

The growth patterns for females, males, mixed sex of *Heterobranchus longifilis* as shown in figure 2-4 depicted fastest-growing patterns from stocking to week two. From week two, fast growth is seen, continuing progressively throughout the weeks especially in the flow-through systems. The stagnant systems for females, males and mixed sex also experienced faster growth for this specie. The mixed sex culture of *Heterobranchus longifilis,* experienced marked and steady growth from week two to week eight in the flow-through system than the stagnant. Growth fluctuations were seen in the growth patterns for the *Heterobranchus longifilis* females, males and mixed sex in the stagnant and flow-through systems, respectively.

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Table 1 Growth Performance of monosex cultured *Heterobranchus longifilis* in flow- through and stagnant systems

Treatments	Growth Performance Indices								
	MIW (g)	**MFW (g)**	**MWG (g)**	**%WG**	**SGR (g/day)**	**FCR**	**FCE**	**PI**	**% Survival**
Heterobranchus longifilis									
THFF	1.22±0.00	5.83±0.01[d]	3.61±0.02[d]	23.20±0.15[d]	3.03±0.01[d]	3.09±0.00[a]	14.60±0.04[d]	3.91±0.02[c]	62.50±0.00[b]
THFS	1.22±0.00	7.86±0.12[a]	5.64±0.12[a]	40.00±0.85[a]	3.80±0.03[a]	3.07±0.00[c]	16.83±0.08[a]	8.95±0.45[a]	95.83±4.17[a]
THMF	1.22±0.00	5.86±0.06[c]	4.04±0.06[c]	26.78±0.02[c]	3.22±0.02[c]	3.08±0.00[b]	15.24±0.08[c]	4.72±0.13[c]	68.75±3.61[b]
THF (Control)	1.22±0.00	6.73±0.14[b]	5.00±0.14[b]	34.60±0.70[b]	3.58±0.04[b]	3.08±0.00[b]	16.30±0.12[b]	7.12±0.53[b]	85.42±5.51[a]
THMS	1.22±0.00	6.84±0.02[c]	4.11±0.02[c]	27.40±0.73[c]	3.25±0.01[c]	3.08±0.00[b]	15.35±0.04[c]	4.47±0.02[c]	62.50±0.00[b]
THS (Control)	1.22±0.00	7.30±0.06[b]	5.08±0.06[b]	35.25±0.25[b]	3.61±0.01[b]	3.07±0.00[c]	16.37±0.04[b]	7.08±0.69[b]	83.33±8.33[a]
P-Value	-	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*

Means on the same column (for each section) with different superscript are statistically significant ($p<0.05$).

Treatments: [1]THMF Treatment *Heterobranchus longifilis* Male Flow-through and THFF Treatment *Heterobranchus longifilis* Female Flow-through, [2]THMS Treatment *Heterobranchus longifilis* Male and THMS Treatment *Heterobranchus longifilis* Female Stagnant. [3]THF Treatment *Heterobranchus longifilis* Mixed sex (control) and THS Treatment *Heterobranchus longifilis* Mixed sex (control).

MIW=Mean Initial Weight, MFW=Mean Final Weight, MWG=Mean Weight Gain, WG=Weight Gain, SGR=Specific Growth Rate, FCR=Food Conversion Ratio, FCE=Feed Conversion Efficiency, PI Performance Index.

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Table 2 Mean Morphometric Measurements and Condition Factor of monosex cultured *Heterobranchus longifilis* in flow- through and stagnant systems

Specie/Sex	**Morphometric Measurement and Condition Factor**			
	Total Length (cm)	**Standard Length (cm)**	**Weight (g)**	**Condition Factor (K)**
Heterobranchus longifilis				
♀	7.64±0.26	6.84±0.26	4.04±0.20	2.66±0.11[a]
♂	7.89±0.24	7.09±0.24	4.05±0.19	2.42±0.08[ab]
♂+♀	7.26±0.37	7.46±0.37	4.04±0.28	2.19±0.11[b]
SEM	*0.16*	*0.17*	*0.16*	*0.20*

Means in the same column (for each section) with different superscript are statistically different ($p<0.05$). ♀= Female, ♂= Male, ♂+♀=Mixed sex (control), SEM=Standard Error of Mean.

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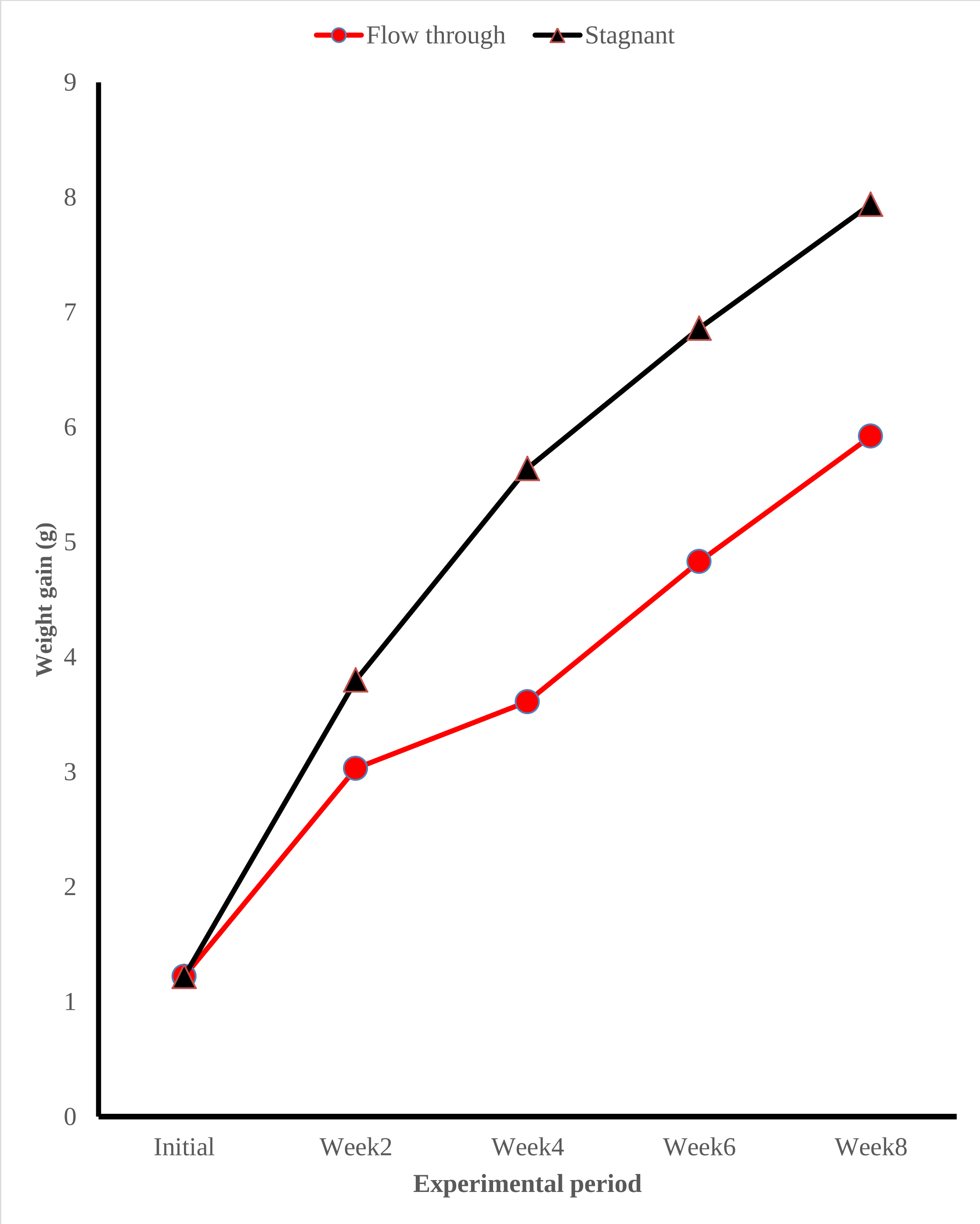

Figure 2: Growth patterns of *Heterobranchus longifilis* females cultured in flow-through and stagnant systems

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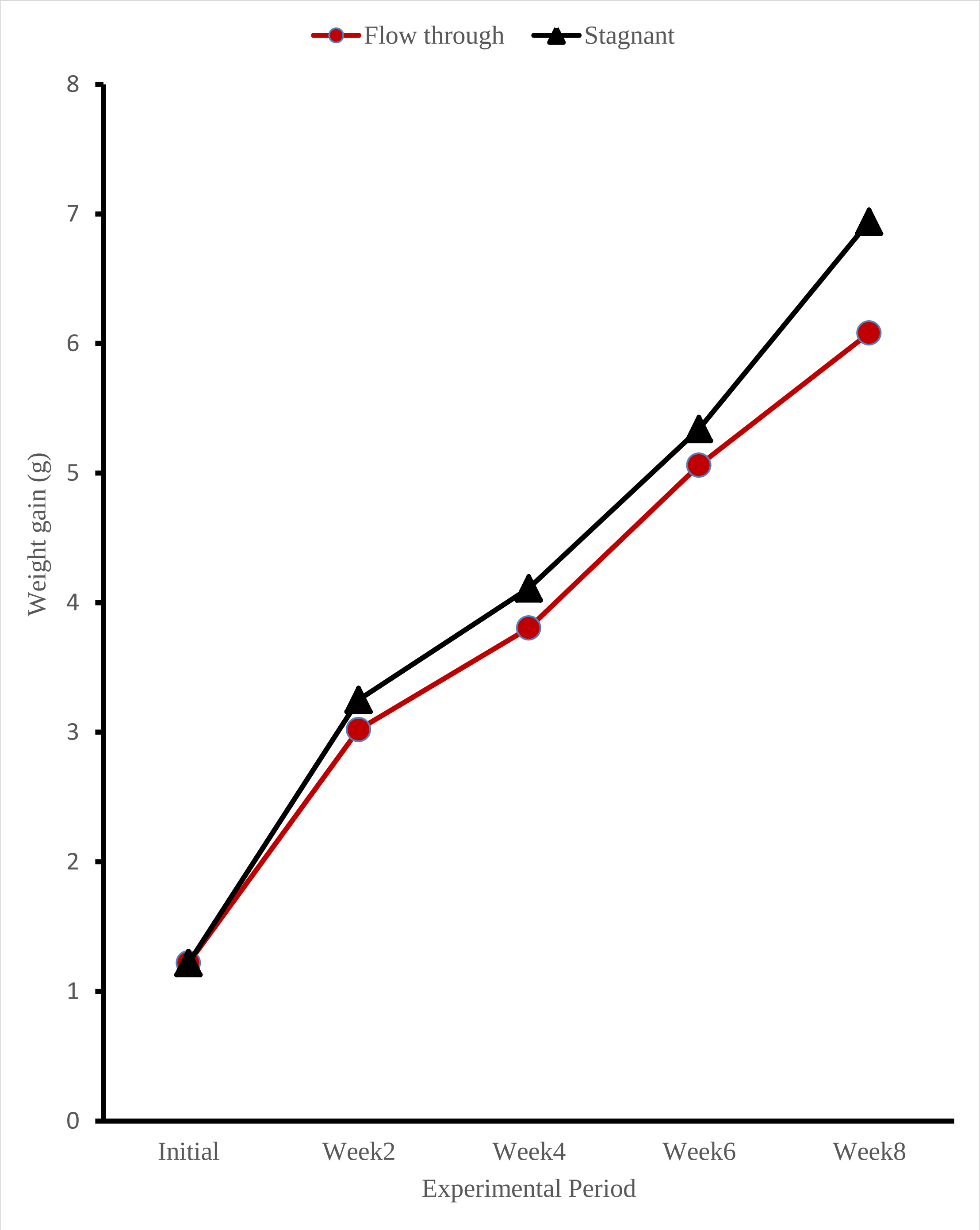

Figure 3: Growth patterns of *Heterobranchus longifilis* males cultured in flow-through and stagnant systems

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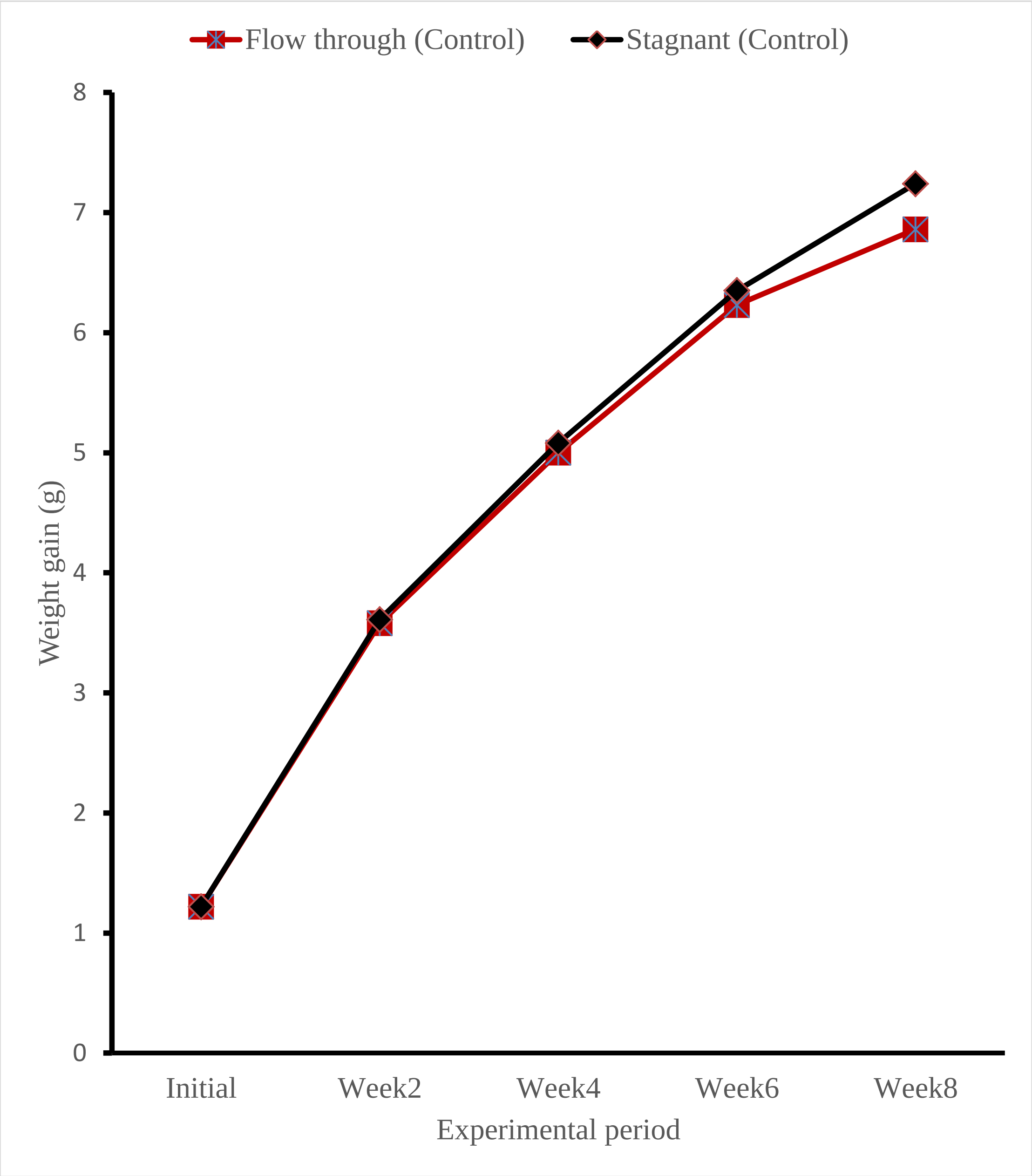

Figure 4: Growth patterns of *Heterobranchus longifilis* mixed sex cultured in flow-through and stagnant system

Length – weight relationship

Table 3 showed the length-weight relationship of *Heterobranchus longifilis* juveniles cultured under flow-through and stagnant water systems. Coefficient of determination (R^2) therefore obtained, showed highest values for *Heterobranchus longifilis* females and mixed sex, than the males in flow-through systems. Coefficient of determination (R^2) also showed very similar values for *Heterobranchus longifilis* females, males and mixed sex species in the stagnant system yet differing values for *Heterobranchus longifilis* females, males and mixed sex flow-through systems.

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Table 3: Length-Weight Relationship Regression of monosex cultured *Heterobranchus longifilis* in flow-through and stagnant systems

Sex	Rearing Systems					
	Flow-Through			Stagnant		
	Intercept (a)	Growth Pattern (b)	Coefficient of determination(R^2)	Intercept (a)	Growth Pattern (b)	Coefficient of determination(R^2)
Heterobranchus longifilis						
♀	1.65	2.44	1.89	2.02	2.98	1.85
♂	1.60	2.34	1.69	2.44	3.47	1.85
♂+♀ (Control)	1.91	2.68	1.94	2.11	3.00	1.84

♀= Female, ♂= Male, ♂+♀=Mixed sex (control)

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Water quality parameters

Table 5 showed pooled results for *Heterobranchus longifilis* female tanks depicting water temperature of the flow-through mediums as 31.06±0.11^{0}C, while the stagnant systems showed a water temperature of 30.68±0.13^{0}C; depicting no significant difference (p>0.05) between the culture systems. Likewise, mean results for *Heterobranchus longifilis* males in the flow-through culture system on Table 5 showed water temperature value of 30.68±0.13^{0}C; while the stagnant systems showed water temperatures of 30.68±0.11^{0}C depicting no significant difference (p>0.05) between the culture systems. Mean results also showed the mixed sex tanks holding the *Heterobranchus longifilis* species in the flow-through culture systems, with water temperature of 30.88±0.08^{0}C while the stagnant systems showed a water temperature of 31.06±0.11^{0}C; depicting no significant difference (p>0.05) in the water temperatures of the mixed sex culture systems.

For the *Heterobranchus longifilis* males also seen on Table 5 held in the flow-through and stagnant systems, mean pH values were 7.42±0.15 and 7.16±0.06 respectively, showing no significant difference (p>0.05) in the pH of the culture mediums. The *Heterobranchus longifilis* females showed pH results of 7.24±0.02 in the flow-through systems and 7.24±0.06 in the stagnant systems, also depicting no significant difference (p>0.05) in the pH of the culture mediums. The mixed sex tanks showed pH readings of 7.46±0.04 and 7.84±0.22 for the flow-through and stagnant systems respectively. pH value for the mixed sex culture systems showed no significant difference (p>0.05), in the pH of the culture mediums.

Results also showed on Table 5, *Heterobranchus longifilis* male flow-through tanks with DO value of 7.84±0.45mg/L, and DO value of 5.12±1.02mg/L for the stagnant systems. Females of *Heterobranchus longifilis* in the flow-through tanks showed DO value of 5.10±1.21mg/L, and DO value of 6.16±0.60mg/L for the stagnant systems. Mixed sex flow-through tanks for *Heterobranchus longifilis* showed DO value of 8.24±0.24mg/L, and 8.32±0.22mg/L as DO value for the stagnant systems. The culture systems holding the males of *Heterobranchus longiflis* showed a significant difference (p>0.05) in DO of the culture mediums; the females of the same specie showed no significant difference (p>0.05) in the DO of the culture mediums; while the mixed sex tanks showed also that, there was no significant difference (p>0.05) in the DO of the culture systems.

Table 5 showed *Heterobranchus longifilis* males under flow-through and stagnant concrete systems with conductivity values of 252.00±28.70 µSc/m and 284.00±26.40 µS/cm respectively. There was no significant difference (p>0.05) in the conductivity values of the culture tanks. Table 5 furthermore showed conductivity measurements for the mixed sex of *Heterobranchus longifilis* as 212.00±12.00 µS/cm and 212.00±17.40 µS/cm for the flow-through and stagnant systems respectively, indicating there was also no significant difference (p>0.05) in the conductivity values of the culture systems. *Heterobranchus longifilis* females, on the other hand

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seen on Table 5, showed the flow-through tanks with conductivity value of 386.00±4.00 µS/cm, while the stagnant systems showed conductivity value of 232.00±4.70 µS/cm; indicating no significant difference (p>0.05) in the conductivities of the culture systems.

In conclusion, *Heterobranchus longifilis* tanks holding the females of this same species, cultured in the flow-through systems indicated highest mean results for conductivity as 386.00±4.00 µS/cm for female *Heterobranchus longifilis*, followed by the male *Heterobranchus longifilis* stagnant systems with conductivity value of 284.00±26.40 µS/cm .

Table 4 Water Quality Parameters of the monosex cultured *Heterobranchus longifilis* in flow-through and stagnant systems

Species/Treatments/ Sex	**Water Quality Variables**			
	Temp (^oC)	**pH**	**DO (mg/L)**	**Conductivity (µS/cm)**
Heterobranchus longifilis				
THF (Control)	$30.88±0.08^{ab}$	$7.46±0.04^{b}$	$8.24±0.24^{a}$	$212.00±12.00^{b}$
THFF	$30.68±0.13^{b}$	$7.16±0.06^{b}$	$5.12±1.02^{c}$	$284.00±26.40^{b}$
THFS	$31.06±0.11^{a}$	$7.42±0.15^{b}$	$7.84±0.45^{ab}$	$252.00±28.70^{b}$
THS (Control)	$31.06±0.11^{a}$	$7.84±0.22^{a}$	$8.32±0.22^{a}$	$212.00±17.40^{b}$
THMF	$30.68±0.13^{b}$	$7.24±0.02^{b}$	$5.10±1.21^{c}$	$386.00±4.00^{a}$
THMS	$31.06±0.11^{a}$	$7.24±0.06^{b}$	$6.16±0.60^{bc}$	$232.00±64.70^{b}$
SEM	*0.26*	*0.31*	*0.64*	*0.47*

Means in the same column (for each section) with different superscript are statistically different (p<0.05).

Treatments: [1] THMF Treatment *Heterobranchus longifilis* Male Flow-through and THFF Treatment *Heterobranchus longifilis* Female Flow-through, [2] THMS Treatment *Heterobranchus longifilis* Male Stagnant and THFS Treatment *Heterobranchus* Female Stagnant. [3] THF and THS Treatment *Heterobranchus longifilis* Mixed sex Flow-through and Stagnant (control).

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Table 5 **Mean Water Quality of monosex cultured *Heterobranchus longifilis* in flow- through and stagnant systems**

Water Quality Parameters/ Specie/Sex	Culture Systems	
	Flow-Through	Stagnant
***Heterobranchus longifilis*♂**		
Temp (^oC)	31.06±0.11	30.68±0.13
pH	7.42±0.15	7.16±0.06
DO (mg/L)	7.84±0.45	5.12±1.02
EC (µS/cm)	252.00±28.70	284.00±26.40
***Heterobranchus longifilis*♀**		
Temp (^oC)	30.68±0.13	31.06±0.11
pH	7.24±0.02	7.24±0.06
DO (mg/L)	5.10±1.21	6.16±0.60
EC (µS/cm)	386.00±4.00	232.00±4.70
***Heterobranchus longifilis*♂+♀**		
Temp (^oC)	30.88±0.08	31.06±0.11
pH	7.46±0.04	7.84±0.22
DO (mg/L)	8.24±0.24	8.32±0.22
EC (µS/cm)	212.00±12.00	212.00±17.40

♀= Female, ♂= Male, ♂+♀=Male and Female (control).

Discussion

Growth performance

Males and females of *Heterobranchus longifilis* in monosex culture and the mixed sex culture showed progressive growths. This study does not agree with Goudie *et al.*, (1994) who stated that females showed slow-growing weights with males of the same species of Channel Catfish. A number of mortalities occurred, with greater losses in the stagnant systems than in the flow-through systems within the first two weeks of the study. These high rate of mortalities were caused by stress. The flow-through systems were continuously aerated resulting in less mortalities. Therefore, it is suggested from this study that the mean final weight of male and female *Heterobranchus longifilis* in monosex culture, reared in flow-through and stagnant concrete systems were almost similar throughout this study. Davies *et al.*, (2006) in his study suggested a higher value for mean final weight of 1.623g for *Heterobranchus longifilis* reared in plastic aquaria and fed twice a day; and a lower mean final weight of 1.338g for *Heterobranchus longifilis* fed once a day.

Percentage Weight Gain (%WG) for this study, as seen on Table 4.1 showed highest weight gain for *Heterobranchus longifilis* female in stagnant system and the mixed sex species in both flow-through and stagnant systems. This could be due to excellent nutrient utilization from the feed taken by this specie. This study therefore deduces that *Heterobranchus longifilis* exhibits higher growth rate and efficiently utilizes its feed. A previous study by Yakubu *et al.*, (2014) suggested that weight gain in *Heterobranchus longifilis* and *Clarias gariepinus* post-fingerlings under water recirculation were 1278.06[a] % and 5128.07[b] % respectively.

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The Specific growth rate (SGR) per day also showed highest growth rates per day, for *Heterobranchus longifilis* male and female in stagnant systems of monosex culture; than the flow-through systems which showed higher specific growth rate for males and females also in monosex culture. The mixed sex tanks also showed high specific growth rate values per day. Specific growth rate for *Heterobranchus longifilis* may be highest due to the fact that this specie is most active at night scavenging on any available food apart from the feed given. Yakubu *et al.,* (2014) reported in their study that, specific growth rate per day(SGR) values in the study of growth performance and survival rate of *Clarias gariepinus* and *Heterobranchus longifilis* post-fingerlings were 2.24g for *Heterobranchus longifilis* and 3.54g for *Clarias gariepinus;* higher than the specific growth rate values seen in this study. Abdulraheem *et al.,* (2012) furthermore reported higher specific growth rate values of 9.65±0.33g, 9.66±0.56g, 7.52±0.43g and 9.07±1.0g respectively, in the study involving growth response of *Clarias gariepinus* hatchlings to different dry feeds.

The Food Conversion Ratio (FCR) as seen from this study, showed that *Heterobranchus longifilis* females, males and mixed sex exhibited good food conversion with almost similar values for the *Heterobranchus longifilis* in monosex flow-through systems. The stagnant culture systems holding the males and females showed lower food conversion ratio values observed in the study. A lower FCR as seen in *Heterobranchus longifis* means that the fish used less feed to gain more weight, while a higher FCR means this fish used more feed yet gained less weight. A lower FCR of 1.51±0.01 obtained for male monosex tilapia means this fish used less feed to gain more weight (Hossain *et al.*, 2005). Values were almost similar for the flow-through and stagnant culture systems of the study taking into consideration both cultured species were fed twice daily.

In an earlier study involving the Nile Tilapia, the best food conversion ratio for tilapia fingerlings and adult Tilapia was gotten from 35% and 45% protein diets with non-significant differences of 1.92 to 2.22 for fingerlings and 2.29 to 2.79 for adult Tilapia (Mohsen *et al.*, 2008); totally at variance with values in this study. The poorest FCR was also obtained at 25% protein diet for fry at 1.81(P>0.05) (Mohsen *et al.*, 2008). Ndome *et al.,* (2011) also suggested that food conversion ratio was highest in fish fed once daily (2.35), followed by fish fed five times daily (2.07) and fish fed four times daily (2.01). Ndome *et al.,* (2011) furthermore opined that fish fed thrice and twice daily had food conversion ratio values of 1.91 and 1.95 respectively for *Clarias gariepinus* male and *Heterobranchus longifilis* female hybrids; with no significant difference (P>0.05) between the two feeding frequencies.

Feed Conversion Efficiency was highest in *Heterobranchus longifilis* female monosex culture stagnant tanks; while the *Heterobranchus longifilis* male and female in monosex, flow-through tanks showed high feed conversion efficiency as seen in the study. The mixed sex culture tanks for *Heterobranchus longilis* also showed similar higher values for feed conversion efficiency. Ndome *et al.,* (2011) suggested that the values gotten for FCE were a reflection of the FCR values; further establishing that, the highest FCE of 52.36% was seen in a three-times per day feeding frequency while a one-time feeding showed a high FCE of 42.45%.

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Percentage survival (% survival) seen from this study, indicated a higher survival rate for *Heterobranchus longifilis* females, males in flow-through systems of monosex culture during this study. The mixed sex of *Heterobranchus longifilis* showed high survival rates as well. Survival was high for the stagnant systems holding *Heterobranchus longifilis* male and female in monosex culture during the study.

Madu *et al.,* (1989) however cited a different opinion, stating that the best survival rate was seen in *Clarias anguillaris* tanks sampled weekly with 92% survival rate and 84% survival rate in tanks sampled bi-weekly. It was observed in a previous investigation into the growth performance and survival rate of both species under a water recirculation system, that the highest survival rate was seen in *Heterobranchus longifilis* than *Clarias gariepinus* (Yakubu *et al.,* 2014). Performance index value for the female and male *Heterobranchus longifilis* flow-through tanks showed lowest performance index for the specie.

The mixed sex tanks also showed similar high PI values, indicating therefore that the highest PI in the study was seen in the *Heterobranchus longifilis* male stagnant tanks. Highest values for PI seen in this study, in female stagnant and male flow-through monosex tanks of *Heterobranchus longifilis* showed this specie's ability to perform excellently in terms of overall growth, nutrient utilization, due to its omnivorous feeding habit and ability to thrive in undesirable conditions. However, this result on Performance Index (PI) does not agree with Yakubu *et al.,* (2014). In their scientific study on growth performance and survival rate of *Clarias gariepinus* and *Heterobranchus longifilis* under water recirculation system, Performance Index (PI) was highest in *Clarias gariepinus* with value 101.90[b], compared to the value obtained for *Heterobranchus longiflis* with value 30.50[a] .

Condition factor observed from this study showed K as being greater than 1, for the monosex and mixed sex treatments. This result showed the fishes grew in good culture conditions and were healthy or in a state of well-being. Condition factor K for this study indicated therefore, higher values than those recorded by Chandra and Jhan (2010) who revealed in their study condition factor values of 1.05-1.89 for *Channa punctata.*

Length-weight relationship

The Length-Weight Relationship (LWR) tool is termed important and essential in assessing growth (Pepple and Offor, 2011). Coefficient of determination (R^2) obtained showed highest values for *Heterobranchus longifilis*, for the monosex and mixed sex culture in flow-through systems as seen from this study.

Davies *et al*., (2013) also reported strong R^2 values of 0.78, 0.86 and 0.90 for male, female and mixed sex in their study of *Clarias gariepinus* in indoor concrete recirculation system; at variance with the results of this study which had stronger R^2 values of 1.69 – 1.94.

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Water quality parameters

The water quality parameters of the treatments in this study as seen from this study, indicated for *Heterobranchus longifilis* monosex and mixed sex culture species, almost similar temperature values. Temperature values for this study were from $30.68{\pm}0.13^{b}$ ^{0}C – $31.06{\pm}0.11^{a}$ ^{0}C, and were within range for freshwater culture. This result was therefore in agreement with Chakroff (1976), who indicated optimal range for temperature as $25^{0}C$ -$35^{0}C$.

pH values for this study stood between $7.16{\pm}0.06^{b}$ and $7.84{\pm}0.22^{a}$ and were within range for freshwater fish culture as advised by Boyd and Lichtkoppler (1979), who stated pH range of 6.7 to 8.6 as ideal for fish culture. Nlewadim *et al.*, (2011) also suggested pH values of 6.5 to 7.1 in their study on growth and survival of *Heterobranchus longifilis* in concrete tanks.

It was further observed in this study, that the effect of dissolved oxygen (DO) stood between 5.10 $\pm 1.21^{c}$ mg/L to $8.32{\pm}0.22^{a}$ mg/L throughout the experimental tanks. These values were higher than 4mg/l which according to Ovie and Adeniji (1990), confirm that fish do not feed nor grow well when dissolved oxygen stays at 4mg/L. Nlewadim *et al;* (2011) however reported, DO values of 3.90 to 4.30mg/L in the study carried out on growth and survival of *Heterobranchus longifilis* in outdoor concrete tanks for six months; these DO values were much lower than the DO values obtained in this study.

Conductivity values indicated for *Heterobranchus longifilis* monosex and mixed sex treatments were from $212{\pm}12.00$ ^{b} µS/cm - $386{\pm}4.00$ ^{a} µS/cm. This result supports (Boyd, 1990) which stated that freshwaters have conductivity levels ranging from 20-1,500 µS/cm, indicating changes in waters and also showing overall ionic effects in the waters used for this study. Ayanwale *et al.*, (2012) also advised conductivity range of 100.60±32.01 µS/cm to 338.00±140.81 µS/cm for artificial fish culture.

Conclusion

Growth per day was uniform for monosex and mixed sex treatments. Percentage survival was highest in female flow-through tanks of monosex culture. Food Conversion Ratio and Feed Conversion Efficiency were similar for monosex culture. Performance index was similar for mixed sex culture, but almost similar for monosex culture. Condition factor showed greater than 1 values for monosex and mixed sex flow-through and stagnant systems. Coefficient of determination showed strong regression for monosex and mixed sex treatments. All values were within range for freshwater fish culture in this study.

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