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COMPARATIVE EFFECTS OF VARYING STOCKING DENSITIES ON THE LENGTH-WEIGHT RELATIONSHIP AND MORPHOMETRICS OF HETEROCLARIAS

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ABSTRACT: Length-weight relationships and morphometrics are crucial indices for assessing the healthiness of a fish under varying stocking densities. Hybrid fingerlings of *Clarias gariepinus* x *Heterobranchus longifilis* were assessed for length-weight relationship and morphometric indices influenced by varying stocking densities for 12 months. Fifteen (15) improvised tarpaulin tanks measuring 1×1×1 m^3 and filled with 250L of water were employed for this study. The study was designed to have five different stocking densities (SD), T_1 = 100fish/m^2, T_2 = 75fish/m^2, T_3 = 38fish/m^2, T_4 = 18fish/m^2 and T_5 = 9fish/m^2 as treatments and were in triplicates. The fish was fed three times daily (08:00, 13:00 and 18:00 hours) using commercial feed at 2.0% body weight. The feed was adjusted monthly with increase in body weight. The initial weight (2.06 ± 0.48 g) and total length (4.13 ± 0.25 cm) of the fingerlings were taken before stocking them in the various tanks which were randomly positioned. At the end of the study, T_1 had the best growth function (2.91) which was closely followed by T_2 (2.81). Condition factor was highest in T_2 (1.04). There was significance ($p<0.05$) in morphometrics such as total weight, standard length, head length and dorsal fin length while total length and anal fin length were insignificant ($p>0.05$) across the different stocking densities. This study recommends 75-100 fish/m^2 stocking densities and proper management of water quality parameters to obtain best growth for aquaculturists interested in raising hybrid catfish.
Keywords: length-weight relationship, morphometric parameters, condition factor, hybrid catfish, Heteroclarias, stocking densities

INTRODUCTION

The continuous growth in aquaculture which according to the United Nations' Food and Agriculture Organization is responsible for 50% of all fish for human consumption (FAO, 2016), which is attributed to the improvement in the state of the fish stock and fisheries management. From FAO (2016) report, aquaculture marginally supplied 7% of fish for human consumption in 1974, which increased to 26% in 1994, and 39% in 2004 but in 2014 the total contribution of aquaculture to total global fish production rose to 44.1%. This has been further increased to 46% in 2018 which accounted for about 18% of total fish production in Africa (FAO, 2020). The rapid increase in global population and fish demand especially from 3rd world countries has been a major boost for these improving statistics. In support of this, species with the best culturable qualities are employed in fish farming and they possess a high proportion of these qualities including; acceptability of supplemental feed, high tolerance to fluctuating water condition, disease resistance, commanding high market value and acceptability, attaining early maturity, efficient feed converter and ability to reproduce during captivity. *Clarias* and *Heterobranchus* species possess a good number of these qualities and thus fit into an average fish farmer's plan of raising marketable size fish within the shortest available time, also taking into consideration their production cycle achievable all year round (Ekelemu and Ekokotu, 1999, Afia *et al*., 2019). In commercial aquaculture production in Nigeria, *Clarias gariepinus* has gained a prominent position because it is tasty, hardy, tolerates poor water quality conditions with ability of reproducing in captivity and growing to a size of about 7.0 kg (Idodo-Umeh, 2003), has an efficient feed conversion, especially in the males (Nweke and Ugwumba, 2005) and so attracts high market price. In a similar vein, *Heterobranchus species* are also important in growing to a size of about 14.0 kg but not as hardy as the *Clarias species* (Idodo-Umeh, 2003). Thus, aquaculturists have been able to harness the qualities of these two species by cross breeding them to produce a hybrid (Heteroclarias) which is hardy and grows to a large size (Keremah and Green, 2005).

A crucial index in assessing the healthiness of a fish under varying stocking densities is the length-weight relationship (LWR) which describes the relationship between the length and weight of a particular fish, and this particular method also assesses the potential differences between individuals of similar species reared in experimental treatments (Ighwela *et al.*, 2001). LWR is an important parameter providing hints on the growth pattern and condition of fish (Efitre *et al.*, 2009) and plays a crucial role in guiding farmers in achieving commercially viable fish sizes at harvest (Nehemia *et al.*, 2012). In the tropics and subtropics water system, factors such as food consumption, environmental changes, rate of spawning, changes in the physical and chemical properties of the medium creates fluctuations in fish growth (Olusegun, 2011; Abowei and Davies, 2009). Length–Weight Relationship (LWR) is a useful tool in fish growth pattern or age determination and fishery assessment (Pepple and Ofor, 2011). Length and mass are employed in determining fish growth and since length is easier to measure, it is often combined with weight in growth studies. Length and weight are related by a power relationship and the equation relating length to weight gives some indication of the growth pattern of fish in a population (Kalu *et al*, 2007). In general, the change in weight of fish can be described by the relationship $W = aL^b$, where W is observed fish weight, L is observed fish length, and a and b are estimated by $\log W = a + b \log L$ (i.e. a is the regression intercept and b is the regression slope or growth function). Therefore, the case where $b<3$ (negative allometric growth) represents fish that become less rotund as length increases, whereas when $b>3$ (positive allometric growth) fish become more rotund as length increases. The aforementioned are both examples of allometric growth. However, when $b = 3$, growth is said to be isometric (growth with unchanged body proportions and specific gravity), although it is possible for shape to change when $b=3$, due to changes in a i.e. regression intercept (Riedel *et al.*, 2007). Length-weight studies have been carried on catfish fishes to measure growth in the wild (Anibeze, 2000; Sawant and Raje, 2009) and in captivity (Davies *et al.*, 2013).

Condition factor refers to the general well-being or relative fitness of the individual species and its degree of fatness, which depends on the weight of the fish sampled (Fafioye and Oluajo, 2005). Condition factor is also crucial for determining the health of a population (Stevenson and Woods, 2006). A model that is sensitive to and reflects small changes in condition can alert a fish culturist to the onset of disease, stress due to overcrowding, or other physiological effects before high mortality rates are suffered. The study of condition assumes that heavier fish of a given length are in better condition. Condition indices have been used by fish culturists as indicators of the general well-being or fitness of the population under consideration including reports of Andem *et al*. (2013), Abdel-Tawwab (2012).

Morphometric study is one of the vigorous tools for measuring discreteness of the same species. Murta (2002) and Pinheiro *et al.* (2005) reported that morphometric variation between stocks can provide a basis for stock culture, and may be applicable for studying short-term environmentally induced variation geared towards successful fisheries management. Earlier, Bailey (1997) had stated that the quantification of specific characteristics of an individual or group of individuals can demonstrate the degree of speciation induced by both biotic and abiotic conditions, and contribute to the definition of different stock of species. Hence, morphometric measurements are widely used to identify differences between fish populations (Torres *et al.*, 2010) and may be linked to body size (Doherty and McCarthy, 2008), sex (Rohollah *et al.*, 2013), age (Adeoye *et al.*, 2016) environment (Solomon *et al.*, 2015) and set of chromosomes (Normala *et al.*, 2017).

There is not enough information on the morphometrics and length-weight relationship of hybrid catfish influenced by stocking density in a controlled medium. Thus, it is not clear whether length-weight relationship, condition factor and morphometric parameters can be influenced by stocking density in this specie. The objective of the current study was to evaluate the influence of varying stocking densities on the length-weight relationship, condition factor and morphometric parameters of hybrid catfish, Heteroclarias.

MATERIALS AND METHODS

Study Area

The study which lasted for 52 weeks was carried out at the Fish Hatchery complex of the Department of Fisheries and Aquatic Environmental Management, University of Uyo (Annex Campus), Akwa Ibom State, Nigeria. This area is between latitudes 4°52' S and 4°51' N and longitudes 7°54' W and 8°03' E. The study made use of using fifteen tarpaulin tanks of 1 M^3 volume.

Experimental Procedures and Design

Fingerlings of Heteroclarias was produced by crossing two female broodfish (*Clarias gariepinus*) and two male broodfish (*Heterobranchus longifilis*) according to method of Ngugi *et al.* (2007). External morphology and eggs characteristics were factors considered before selection. Fifteen (15) improvised tarpaulin tanks measuring 1×1×1 m^3 and filled with 250L of water were employed for this study. The study was designed to have five different stocking densities (SD), T_1 = 100fish/m^2, T_2 = 75fish/m^2, T_3 = 38fish/m^2, T_4 = 18fish/m^2 and T_5 = 9fish/m^2 as treatments and were in triplicates. The fish was fed three times daily (08:00, 13:00 and 18:00 hrs) using commercial feed at 2.0% body weight. The feed was adjusted monthly with increase in body weight. The initial weight (2.06 ± 0.48 g) and total length (4.13 ± 0.25 cm) of the fingerlings were taken before stocking them in the various tanks which were randomly positioned.

Water Quality Assessment

Partial flow through method was employed in refreshing total water in the tank daily. The various water quality parameters were monitored at monthly intervals. Temperature was determined using a mercury thermometer calibrated 0° - 50°C, pH using a pen type pH meter (pH-009 111) and dissolved oxygen using dissolved oxygen meter (HI 9461).

Data Collection

Length-weight relationship was calculated from the data collected from fish samples at the initial stocking, at the 6th month into the experiment and at the 12th month which was the end of the experiment. For each individual fish, total length (TL) was measured to the nearest 0.1 cm using a meter rule and body weight (Wt) was measured to the nearest 0.01 g using electronic weighing balance (TD6002A). The mathematical relationship between length and weight of the fish in each experimental unit was estimated as

$$W = aL^b$$

Where:

W is weight of fish in grams (g); L is length of fish in centimeters (cm); a is intercept or the initial growth coefficient; and b is slope or growth co-efficient. The relationship between length-weight was then converted into the logarithmic form to give a straight-line relationship using

$$Log\,W = a + b\,Log\,TL$$

Where:

a = constant; b = slope of the line

The Condition Factor (K) was estimated using Fulton's condition equation from the relationship,

$$K = \frac{W}{TL^3} x\ 100$$

K values of individual fish was pooled to calculate the mean at the end of the experiment.

The following morphometric characters were measured according to (Wiecaszek and Krykawski, 2010). Total Length (TL) was measured from the snout to the base of the caudal fin rays. Measurements were taken to the nearest 0.1 cm and using measuring board for length. Standard Length (SL) measured from the maxilla to the end of the caudal peduncle, Head Length (HL) horizontal distance from the maxilla to the most posterior point of the opercula on the ventral side, Dorsal Fin Length, (DFL) measured from the origin of the dorsal fin to its end, and Anal Fin Length (AFL) taken from the beginning of the caudal fin to its end. These measurements were taken at the end of the experiment. Samples of fish were taken from each tank and measured using a string which will be taken to a meter rule for specification and recording in centimeter (cm).

Statistical Analyses

Water quality parameters and morphometric parameters were subjected to one-way analysis of variance (ANOVA) to evaluate mean differences at 0.05 significant levels. Results with p≤0.05 were considered significantly different. Duncan multiple range test was used to compare significant difference among the treatments. The statistical analyses were done using IBM SPSS Inc. (Windows version 25). LWR graphs were determined using PAST Statistical Software (version 3.2).

RESULTS

Water Quality

Table 1 shows water quality at different stocking densities after 12 months study. Temperature, pH and dissolved oxygen showed no significant difference (p>0.05).

Table 1: Water quality parameters for T_1-T_5 during the study period

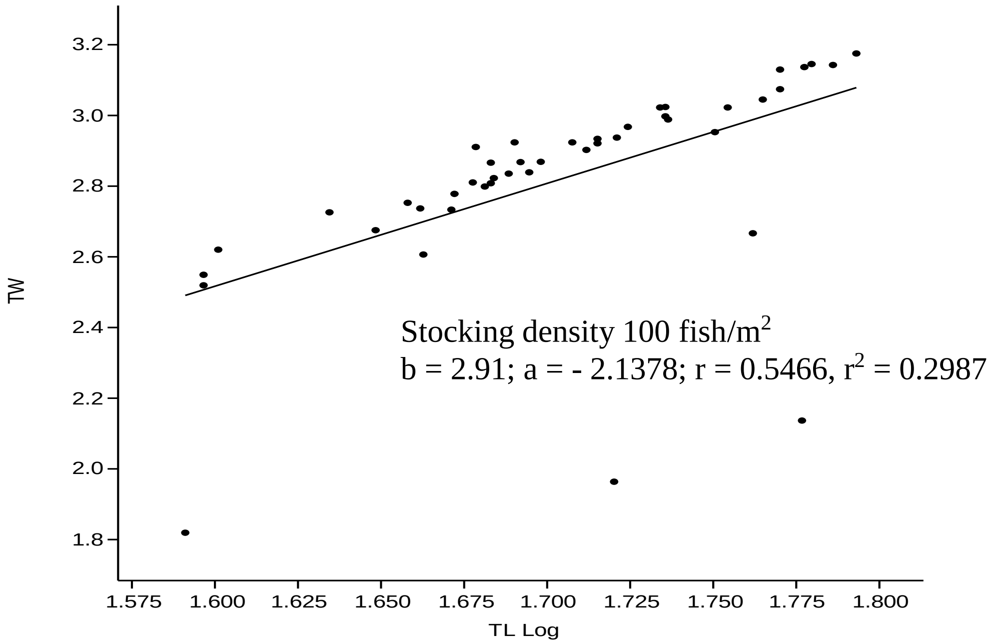
Stocking densities	Temperature (°C) Mean ± SE	pH Mean ± SE	Dissolved Oxygen mg/l Mean ± SE
T_1	$28.62±0.07^a$	$7.31±0.15^a$	$5.03±0.05^a$
T_2	$28.70±0.09^a$	$7.63±0.14^a$	$5.03±0.06^a$
T_3	$28.80±0.11^a$	$7.06±0.15^a$	$4.97±0.06^a$
T_4	$28.68±0.10^a$	$7.28±0.14^a$	$5.01±0.05^a$
T_5	$27.98±0.75^a$	$7.34±0.15^a$	$5.00±0.06^a$

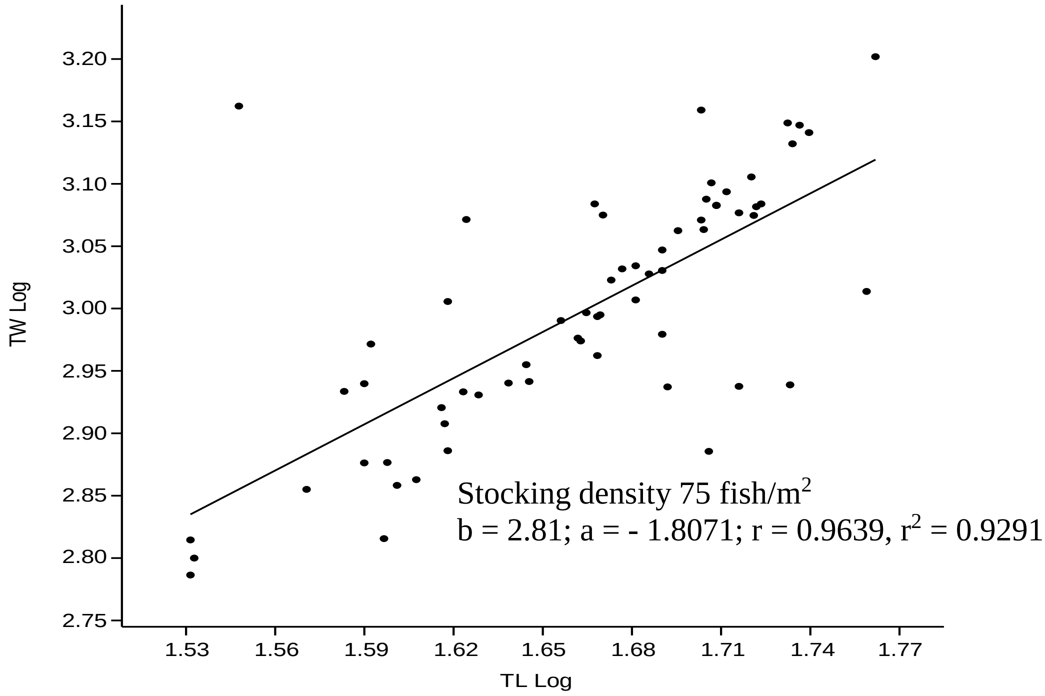
Means within same column with same superscript are not significantly different (p>0.05)

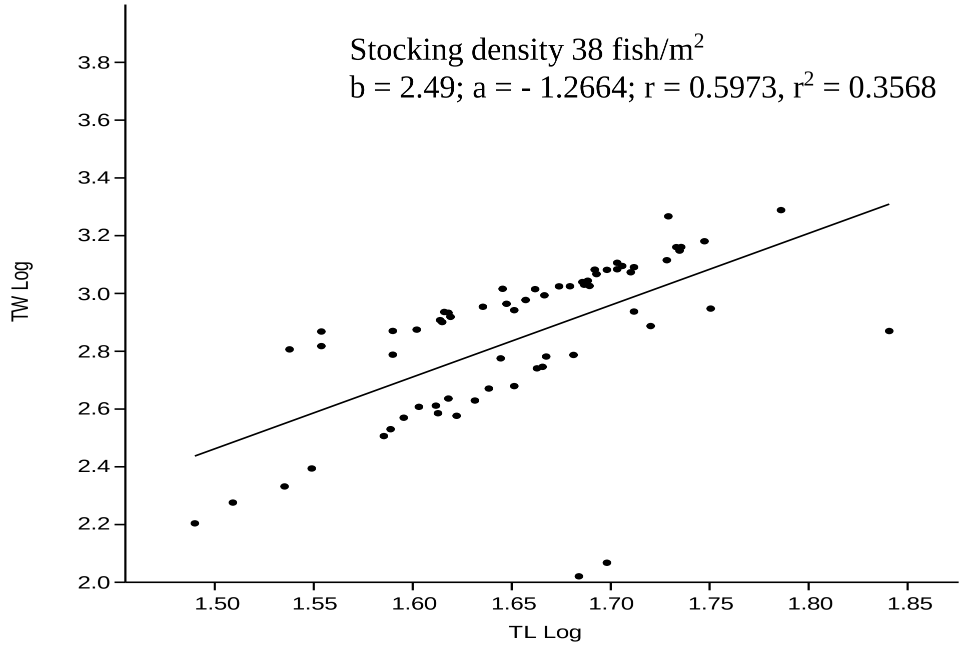
Length-weight Relationship

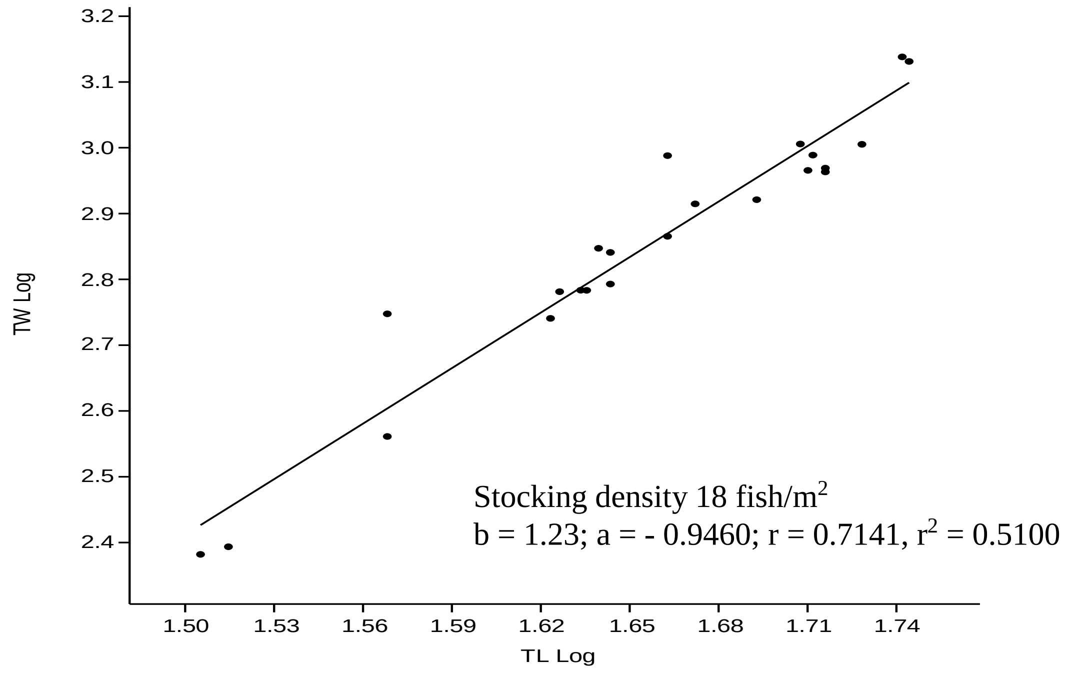
At initial stocking, that is, before the commencement of the feeding trial, the values obtained for b, a, r, r^2 were 2.10, -0.87, 0.78, 0.62 for T_1; 1.75, -0.59, 0.68, 0.46 for T_2; 2.09, -0.82, 0.84 and 0.71 for T_3; 2.33, -0.96, 0.86 and 0.74 T_4 and 2.59, -1.23, 0.71, and 0.51 for T_5. At Six (6) months into the study, the values obtained for b, a, r, r^2 were 2.87, -1.98, 0.89, 0.79 for T_1; 2.91, -2.07, 0.85, 0.73 for T_2; 2.88, -2.02, 0.89, 0.79 for T_3; 2.24, -1.04, 0.80, 0.64 for T_4 and 2.26, -1.02, 0.86, 0.74 for T_5 respectively.

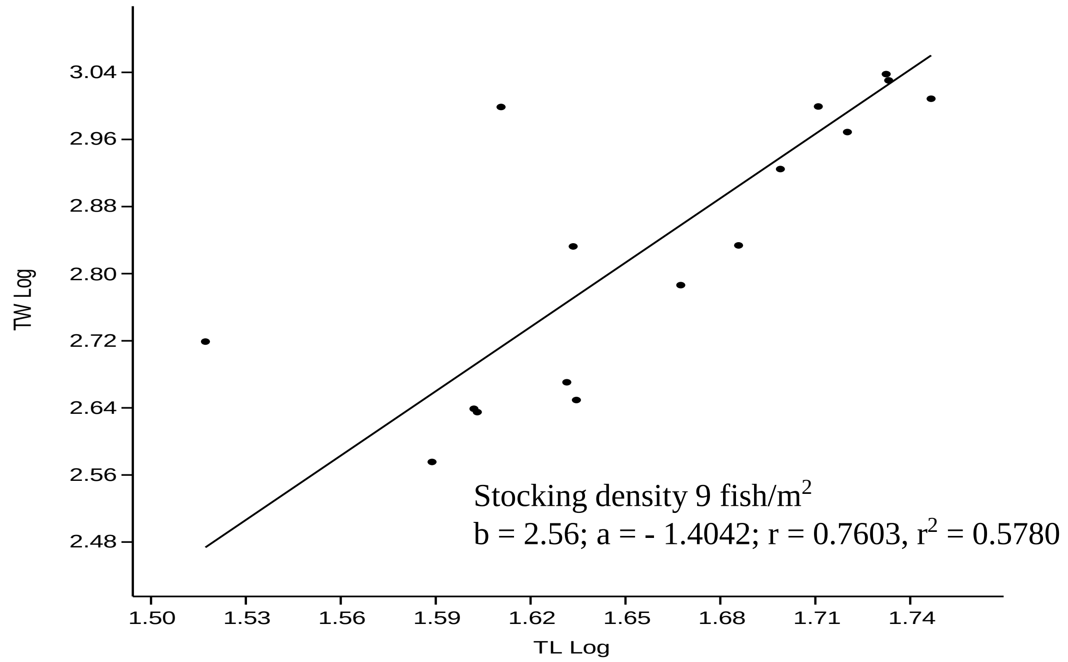
At twelve (12) months, that is, end of the experiment, values for b, a, r and r^2 were 2.91, -2.14, 0.55, 0.30 for T_1; 2.81, -1.81, 0.96, 0.93 for T_2; 2.49, -1.27, 0.60, 0.36 for T_3; 1.23, -0.95, 0.71, 0.51 for T_4 and 2.56, -1.40, 0.76, 0.58 for T_5 (Figures 1-5).




Stocking density 75 fish/m2
b = 2.81; a = - 1.8071; r = 0.9639, r2 = 0.9291
TW Log
3.20
3.15
3.10
3.05
3.00
2.95
2.90
2.85
2.80
2.75
1.53
1.56
1.59
1.62
1.65
1.68
1.71
1.74
1.77
TL Log


Stocking density 38 fish/m2
b = 2.49; a = - 1.2664; r = 0.5973, r2 = 0.3568
TW Log
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.50
1.55
1.60
1.65
1.70
1.75
1.80
1.85
TL Log





Condition Factor

Significance ($p<0.05$) was observed for condition factor between T_1 and T_5 and from other treatments. On the other hand, there was no significant difference ($p>0.05$) between T_2, T_3 and T_4.

Table 2: Condition factor of hybrid catfish at varying densities

Stocking densities	K
T_1	0.56±0.02 [c]
T_2	1.04±0.05 [a]
T_3	0.84±0.04 [a]
T_4	0.77±0.02 [a]
T_5	0.65±0.07 [b]

Means with same superscript within same row are not significantly different (p>0.05) from each other

Morphometric Characteristics

There were no significant differences (p>0.05) observed in total length (TW) (52.21 ± 2.76, 49.43 ± 1.41, 51.75 ± 1.25, 50.46 ± 1.13 and 47.57 ± 1.51) and anal fin length (AL) (6.72 ± 0.30, 6.68 ± 0.15, 6.90 ± 0.26, 7.97 ± 1.30 and 6.55 ± 0.27) among the different stocking densities. However, significant differences (p<0.05) were noticed in body weight (BW) (1224.55±174.16, 1207.85±50.71, 1074.12±123.46, 874.19±63.89 and 711.89±71.94), (standard length (SL) (45.45 ± 2.16, 37.35 ± 3.89, 43.37 ± 1.27, 44.53 ± 0.99 and 41.79 ± 1.80), head length (HL) (12.66 ± 0.58, 12.91 ± 0.24, 13.72 ± 0.28, 13.62 ± 0.57 and 11.91 ± 0.38) and dorsal fin length (DL) (22.12 ± 1.40, 23.81 ± 0.48, 24.73 ± 0.53, 23.75 ± 1.26 and 21.32 ± 1.10) among the varying stocking densities.

Table 3: Morphometric characteristics of hybrid catfish during study period

Indices	T_1	T_2	T_3	T_4	T_5
TW (g)	1224.55±174.16 [a]	1207.85±50.71 [sa]	1074.12±123.46 [ab]	874.19±63.89 [bc]	711.89±71.94 [c]
TL (cm)	52.21±2.76 [a]	49.43±1.41 [a]	51.75±1.25 [a]	50.46±1.13 [a]	47.57±1.51 [a]
SL (cm)	45.45±2.16 [a]	37.35±3.89 [b]	43.37±1.27 [ab]	44.53±0.99 [a]	41.79±1.80 [ab]
HL (cm)	12.66±0.58 [ab]	12.91±0.24 [ab]	13.72±0.28 [a]	13.62±0.57 [b]	11.91±0.38 [b]
DL (cm)	22.12±1.40 [ab]	23.81±0.48 [ab]	24.73±0.53 [a]	23.75±1.26 [ab]	21.32±1.10 [b]
AL (cm)	6.72±0.30 [a]	6.68±0.15 [a]	6.90±0.26 [a]	7.97±1.30 [a]	6.55±0.27 [a]

Means with same superscript within the same row are not significantly different (p>0.05)

DISCUSSION

Environmental parameters influence significantly the maintenance of a healthy aquatic environment and production of natural food organisms (Haque et al., 2003). The water quality parameters measured such as temperature (<40 °C), pH (7.0 – 8.5) and dissolved oxygen (>4 mg/L) were within acceptable range for aquaculture (APHA, 1998; Ekubo and Abowei, 2011; Dienye and Olumuji, 2014; Afia *et al.*, 2018).

The overall growth exponent 'b' obtained in this study ranged from 1.23 to 2.91. Many authors had earlier opined that length-weight relationships can vary significantly even within the same species as it is affected by factors such as sexes, season variation, growth phases, stomach contents, gonadal development, as well as health (Hossain *et al.*, 2006; Leunda *et al.*, 2006; Gaspar *et al.*, 2012). Fish weight is considered to be a function of length (Zafar *et al.*, 2003). For an ideal fish which maintains dimensional equality, the isometric value of b is 3.0. This has occasionally been observed (Thomas *et al.*, 2004). A value significantly larger or smaller than 3.0 indicates allometric growth. A value less than 3 shows that the fish has negative allometry while greater than 3 indicates that the fish has positive allometry for a particular length as it increases in size (Zafar *et al.*, 2003). Catfish hybrids under the current study all showed a negative allometry across the different stocking densities with stocking density 75 fish/m^2 demonstrating best growth function at 6 months and at the end of the study period. Fishes in stocking density 9 fish/m^2 displayed the least growth function during the study period.

According to Adeyemi *et al.* (2009), negative allometric growth pattern in fish implied that the weight increases at a lesser rate than the cube of the body length. Fagbenro *et al.* (1991) had submitted that obedience to the cube law (isometric growth, b=3) was rare in a majority of fishes and this was true of hybrid catfish used in this study in which there was a deviation from the cube law. Current study showed negative allometric growth at the different stocking densities implying that they tended to become thinner as they grew larger. As with the current study, there has been reports of negative allometric growth patterns. Negative allometric growth (b = 2.15) have also been reported for *Heterobranchus longifilis* from Idodo river, Nigeria (Anibeze, 2000); (b = 2.58) for *Clarias gariepinus* reared in Recirculatory Aquaculture System (Okomoda et al., 2018). However, positive allometric growth (b = 7.87) have been reported for *Clarias gariepinus* juveniles reared in concrete tanks (Davies *et al.*, 2013); (b = 5.7) for *Heterobranchus longifilis* from Akpoha River, Nigeria (Ude and Ukanyikwa, 2013). The b value (2.91) gotten from the current study deviates a bit from (3.07) obtained by Effiong and Peter (2019) under the same stocking density for a similar species, Clarobranchus (*Clarias gariepinus* x *Heterobranchus bidorsalis*). varying b values from these studies can be attributed to the distribution of one or more factors such as: number of specimens examined, seasonal effect, degree of stomach fullness, gonadal maturity, sex, health, age, prevailing ecological conditions in the different water bodies and general fish condition as reported by other authors (Hossain *et al.*, 2006; Leunda *et al.*, 2006; Gaspar *et al.*, 2012).

The correlation coefficients (r) of the fishes ranged between 0.55 and 0.96. This indicated low to high degree of positive correlation between their total lengths and body weights. The implication is that the body weights of the fish increased with increase in body length, but the rate of increase in weight was less than the rate of increase in length as explained in the previous paragraph. From the present study, fishes stocked at 75 fish/m^2 exhibited the highest degree of fairly close relationship between total length and total weight while fish stocked at 100 fish/m^2 presented lowest positive interaction between growth indices. High degree of positive relationship obtained in fish stocked at 75 fish/m^2 is similar to values obtained in reports of Anibeze (2000), Davies *et al.* (2013), Ude and Ukanyikwa (2013), and Okomoda *et al.* (2018).

The condition factor K gives information on the physiological condition of fish in relation to its welfare. The condition factor values obtained were mostly less than 1. Examination of the K values indicated that hybrid fish at the different stocking densities but for treatment 2 (75fish/m^2) displayed poorer growing conditions. The hybrid fish with K values less than 1 does not imply that they were not in good physiological condition in the culture environment. It is not uncommon for indices such as sex, age, state of maturity, size, state of stomach fullness, sample size and environmental conditions not to influence K values (Ama-Abasi, 2007; Yem *et al.*, 2007; Adeyemi *et al.*, 2009); gonad development, decrease in feeding activity, changes in density, climate or population and availability of food (Anibeze, 2000). Fishes in tarpaulin tanks stocked at 75fish/m^2 were healthy and exhibited robust condition as condition factor was greater than 1 and similar to that obtained by Davies *et al.* (2013) but dissimilar with report of Okomoda *et al.* (2018). Condition factor from this study supports earlier reports of Huang and Chiu (1997) and Abdel-Twwab (2012), which all stated that condition factor is not influenced by stocking density and alongside Andem *et al.* (2013) supported the notion that fishes with allometric growth pattern as observed in this study tends to end with condition factor values less than 1 as observed in this study.

Morphometric study is one of the vigorous tools for measuring discreteness of the same species. It is widely accepted that morphometric characters can show high plasticity in response to differences in environmental conditions, such as food abundance and temperature (Turan *et al.*, 2005). Results of this study revealed that hybrid fish reared at stocking density 100fish/m^2 (highest density) recorded significantly ($p<0.05$) the highest mean body weight, total length and standard length ($p<0.05$), this was closely followed by stocking density 38fish/m^2. This is similar to the report of Udoh *et al.* (2015) who observed significant difference in morphometric parameters of hybrid catfish from fish farms. Solomon *et al.* (2015)

observed changes in morphometric parameters and meristic count between cultured and wild *Clarias gariepinus*, so did Nkongho *et al.* (2015). These variations are attributed to fish susceptibility to environmentally induced morphological variations which is greater than what is obtained in any other vertebrate (Wimberger 1992). Studies on the morphometric and meristic relationships of fishes are very few, but there is sufficient evidence to prove that this likely varies among different species and culture environments. There are no previous studies to compare that differences observed are attributed to stocking densities alone but could play a role in the variations observed in morphometrics. Heteroclarias at stocking density 9fish/m^2 (lowest density) failed to produce the best morphometric characteristics. The assumption that low stocking density which allows for more space and less competition for feed, hence, enhanced morphometric traits did not play out. Murta (2002) and Pinheiro *et al.*, (2005) reported that morphometric variation between stocks can provide a basis for stock culture, and may be applicable for studying short-term environmentally induced variation geared towards successful fisheries management. Hence morphometric measurements are widely used to identify differences between fish populations (Torres *et al.*, 2010).

CONCLUSION

The length-weight relationship of hybrid catfish at the end of 6 months study indicated that stocking density of 75 fish/m^2 had the best values for growth function (b) and coefficient of regression (r) while at the expiry of the experiment (12 months), stocking density of 100 fish/m^2 had the best values for growth function (b) and coefficient of regression (r). The best condition factor value was obtained at stocking density 75 fish/m^2 while the most significant indices of morphometrics were highest in stocking density 100 fish/m^2. This study recommends 75-100 fish/m^2 stocking densities and proper management of water quality parameters to obtain best growth for aquaculturists interested in raising hybrid catfish with optimum feeding level of 2% for extensive culture period.

REFERENCES

Abdel-Tawwab, M. (2012). Effect of dietary protein levels and rearing density on growth performance and stress response of Nile tilapia *Orechromis niloticus* (l1). *International Aquatic Research,* 4(3):1-13.

Abowei, J. F. and Davis, A. O. (2009). Some population parameters of *Carotes laticeps* (Rupell, 1829) from the freshwater reaches of the Lower Nun River, Niger Delta, Nigeria. *American Journal of Scientific Research*, 2: 15-19.

Adeoye, A. A., Rotimi, E. A. and Udoh, J. E. (2016). Quantitative Characterization of Farmed African Catfish (*Clarias gariepinus*) in Okitipupa, Ondo State, Nigeria. *World Scientific News*, 47(2): 329-339.

Adeyemi, S. O., Bankole, N. O., Adikwu, I. A. and Akombo, P. M. (2009). *Age, growth and mortality of some commercially Nigerian fish species in Gbadikere Lake, Kogi State, Nigeria. International Journal of Lakes and Rivers Resources*, 2(1):63-69.

Afia, O. E., David, G. S. and Effiong, I. B. (2018). Comparative effect of different stocking densities of *Heteroclarias* on plankton abundance in tarpaulin tanks. *Journal of Aquatic Science and Marine Biology*, 1: 5-12.

Afia, O. E., David, G. S. and Udo, I. U. (2019). Studies on the effects of feeding levels on growth response and nutrient utilization of *Heteroclarias* (hybrid catfish). *Journal of Applied Sciences*, 19(7): 725-730.

American Public Health Association (APHA) (1998). Standard Methods for the Examination of Water and Wastewater, 20th edn. American Public Health Association, Washington DC.

Andem, A. B., Ekpo, P. B., Etta, S. E., Udoh, A. G. and Eyo, V. O. (2013). Effect of different feed application rates on growth performance and body composition of African catfish, *Clarias* *gariepinus* fingerlings. *International Journal of Scientific Research and Management*, 1(9): 471-475.

Anibeze, C. I. P. (2000). Length-Weight Relationship and Relative Condition of *Heterobranchus longifilis* (Valenciennes) from Idodo River, Nigeria. *Naga, The ICLARM Quarterly*, 23(2): 34-35.

Bailey, K. M. (1997). Structural dynamics and ecology of flatfish populations. *Journal of Sea Resources*, 37(2-4): 269-280.

Davies, O. A., Tawari, C. C. and Kwen, K. (2013). Length –weight relationship, condition factor and sex ratio of *Clarias gariepinus* juveniles reared in concrete tanks. *International Journal of Scientific Research in Environmental Sciences*, 1(11): 324-329.

Dienye, H. E. and Olumuji, O. K. (2014). Growth performance and haematological responses of African mud catfish *Clarias gariepinus* fed dietary levels of *Moringa oleifera* leaf meal. *Net Journal of Agricultural Science*, 2: 79-88.

Doherty, D. and McCarthy, T. K. (2000). The metazoan parasites, diets and general biology of Arctic Char, L., in two Irish Lakes. Archives for Hydrobiology. *Special Advances in Limnology, 27*, 1056-1061.

Efitre, J., Chapman, L. J. and Murie, J. D. (2009). Fish condition in introduced tilapias of Ugandan crater lakes in relation to deforestation and fishing pressure. *Environmental Biology of Fishes*, 85(1): 63-75.

Ekelemu, J. K. and Ekokotu, P. A. (1999). Principle and Practice of Fish seed production. In: Issues in Animal Science, Omeje, S. I. (Eds.), Raykenedy Scientific Publishers Enugu. 182-196pp.

Ekubo, A. A. and Abowei, J. F. N. (2011). Review of some water quality management principles in culture fisheries. *Research Journal of Applied Science, Engineering and Technology,* 3: 1342-1357.

Fafioye, O. O. and Oluajo, O. A. (2005). Length-weight relationship of five fish species in Efe lagoon, Nigeria. *African Journal of Biotechnology*, 4: 749-751.

Fagbenro, O. A., Olaniran, T. S. and Esan, A. O. (1991). Some aspects of the biology of the catfish, *Heterobranchus bidorsalis*

Geoffrey Saint-Hillarie, 1809 (Clariidae) in River Ogbese, Nigeria. *Journal of African Zoology*, 105: 363 - 372.

Food and Agriculture Organization (FAO) (2016). The state of world fisheries and aquaculture 2016 – contributing to food security and nutrition for all. FAO Fisheries Department, Rome. 200pp.

Food and Agriculture Organization (FAO). (2020). The state of world fisheries and aquaculture 2016 – sustainability in action. Rome: FAO Fisheries Department, Rome. 224pp.

Gaspar, S., Tobes, I., Miranda, R., Leunda, P. M. and Peláez, M. (2012). Length–weight relationships of sixteen freshwater fishes from the Hacha River and its tributaries (Amazon Basin, Caquetá, Colombia). *Journal of Applied Ichthyology*, 28(4):667– 670.

Haque, M. M., Narejo, N. T., Salam, M. A., Rahmatullah, S. M. and Islam, M. A. (2003). Determination of optimum stocking density of *Macrobrachium rosenbergii* in carp polyculture in earthen pond. *Pakistan Journal of Biological Sciences.*, 6: 898-901.

Hossain, M. Y., Ahmed, Z. F., Leunda, P. M., Jasmine, S., Oscoz J., Miranda, R. and Ohtomi, J. (2006). Condition, length–weight and length–length relationships of the Asian striped catfish, *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, Southwestern Bangladesh. *Journal of Applied Ichthyology*, 22: 304–307.

Huang, W. B. and Chiu, T. S. (1997). Effects of stocking density on survival, growth, size variation and production of tilapia fry. *Aquaculture Resources*, 28: 165-173.

Idodo-Umeh, G. (2003). Freshwater Fishes of Nigeria (Taxonomy, ecological notes, diets and utilization). Idodo Umeh Publishers Limited, Benin City. 232pp.

Ighwela, K. A., Ahmed, A. B. and Abol-Munafi, A. B. (2011). Condition factor as an indicator of growth and feeding intensity of Nile tilapia fingerlings (*Oreochromis niloticus*) fed on different diets of maltose. *Journal of Agricultural and Environmental Science*, 11(4): 559-563.

Kalu, K.M., Umeham, S.N. and Okereke, F. (2007). Length- weight relationship and condition factor of *Clarias gariepinus* and *Tilapia zilli* in Lake Alau and Monguno Hatchery, Borono State, Nigeria. *Animal Research International*, 4(1):635-638.

Keremah, R. I. and Green, H. J. (2005). Effect of replacing fish meal with graded levels of fish offal on growth and survival hybrid catfish fingerlings. In Proceedings of the 20*th* Annual Conference of the Fisheries Society of Nigeria (FISON), Port Harcourt 14th - 18th November, 2005. 144 – 149pp.

Leunda, P. M., Oscoz, J. and Miranda, R. (2006). Length–weight relationships of fishes from tributaries of the Ebro River, Spain. *Journal of Applied Ichthyology,* 22: 299–300.

Murta, A. G. (2002). Morphological variation of horse mackerel (*Trachurus trachurus*) in the Iberian and North African Atlantic: Implications for stock identification. *Journal of Marine Science*, 57(4): 1240:1248.

Nehemia, A., Maganira, J. D. and Rumisha, C. (2012). Length-weight relationship and condition factor of tilapia species grown in marine and fresh water ponds. *Agriculture and Biology Journal of North America*, 3(3), 117-124.

Ngugi, C. C., Bowman, J. and Omolo, B. A. (2007). A new guide to fish farming in Kenya. Aquaculture Collaborative Research Support Programme, Corvallis, Ore.

Nkongho, G. O., Oben, B. O., Sanni, M. T., Agbebi, O. T., Obie, A. E., Makombu, J. G., Narika, A. F., Arrey, M. A. and Oben, P. M. (2019). Morphological and molecular characterization of some wild and cultured *Clarias* (Clariidae, Siluriformes) fish species from Cameroon. *International Journal of Research Studies in Biosciences,* 7(3): 16-26.

Normala, J., Mohd, A. A., Abol, M. A. B., Nur, A. A. Khor, W., Okomoda, T. V. and Shahreza, M. S. (2017). Morphometric variations between triploid and diploid Clarias gariepinus (Burchell, 1822). *Croatian Journal of Fisheries*, 75: 113-121.

Nweke, S. and Ugwumba, A. (2005). Effects of replacement of fishmeal with duckweed (*Lemna paucicostata*) meal on the growth of

Clarias gariepinus (Burchell, 1822) fingerlings. In: Proceedings of the 20th Annual Conference of the Fisheries Society of Nigeria (FISON), Port Harcourt, 14th -18th November, 163-167pp.

Okomoda, V. T., Koh, I. C. C., Hassan, A., Amornsakun, T. and Shahreza, S. M. (2018). Length-weight relationship and condition factor of the progenies of pure and reciprocal crosses of *Pangasianodon hypophthalmus* and *Clarias gariepinus*. *AACL Bioflux,* 11(4): 980-987.

Olusegun, A. S. (2011). Length-weight relationship and condition factor of *Synodontis robbianus* at Idah area of River Niger, Kogi State, Nigeria. *Pakistan Journal of Nutrition,* 10(6): 505-508.

Pepple, P. C. G. and Ofor, C. O. (2011). Length–weight relationship of *Heleterobranchus longifilis* reared in earthen Ponds. *Nigerian Journal of Fisheries*, 8(2): 315-321.

Pinheiro, A., Teixeira, C. M., Rego, A. L., Marques, J. F. and Cabral, H. N. (2005). Genetic and morphological variation of *Solea lascaris* (Rissa, 1810) along the Portuguese Cost. *Fish Resources,* 73(1-2): 67-78.

Rohollah, A., Rahbar, M. and Karimi, M. J. (2013). Comparative survey of morphormetric-meristic male and female anjak fish (*Schizocypris brucei,* Annandale and Hora, 1920) of Hamoun wetland in South East Iran. *Middle-East Journal of Scientific Research,* 14(5): 620-623.

Sawant, P. B. and Raje, S. G. (2009). Morphometry and length weight relationship of the Catfishes *Arius caelatus* (Valenciennes, 1840) and *Arius thalassinus* (Ruppell, 1837) off Mumbai, Veraval and Vishakhapatanam coasts. *Asian Fisheries Science*, 22: 215-228.

Solomon, S. G., Okomoda, V. T. and Ogbenyikwu, A. I. (2015). Intraspecific morphological variation between cultured and wild Clarias gariepinus (Burchell) (Clariidae, Siluriformes) – *Archives of Polish Fisheries*, 23: 53-61.

Stevenson, R. D. and Woods, W. A. (2006). Condition indices for conservation: New uses for evolving tools. *Integrative and Comparative Biology*, 46(6): 1169-1190.

Thomas, J., Venus, S. and Kurup, B. M. (2004). Length weight relationship of some deep- sea fish inhibiting continental slope beyond 250m depth along West coast of India. *Naga, World Fish Center Quarterly*, 26: 17-21.

Torres, R. G. A., Gonzalez, P. S. and Pena, S. E. (2010). Anatomical, histological and ultrastructural description of the gills and liver of the Tilapia (*Oreochromis niloticus*). *International Journal of Morphology*, 28(3): 703-712.

Turan, C., Yalçin, S., Turan, F., Okur, E. and Akyurt, I. (2005). Morphometric comparisons of African catfish, *Clarias gariepinus*, populations in Turkey. *Folia Zoology*, 54(1–2): 165–172.

Ude, E. F. and Ukanyikwa, A. C. (2013). Length-weight relationship of five clariid species from Akpoha River, Nigeria. *Advances in Science and Technology*, 7(2): 69 – 73.

Umoh, I. A., Nlewadim, A., Obuba, L. E. and Oguntade, O. R. (2015). Morphometric and meristic characteristics of hybrid catfish from selected fish farms in southern Nigeria. *International Journal of Biotech Trends and Technology*, 5(1): 30-35.

Wiecaszek, B., Krzykawski, S., Antoszek, A., Kosik, J. and Serwolka, P. (2010). Morphometric characteristics of the juvenile North African Catfish *Clarias gariepinus* (Burchell, 1822) from the heated water aquaculture. *Electronic Journal of Polish Agricultural Universities*, 13:2.

Wimberger P. H. (1992). Plasticity of fish body shape, the effects of diet, development, family and age in two species of *Geophagus* (Pisces: Cichlidae) – *Biological Journal of the Linnaean Society*, 45: 197-218.

Zafar, M., Mussaddeq, Y., Akhter, S. and Sultan, A. (2003). Weight-length and condition factor relationship of Thaila, *Catla Catla* from Rewal Dam Islamabad, Pakistan. *Pakistan Journal of Biological Sciences*, 6(17): 1532-1534.