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Research Article

THE UNDERUTILIZED ALBINO CATFISH (*CLARIAS CAVERNICOLA*) CAN POTENTIALLY IMPROVE THE GENETICS OF THE NORTH AFRICAN CATFISH (*CLARIAS GARIEPINUS*)

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Abstract

Given the recent genetic bottleneck that has negatively impacted productivity in the African catfish (*Clarias gariepinus*), assessing the possibility of its genetic improvement is important for continual contribution to food availability. We assessed the potential of utilizing the blind catfish (*Clarias cavernicola*) in the improvement of *Clarias gariepinus*. Two broodstock parents each from *Clarias gariepinus* and *Clarias cavernicola* were subjected to reciprocal crossing to produce four catfish breeds. The crosses were thus: Cc♀ × Cc♂: Female *Clarias cavernicola*× male *Clarias cavernicola*, Cg♀ × Cg♂: Female *Clarias gariepinus*× male *Clarias gariepinus*, Cg♀ × Cc♂: Female *Clarias gariepinus*× male *Clarias cavernicola* and Cc♀ × Cg♂: Female *Clarias cavernicola* x male *Clarias gariepinus*. The hybrid crosses had the highest body weight and length. Weight and length showed a positive correlation. The highest coefficient of determination (R^2) was obtained from a hybrid cross of Cc♀ × Cg♂ using total length ($Y = -46.728+4.779X$ and $R^2 = 0.942$). There were variations in the hybrids' qualitative traits, while the two pure breeds bred through. Following the findings from the hybrid crosses, *Clarias cavernicola* could be a potential candidate for reducing inbreeding in *Clarias gariepinus* and its general genetic improvement.

Keywords: Crossbreeding, Inbreeding depression, Vigour, Blind Catfish, Linear association.

INTRODUCTION

Fish is an indispensable source of high-quality protein and essential amino acids for human beings, which are necessary for the growth and maintenance of muscle tissues. In many diets around the world, fish protein constitutes a complete protein source. Fresh fish, in particular, is rich in high-quality proteins that can help maintain an active metabolism (Ayoola, 2011). Due to their rapid growth rate, nutritional and commercial values, fish farming has become an essential industry that serves various purposes, supports the feeding habits of the Nigerian population, and generates income for investors. Fish are also a rich source of Omega-3 fatty acids, which play a crucial role in normal growth, particularly for blood vessels and nerves (Ayoola, 2011). The African catfish, *Clarias gariepinus*, is a highly sought-after cultured fish in Nigeria. A recent fish demand survey in Nigeria revealed that catfish is preferred over other freshwater species such as tilapia, carp, and others (Ajah *et al.,* 2022). Notably, it is the most widely cultured fish in Nigeria and Africa, ranking third globally (Adeogun *et al.,* 2007; Adewunmi and Olaleye, 2011). Its market value, fast growth rate, and resilience to harsh conditions, particularly low oxygen content, make it a popular choice for aquaculture (Adewolu *et al.,* 2008). Its adaptability to varying environmental conditions and unique culturable attributes have earned it the moniker 'farmers' fish' (Dan-Kishiya, 2013). According to Owodeinde and Ndimele (2011), catfish species are pivotal to the sustainability of the aquaculture industry in Nigeria. The escalating demand for catfish among fish consumers has led to a significant increase in the demand for Clarias, and the conventional methods of unregulated fishing from the wild are no longer able to meet this high demand. Despite being one of the most readily acceptable species of Clarias in Nigeria, the qualities of catfish have gradually declined over the years. This decline in performance could be attributed to inbreeding depression resulting from the consistent mass reproduction of the species to meet the high market demand. Factors such as poor nutrition (Fagbuaro, 2015), hazardous effect of environmental waste (Olatunji-Akintoye *et al.,* 2010), oxygen deficiency, salinity and temperature changes (Mancini *et al.,* 2006), as well as pollution that threatened the ecosystem, have contributed to the inability to meet the increasing market demand for catfish (Fagbuaro & Oso, 2011). To address this issue, inter-specific breeding has been identified as a potential solution that can eliminate inbreeding depression and restore hybrid vigor in catfish. The application of genetic principles of selection and breeding for genetic improvement has played a significant role in enhancing fish production (Awe, 2017). Fish hybridization, one of the genetic techniques that concentrate desirable characters in hybrids (Adah *et al.,* 2014) has been instrumental in the genetic improvement of fish production. Hybrid lines usually exhibit a combination of traits inherited from both parental species, resulting in unique phenotypes that may surpass the parent species. The practice of inter-specific breeding can potentially solve the problem of inbreeding depression in catfish and restore hybrid vigor. The *Clarias cavernicola*, a member of the Clarias genus, has been identified as one of the rarest fish species in Africa and one of the most endangered in the world. Skelton (1990) reported that this species has an estimated population of only 200-400 individuals and is found in an underground lake in Aigamas cave, north of Otavi and west of Grootfontein, Namibia. Although the resistance of *Clarias cavernicola* to harsh environmental conditions is known to be higher than that of

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Clarias gariepinus, very little information is available on the basic aspects of its life history, particularly its mating behaviours and reproduction. Despite the vast literature available on *Clarias gariepinus* reproduction and cross-breeding, the mating behaviours of *Clarias cavernicola* are not well understood (Bruton, 1995; Jacobs *et al.,* 2019). Due to the albino appearance, many consumers have less preference for it as a food source. Because the *Clarias cavernicola* is in the same genus as the *C. gariepinus*, it is considered a close relative and suitable for inter-specific cross. Cross-breeding these two species may result in unique species with improved genetic vigour, potentially aiding in the reduction of inbreeding depression in *C. gariepinus*. The performance improvement will consequently contribute to food availability by utilization of fish as a reliable protein source. Therefore, this research was carried out to evaluate the relationship in the growth charters of purebreds and hybrid crosses between *C. gariepinus* and *C. cavernicola*, particularly aiming to improve the performance of *C. gariepinus* through cross-breeding with the underutilized albino catfish.

MATERIALS AND METHODS

Study area and sampling

The experiment was carried out using fish hatchery facilities of the Institute of Oceanography, University of Calabar Fish Farm (UCFF), Calabar, Nigeria. Calabar is located in the south-south region of Nigeria and lies between latitude 04.15°N of the equator and longitude 08.12°E of the Greenwich meridian with an annual rainfall ranging from 1260-1280mm, relative humidity of 70-80% and an elevation of 99m above the sea level (NMA, 2020). Broodstock of *Clarias gariepinus* (African catfish) were procured from the University of Calabar fish farm, Calabar, while the broodstock of *Clarias cavernicola* (light-skinned catfish) were procured from Sebore Farms EPZ, Mayo Belwa, a highly reputable animal farm located in Adamawa State, Nigeria. The *C. cavernicola* broodstocks were placed in a 50L container of water and transported by bus to the experimental site. The broodstock comprised two sexually matured males and two females of at least 2kg each of *C. gariepinus* and *C. cavernicola*, respectively.

Mating protocol

Mating was carried out in the following order with a stocking density of 300 fingerlings per breed:

1. *Clarias gariepinus* ♀ ×*Clarias gariepinus* ♂ (pure breed)- injected with synthetic hormone - ovaprim)
2. *Clarias cavernicola* ♀ ×*Clarias cavernicola* ♂ (pure breed)- injected with synthetic hormone- ovaprim
3. *Clarias gariepinus* ♀ ×*Clarias cavernicola* ♂ (hybrid)- injected with synthetic hormone-ovaprim
4. *Clarias cavernicola* ♀ ×*Clarias gariepinus* ♂ (hybrid)- injected with synthetic hormone ovaprim

Ethical statement

This research was conducted under the ethical approval of the Faculty of Biological Sciences Ethical Committee, University of Calabar, Nigeria.

Measurement of growth characters

The following growth measurements were taken from each fish sample at two weeks intervals after the initial one month of acclimatization: body weight, total length and standard Length (SL) were measured on all the fish. The qualitative characters were taken through observation and counting.

Statistical analysis

All the data were subjected to a one-way analysis of variance (ANOVA) and significant means were separated using the Least Significant Difference (LSD) test at a 5% level of probability. Pearson correlation was performed to assess the relationship between weight and length in the four breeds, while the regression model was used for body weight prediction; where Y= Dependent variable (body weight) and X= Independent variables (total length and standard length). The qualitative characters were assessed by phenotypic observation and counting.

RESULTS

Variations in growth characters

The results of the variation in weight and lengths of the four fish breeds are presented in Table 1. There were significant variations (P<0.05) in the weight measurements of the fish breeds. At weeks 2 and 4, the highest weights were obtained from the two hybrids, while the pure breeds were statistically similar (P>0.05). At week 6, the hybrid cross between female *C. cavernicola* and male *C. gariepinus* had the highest weight (22. 23g; P<0.05). In the same week, the two pure breeds and hybrid cross of female *c. Gariepinus* and male *c. Cavernicola* were statistically similar in weight (P>0.05). The total length was also observed to be higher in the two hybrids than in the purebreds at weeks 2 and 4. Also, a significantly higher total length was obtained in the hybrid cross of female *C. cavernicola* and male *C. gariepinus* (14.43g) followed by a hybrid cross of female *C. gariepinus* and male *C. cavernicola* (13.20g), pure breed of *C. cavernicola* (12.64g) and *C. gariepinus* (11.60g). A similar trend in standard length measurements persisted at weeks 2 and 4. Again, the hybrid cross of female *C. cavernicola* and male *C. gariepinus* had the highest weight measurements at week 6. Generally, the weight and lengths were increased age of the fish.

Evaluation of linear relationship

The results of the relationship between body weight and lengths (total length and standard length) of the four breeds of fish used in this study are presented in Table 2-5. There were highly significant and positive relationships between the body weight and lengths of all the fish breeds. Table 2 shows the highly significant relationship in the pure breed of *C. gariepinus* with the highest correlation as r=0.921; P<0.01 between weight and total length. On the other hand, the highest correlation in the pure breed of *C. cavernicola* was recorded between weight and standard length (r=0.923). In the two hybrids, the highest correlation was between weight and total length (r = 0.969; P<0.01 and r = 0.971; P<0.01) in Tables 4 and 5, respectively. It was observed that the hybrids were more consistent and also showed significantly higher correlations between weight-length measurements than the pure breeds.

Table 1. Variation in weight and lengths of *Clarias gariepinus*, *Clarias cavernicola* and hybrids

	Breeds	2 WEEKS	4 WEEKS	6 WEEKS
Weight(g)	[1]Cg♀ × Cg♂	0.97±0.09[b]	3.11±0.25[b]	12.40±0.81[b]
	[2]Cc♀ × Cc♂	1.00±0.09[b]	1.72±0.25[c]	13.95±0.36[b]
	[3]Cg♀ × Cc♂	2.98±0.39[a]	4.66±0.36[a]	15.74±1.40[b]
	[4]Cc♀ × Cg♂	3.00±0.25[a]	4.77±0.53[a]	22.23±2.35[a]
Total Length(cm)	[1]Cg♀ × Cg♂	4.76±0.17[c]	6.62±0.23[b]	11.60±0.26[c]
	[2]Cc♀ × Cc♂	5.46±0.17[b]	5.78±0.35[b]	12.64±0.24[bc]
	[3]Cg♀ × Cc♂	7.39±0.30[a]	8.28±0.28[a]	13.20±0.44[b]
	[4]Cc♀ × Cg♂	7.21±0.20[a]	8.22±0.37[a]	14.43±0.48[a]
Standard length (cm)	[1]Cg♀ × Cg♂	3.65±0.15[c]	5.20±0.20[b]	10.00±0.30[b]
	[2]Cc♀ × Cc♂	4.31±0.18[b]	4.40±0.31[b]	10.70±0.21[b]
	[3]Cg♀ × Cc♂	6.01±0.30[a]	6.30±0.26[a]	11.10±0.38[b]
	[4]Cc♀ × Cg♂	5.84±0.25[a]	6.30±0.33[a]	12.30±0.63[a]

Mean values with different superscripts along the same vertical axis for each character are significantly different ($P<0.05$)

[1]Cg♀ × Cg♂: Female *Clarias gariepinus* x male *Clarias gariepinus*

[2]Cc♀ × Cc♂: Female *Clarias cavernicola* x male *Clarias cavernicola*

[3]Cg♀ × Cc♂: Female *Clarias gariepinus* x male *Clarias cavernicola*

[4]Cc♀ × Cg♂: Female *Clarias cavernicola* x male *Clarias gariepinus*

Table 2. Relationship between weight and lengths of [1]Cg♀ × Cg♂

		Weight (g)	Total Length (cm)	Standard length (cm)
Weight(g)	Pearson Correlation	1	0.921**	0.837**
Total Length(cm)	Pearson Correlation	0.921**	1	0.812**
Standard length (cm)	Pearson Correlation	0.837**	0.812**	1

**. Correlation is significant at the 0.01 level (2-tailed)

[1]Cg♀ × Cg♂: Female *Clarias gariepinus* x male *Clarias gariepinus*

Table 3. Relationship between weight and lengths of [1]Cc♀ × Cc♂

		Weight (g)	Total Length (cm)	Standard length (cm)
Weight(g)	Pearson Correlation	1	0.887**	0.923**
Total Length (cm)	Pearson Correlation	0.887**	1	0.783**
Standard length (cm)	Pearson Correlation	0.923**	0.783**	1

**. Correlation is significant at the 0.01 level (2-tailed)

[1]Cc♀ × Cc♂: Female *Clarias cavernicola* x male *Clarias cavernicola*

Table 4. Relationship between weight and lengths of [1]Cg♀ × Cc♂

		Weight (g)	Total Length (cm)	Standard length (cm)
Weight(g)	Pearson Correlation	1	0.969**	0.899**
Total Length (cm)	Pearson Correlation	0.969**	1	0.924**
Standard length (cm)	Pearson Correlation	0.899**	0.924**	1

**. Correlation is significant at the 0.01 level (2-tailed)

[1]Cg♀ × Cc♂: Female *Clarias gariepinus* x male *Clarias cavernicola*

Table 5. Relationship between weight and lengths of [1]Cc♀ × Cg♂

		Weight(g)	Total Length (cm)	Standard length (cm)
Weight(g)	Pearson Correlation	1	0.971**	0.944**
Total Length (cm)	Pearson Correlation	0.971**	1	0.918**
Standard length (cm)	Pearson Correlation	0.944**	0.918**	1

**. Correlation is significant at the 0.01 level (2-tailed).

[1]Cc♀ × Cg♂: Female *Clarias cavernicola* x male *Clarias gariepinus*

Table 6. Linear regression equations (prediction equation) for weight on length measurements Y = a + bx

Breeds	Total length	Standard length
[1]Cg♀ × Cg♂	Y= -20.856+2.867X	Y= -10.475+2.888X
R^2	0.848	0.701
Sig. reg.	$P<0.001$	$P<0.003$
[2]Cc♀ × Cc♂	Y= 10.828+0.247X	Y= 11.723+0.207X
R^2	0.028	0.015
Sig. reg.	$P>0.05$	$P>0.05$
[3]Cg♀ × Cc♂	Y= -24.461+5.046X	Y= -21.053+3.315X
R^2	0.939	0.807
Sig. reg.	$P<0.001$	$P<0.001$
[4]Cc♀ × Cg♂	Y= -46.728+4.779X	Y= -20.909+4.779X
R^2	0.942	0.892
Sig. reg.	$P<0.001$	$P<0.001$

[1]Cg♀ × Cg♂: Female *Clarias gariepinus* x male *Clarias gariepinus;* [2]Cc♀ × Cc♂: Female *Clarias cavernicola* x male *Clarias cavernicola*

[3]Cg♀ × Cc♂: Female *Clarias gariepinus* x male *Clarias cavernicola;* [4]Cc♀ × Cg♂: Female *Clarias cavernicola* x male *Clarias gariepinus*

Y= Dependent variable (body weight); a= Constant (intercept); b= Regression coefficient. X= Independent variable (total length and standard length); R^2= Determination coefficient and Sig. reg.= Significant of regression.

Table 7. Qualitative characters of four catfish breeds

	Number of eyes				Colouration				Number of pectoral fins		
Breeds	[5]N	Two	One	None	Black	White	Brown	Grey	Two	One	None
[1]Cc♀ × Cc♂:	300	0	0	300	0	300	0	0	300	0	0
[2]Cg♀ × Cg♂	300	300	0	0	300	0	0	0	300	0	0
[3]Cg♀ × Cc♂	300	278	20	2	82	0	151	67	121	162	17
[4]Cc♀ × Cg♂	300	286	9	5	4	0	243	53	185	97	18

[1]Cc♀ × Cc♂: Female *Clarias cavernicola* x male *Clarias cavernicola*
[2]Cg♀ × Cg♂: Female *Clarias gariepinus* x male *Clarias gariepinus*
[3]Cg♀ × Cc♂: Female *Clarias gariepinus* x male *Clarias cavernicola*
[4]Cc♀ × Cg♂: Female *Clarias cavernicola* x male *Clarias gariepinus*
[5]N = sample size

Table 6 shows the linear regression model for predicting body weight using total length and standard length. Total length was observed with a higher coefficient of determination (R^2) than standard length in all the breeds of fish used in this research. Apart from the pure breed of *C. cavernicola* where weight was not significantly predicted by the regression model, all the other three breeds showed consistent prediction of weight using total and standard lengths. The highest coefficient of determination (R^2) for predicting body weight was obtained from the hybrid cross of female *C. cavernicola* and male *C. gariepinus* using total length ($Y = -46.728+4.779X$ and $R^2 = 0.942$).

Qualitative characters

The qualitative characters obtained on the different breeds of fish are presented in Table 7. The pure breed of *C. gariepinus* all had both eyes, and two pectoral fins and were all back-skinned. All the samples of *C. cavernicola* purebreed were without eyes (blind) and were all white-skinned with two pectoral fins present. Out of the 300 samples from the hybrid cross of female *C. gariepinus* and male *C. cavernicola*, 278 (92.66%) had both eyes, 20 (6.66%) had one eye, while 2 (0.66%) were eyeless. In terms of colouration, there were 82 (27.33%) black, 151(50.33%) brown and 67 (22.33%)greys. There were 121 (40.33%) with two pectoral fins, 162 (54%) with only one pectoral fin and 17 (5.66%) did not have pectoral fins. The qualitative characteristics of the hybrid cross of female *C. cavernicola* and male *C. gariepinus* revealed that 286 (95.33%) had both eyes, 9 (3.0%) had one eye and 5 (1.66%) were eyeless. There were 4 (1.33%) black, 243 (81%) brown and 53 (17.66%) grey while variation in pectoral fin development showed that 185 (61.66%) individuals had both pectoral fins, 97 (32.33%) had one and 18 (6.0%) did not have pectoral fins.

DISCUSSION

Morphological characterization of fish is a preliminary measure usually taken to understand the population dynamics which could help in management strategy for effective yields. There were significant variations in the body weight, total length, and standard length measurements among the fish, with the hybrids performing significantly higher. This was similar to the submission of Ola-Oladimeji and Awodiran (2016) who also observed significant variation in the growth of *C. gariepinus*. Body weight and length characteristics, such as total and standard lengths, are critical growth parameters in the evaluation of catfish yield. The significant variations noted among the fish breeds could be a result of their inherent genetic architecture as well as environmental effects, which may be influenced by physical and biological factors such as sex, age, season, diet, habitat, temperature, salinity, and geographical distribution (Atama *et al.* 2013; Uneke *et al.,* 2017; Lawal *et al.* 2019). These factors, which were not considered in this study, could interplay to impact the fish responses. The heritability resulting from the cross-breeding of the two Clarias species may be attributed to the observed improvement in the weight and length of the hybrids. Notably, the cross between female *C. cavernicola* and male *C. gariepinus* yielded significant variation in body weight and length, consistent with previous findings by Eyo *et al.* (2016). The growth characteristics of the fish were observed to increase with age, indicating the influence of age on their growth.

The continuous growth of aquaculture is hinged on the production of fish seeds with high hatchability, survival rates and high growth rates among other factors (George *et al.,* 2010). The length and weight relationship is a useful biological tool that has been applied to examine the effect of environmental changes on the well-being of fish. This relationship is very important for the proper exploitation and management of the population of fish species (Anene, 2005; Pervin and Mortuza, 2008). The present findings revealed a positive and significant relationship between the weight and length of the fish, indicating a linear correlation between these two features. Therefore, selecting catfish for weight improvement could lead to an overall enhancement in both the total and standard lengths of the fish. This is in agreement with Sadauki *et al.* (2023) who also observed a significant and positive relationship in *C. gariepinus*. This was more prominent in the hybrid cross of female *C. cavernicola* and male *C. gariepinus*. This aligns with David *et al.* (2010) findings, where *Clarias gariepinus* had a high regression coefficient among catfish breeds. Therefore, the significant vigour in the growth of the hybrid fish suggests the potential benefits that can be derived from utilizing *Clarias cavernicola* for the mass production of fish seeds for commercialization. The regression model indicates that fish body weight can be predicted using both total and standard lengths as predictors. However, the total length appeared to be more consistent, with a higher coefficient of determination. This was following previous findings of Omodu *et al*. (2017) and Olapade *et al.* (2019). These results suggest that total length may be a more reliable indicator trait for catfish breeders to utilize in the selection of catfish for breeding programmes. The fish breeds exhibited a similar pattern for both correlation and regression analyses, with the hybrid cross of female *C. cavernicola* and male *C. gariepinus* displaying a higher coefficient of determination for total length on weight. This finding may prove useful for breeders seeking to optimize their selection of catfish for breeding purposes. The present also investigated the qualitative character variations observed during the hybridization of *Clarias gariepinus* and *Clarias cavernicola*. There were significant variations in the qualitative characters, indicating the influence of genetic recombination in the hybridization process. The parent stocks used for crossing were purebred of *C. gariepinus* with black-skinned, two eyes, and two pectoral fins, while *C. cavernicola* was white-skinned with no eyes but with two pectoral fins. Interestingly, the hybridization process brought about different ratios of qualitative characters. The hybrids displayed a blend of the original skin color, exhibiting either brown or grey skin colour. Previous research also reported variations in the pattern of colour inheritance in African catfish (Nwachi *et al.,* 2023). Additionally, the development of eyes and pectoral fins in the hybrids showed variations, with some hybrids having either one or no eyes and pectoral fins. These variations in the studied characters may be attributed to maternal effects during the hybridization process. The present study provides valuable insights into the qualitative character variations observed during the hybridization of *C. gariepinus* and *C. cavernicola*. The findings have implications for the further development and improvement of hybridization techniques in aquaculture.

Conclusion

This study evaluated the weight-length relationship in four catfish breeds, including two pure breeds and two hybrids. The results showed a positive correlation between weight and length in all breeds, with total length exhibiting a higher coefficient of determination (R2) than standard length. The highest coefficient of determination (R2) for predicting body weight was obtained from a hybrid cross of Cc♀ x Cg♂ using total length. The study also revealed observable variations in eye formation, colouration, and pectoral fin development among the hybrids. This information can be utilized by catfish breeders for selection and breeding improvement. Overall, the study indicated the genetic potential of the underutilized albino catfish (*C. cavernicola*) in the improvement of *C. gariepinus*.

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