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Assessment of Morphological Variation in Wild and Cultured Populations of Tilapia Fish (*Oreochromis niloticus*)

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Authors' contributions

This work was carried out in collaboration between all authors. Author EEE designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EVI and OUU managed the analyses of the study. Author MOO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Reliable estimates of morphometric traits are required for all traits of economic importance to predict response to selection, choose various breeding plans, estimate economic returns and to predict breeding values of stocks for selection. The present study was aimed at assessing the morphometric variation of tilapia fish (*Oreochromis niloticus*) from different populations. A total of two hundred samples from four populations that cut across two wild [Anantigha river (AN) and Ifiayong river (IF)] and two cultured [Unical fish farm (UN) and Domita fish farm (DM)] were used for the study with fifty samples from each population, respectively. A total of twenty morphormetric traits were measured on each fish. The data were transformed and subjected to multivariate analysis. Results obtained revealed that there were significant differences ($P<0.05$) in the morphometric traits of the different populations. Body weight was highest in the wild populations (AN =2.32 g; IF = 2.21 g). Correlation analysis revealed high and significant correlation coefficient between the measured traits, where the highest was observed from origin of the dorsal fin to the

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insertion of the pelvic fin (ODIP) and dorsal origin of the caudal fin to the ventral origin of the caudal fin (DCVC) with correlation coefficient of r= 0.955, P<0.01. Path coefficient analysis revealed that body depth, total length and posterior end of the dorsal fin to origin of the anal fin (PDOA) had the highest direct and positive contributions to the body weight of the fish with path coefficient values of 1.359, 0.943 and 0.673, respectively. Principal component analysis extracted four principal components (PC1 = 65.543%; PC2 = 10.869%; PC3 =7.364% and PC4 =1.327%) contributing to the observed variability among the populations. Hierarchical cluster analysis separated the tilapia fish samples into two major clusters, where fish samples from wild population were group majorly within the same cluster and samples from cultured population also grouped majorly within a common cluster. The findings suggest the strength of morphological traits in distinguishing tilapia populations as well as identifying the morphological traits with high contribution to the weight of tilapia fish which could be targeted for weight improvement.

Keywords: Tilapia; Oreochromis niloticus; multivariate; morphology; variation.

1. INTRODUCTION

Tilapia is a common name given to Cichlids which are common in Africa. It is found in the genus *Oreochromis*, consisting of three species that are all endemic to Africa, which are the Nile tilapia (*Oreochromis niloticus*), Blue tilapia (*Oreochromis aureus*) and Mozambique tilapia (*Oreochromis mossambicus*). Among the bony fish in Africa, Nile tilapia is the most popular [1] and the most common of the *Oreochromis* genus in Nigeria. This is partly due to its positive aquaculture qualities such as ability to withstand poor water quality and wide range of feed [2]. Tilapia is a rich source of protein and other forms of nutritionally essential elements like potassium, phosphorus, vitamin B-12 with low fat content [3] that are required for body growth and build up. Authors [4] reported high proximate and mineral content of wild and cultured tilapia (*Oreochromis niloticus*).

There are evidence that the consumption of sea food and fish oils is positively linked with cognitive development and a reduced risk of chronic conditions including coronary heart diseases, cancers, diabetes, rheumatoid arthritis, dementia and Alzheimer's disease [5]. Considering the increasing demand of tilapia fish and its promising nutritional values, these chronic diseases may be reduced among tilapia consumers.

Although tilapia fish has received huge recognition in the fight against protein malnutrition, very little is known about its genetic architecture. The continuous exploitation and indiscriminate fishing of tilapia from the wild by local fishermen in the quest to meet the market demands is increasingly becoming a threat as it could lead to genetic erosion of this species. It thus suggests that there is the need to intensify efforts in tilapia fish research to encourage its domestication. This will start by identifying methods to assess and manage the genetic blue-print of tilapia fish. According to [6], management of aquaculture genetic resources including tilapia should incorporate a number of activities such as keeping proper record of the genetic resources and the various ecosystems where they are found, identifying and classifying these resources to estimate the genetic variation and conservation potential, determination of direct and indirect economic potential of the resources and utilization in sustainable genetic improvement schemes.

Genetic diversity studies which assess the variation existing in a population as it relates to their allelic differences have recently become an integral part in agricultural programmes as a tool for selection of breeding stock and identification of endangered species for possible conservation measures [7]. Variation in the morphological features of species is often used as the preliminary measurement of the genetic differences that may exist in a population. Measurement of morphological characters is the simplest method used in identification and characterization of tilapia. Therefore, good estimation of morphological characters is required for prediction of selection response, economic returns and breeding values of stocks required in breeding programmes [8,9]. Authors [10] reported that a good insight into the pattern of transmission of morphological characters is a requisite when breeding for improvement in economic traits as well as in confirming hybridization in wild and farmed stocks. The present research is thus focused on the assessment of variation in morphological traits of tilapia fish (*Oreochromis niloticus*) and estimation

of the contribution of these traits to the body weight of this economically important species as a step towards making relevant recommendations for selective breeding and conservation.

2. MATERIALS AND METHODS

2.1 Location and Sample Collection

A total of 200 matured tilapia fish (*Oreochromis niloticus*) were collected from four different locations that cut across the wild and cultured populations. The wild populations included Anantigha River (AN) in Cross River State located at approximately 4°5'2"N, 8°2'27"E and Ifiayong River (IF) in Akwa Ibom State located at approximately 5°23'45"N, 8°2'22"E while cultured populations included UNICAL fish farm (UN) in Cross River State at approximately 4°35'32"N, 8°20'27"E and Domita fish farm (DM) in Akwa Ibom State at approximately 5°1'4"N, 7°59'52"E. Fifty samples were obtained from each location respectively.

2.2 Morphometric Measurements of the Fish

Identification and morphometric measurement of all the samples was carried out in the Animal House Unit, Department of Genetics and Biotechnology, University of Calabar, Nigeria. All measurements were taken on the left side of the fish to maintain uniformity using Vernier Caliper adjusted to the nearest 0.01 mm, while weighing balance was used to obtain the weight of each fish. A total of 20 morphometric characters were measured on each fish as follows: body weight (BW), total length (TL), standard length (SL), body depth (BD), head length (HL), head depth (HD), snout length (SnL), base length of dorsal fin (BDF), posterior end of the dorsal fin to dorsal origin of the caudal fin (PDDC), dorsal origin of the caudal fin to ventral origin of the caudal fin (DCVC), ventral origin of the caudal fin to insertion of the anal fin (VCIA), length of the anal fin (LA), base length of the anal fin (BA), origin of the anal fin to insertion of the pelvic fin (OAIP), length of the pelvic fin (LP), posterior end of the dorsal fin to insertion of the anal fin (PDIA), posterior end of the dorsal fin to origin of the anal fin (PDOA), origin of the dorsal fin to insertion of the pelvic fin (ODIP), caudal peduncle length (CL) and caudal peduncle depth (CD) according to [11].

To avoid possible biases from size effect on morphometric variables, all morphometric measurements were standardized using the fromular: $AC_i = LogOC_i - [\beta (LogBW_i - LogMBW)]$ [12] with modification. Where: AC_i = Adjusted character measurement of the ith specimen; OC_i = Unadjusted character measurement of the ith specimen; β = Common within group regression coefficient of that character against body weight after logarithmic transformation of both variables; BW_i = Body weight of the ith specimen and MBW = Overall mean body weight.

2.3 Statistical Analysis

Analysis of variance (ANOVA) was used to partition the variance components of the morphometric data obtained from the fish and significant means were separated using the least significant difference (LSD) at 0.5 level of probability. All the data were then subjected to multivariate analysis using principal component analysis (PCA) to account for the contribution of the morphological character to the observed variability. Pearson product moment correlation between the measured traits was performed. Path coefficient analysis of the morphometric traits was carried out using body weight as the dependent variable. Fifty five samples with most distinguishing morphological variations were selected across the four populations for hierarchical cluster analysis (HCA) to generate dendogram based on Euclidean distance between the populations. All analyses were carried out using SPSS software version 20.0.

3. RESULTS

3.1 Analysis of Variance of Morphometric Traits

Results of analysis of variance showed that there were significant differences ($P< 0.05$) in the different traits measured between the four populations (Table 1). The body weight was highest in fish obtained from wild populations of AN (2.32 g) followed by wild population of IF (2.21 g) and cultured population of DM (1.96 g), while the least mean body weight was recorded among cultured samples of UN (1.92 g). Generally, majority of the body traits were highest in the two wild populations including total length (TL), standard length (SL), body depth (BD), head length (HL), PDDC, DCVC, VCIA, LA, BA, DAIP, LP, PDIA, PDOA ODIA, CL and CD. There was no statistical difference ($P>0.05$) in base length of the dorsal fin (BDF) of fish in the four populations.

Table 1. Morphometric variation in growth parameters of *O. niloticus* from different populations

Traits (cm)	AN	IF	DM	UN
TL	$1.32^{a} \pm 0.07$	$1.19^{a} \pm 0.20$	$1.15^{a} \pm 0.74$	$0.81^{b} \pm 0.08$
SL	$1.20^{a} \pm 0.05$	$1.18^{ab} \pm 0.02$	$1.04^{b} \pm 0.25$	$0.71^{c} \pm 0.08$
BD	$0.86^{a} \pm 0.08$	$0.83^{a} \pm 0.03$	$0.63^{c} \pm 0.05$	$0.38^{d} \pm 0.02$
HL	$0.72^{a} \pm 0.03$	$0.63^{ab} \pm 0.06$	$0.56^{b} \pm 0.05$	$0.39^{c} \pm 0.04$
HD	$0.76^{a} \pm 0.03$	$0.74^{a} \pm 0.02$	$0.57^{b} \pm 0.07$	$0.44^{c} \pm 0.03$
SnL	$0.31^{a} \pm 0.21$	$0.34^{a} \pm 0.07$	$0.18^{b} \pm 0.06$	$0.26^{a} \pm 0.01$
BDF	$l.11^{a} \pm 0.10$	$1.09^{a} \pm 0.09$	$0.90^{a} \pm 0.01$	$0.98^{a} \pm 0.02$
PDDC	$0.37^{a} \pm 0.02$	$0.34^{a} \pm 0.08$	$0.16^{b} \pm 0.02$	$0.28^{ab} \pm 0.02$
DCVC	$0.43^{a} \pm 0.05$	$0.41^{a} \pm 0.04$	$0.28^{b} \pm 0.05$	$0.25^{b} \pm 0.02$
VCIA	$0.34^{a} \pm 0.03$	$0.32^{a} \pm 0.02$	$0.18^{b} \pm 0.05$	$0.21^{b} \pm 0.03$
LA	$0.78^{a} \pm 0.01$	$0.78^{a} \pm 0.02$	$0.61^{b} \pm 0.03$	$0.67^{b} \pm 0.02$
BA	$0.47^{a} \pm 0.03$	$0.43^{a} \pm 0.02$	$0.32^{b} \pm 0.06$	$0.35^{ab} \pm 0.02$
OAIP	$0.80^{a} \pm 0.04$	$0.81^{d} \pm 0.02$	$0.60^{b} \pm 0.05$	$0.62^{b} \pm 0.02$
LP	$0.74^{a} \pm 0.04$	$0.66^{ab} \pm 0.05$	$0.60^{bc} \pm 0.03$	$0.54^{c} \pm 0.02$
PDIA	$0.48^{a} \pm 0.02$	$0.42^{a} \pm 0.03$	$0.29^{b} \pm 0.03$	$0.12^{c} \pm 0.05$
PDOA	$0.73^{a} \pm 0.01$	$0.68^{a} \pm 0.04$	$0.48^{b} \pm 0.04$	$0.49^{b} \pm 0.02$
ODIP	$0.97^{a} \pm 0.07$	$0.97^{a} \pm 0.06$	$0.75^{b} \pm 0.08$	$0.78^{ab} \pm 0.03$
CL	$0.30^{a} \pm 0.02$	$0.26^{ab} \pm 0.02$	$O.11^{c} \pm 0.06$	$0.18^{bc} \pm 0.02$
CD	$0.41^{a} \pm 0..03$	$0.39^{a} \pm 0.04$	$0.21^{b} \pm 0.02$	$0.32^{b} \pm 0.02$
BW(g)	$2.32^{a} \pm 0.00$	$2.21^{b} \pm 0.00$	$1.96^{c} \pm 0.00$	$1.92^{d} \pm 0.00$

Mean values with different superscript along the same row are significantly different (p<0.05).
AN= Anantigha river; IF= Ifiayong river; DM= Domita fish farm; UN= Unical fish farm

3.2 Correlation Analysis

The results obtained from the Pearson product moment correlation matrix are presented in Table 2. The results showed that all the morphometric traits were positively correlated. There were very highly positive correlation between ODIP and DCVC (r= 0.955; P<0.01), DCVC and BDF (r= 0.916, P<0.01), OAIP and DCVC (r= 0.907; P<0.01), DCVC and HL (r= 0.883; P<0.01). Body weight of the fish was considered as the dependent variable in the study. It was observed that PDIA (r= 0.904; P<0.01), PDOA (r= 0.680; P<0.01), LA (r= 0.638; P<0.01) and CD (r= 0.618; P<0.01) correlated significantly with body weight. The lowest correlation was between LP and SnL (r= 0.039; P>0.05) and PDIA and SnL (r= 0.075; P>0.05).

3.3 Path Coefficient Analysis

Path coefficient analysis presented in Table 3 showed both the direct and indirect contribution of all the morphometric traits to the weight of the fish. Here, body weight was used as the dependent variable and the result revealed that body depth had the highest positive contribution to the weight (1.359) followed by total length (0.943) and PDOA (0.673).

3.4 Principal Component Analysis

From Table 4, the principal component analysis of all the morphometric traits extracted four principal components (PC1, PC2, PC3 and PC4). The highest variance to the total variability was contributed by PC1 (65.543%). PC2, PC3, and PC4 contributed 10.869%, 7.364% and 1.327% variance to the total variability respectively. From the component matrix of PCA, all the traits contributed highly to PC1 with the highest contributions from OAIP (0.944), DCVC (0.943), HD (0.941), ODIP (0.922) and HL (0.921). Variation in PC2 was contributed mostly from LP (0.674) and PDIA (0.622), while variability in PC3 and PC4 was contributed mostly by PDDC (0.518) and BW (0.632) respectively. The highest communality was from BDF (0.977) while the lowest was from SnL (0.719).

3.5 Hierarchical Cluster Analysis

Cluster analysis using ward linkage method revealed that tilapia samples from the four populations were grouped into two major clusters. All samples from UNICAL population were found within the same sub-cluster. Similarly, most of the samples from Domita fish farm which also served as the cultured population were found within the same sub-

cluster. Samples from the two wild populations (AN and IF) were mostly grouped in the same cluster (Fig. 1).

4. DISCUSSION

The most important economic trait to be improved in selection programmes is growth [13] which has a component related to body shape that is estimated by morphological measurements [14]. The understanding of the process involved in growth, such as changes in the size, shape and body composition of livestock is fundamental to all aspects of animal production as it can affect the quantity of functional product found in the market place [15]. Tilapia fish is a promising animal protein with essential elements such as phosphorus, potassium, Selenium, niacin and Vitamin B-12 [16]. Despite its importance, there is lack of interest in tilapia fish research caused by the view of fish farmers that tilapia does not grow fast and as such will not have good market competition. Thus, the genetic architecture of this important species is almost unknown. Research should therefore be geared towards identification, characterization and domestication of tilapia fish for continuous utilization as a protein source.

In the present work, body weight was used as independent variable for the analysis of the relationships between different body traits. The results of the analysis can be used for assessing the contribution of all body traits measured to body weight. Importantly also, in the market, fish is priced based on weight. Thus, identifying morphometric traits that contributes better to weight gain could be an eye opener in selective breeding of tilapia fish with the aim of weight improvement.

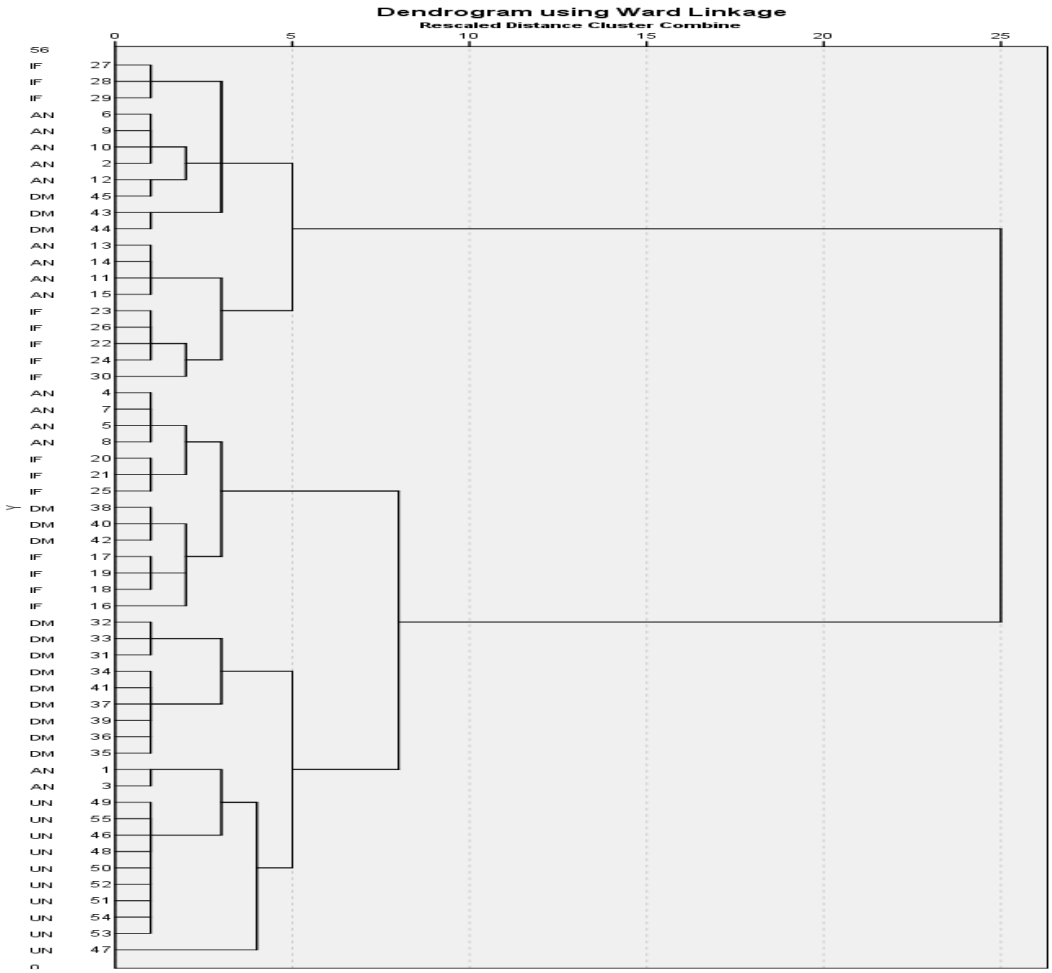

Fig. 1. Hierarchical clustering of morphometric traits of *O. niloticus* from four populations
AN= Anantigha river; IF= Ifiayong river; DM= Domita fish farm; UN= Unical fish farm

Table 2. Pooled correlation matrix or morphometric traits of *O. niloticus*

Traits	BW	TL	SL	BD	HL	HD	SnL	BDF	PDDC	DCVC	VCIA	LA	BA	OAIP	LP	PDIA	PDOA	ODIP	CL	CD
BW	1																			
TL	0.471**	1																		
SL	0.546**	0.959**	1																	
BD	0.598**	0.861**	0.877**	1																
HL	0.503**	0.838**	0.863**	0.821**	1															
HD	0.591**	0.881**	0.915**	0.839**	0.844**	1														
SnL	0.326*	0.318*	0.438**	0.430**	0.414**	0.617**	1													
BDF	0.268*	0.625**	0.601**	0.780**	0.791**	0.633**	0.418**	1												
PDDC	0.351**	0.121	0.183	0.334*	0.567**	0.262	0.204	0.635**	1											
DCVC	0.441**	0.791**	0.783**	0.868**	0.883**	0.827**	0.525**	0.916**	0.520**	1										
VCIA	0.503**	0.686**	0.712**	0.716**	0.768**	0.834**	0.662**	0.736**	0.445**	0.872**	1									
LA	0.638**	0.456**	0.549**	0.544**	0.622**	0.740**	0.678**	0.494**	0.441**	0.645**	0.694**	1								
BA	0.383**	0.738**	0.721**	0.738**	0.742**	0.855**	0.663**	0.759**	0.300*	0.872**	0.878**	0.724**	1							
OAIP	0.547**	0.763**	0.787**	0.834**	0.802**	0.883**	0.662**	0.804**	0.402**	0.907**	0.888**	0.783**	0.909**	1						
LP	0.457**	0.496**	0.471**	0.651**	0.671**	0.389**	0.039	0.714**	0.643**	0.631**	0.404**	0.352**	0.379**	0.404**	1					
PDIA	0.904**	0.549**	0.623**	0.635**	0.646**	0.490**	0.075	0.391**	0.480**	0.461**	0.339*	0.407**	0.252	0.401**	0.759**	1				
PDOA	0.680**	0.535**	0.616**	0.565**	0.996**	0.753**	0.485**	0.558**	0.654**	0.682**	0.712**	0.862**	0.651**	0.735**	0.514**	0.589**	1			
ODIP	0.399**	0.718**	0.712**	0.835**	0.828**	0.808**	0.576**	0.423**	0.523**	0.955**	0.839**	0.688**	0.892**	0.911**	0.531**	0.357**	0.675**	1		
CL	0.470**	0.625**	0.627**	0.561**	0.663**	0.791**	0.587**	0.542**	0.310*	0.689**	0.760**	0.809**	0.803**	0.802**	0.203	0.235	0.737**	0.733**	1	
CD	0.618**	0.618**	0.489**	0.644**	0.669**	0.527**	0.292*	0.730**	0.705**	0.702**	0.596**	0.638**	0.555**	0.692**	0.792**	0.660**	0.723**	0.686**	0.507**	1

***Correlation is significant at 0.01 level (2-tailed); *Correlation is significant at 0.05 level (2-tailed)*

Table 3. Direct (underlined) and indirect contribution of morphometric traits to body weight of tilapia fish (*O. niloticus*)

Traits	TL	SL	BD	HL	HD	SnL	BDF	PDDC	DCVD	VCIA	LA	BA	OAIP	LP	PDIA	PDOA	ODIP	CL	CD
TL	**0.943**	0.904	0.812	0.790	0.831	0.300	0.590	0.114	0.746	0.647	0.430	0.700	0.720	0.468	0.518	0.505	0.677	0.589	0.583
SL	-0.637	**-0.664**	-0.582	-0.573	-0.608	-0.291	-0.399	-0.122	-0.520	-0.473	-0.365	-0.479	-0.523	-0.313	-0.414	-0.409	-0.473	-0.416	-0.325
BD	1.170	1.192	**1.359**	1.116	1.140	0.582	1.060	0.454	1.180	0.973	0.739	1.133	0.885	0.884	0.863	0.768	1.135	0.762	0.875
HL	-0.483	-0.497	-.0473	**-0.576**	-0.486	-0.238	-0.456	-0.327	-0.509	-0.442	-0.358	-0.427	-0.462	-0.386	-0.372	-0.574	-0.477	-0.382	-0.385
HD	-0.359	-0.373	-0.342	-0.344	**-0.408**	-0.252	-0.258	-0.107	-0.337	-0.340	-0.302	-.0349	-0.360	-0.159	-0.159	-0.199	-0.307	-0.323	-0.215
SnL	0.066	0.090	0.089	0.085	0.127	**0.206**	0.086	0.042	0.108	0.136	0.140	0.137	0.136	0.008	0.015	0.099	0.119	0.121	0.060
BDF	-0.476	-0.457	-0.594	-0.602	-0.482	-0.318	**-0.761**	-0.483	-0.697	-0.560	-0.376	-0.578	-0.612	-0.543	-0.298	-0.425	-0.322	-0.412	-0.556
PDDC	0.040	0.061	0.111	0.188	0.087	0.068	0.210	**0.331**	0.172	0.147	0.146	0.099	0.133	0.213	0.159	0.216	0.173	0.103	0.233
DCVC	0.016	0.016	0.017	0.019	0.017	0.011	0.018	0.010	**0.020**	0.017	0.013	0.017	0.018	0.013	0.009	0.014	0.019	0.014	0.014
VCIA	0.235	0.248	0.250	0.268	0.291	0.231	0.257	0.155	0.304	**0.349**	0.242	0.306	0.108	0.141	0.118	0.248	0.293	0.265	0.208
LA	0.087	0.104	0.103	0.118	0.141	0.129	0.094	0.084	0.123	0.132	**0.190**	0.138	0.149	0.067	0.077	0.164	0.131	0.154	0.121
BA	-0.160	-0.156	-0.160	-0.161	-0.186	0.144	-0.164	0.065	0.189	-0.191	-0.157	**-0.217**	-0.197	-0.082	-0.055	-0.141	-0.194	-0.174	-0.120
OAIP	0.093	0.096	0.102	0.098	0.108	0.081	0.098	0.049	0.111	0.108	0.096	0.111	**0.122**	0.049	0.049	0.089	0.121	0.098	0.084
LP	0.105	0.010	0.138	0.142	0.082	0.008	0.151	0.136	0.134	0.086	0.043	0.080	0.086	**0.212**	0.161	0.109	0.113	0.043	0.168
PDIA	-0.081	-0.092	-0.094	-0.100	-0.073	-0.011	-0.058	-0.071	0.068	-0.058	0.086	0.037	-0.059	-0.112	**-0.148**	-0.087	-0.053	-0.035	0.098
PDOA	0.360	0.415	0.380	0.670	0.507	0.326	0.376	0.440	0.459	0.479	0.580	0.438	0.495	0.346	0.396	**0.673**	0.454	0.496	0.487
ODIP	-0.538	0.533	-0.625	-0.620	0.605	0.431	0.317	-0.392	0.715	-0.628	-0.515	0.668	0.682	-0.398	-0.267	-0.506	**-0.749**	0.549	0.514
CL	0.035	0.035	0.031	0.037	0.044	0.033	0.030	0.017	0.039	0.043	0.045	0.045	0.045	0.011	0.013	0.041	0.041	**0.056**	0.028
CD	0.073	0.058	0.076	0.079	0.062	0.034	0.086	0.083	0.083	0.070	0.075	0.065	0.082	0.093	0.078	0.085	0.081	0.060	**0.118**

Table 4. Principal component analysis (PCA) of morphometric traits of *O. niloticus*

Morphormetric traits	Communality	PC_1	PC_2	PC_3	PC_4
Eigen value	-	13.109	2.173	1.473	1.327
Proportion of variance (%)	-	65.543	10.869	7.364	1.327
Cumulative variance (%)	-	65.543	76.410	83.775	90.410
BW	0.857	0.635	-	-	0.623
TL	0.968	0.818	-	-0.535	-
SL	0.959	0.851	-	-0.457	
BD	0.911	0.887	-	-0.342	-
HL	0.887	0.921	-	-	-
HD	0.961	0.941	-	-	-
SnL	0.719	0.590	-0.504	-	-
BDF	0.977	0.835	-	-	-0.512
PDDC	0.884	0.544	0.530	0.518	-
DCVC	0.965	0.943	-	-	-
VCIA	0.855	0.884	-	-	-
LA	0.912	0.791	-	0.394	0.327
BA	0.921	0.877	-0.358	-	-
OAIP	0.939	0.944	-	-	-
LP	0.911	0.644	0.674	-	-
PDIA	0.927	0.605	0.622	-	0.345
PDOA	0.891	0.833	-	0.394	-
ODIP	0.964	0.922	-	-	-0.314
CL	0.816	0.787	-0.369	-	-
CD	0.857	0.776	0.444	-	-

It was observed that significant differences existed among the morphometric traits measured. The morphometric traits were higher in the wild populations than cultured populations. This may be due to the age differences between samples in these populations. Since the ages of samples were not determined, it is possible that samples from the wild may have existed in their habitat for a longer time than the cultured. This finding is similar to the earlier report of [6] on the existence of higher morphological variation in wild than cultured tilapia populations. Similarly, [11] reported significant variation in the phenotypic traits of wild and cultured tilapia populations. Although the origin of the cultured population could be traced to wild stock, the differences in the morphometric traits measured in this study indicate the existence of morphological discrimination between sub-populations that may have been derived from a single gene pool. It is worthy of note to say that environment may have played a major role in creating these variations.

The relationship between morphological traits is very critical in any breeding programme. This relationship is often measured by correlating multiple traits through multivariate analysis. Results obtained on correlation between body traits of the tilapia fish showed all significant positive and highly correlated values. This may be an indication that the morphological traits are influenced by the same or related genes [17,18]. The implication here is that selection of one trait will lead to gains in other correlated variables in selection programmes. Importantly, PDIA, PDOA, LA, CD, BD and TL were highly correlated with body weight of the tilapia fish. Path coefficient analysis gives us a more insight into the relevance of these relationships in contributing to body weight of the fish. It is important to note that fish is marketed by weight. Thus, the more the weight of fish, the more market price it commands. Therefore, any morphological feature of fish that contributes to weight gain will be of paramount interest to a fish farmer. From this study, it was noted that body depth, total length and PDOA had the highest and direct positive contribution to the enhancement of body weight of the tilapia fish as revealed by path coefficient analysis. The implication here is that these traits could be specifically targeted in selective breeding for weight gain of tilapia fish.

Principal component analysis (PCA) is a further statistical tool used to assess the relationship between morphological traits and their contribution to observed variability. In this study, four components were extracted with the highest

variability in PC1 (65.543%). All the measured traits were found within this component which further shows their relatedness and contribution to genetic variability. Authors [16] reported three PC in morphological traits of tilapia fish with highest variability in PC1 (39.99%). Similarly, [19] reported three principal components in morphological traits of two tilapia species with the highest variability in PC1 (20.6%). The high communality values obtained for all measured traits in the present study may be an indication of their contribution to the observed variability between the populations. These variations are important for their survivability in the advent of environmental changes. Hierarchical cluster analysis separated the samples into two majority clusters with samples from cultured and wild populations grouped majorly into separate major clusters. This is similar to the findings of [19] who earlier reported clustering of wild and cultured tilapia population into separate clusters. The implication here is that morphometric characters may be effective in characterization of tilapia fish and should serve as investigative tool in identification and characterization of tilapia fish. The results of this work provide useful information for the identification and characterization based on the morphological traits of wild and farmed tilapia fish. Our research team is currently working on characterization of this species using molecular approaches.

5. CONCLUSION

This study revealed the existence of morphological variations in cultured and wild populations of tilapia fish. Importantly, with the growing interest in the genetic improvement of tilapia fish to meet market demands, selective breeding is recommended from the populations used in this study. Also, in selecting these species for breeding improvement, morphological traits such as total length, body depth and posterior origin of the dorsal fin to origin of the anal fin could serve as primary target toward weight improvement of tilapia fish. While this is promising, the environmental contribution to their performance should be well considered.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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