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RESEARCH ARTICLE

CHARACTERIZATION OF *OREOCHROMIS NILOTICUS* STRAINS OF FWANYANGA FISHERY OF ZAMBIA USING MORPHOMETRIC METHODS

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ABSTRACT

Oreochromis niloticus fish was collected from Fwanyanga Fishery in April, 2020. A Dendrogram was used to delineate the sampled specimens using PC-ORD™ Software and the differences among strains were tested using One-way ANOVA in Statistix 9 Software (P = 0.05). Morphometric analysis showed that the sampled fish could be characterized into three different strains. These results showed that the tested fish samples could be grouped into 3 types based on morphometric characters. The morphometric differences among the sampled O. *niloticus* strains may have appeared due to genetic differences among the collected specimens. The studied fish were all in good condition (K = 1.66 to 1.86).

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INTRODUCTION

The Nile *Tilapia*, *Oreochromis niloticus* (Linnaeus, 1758) (Cichlidae; Teleostei), is a widespread species used in tropical aquaculture. Natural populations of these fish occur in Africa and the species O. *niloticus* has been introduced to almost every tropical country in the world for aquaculture purposes (Nchimunya *et al*., 2018). The Fisheries sub-sector in Zambia contributes approximately 3.2% to the National Gross Domestic Product (GDP). The Aquaculture sub-sector currently contributes 27% of the total fish produced in Zambia. The sector has experienced some increase in production from 12, 998 metric tonnes in 2012 to 32, 888 metric tonnes in 2017. Aquaculture production is expected to increase by 1, 148 metric tonnes by December, 2020 due to the various interventions by the Zambian Government (Zambia Daily Mail, 2020). The increase in fish production is attributed to the commercialization of the Fisheries sub-sector which has witnessed an increase in the number of people venturing into fish farming. Fish exports amounted to US$503, 649 in 2015 (Nchimunya *et al*., 2018) and by December, 2020 fish exports are targeted to soar upto US5.0 million (ZAEDP, 2019). Besides the economic returns from *Tilapia* Aquaculture, tilapiines have also been adopted for use as control-agents for aquatic vegetation and elimination of unwanted aquatic fauna such as snails and mosquitoes (Bradbeer *et al*., 2018). *Oreochromis niloticus* is the most widely cultured bream in Zambia and its success in Lake Kariba Culture Fisheries is because it is extremely hardy, it has a wide range of trophic and ecological adaptations, and it possesses adaptive life history characteristics such as fast growth, high fecundity, big egg sizes that have few predators, high dietary overlap across size, class, habitat and season (Nyingi *et al*., 2009; Zengeya *et al*., 2012; Nyirenda, 2017). 'Characterization' refers to the description of a character or quality of an individual or entity (Merriam-Webster, 1991). The word 'characterize' is synonymous to the word 'distinguish', that is, to mark as separate or different, or to separate into kinds, classes or categories. This identification may in broad terms refer to any difference in the appearance or make-up of an accession. The term 'characterization' refers to the description of characters that are usually highly heritable, easily seen by the eye and equally expressed in all environments (Siankuku, 2016). Morphometric and the meristic methods remains the simplest and most direct way among methods of species identification.

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From previous studies (Katongo, 2005; Yakubu and Okunsebor, 2011; Samaradivankara *et al*., 2012; Chuhila, 2015), it is understood that the analysis of phenotypic variation in morphometric characters or meristic counts is the method most commonly used to delineate stocks of fish. Despite the advent of techniques which directly examines biochemical or molecular genetic variation, these conventional methods continues to have an important role in stock identification even to date (Bradbeer *et al*., 2018). The general objective of the study was to characterize *Oreochromis niloticus* strains of Fwanyanga Fishery using morphological methods. The study used simple and cheap methods to establish whether or not the O. *niloticus* fish species being reared at Fwanyanga Fishery were the same or not. It is important to characterize the cultured fish species in order to re-strategize management practices and adopt species-specific management tools. It is hoped that the results of this study will form the basis of taxonomic description of O. *niloticus* strains of Fwanyanga Fishery.

MATERIALS AND METHODS

The study was conducted from Lake Kariba (Figure 1) which lies between latitude 16º28'S and 18º06' S, and longitude 26°40'E to 29º03' E. Lake Kariba has a catchment area of 663,000km^2 with a maximum length and maximum width of 280km and 40km. Lake Kariba has a total surface area of 5,580km^2. Lake Kariba has a water storage capacity of 185 km^3, making it the largest man-made lake in Southern Africa (Yalelo, 2012). Fish samples were collected from cage Aquaculture fish farm of Fwanyanga Fishery. The research was conducted from Lake Kariba because it is the largest man-made Lake in Zambia that has diverse ecological habitats that are rich in fish biodiversity. Fwanyanga Fishery is a subsistence Fishery which is located in Kabyobyo bay of Lake Kariba. Fwanyanga Fishery lies along longitude 28.68° E and latitude -16.52° S. Fwanyanga Fishery lies at an elevation of 475m above sea level. Fwanyanga Fishery consists of two cages that measure 6m by 6m by 6m. This Fishery has a maximum fish production capacity of about 90 metric tonnes per year. 81 fish samples were collected from Fwanyanga Fishery for this study.

A total of 23 morphological characters were used for this study. 22 morphometric measurements were conducted on each fish species using Vernier callipers, dividers and fish measuring boards while weight was measured using an SF-400A electronic scale. The 22 morphometric measurements were measured to the nearest 0.1cm while body weight was measured to the nearest 0.1g.Morphometric measurements included (Figure 2) total length (TL), standard length (SL), head depth (HD), body height (BH), head length (HL), pre-dorsal distance (PDD), pre-anal distance (PAD), pre-pectoral distance (PPD), pre-ventral distance (PVD), pectoral fin length (PFL), ventral fin length (VFL), dorsal fin base length (DFBL), anal fin length (AFL), inter-orbital distance (IOD), eye diameter (ED), snout length (SNL), caudal peduncle length (CPL), Caudal peduncle depth (CPD), greatest dorsal spine length (GDSL), third anal spine length (TASL), longest anal ray length (LARL) and post-orbital length (POL). To avoid possible biases produced by size effects on the morphometric variables, all morphometric characters were standardized in PC-CORD^{TM} Software version 5.10 (McCune and Melford, 2006) before dendrogram construction. The number of strains was identified at 50% similarity index. Statistix Software version 9.0 (Analytical Software, 2009) was used to determine significant differences (P = 0.05), if any, among the morphometric variates of the identified strains. IBM Statistics Software version 21.0 (SPSS, 2012) was used in multivariate analysis to determine the number of principal components and in the computation of the communalities test that was used to find the most important morphometric measurement that was important in the characterization of the sampled fish species. The identified strains were delineated based on growth exponent coefficients and condition factors. The growth exponent coefficient (b) was determined by linear regression from the length-weight relationship (LWR) in Microsoft Excell, 2016 (Analytical Software, 2016) using the equation by Pauly, (1993): $W = aL^b$

where W = weight in grams, L = total length in centimeters, a is a scaling constant and b the growth exponent coefficient. This equation was logarithmically-transformed and expressed as: log Weight = a + b log Total length.

Condition factors (K) were calculated using the formula: $K = 100,000\ W/L^3$

Where W is the weight in grammes, L is the total length in centimetres and 100, 000 is a factor to bring the value of K near unity (Ndiaye *et al*., 2015). Fish species with Condition factor values greater than or equal to one (≥ 1) were considered to be in good condition and healthy while fish species with Condition factors less than one (< 1) were considered to be in bad condition and unhealthy (Adeosun *et al*., 2017).

RESULTS

The dendrogram that was constructed to characterize the collected *Oreochromis* fish samples of Fwanyanga Fishery based on morphometric measurements is given in Figure 3. The dendrogram in Figure 3 showed that morphometrically, the sampled fish specimens of Fwanyanga Fishery can be characterized into 3 different strains (types) at 50% similarity index. One-way Analysis of Variance (ANOVA) conducted on the morphometric variates of the identified strains using Statistix Software version 9.0 (Analytical Software, 2009) showed that there were significant differences (P = 0.0000) among the morphometric variates of the 3 *Oreochromis niloticus* strains at Fwanyanga Fishery. The strain means were then separated using the Least Significant Difference (LSD) All-Pairwise Comparison Test in Statistix Software version 9.0 (Analytical Software, 2009) in order to determine which strain mean is significantly different (P = 0.05) from the other (Table 1). The LSD results showed that there were two groups with statistically distinct means which are groups A and B. The mean morphometric variate of strain 3 (56.476) was statistically different from the mean morphometric variates of strains 1 and 2. The mean morphometric variates of strain 1 and 2 were similar to each other and they were placed in the homogenous group A. The mean morphometric variate of strain 3 was the smallest and different from the other two and it was placed in a separate homogenous group of B. The five extracted principal components had eigen values that ranged from a low of 1.140 for principal component 5 to a high of 10.859 for principal component 1. Principal components 2, 3 and 4 had the eigen values 2.412, 1.418 and 1.178.

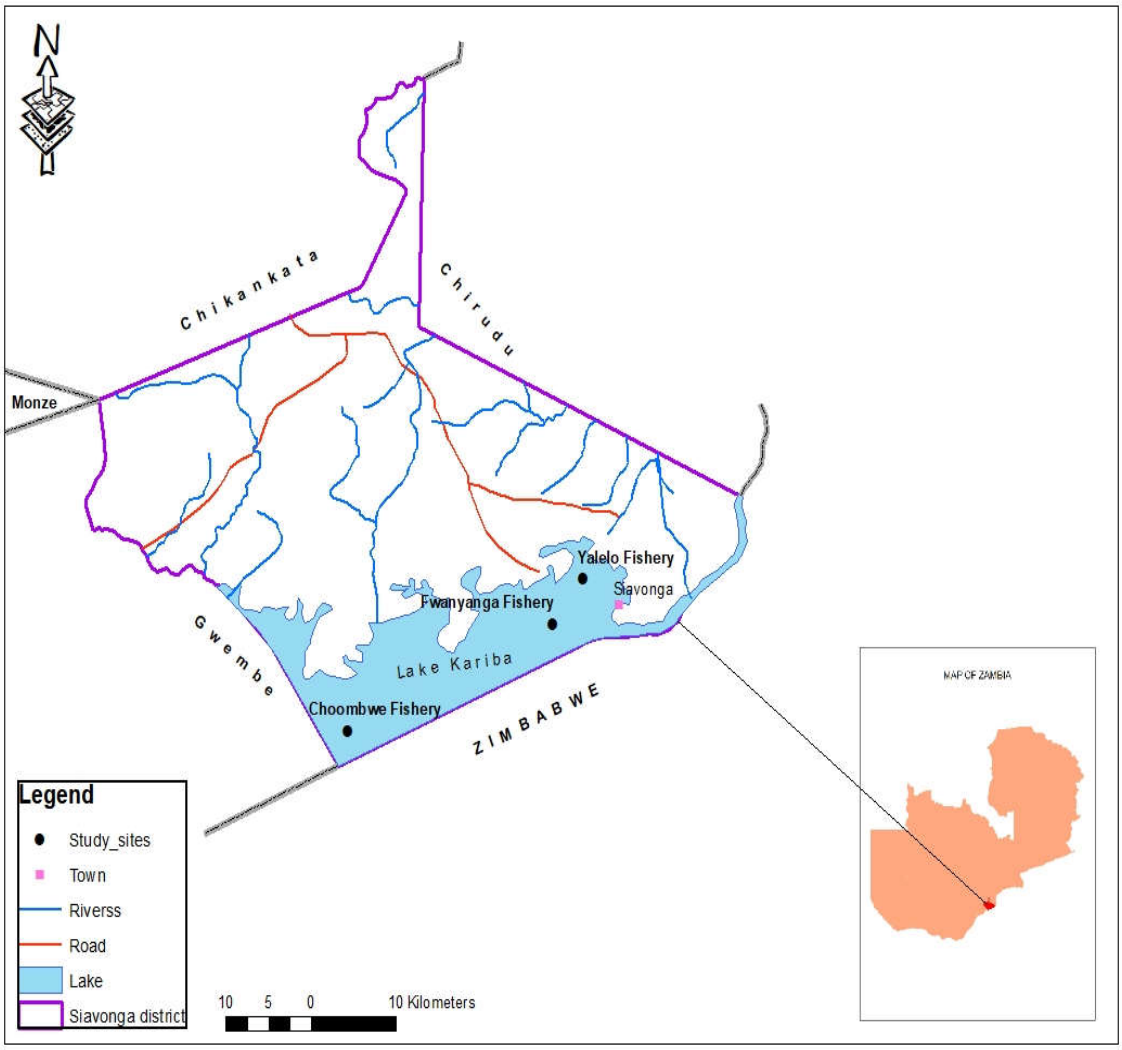

Figure 1. Location of Fwanyanga Fishery within Lake Kariba

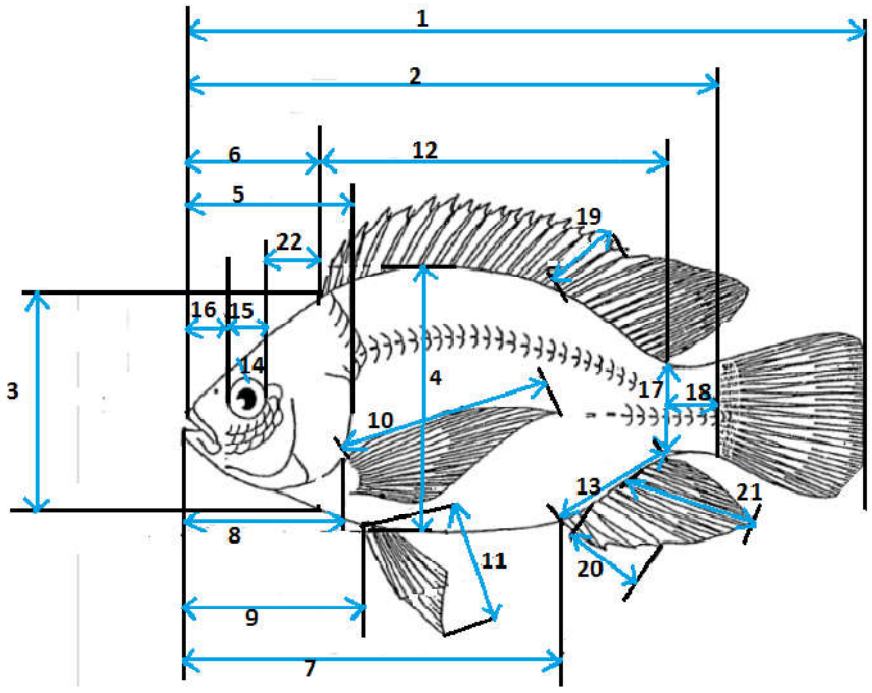

Figure 2. Diagram of morphometric measurements (Adopted from Vreven *et al*., 1998)

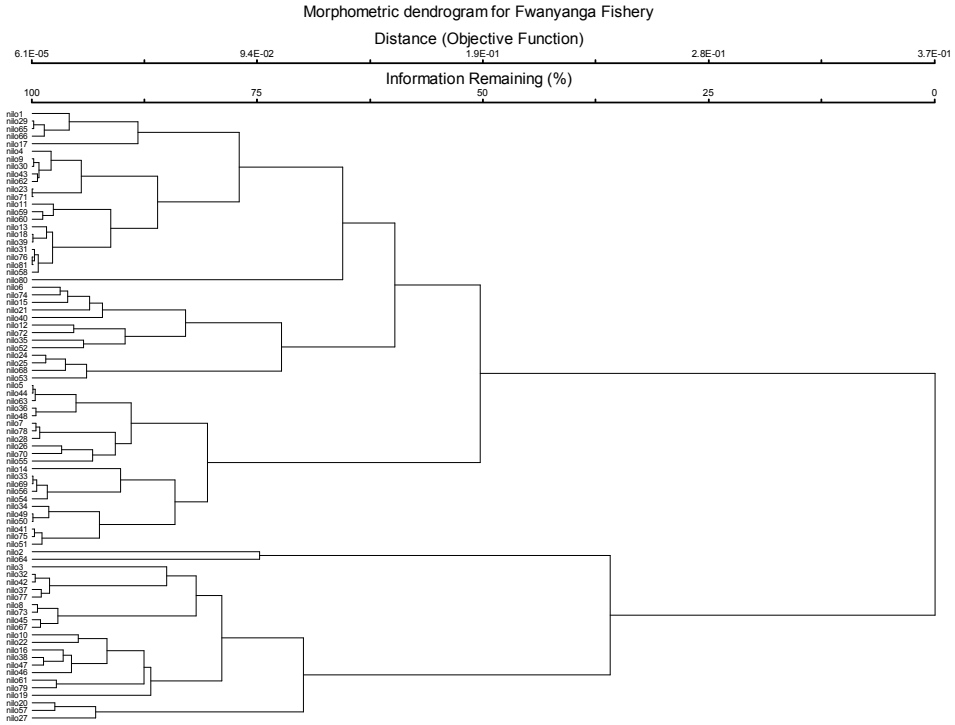

Figure 3. Dendrogram of morphometric measurements of sampled fish from Fwanyanga Fishery

The five extracted principal components accounted for a cumulative percent variance of 73.943. Table 2 shows the contribution of each morphometric variate to the observed variations in each of the 5 principal components. The communalities test that was conducted using IBM Statistics Software version 21.0 (SPSS, 2012) in order to find out the overall influence of the 23 morphometric characters to the observed variations and hence determine the most important character in the description of *Oreochromis niloticus* strains of Fwanyanga

Table 1. LSD All-Pairwise Comparison Test results of morphometric variates of Fwanyanga Fishery

Variable	Mean	Homogeneous group
Strain 1	66.667	A
Strain 2	66.5	A
Strain 3	56.476	B

Table 2. Principal components, eigen values, percent variance and cumulative percent Variance of morphometric variates of Fwanyanga Fishery

Principal component number	Eigen value	Percent variance	Cumulative percent variance
1	10.859	47.214	47.214
2	2.412	10.485	57.699
3	1.418	6.165	63.865
4	1.178	5.120	68.985
5	1.140	4.958	73.943

Table 3: Growth exponent coefficients and associated statistical results of identified strains

Strain	Average TL	Average BW	K	r	r^2	b	p	Comment
1	21.8	172	1.66	0.934	0.866	3.64	0.000	*
2	19.6	140	1.86	-	-	2.97	-	-
3	18.1	106	1.79	0.988	0.975	2.86	0.000	*

Key: TL means Total length, BW means body weight, r is the Pearson's correlation coefficient, r2 is the coefficient of determination, b is the growth exponent coefficient, p is the probability (determined at 5%), * means significant.

Fishery showed that total length with an extraction coefficient of 0.965 contributed the most to the observed variations. Eye diameter contributed the least to the observed differences (extraction coefficient = 0.482). The variations in growth exponent coefficients and condition factors among the identified strains of Fwanyanga Fishery are given in Table 3.

DISCUSSION

The general sentiment shared by Fisheries managers regarding Lake Kariba Culture Fisheries is that there are many different strains of *Oreochromis niloticus* being farmed by Aquaculture farmers (Nasilele, 2020). Morphometric results of this study showed that there are 3 strains of *Oreochromis niloticus* being farmed at Fwanyanga Fishery. These morphometric results are in agreement with other studies by Chuhila (2015) who morphometrically identified two species of *Oreochromis niloticus* at Lake Barigo. Vreven *et al*., (1998), and Yakubu and Okunsebor (2011) also identified two specie of *Oreochromis niloticus* using morphometric analyses. Samaradivankara *et al*., (2012) also delineated *Tilapia* samples from Reservoirs in Sri Lanka into four groups using morphological methods. The results of the study agree with Rafael *et al*., (2018) hypothesis that most fish farmers keep more than one *Tilapia* strain and there is a possibility of the presence of inter-strain hybrids. *Oreochromis niloticus* strains 2 and 3 exhibited negative allometric growth because growth coefficients ranged from a low of 2.86 in strain 3 to a high of 2.97 in strain 2. The coefficient of determination values (Pearson's adjusted r^2) for length-weight relationships were high for all strains at Fwanyanga Fishery which indicated that the length increased with increase in weight of the fish. This was in agreement with previous studies on different fish species from various water bodies (Dalu *et al*., 2013; Ndiaye *et al*., 2015; Saha *et al*., 2019).

A positive allometric growth exponent coefficient (b = 3.64) was observed for O. *niloticus* strain 1.The positive allometric growth for strain 1 of Fwanyanga Fishery is in agreement with positive allometric growth coefficients reported by Olurin and Aderibigbe, (2006) in pond-reared *Oreochromis niloticus* in Nigeria (b = 3.10), in the cages of Lake Victoria, Kenya by Ngodhe and Owuor, (2019) (b = 3.09), in various fish farms of Western Kenya by Musa *et al*., (2012) (b = 3.44) and in wild *Oreochromis niloticus* of Lake Kariba by Nyirenda, (2017) (b = 3.24).The determined growth exponent coefficients from length-weight relationships are helpful for estimating the weight of a fish of a given length and can be used in studies of gonad development, rate of feeding, metamorphosis, maturity and computing conditionfactors which indicates the wellbeing of fish (Pauly, 1993). Growth exponent coefficients are also used to estimate the weight at age from total catch which is useful in formulation of fish stock assessment models. Musa *et al*., (2012) reported a lower Condition factor (K = 1.12) just like Ngodhe and Owuor, (2019) (K = 1.14) and Keri *et al*., (2011) (K = 1.64 to 1.79). Condition factor values obtained by Nyirenda, (2017) (K = 2.108 to 2.191) were higher than the results from the present study. Condition factor results of this study were in the same range with results obtained by Khallaf *et al*., (2018) in the Egyptian Delta region (K = 1.67 to 2.43).

Conclusion

Phenotypically, this study delineated *Oreochromis niloticus* fish species of Fwanyanga Fishery using morphometric measurements. The study revealed that Fwanyanga Fishery is hosting more than one type of *Oreochromis niloticus*. Application of molecular genetic markers such as microsatellites, cytochrome c oxidase subunit 1 (CO 1) gene and the displacement loop (D-loop) region would be effective methods of examining the discreteness of *Oreochromis niloticus* strains of Fwanyanga Fishery and facilitate the development of species-specific management strategies.

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