Phenotypic Variability Revealed Discriminate Pectoral Spine Variants in Small Population of *Clarias gariepinus* (Burchell, 1822) of Hydrodynamic Environment

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Abstract: Phenotypic variability and discriminate factors were assessed to determine trend of adaptation of a declining population of *Clarias gariepinus* in a hydrodynamic freshwater Lake. Morphometric and meristic values (MoV and MeV) of fins and some other adaptive traits of *C. gariepinus* catches (38) from fishermen's landings during 24months bimonthly sampling of Asejire Lake were characterized. Phenotypic heterogeneity (Coefficient of Variability > 10%) and multiple modes in MeV were assessed to imply plasticity and taxonomic complications respectively. To identify responsible discriminate factor(s), phenotypes of subgroups of sex, size, and grades of variation in Possession of Anteriorly Serrated Pectoral Spine (PASPS, observed during sampling) were assessed for significant differences (P<0.05) followed by Discriminate Factor Analysis (DFA). Heterogeneity occurred in 75 % MoV including Pectoral Spine Length of left and right sides (PECSL- L&R) and MeV (Dorsal Ray count (DR), Possession of Anteriorly Serrated Pectoral Spine on Left (PESES- L) and on the right sides (PESES- R). PECSL-R and PESES-R had highest CV among MoV and MeV respectively. DR had multiple modes and were significantly different (p<0.05) between the four size subgroups (ranged from 63 to 71). Anal fin lengths were significantly different between the three PASPS subgroups (ranged from 39.0 and 44.0% of standard lengths). DFA revealed size and PASPS sub-grouping were 46.3% and 50.8% correct as canonical classification units; after data were corrected for size effect, PASPS sub-grouping was 93.8 % correct. *Clarias gariepinus* population reflected pectoral spine morphological types resulting from plasticity of fins as coping mechanism in hydrodynamic environment.
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1. Introduction

Fisheries and aquaculture play an essential role in the livelihood of millions of people around the world (FAO, 2008). Despite this, FAO (2004) reported that many marine fish stocks are in decline while inland fish stocks are under threat from environmental change and impacts. The diversion of freshwater for multiple uses has been one of the main challenges to the lives of aquatic organisms and this has been threatening their sustainable production. Lind *et al*., (1996) observed that dam and water diversion projects causes declines of many native aquatic resources and affect breeding habitat and egg survival in fish.

The International Conservation News, ICN, (1988) opined that habitat destruction and fragmentation of wildlife populations in dam systems are the primary factors reducing biological diversity. According to IUCN, International Union for Conservation of Nature (1996), the effect of dam construction is more felt in freshwater environment and a total of 84% of globally threatened fish species are from the fresh water. Many species in these environments are gradually becoming reduced or rather small and such habitat may be so degraded that they no longer support native wildlife (NWF, National Wildlife Foundation, 2012). Meanwhile, most inland rivers are being dammed to form artificial lakes used for multiple purposes without recourse to whatever happens to its fisheries.

Management of Lakes usually creates hydrodynamic situation which have potentials of threatening fish life. The dynamics of opening of gate-valve of impounded water in order to exchange water, control flood, reduce water depth to enhance catch as well as influx of diverse nature of water from watershed areas are some of the issues of interest in this regard. The multiple and unpredictable pumping of water from the lake for municipal water supply and other industrial activities also had their contribution to the dynamic water situations of a Lake. Populations under hydrodynamic condition can be diminished due to lack of adaptation to prevailing environmental challenges, which will ultimately affect viability and reproduction (Lande, 1988). Most importantly, fish will have to evolve mechanisms to overcome drag, created by flow condition during gate-valve opening in fresh water Lake Systems.

According to Fletcher *et al*. (2014), drag reduction is an important adaptive mechanism of extant nektonic organisms in order to overcome challenges of hydrodynamic condition, and diverse adaptations could contribute to drag reduction in modern fishes. Usually,

trend of adaptation in drag reduction will involve flexibility of phenotypic attributes. Adaptation to drag condition could involve the use of body shape, surface roughness, fins and gills, stabilizing structures (fins) etc. However, environmental challenges may influence pattern of adaptation and or adaptive traits in fish and this could vary with time.

Kardong (2009) and Long (2011) observed that there is shift in early fish evolution from defensive exoskeleton armor to a faster, supposedly lighter morphology. This signifies the need to document changing trends in morphology of fish species but this, according to the authors, has not been convincingly quantified. The eventual consequence of impoundment may trigger some morphological divergence in species (Santos *et al*., 2011). Information on trend of morphological adaptation of fish in dynamic flow condition especially, the gate-valve controlled Lakes, is scarce. Meanwhile, fisheries of some of the lakes seems to be showing declining status.

Opening of gate valve of dams creates drag force on living organisms occupying the water catchment thus creating a challenge, to which fish will have to cope or face the threat of been swept away. It is of interest to understand the trend of adaptation in specific hydrodynamic condition as this would inform important management issues for the inhabiting fisheries. Phenotypic (morphometric and meristic) data are the oldest and most economic methods employed in fish stock identification, population structure, adaptation, evolution studies (Skelton, 1993; Orlov and Cotton, 2011) and taxonomy (Mayr 1969; Schreck and Moyle 1990; Rohlf, 1990). Levels of phenotypic variation can influence rates of evolution and bias evolutionary trajectories (McGuigan, *et al*., 2005). Among vertebrates, phenotypic plasticity is considered to be greatest in fish, which have relatively higher within-population coefficients of variation of phenotypes (Carvalho, 1993). Studies on phenotypic variability would show trends of adaptation and divergence. This morphological divergence can sometimes be large enough, that even small population shows presence of canonical taxonomic groups.

Clarias gariepinus has increasing commercial importance in fisheries and aquaculture (Turan *et al.,* 2005). However, it is diminishing in Asejire Lake (Omoike, 2004; Oyebola, 2014). The lake is a typical hydrodynamic environment; it has two water inlet sources, many tributaries and it is gate-valve controlled. Aside fish supply, the water-body serves multiple purposes such as pump station for municipal water and other water dependent industries. The *C. gariepinus population* was observed to be small

probably due to presence of a threat in the water-body and in such case; the surviving population would have been adapting using different traits and possibly evolving adaptive traits. Although several factors could be responsible for the decline, trend of adaptation to hydrodynamic condition was proposed to be major and this could be traced through phenotypic variability studies.

Therefore, for improved management, morphological variation and discriminate factors for morphological divergence within the small *C. gariepinus* population, in response to the environmental challenges of the hydrodynamic - gate-valve controlled Asejire Lake were studied.

2. Materials and Methods
Sampled Site

Sampled site was Asejire Lake, a major artificial dam constructed on River Osun which links the Ogun River and drains ultimately to the Lagos Lagoon in south western Nigeria. It lies at borderline between Oyo and Osun States of Nigeria, on latitude 04^0 07'E and $07^0$21'N at an altitude of 137 m above sea level. Asejire River is one of the series of West African Rivers that do not drain into Niger system but discharge into coastal lagoons and creeks bordering the Atlantic Ocean (Omoike, 2004). The reservoir has an approximately 7,403 million litres capacity and a flooded area of 6 km^2 (Welcomme, 1985). The Lake receives supply from Rivers Osun and Oba at the left arm, while Agbora arm feeds the dam from the right, making the reservoir to have a Y shape when viewed from the point of impoundment. Its entire length is 11.2 km, catchment area above the dam is about 7,800 km^2 and the impounded area is 2,342 hectares. According to Elliott (1986), the area is well watered as numerous tributaries of the Osun River cut through the surrounding rolling country area; however, most of the smaller tributaries dry up from November to March and refill during the rains in May.

Asejire Lake has served socio-economic and research purposes in the south western Nigeria. It supplies raw materials for Municipal water supply for Oyo and Osun States, and some Breweries. The adjourning villages depend on its fisheries for sustenance because the majority of their populace are fisher-folks. Villagers utilize its water resource for domestic, small-and medium-scale food processing, agriculture, laundry and for spiritual activities. According to Obadara (2006), Asejire Lake contributes largely to fish supply for research and consumption. A map of the study area is presented in Figure 1.
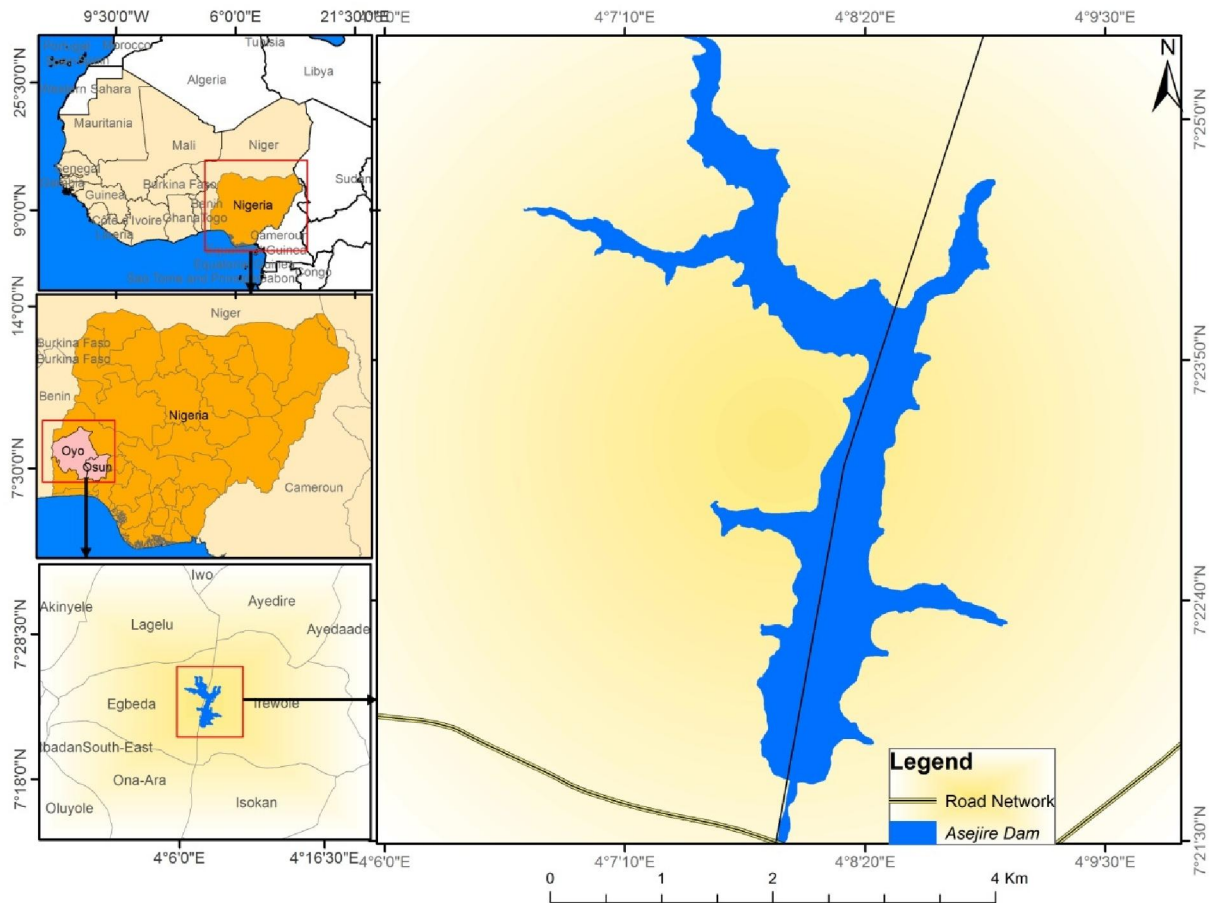
Figure 1: Map showing location of the study area

Sample Collection Procedure

Specimens of *C. gariepinus* were collected from fishermen at landing sites during a two-year bimonthly sampling of the lake's catchment covering wet and dry seasons. Collections were carried out with caution, in order to safeguard mix-up of catches from sources outside the catchment. Collected fish samples were preliminarily identified at the landing site using taxonomic keys (Lowe McConnell 1972; Holden and Reed, 1978) and transported to the University of Ibadan. The identified Clarias *gariepinus* samples were further screened using number of dorsal and anal fin ray counts (61-80 and 45-65 respectively) as a guide. The screening criteria followed the descriptions of the species by Teugels (1986). Individuals within the species with values below or above the reported value in either one or both counts were screened out while the entire remaining specimens were utilized for the study.

Data collection for determination of phenotypic values

Thirteen morphometric and nine meristic attributes were characterized. Data were collected from 37 individuals, being the entire population size after samples were screened. Measurements were taken from the left and right sides of paired fins of each fish sample. Morphometric measurements were taken in all the collected individuals and measured to the nearest 0.01cm, using Vernier calipers. All length (morphometric) measurements were taken between identical points along the anterior to the posterior axis of the fish, whereas body depths were taken perpendicularly between the identified points taken at the base of the 1st dorsal ray and at caudal peduncle (BD MAX and BDMIN, respectively). However, caudal fin width (CFW) was taken as the point of greatest perpendicular length from dorsal position of caudal fin to its ventral position. The 13 morphometric traits were measured. Landmarks showing the measured traits are presented in Figure 2.
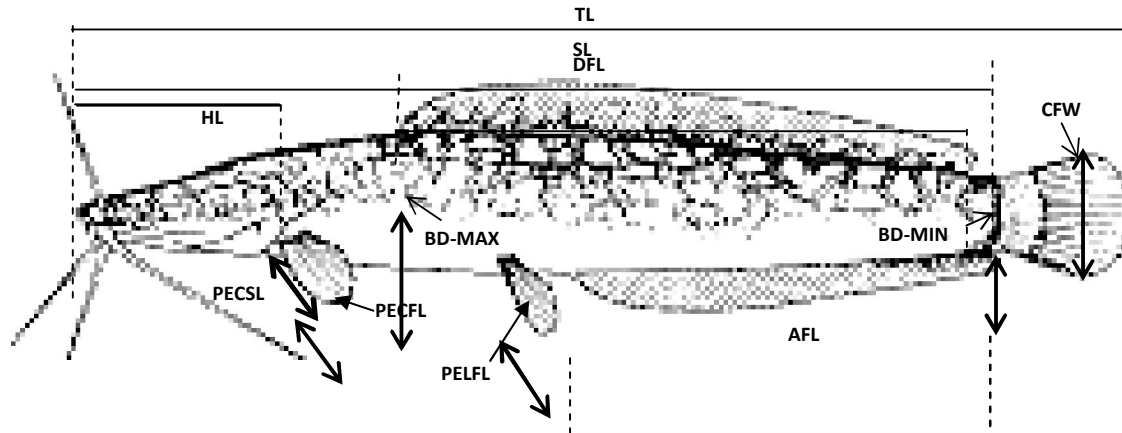
Figure 2: Landmarks showing the measured traits

The measured morphometric traits were Standard length (SL), Head length (HL), Maximum body depth (BD-MAX),Minimum body depth(BD-MIN), Pectoral fin length of left side fin (PECFL-L),Pectoral fin length of right side fin(PECFL-R), Pectoral spine length of left side fin (PECSL-L),Pectoral spine length of right side fin (PECSL-R), Dorsal fin length (DFL), Pelvic fin length of left side fin (PELFL-L), Pelvic fin length of right side fin (PELFL-R),Anal fin length (AFL) and Caudal fin width (CFW). The measured 9 meristic attributes were Pectoral fin rays count on left side (PECFR-L), Pectoral fin ray count on the right side (PECFR-R), Possession of anteriorly serrated spine on the left side (PESES-L), Possession of anteriorly serrated spine on the right side (PESES-R), Pelvic fin rays counts on left side (PELFR-L), Pelvic fin rays counts on right side (PELFR-R), Dorsal fin rays counts (DFR), Anal fin rays counts (AFR) and Caudal fin rays counts (CFR). Each meristic attribute were counted and the number obtained was taken as their phenotypic value. However, PESES was observed in the binary form, in which presence of serration at anterior position of pectoral spine was taken as 1, while absence was taken as zero (0). Measurements were taken by the same person to maximize consistency. Meristic counts were repeated on the same specimens using hand-held magnifying lens to ensure accuracy.

Data Processing

Morphometric and meristic data were separately processed for analysis. These types of variables are different (morphometric are continuous and can be susceptible to environmental factors while meristics are discrete and are fixed early during development (Samaradivakara *et al.,* 2011). Data on each of the morphometric attributes were processed for phenotypic value determined as morphometric value divided by standard length, multiplied by 100 percent. This is a preferred method for removing size variation in characters among individuals (Reist, 1985). Standard Length was preferred because its values were consistent compared to total length. The consistency of standard length has also been observed by Turan *et al.* (2005) and Gunawickrama, (2007). Meristic characters are independent of size of the fish and do not change during growth (Strauss, 1985; Murta, 2000). Therefore, raw meristic data were taken as phenotypic values and used for analysis. The mean and respective standard deviation of each of the attributes (morphometric and meristic traits) was used to derive Coefficient of Variation (CV), expressed as standard deviation divided by mean phenotypic value, multiply by 100percent.

Determination of Phenotypic Variability and Trend of adaptation in Populations' Phenotypic Data

Data on phenotypic value and Coefficient of Variation (CV) of each of the phenotypes were used as tools in assessing within-population variation, trend of adaptation and discriminant factors. The CV of each phenotype was taken as indices of flexibility or plasticity of the character. Heterogeneity of each phenotype was taken at CV> 10%. Phenotypic plasticity was taken as indices of adaptability of the attributes. Percentage of number of the phenotypes that showed heterogeneity was documented as indices of phenotypic plasticity of the population in the catchment. For each phenotype, CV, multiple modal values and difference between values from left and right sides of paired fins were assessed and compared. Attributes having the highest CV, differences in values from left and right phenotypes (paired fins) and multiple modes were considered as most varied/flexible adaptive traits of the species in the environment.

Assessment of Sources of Heterogeneity and taxonomic complications in Phenotypes' Data

Heterogeneity of phenotypes was taken as indicative of plasticity and or taxonomic complication

in the population, hence, the need to delineate the population's phenotype by potential responsible factor(s). Presence of heterogeneity in values of morphometric traits alongside multiple modes in important taxonomic traits (dorsal fin ray count- DR and Anal fin ray count- AFR) were taken as indicative of taxonomic complications in the population following Mayr (1969). The DR and AFR were taken as important taxonomic factors, being the main identification keys for the species (Holden and Reeds, 1978 and Teugels, 1986). In situations of heterogeneity in morphometric traits alongside multiple modes in meristic traits, phenotypes were re-grouped to subgroups of sex, size and PESES/PASPS (pectoral spine variants). Sex and size were considered as factors in order to assess effect of sexual dimorphism and allometric growth pattern in the population, while PESES/PASPS was selected as potential discriminate factors based on field observation that the population has individuals possessing graded variations of anterior serration of pectoral spine. These cases were considered as potential factors for discriminating /delineating the phenotypes of the population being possibly contributory to the populations' phenotypic structure. Sub-groups of sex and PESES/PASPS were identified via visual examination, while linear measurements were the basis for sub-grouping the size re-grouped case.

The studied sample was separated into sex sub-groups of male and female by observing external genital organs, following FAO (1996) and their data separated. Data was regrouped to four size sub-groups based on standard length measurements. The subgroups were 10.1 - 20.0 cm, 20.1 - 30.0 cm, 30.1 - 40.0 cm, and 40.1 - 50.0 cm (groups 1-4 respectively). Sub-division of the population based on pectoral spine variation (PESES/PASPS) utilized presence and absence of toothed spines at anterior portions of pectoral spine in individuals of *C. gariepinus*. This was based on the observed trend during sample collection period. Samples that did not possess toothed pectoral spine at the anterior portion of their pectoral spine were referred to as smooth, denoted as S and grouped as S-PESES/PASPS subgroup. Those with only one of grouped as C-PESES/PASPS sub-group. Phenotypic values of the subgroups of the regrouped cases were determined following the earlier described method for the entire population. These were carried out separately for the sub-groups of the three regrouped cases.

Values for morphometric and meristic were determined and used for assessment of canonical (fundamental) discriminate factors for delineating the population. Strength of each of the regroup cases as canonical factor was analyzed and used to the two spines serrated were referred to as partial, denoted as P and grouped as P-PESES/PASPS subgroup. Those with

the two spines serrated were referred to as complete, denoted as C and were establish that the subgroups in it were statistically significant morphologically types.

Assessment of Phenotypic Subgroups as Canonical Taxonomic Units

Steps to assessment of canonical classification unit presented by Gunawickrama (2007), was followed for screening subgroups as taxonomically canonical units. Phenotypic values were compared at all the morphometric and meristic sites among the sex, size, and pectoral spine variant sub-groups. When significant difference occurred in at least one of the phenotypic sites between the subgroups in each regroup case, such grouping was considered for stepwise Discriminant Function Analysis (DFA) using statistical tools. The DFA re-classified individuals to canonical groups and then compared the grouping with the initial group of that individual to get the percentage of classification success. The classification successes of the subgroups were noted. Aside size subgroups, data of other groupings were corrected of size effect before being further subjected to DFA. Sub-groups having significant DFA were considered as morphological classification units, the main responsible factor for the taxonomic complication.

Statistical Analysis

Univariate statistics such as minimum, maximum, mean, mode and standard deviation was used to describe phenotypes. Phenotypic values of subgroups of sex were compared using student *t-test*. One-way analysis of variance (ANOVA), followed by Turkey multiple comparison test for unequal sample sizes (Zar, 1984), was used to establish significant difference in size and pectoral spine subgroups. Significant differences were taken at $p < 0.05$. Burnaby size correction package was used to correct Allometry (size variation) effect in data. Within and between subgroup members relationships were established through cluster analysis while correctness of sub groupings as canonical units was tested by Discriminate Function Analysis (DFA). All analyses were conducted using computer software (SPSS 15.0 Windows Evaluation).

3. Results

Phenotypic values of the entire screened *C. gariepinus* catch (38 specimens) showed heterogeneity which could have taxonomic implication. It also showed that pectoral fin characters (PECSL and PESES) were the respective most varied morphometric and meristic characters. Descriptive of the phenotypic values of the morphometric and meristic attributes are presented in Table 1. A total of 75 % of morphometric attributes were heterogeneous (CV >10 %). All, except PECSL, had multiple modal values. Pectoral Spine Length (PECSL) was the most varied (functional) adaptive attribute among morphometric phenotypes;

CV was highest and lowest in it (7.3% for PECSL-L and 31.5 % for PECSL-R, respectively) and the widest difference between left and right side values' variability occurred in it. The PESES was the most varied meristic attribute; highest CV and greatest difference between left and right side phenotypic values of paired fins were observed in it. Among meristic attributes, PESES-L (left) and PESES-R (right) and DR reflected heterogeneity. All meristic attributes had small and similar CV (7.1-8.9%) except in PESES-L (64.7%) and PESES-R (68.1%) while DR was the only meristic phenotype that had multiple modes. The widest variation between left and right sides values also occurred in PESES (Left -L, against Right –R). Skeletal view of the discovered pectoral spine (PESES) variants is presented in Plate 1.

Table 1: Phenotypic values (as %SL.) and Coefficient of Variation (CV) of morphometric attributes of the studied *Clarias gariepinus* population (N=37)

Phenotype	Mean± SD	CV (%)	Mode	Phenotype	Range	CV (%)	Mode	
Morphometric	**Meristics**							
HL	28.5±2.2	7.7	27.0a	PECFR-L	7.0-10.0	7.7	9.0	
BD MAX	10.9±2.1	19.3	8.9a	PECFR-R	7.0-10.0	7.5	1.0	
BDMIN	6.2±1.3	22.3	4.6a	PESES-L	0.0-1.0	64.7	1.0	
PECFL-L	11.3±1.6	14.5	11.1a	PESES-R	0.0-1.0	68.1	1.0	
PECFL-R	11.2±1.6	14.2	8.5a	PELFR-L	5.0-7.0	7.9	6.0	
PECSL-L	6.5±2.1	31.5	6.7a	PELFR-R	5.0-7.0	7.1	6.0	
PECSL-R	6.6±1.6	24.7	7.9	**DR**	**45.0-78.0**	**7.9**	**67.0a**	
DFL	63.2±4.6	7.3	61.7a	AFR	45.0-65.0	8.9	51.0	
PELFL-L	9.1 ±1.3	14.6	8.9a	CFR	15.0-23.0	7.5	19.0	
PELFL-R	9.1±1.2	12.8	9.0a					
AFL	2.2±3.5	8.3	40.4a					
CFW	13.9±1.6	11.6	13.3a					

a=Multiple modes, N= population size

Plate 1: Skeletal view of variations with respect to serrations of Pectoral Spine in *C. gariepinus* (Mag. =100mm lens x 50mm height)

Analysis of phenotypic values of morphometric and meristic attributes for significant difference among the sex, size and pectoral spine sub-groups is presented in Table 2. Phenotypes of the sexes were not significantly differentiated (p>0.05). The sex regrouped case was therefore excluded from further analysis. However, it was noted that minimum body width (BDMIN) was close to significance, having *p-value* of 0.051. Size groups were significantly differentiated at a morphometric and a meristic phenotype (Caudal Fin Width- CFW and Dorsal Ray count – DR respectively). However, these values did not follow the fundamental pattern of size increment in living organisms during growth period.

Table 2: Summary of Results on Phenotypic Values and Analysis of Morphometric (expressed as % SL., mean ± SD) and Meristic Attributes for Significant Difference among the Sex, Size and Pectoral Spine Sub-groups of *Clarias gariepinus* Population in Asejire Lake

| Phenotypes | Sex Subgroups | | Size Subgroups | | | | Pectoral Spine Subgroups | | | |
	Male (N=11)	Female (N=26)	1 (N=8)	2 (N=15)	3 (N=8)	4 (N=6)	S (N=9)	P (N=6)	C (N=22)
HL	27.2±1.3	29.1±2.4	29.4±2.4	28.2±1.9	28.1±2.4	28.7±2.0	29.0±2.4	29.2±1.5	28.7±2.2
BD MAX.	11.1±1.6	10.8±2.3	11.1±1.5	11.1±1.8	10.4±2.8	10.8±3.5	10.7±2.7	10.4±2.0	11.3±2.0
BDMIN	6.9±1.5	5.9±1.2^b	5.7±0.6	6.6±1.3	6.0±1.8	6.0±1.7	5.5±1.3	6.7±1.9	6.4±1.3
PECFL-L	11.7±1.9	11.1±1.5	11.3±1.2	11.4±1.7	11.0±2.1	11.4± 0.4	11.1±1.5	10.2±2.1	11.4±1.0
PECFL-R	11.5±1.7	11.1±1.5	11.3±1.5	11.2±1.5	11.2±2.1	10.7±1.2	10.5±1.2	10.5±1.8	11.6±1.6
PECSL-L	6.9±0.8	6.3±2.5	6.2±1.5	6.1±1.6	7.2±0.4	7.4±1.9	7.8±2.9	5.5±2.4	6.1±1.4
PECSL-R	7.1±1.3	6.4±1.7	7.5±0.7	6.2±1.5	6.2±2.4	7.4±0.7	7.4±1.0	6.1±8.0	6.3±1.7
DFL	61.5±2.5	63.9±5.1	61.6±2.2	61.5±1.9	66.4±6.7	63.0±3.5	64.9±6.0	65.1±8.0	62.6±3.5
PELFL-L	8.8±1.1	9.3±1.3	9.2±0.8	9.1±1.5	9.0±1.7	9.4±0.9	9.1±1.6	8.5±1.3	9.1±1.2
PELFL-R	8.8±1.1	9.2±1.2	9.0±0.7	8.9±1.2	9.0 ±1.6	9.8±0.4	9.2±0.9	8.2±1.2	9.1±1.3
AFL*	41.5±1.8	42.5±4.0	41.6±1.4	41.6±2.2	45.0±6.0	42.3±1.4	41.4±2.0^a	38.7±3.1^a	43.4±3.8^b
CFW*	13.6±1.7	14.1±1.6	15.2±1.1a	13.6±1.8b	13.7±1.1b	14.2±0.6ab	13.7±1.7	13.0±2.0	14.0±1.7
PECFR-L	9.0±0.6	9.0±0.7	9.0±0.8	9.0±0.6	8.5±0.9	8.9±0.4	9.0±0.5	9.0±0.0	8.7±0.8
PECFR-R	9.0±0.8	8.7±0.6	9.0±0.0	9.0±0.6	8.6±0.9	8.9±0.6	9.1±0.3	8.7±0.9	8.7±0.7
PESES-L	0.8±0.4	0.6±0.4	0.8±0.3	0.3±0.2	0.8±0.3	0.7±0.4	nd	nd	nd
PESES-R	0.8±0.3	0.6±0.5	0.8±0.4	0.7±0.1	0.8±0.3	0.7±0.4	nd	nd	nd
PELFR-L	6.0±0.3	5.7±0.5	5.5±0.5	6.0±0.6	5.7±0.5	6.0±0.0	5.7±0.7	6.0±0.0	6.0±0.4
PELFR-R	6.0±0.0	5.8±0.4	5.5±0.5	6.0±0.0	5.8±0.3	6.0±0.3	5.7±0.4	6.0±0.0	5.9±0.4
DR*	68.6±2.6	68.6±6.2	68.8±3.5^a	70.3±1.7^c	62.5±7.9^b	69.9±4.0^{abc}	68.7±3.7	69.5±3.1	68.1±6.7
AFR	50.8±2.3	51.6±5.2	51.3±5.1	54.8±5.7	52.5±5.2	50.8±3.3	51.6±3.9	49.2±3.1	52.2±5.4
CFR	18.6±1.8	18.3±1.1	18.5±1.0	18.1±1.1	18.5±2.5	18.5±2.5	18.7±1.0	18.7±0.9	18.5±1.5

* Asteric indicate attribute possessing significantly different mean value (p<0.05) in a group; Different superscript along the same row under same grouping indicate significant difference (p<0.05) among subgroups. Sample size is given in brackets. While nd indicates not used for analysis. Values for PESES were mean of scores for individuals possessing serration (scored as 1) and those not possessing serration (scored as zero)
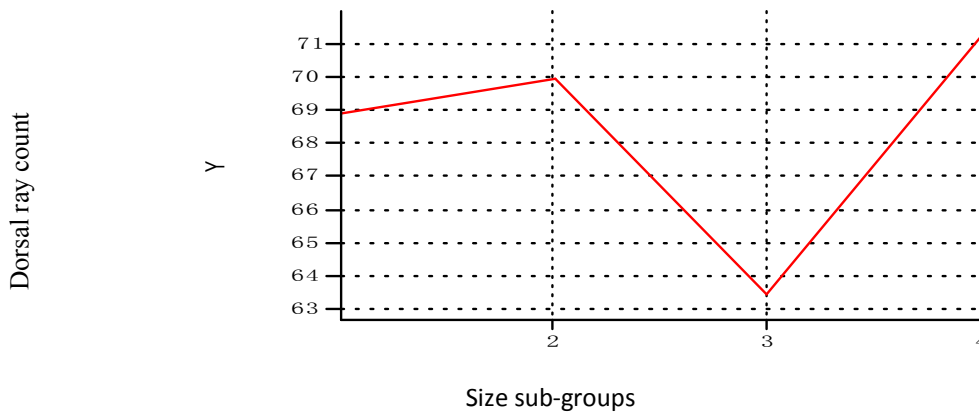

Figure 2: A graphical presentation of showing pattern of DR (dorsal ray count) of the size subgroups (1-4)
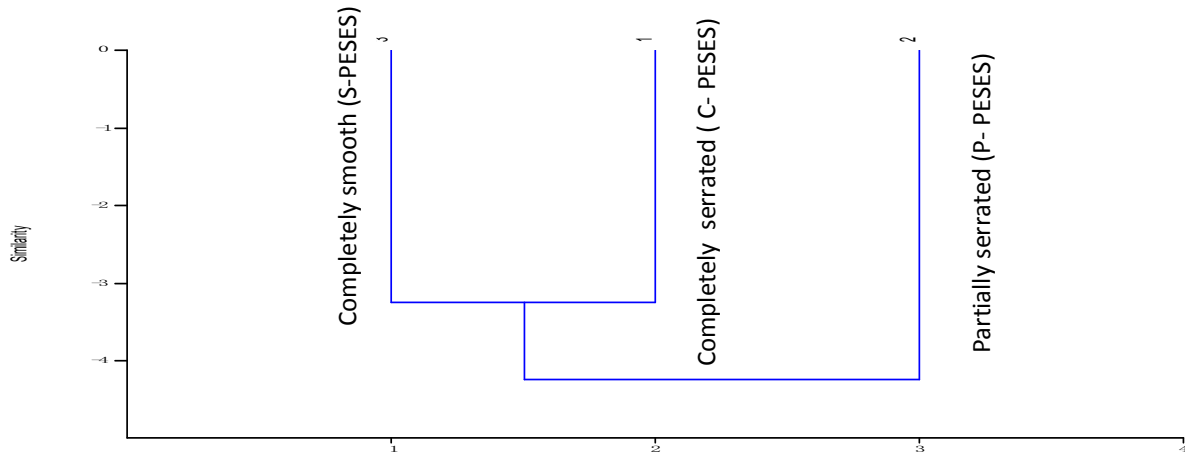
Figure 3: The Euclidean similarity matrix of Anal Fin Length (AFL) in pectoral spine variant sub-groups (S, P and C) of *C. gariepinus* in Asejire Lake

Table 3: Results of canonical classification analysis of the size sub-groups in *C. gariepinus* of Asejire Lake

| Subgroups' score | Predicted group membership | | | | |
	0.00	1.00	2.00	3.00	Total
Original Count					
0.00	7	6	3	0	16
1.00	0	13	6	0	19
2.00	4	9	11	2	26
3.00	2	2	2	0	6
Ungrouped Cases	2	2	2	0	6
%					
0.00	43.6	37.5	18.8	0	100
1.00	0	68.4	31.6	0	100
2.00	15.4	34.6	42.3	7.7	100
3.00	33.3	33.3	33.3	0	100

  *46.3% original group cases correctly classified
  * 0.00= Subgroup 1, 1.00= Subgroup 2, 2.00= Subgroup 3 and 3.00= Subgroup 4.

Table 4: Results of canonical classification analysis of the pectoral spine sub-groups phenotypes of *C. gariepinus* before correction for size effects

| Subgroups' score | Predicted group membership | | | |
	0.00	1.00	2.00	Total
Original Count				
0.00	7	6	3	16
1.00	0	13	6	19
2.00	6	9	11	26
Ungrouped Cases	2	2	2	6
%				
0.00	43.8	37.5	18.7	100.0
1.00	0.0	68.4	31.6	100.0
2.00	23.1	34.6	42.3	100.0

50.8% original group cases correctly classified for the Allometry uncorrected sample.
  * 0.00 = Subgroup S, 1.00= Subgroup P, 2.00= Subgroup C

Table 5: Results of canonical classification analysis of phenotypes of pectoral spine sub-groups after data was corrected for effect of allometric growth

Subgroups' score		Predicted group membership			
		0.00	1.00	2.00	Total
Original Count					
	0.00	4	0	0	4
	1.00	0	2	0	2
	2.00	1	0	9	10
%					
	0.00	100.0	0.0	0.0	100.0
	1.00	0.0	100.0	0.0	100.0
	2.00	10.0	0.0	90.0	100.0

*93.8% original group cases correctly classified.

CFW was greatest in group 1 and greatest in group 2, following the pattern- group1> 4> 3> 2. Similarly, values of DR (a meristic attribute) were greatest in group 2 and lowest in group 3, following the pattern- group 2> 4> 1> 3. The table also revealed significant difference (p<0.05) between the PESES groups at morphometric trait AFL (anal fin length), following the pattern C>S>P. The dendrogram obtained from Euclidean similarity matrix of the PESES subgroups values of AFL revealed that partially serrated (P) subgroup was intermediate between completely serrated (S) and completely smooth(C) subgroups. A graphical presentation of mean DR (dorsal ray count) of the subgroups of size is presented in Figure 2 while dendrogram showing the relationship between AFL of the PESES subgroups is presented in Figure 3.

Canonical classification function of the size sub-group (Table 3) showed that 46.3% individuals of the original grouped cases were correctly classified. Meanwhile, 50.8% individuals in the *a priori* group were correctly classified (Table 4) when PESES) subgroups was analyzed. After PESES data were corrected for effect of sizes (allometric growth), 93.8 % classification success was recorded for the pectoral spine sub-groups (Table 5).

4. Discussions

The sets of results of the present study indicate an agreement with Gunawickrama, (2007), who observed that some morphological characters of fish were useful in generating heterogeneity in morphology. It also signifies congruence with the hypothesis that organisms inhabiting an environment will have to adapt in order to survive and the trend of adaptation could be detected through morphological studies.

Attributes showed different degree of variability within the studied population, thus agreeing with the observation that phenotypes variability could vary within a single population (Mayr, 1969). The observed differences in variability in phenotypic values of the studied attributes could indicate plasticity of phenotypic traits of the population and this could be in response to variations in environmental conditions of the Lake. Wimberger (1991, 1992) have revealed that there is great phenotypic plasticity of fishes in response to changes in environmental factors. Bock (1990) reported that morphological features are adaptive; that is, they evolve and diversify owing to competition, predation, or other biotic interactions which would lead to changing structure as a result of complex interactions with other species or new environmental constraints. Therefore, pattern of variation in the phenotypes could indicate trend of morphological adaptation to the conditions of the environment.

The most varied among morphometric and meristic traits of the population were the pectoral fin attributes: PECSL (pectoral spine length) and PESES (possession of anteriorly serrated pectoral spine) respectively. It can be insinuated that pectoral spine attributes were under serious selective pressure and individuals of the population are showing flexibility of this attributes at different extent. Hence, the highest variability or flexibility of the pectoral spine attributes. Species morphology has been linked to habitat use, its performed niche and alteration in the environment, such as those resulting from dam construction (Santos *et al*., 2011).The phenotypic variation pattern observed in this study, might have emanated from the need for flexibility of the species structures in order to cope with the complex interactions of biotic and abiotic factors in the hydrodynamic environment and the most challenged attribute is the pectoral spine. It is expected that morphology would reflect fish adaptation to reservoir conditions (Santos *et al*., 2011). Therefore occurrence of PECSL as the most varied morphometric attribute could be community-based and or habitat-induced.

It is interesting that a hard structure such as pectoral spine could be the most varied with respect to its length. Pectoral spines serve locomotory and protective roles in *C. gariepinus*. The spines are

extended while crawling through shallow pathways (Gunder, 2004). The morphometric values of PECSL could vary based on level of its use in the habitat thus indicating that the greatest operation in the habitat could have to do with the use of this trait while *C. gariepinus* individuals expressed it at different extent.

Habitat generalists would adapt to hydrodynamic situation through behavioural and morphological plasticity of individuals (Vanderpham*et al.,* 2013). The studied hydrodynamic environment was observed to be characterized by gate-valve controlled dam. Opening of gate valve of the dam would create drag force to which fish will have to adapt or face the challenges of been swept away. Also, water withdrawal from the lake during such dam gate opening results in exposure of shore areas of the Lakes catchment (Oyebola, 2014). *Clarias gariepinus* occupies swamps, it is a versatile species possessing features for air-breathing, and it could take walk using its pectoral spines (Gunder, 2004). Individuals of the species would react to exposed shore by taking walk to the nearest favourable areas via its pectoral spine. Behavioural adaptation for organisms that are adapted for air-breathing and land movement such as *C. gariepinus* would be to take a walk to holes at the nearby swamp while using their air-breathing attributes to survive respiratory challenges during such walk. *C. gariepinus* could also adapt to drag from water withdrawal in the hydrodynamic environment by using the pectoral spine to hold to the lake floor before embarking on walk. Therefore, pectoral spine could be an adaptive trait to resist drag effects when water is withdrawn from the Lake.

Except the pectoral spine length, all morphometric attributes had multiple modes. Apart from heterogeneity, this situation indicates possibility of a trend of compromising identity which may be emanating in response to the habitat condition. Habitats can endanger the genetic identity of a species; interrupting gene flow and consequently modifying population structure and diversity (Horreo *et al.,* 2011). Such trend of compromising identity within a small population may signal an evolving trend of adaptation which could have taxonomic implications.

Meristic characters are countable structures that are fixed in embryos or larvae (Turan, 2004). Characters such as number of spines and fin rays permit greater accuracy than linear measurements in the systematic populations of fishes (Mayr, 1969). The PESES and DR were the most important attributes with respect to variation pattern in meristic attributes. All meristic traits had variation value below 10%, except PESES-L&R. Heterogeneity of these meristic attributes, coincided with multiple modes occurring at only the dorsal ray count (DR). The high coefficient of variation, with mono-modal value in PESES implies

that pattern of variability at this site, is a general trend in the population. The presence of strong pectoral fins with spines that are serrated on the outer side referred to as PESES in this study has been reported in *C. gariepinus* (Teugels, 1986). However, the trait was observed at three different levels in the current study. This indicates a possible source of high coefficient of variation as observed in the population's phenotypes. A similar trend of phenotypic variation in pectoral spine was observed to be related with morphological types of *Pimelona chagressi.* A further analysis of the population confirmed presence of haplotypes (Martin and Birmingham, 2000). Presence of taxonomic sub-group in the population could be suspected because heterogeneity of the PESES (a meristic attribute) occurred concurrently with that of most of the morphometric attributes and especially, with multiple modes occurring in the DR, another meristic attribute.

Multiple modal values obtained in the DR alongside heterogeneity of most morphometric traits and a meristic traits-PESES underlines need for delineating the population to morphotypes. This is necessary because, multiple modes may indicate presence of morphologic types in fish (Eastman and Devries 1997; Guiger *et al*., 2002) especially when the affected attribute is a strong taxonomic trait. According to Holden and Reed (1978), the most vital external characteristics for identifying fish are fin ray counts, especially those of the dorsal and anal fins. Turan *et al*. (2005) had observed high phenotypic differences in *C. gariepinus* and asserted that this may be due to presence of other taxa in the population. Meanwhile, Mayr (1969) opines that precise measurements sometimes display bi-modal characteristics and there are differences in the number or structure of the chromosomes. Although, chromosomal studies were not carried out in the current study, presence of morphologic types could be suggested with respect to the current population.

Delineating phenotypically heterogeneous population by factors that may have contributed to the development is important and it could reveal population structure and evolutionary trend. Assessment of discriminate factors for the populations' phenotypic structure showed that significant difference did not occur between male and female sub-populations phenotypes. This implies that sexual dimorphism was not confirmed. The result contradicts Skelton (1993), who reported sexual dimorphism in *Clarias gariepinus*. The reason for this observed result could be traced to the report of Kutano *et al*. (2012) who observed that magnitude of sexual dimorphism can be influenced by nature of habitat. Also, Oliveira and Almeida (2005) observed that size structure may reduce probability of sexual dimorphism in fish samples. The insignificant difference in phenotypes of

sex subgroups could therefore be linked to the conditions of the habitat and or the size structure of the population.

Size subgroups were significantly differentiated at DR. However, the pattern of DR values of the size subgroups did not follow the ideal pattern for allometric growth. Assuming the meristic attribute grows, a growing attribute would increase in value along size grades but this was not obtained in the studied population. Interestingly, the significant difference in DR of size subgroups was not retained when the phenotypes were regrouped by PESES. This indicates that the abnormal values of DR in the size subgroups may have a link with PESES subgroups. Hence, the differences disappeared when the population was delineated to the PESES subgroups. Meanwhile, classification function confirmed that PESES had strongest implication as a discriminant factor for the studied population because the subgroups were confirmed as canonically significantly different classification units. Identification of the PESES attribute as a strong discriminate factor, agreed with the earlier observation, that trend of variation in pectoral spine could have taxonomic implication, similar to the reported of Martin and Birmingham (2000) and Beland (2004). Hence, the PESES subgroups can be viewed as morphs of the studied *C. gariepinus* population.

Presence of morphs could have genetic and or environmental basis. Santos *et al.,* (2011) reported that morphological changes among species reflect at least, in part, the differentiated use of resources and ecological differences. Although, genetic analysis of the PESES was not within the scope of the current study, ecological implication of the PESES could be traced by the functional role of the attribute that differentiated the morphs. The PESES subgroups were morphometrically differentiated at anal fin length (AFL). Anal fin is a median fin. The relevance of this attribute in differentiating morphs was mentioned by Arbour *et al*. (2011), when discussing sympatric morphs of Arctic char of *Salvelinus alpines.* Lauder and Drucker (2004) noted that these fins play an important role in acceleration in swimming. Long anal fin contributes to fast starts and maneuver by increasing thrust-producing surface area of the caudal peduncle region while small anal fin would be beneficial in improving flow regimes across the caudal peduncle. Manipulation for thrust and flow regimes are important adaptation strategy by extant fish in hydrodynamic environments (Fletcher *et al*., 2014). Fish adapt to drag in hydrodynamic condition by maintaining attached laminar flow as the ideal flow regime (Fish, 1998), or inducing and controlling turbulent flow (Bushnell and Moore, 1991, Blake, 1983). Variations resulting in PESES subgroups might have evolved as a result of necessity to adjust to fast start and maneuvers in swimming as demanded by flow condition of the studied hydrodynamic environment. This kind of movement would be necessary under the studied environment. This will be relevant because, opening of dams gate-valve comes suddenly and species would have to navigate quickly as well as maneuver towards a seemingly save area. This would call for adjustment of the anal fin length. The discovered pectoral spine variants (PESES) would have differential adaptive strength in the hydrodynamic habitat. Phenotypic plasticity of fishes has been reported by Wimberger, (1991), cited in Gunawickrama, (2007). The variability in PESES/PASPS was likely to have arisen from the great phenotypic plasticity of *Clarias gariepinus* in response to changes in environmental conditions of the Asejire Lake. Phenotypic plasticity is involved in forming adaptive variations and resource polymorphism (Skulason and Smith, 1995; Smith and Skulason 1996, cited in Svanback and Eklon, 2006). Phenotypic plasticity is an environment-induced phenotypic change that occurs within an organism's lifetime and it is likely to play an important role in the process of diversification. Fluctuating environmental condition of the gate-valve controlled Lake may have favoured the observed pattern of phenotypic plasticity in the population. The most plastic attribute- pectoral spine is a locomotive attribute in *C. gariepinus* (Bruton, 1979; De Moor and Bruton, 1988 and Gunder, 2004). According to McHenry and Lauder (2006), locomotors in fish may disproportionately increase in span owing to hydrodynamic changes. Hence, variation in pectoral spine attributes could be one the main survival strategies of the species against fluctuations in water condition of the hydrodynamic environment. Aside the canonical significance of the observed pectoral spine variants, pectoral spine length also reflected the highest flexibility among phenotypes. This information indicates that pectoral fin attributes were the most flexible. The current result agreed with Santos *et al*., (2011), who reported that morphology would reflect trend of fish adaptation to reservoir condition.

In conclusion, the studied *C. gariepinus* population was characterized by heterogeneity of phenotypic values and the population can be taxonomically discriminated by pectoral spine morphological types. The morphotypes can further be identified through anal fin lengths. The anal fin length differences were indicators of adaptation to quick swim and maneuvers for varying flow conditions possibly necessitated by water pull force emanating from opening of dams gate-valve of the Asejire Lake.

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