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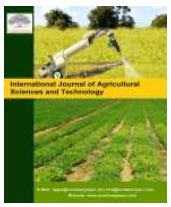

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Genetics of Quantitative Phenotypes of Silver Catfish (*Chrysichthys nigrodigitatus*) from River Taraba, Tella, Nigeria

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Abstract

Genetics of quantitative phenotypes of Silver Catfish (*Chrysichthys nigrodigitatus*) from River Taraba, Tella, Nigeria. Sixty (60) samples of *Chrysichthys nigrodigitatus* of different sizes were bought from artisanal fisherfolk. Phenotypic heterogeneity (coefficient of variability, CV, > 10%) and multiple modes in morphometric and meristic values were assessed to imply plasticity and taxonomic complications, respectively. Twenty-one (21) morphometric and nine (9) meristic attributes were measured in all the collected individuals to the nearest 0.01 cm. A total of 77.78% of meristic attributes were heterogeneous (CV > 10%). All the meristic attributes except DFR and CFR have heterogeneous status (CV = 6.83% and 6.85% respectively). Multiple modal was recorded only in PECFR-L. Among the meristic attributes, DFR does not correlate significantly with any other attribute while a total of 100% of morphometric attributes were heterogeneous (CV >10%). Meanwhile, multiple modes were recorded in 61.90% of the morphometric attributes with significant correlations. Also, meristic attributes have significant correlations with morphometric attributes. The studied *C. nigrodigitatus* strains was characterized by heterogeneity of quantitative phenotypic values, and the population can be taxonomically discriminated.

Keywords: *Genetics; Morphometric; Meristic count; Heterogeneity; Quantitative Phenotypes*

1. Introduction

Quantitative phenotypes are the phenotypes that are measured, such as length, weight, eggs/kg female, or feed conversion. Quantitative phenotypes differ from qualitative phenotypes in that individuals do not fall into discrete, non-overlapping categories. When a geneticist describes a quantitative phenotype, he creates only a single category, such as weight. Fish are not grouped into discrete categories such as “light” or “heavy.” Instead, individuals are arranged along a continuum, and an individual’s phenotypic value is determined by the unit of measurement that the farmer uses (millimeters, centimeters, grams, kilograms, etc.). Because an individual’s phenotypic value is determined by measurement (for example, length in millimeters) rather than by descriptive category (for example, colour), the differences between two individuals is a matter of degree (millimeter) rather than of kind (colour) (Falconer and Mackay, 1996).

The silver catfish, *Chrysichthys nigrodigitatus* (Lacepede, 1803) is a highly valued food - fish included among the dominant commercial catches exploited in major rivers of Africa (Offem *et al*., 2008). In the Taraba water bodies, *Chrysichthys* (Pisces: Siluriformes: Claroteidae) species are of high commercial and economic importance and consistently supports inland artisanal fisheries where this taxon contributed to about 15 - 30% of fish productions. Indeed,

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C. nigrodigitatus is more less abundantly found in natural water bodies such as mangrove habitats, coastal lagoons, estuaries, freshwater lakes, creeks, streams and rivers where the stock is currently declining due to environmental degradations and overfishing. Therefore, a short-term solution to cope with stock decline and species recovery is to develop the aquaculture of this highly consumed claroteid in order to reduce the fishing pressures and to increase the grassroot income (Daniel and Sambo, 2014).

The fish is caught with drag net, hook and line, bottom-set gillnet and bottom-set traps because of the bottom dwelling habit. There is acute reduction in population of this species in Nigeria because of the over exploitative nature of indigenous fishers that destroy the habitats of this species. As reported by Gbaguidi *et al*. (2016) the success of fisheries management, species conservation and aquaculture development require knowledge on trophic ecology of the target species. Evaluating the prominence and establishment of a species in a man-made lake requires extensive qualitative and quantitative data on the exploitation and utilization of the food resources considered as energy sources for species survival, growth and active spawning. Hence, investigation into genetics of quantitative phenotypes of Silver Catfish (*Chrysichthys nigrodigitatus*) from River Taraba, Tella, Nigeria.

2. Materials and Methods

2.1. Description of the Study Area

Tella is a town near the Taraba River in Gassol local Government Area of Taraba State. River Taraba is located on latitude 8°34'N and longitude 10°15'E and Tella on latitude 8°24'N and 10°32'E. A 100 kilometer around River Taraba has an approximate population of 14,326 people and an elevation of 178 meters above sea level (Primary health care priority tables, 2006). The river has its source in the Mambilla Plateau of Sardauna Local Government of Taraba state. The River traverses the three districts of Gashaka, Bukundi, Bali, and Gassol local Government Area. It has a wet and dry climate, with the wet season from April to October and the dry season from November to March (Aruonye and Abbas, 2011). The people of Tella engage in fishing and agricultural activities all year round. In addition to fishing activities, livestock are reared in large quantities along the river valleys including farming of food crops around River banks (Aruonye and Abbas, 2011). Figure 1 shows the map of the study area indicating the various sampling sites along the River.

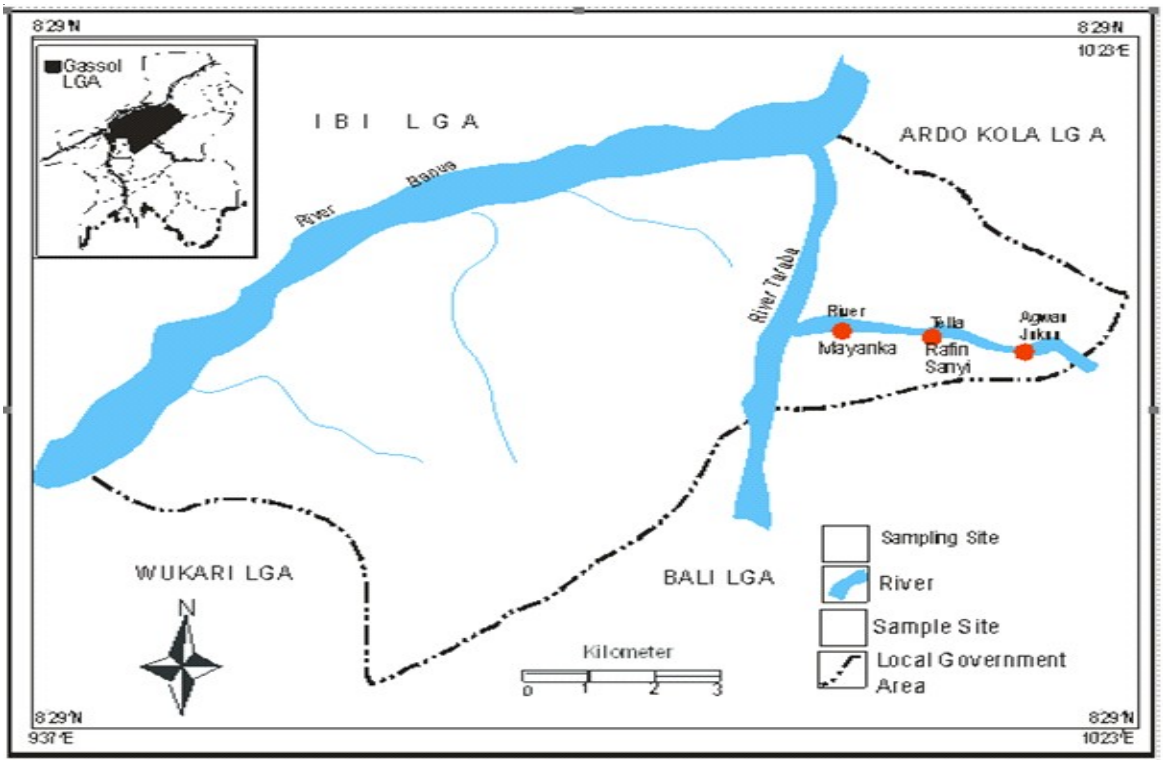

Figure 1: Map of Gassol Local Government Showing River Taraba Tella, Nigeria

Source: *Ministry of Land and Survey Jalingo, Taraba State*

2.2.1. Fish Collection and Sampling

A total of Sixty (60) fish samples of *Chrysichthys nigrodigitatus* were bought from artisanal fishermen caught with various fishing gear at the landing site of River Taraba, Tella Gassol LGA, Taraba State, Nigeria from October to December 2023. Gross physical examination of the external features of the samples will be undertaken for abnormalities at the main landing site and samples will thereafter be transported in a 25 liters' plastic container to central Laboratory, Federal University Wukari, for identification and examination.

2.2.2. Identification of Fish Sample

Chrysichthys nigrodigitatus were identify using the description of Risch and Vreven (2007).

2.2.3. Sexing of Fish

Sex of fish sample were determined by physical observation of the urogenital papillae (Imam and Dewu, 2010).

2.2.4. Measurements of Fish Sample

The standard length (cm) was measured using a measuring board (Goselle *et al*., 2008) while the weight (g) were measured using sensitive weighing balance (model; mettler Toledo).

2.2.5. Assessment of Fish Sample for Phenotypic Variability

1. **Data collection for determination of phenotypic values**

   Twenty-one morphometric and nine meristic attributes was characterized. Data were collected from 60 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. The morphometric traits were measured as described by Uruku *et al*. (2021). Landmarks showing the measured traits are presented in Figure 2.

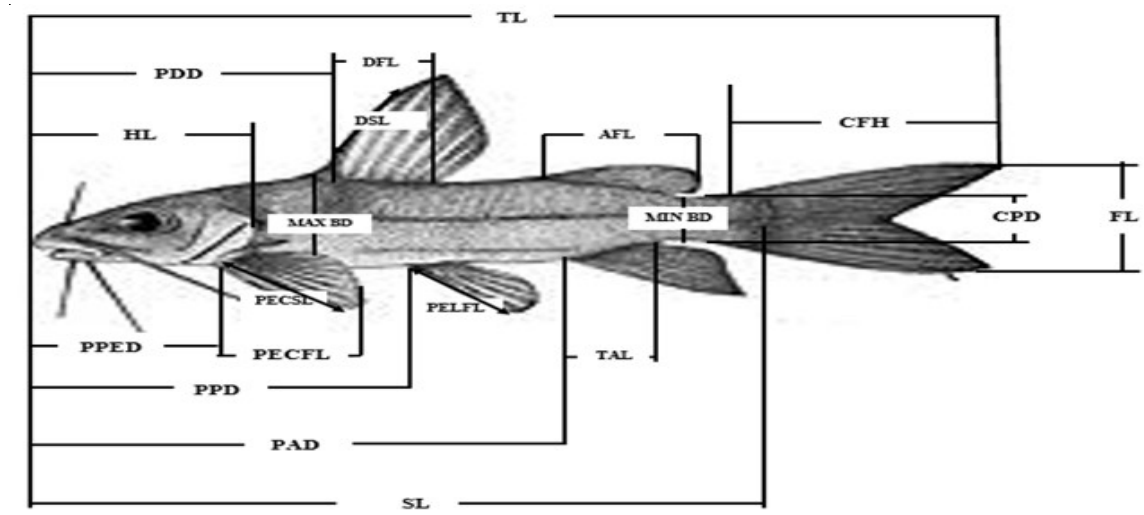

Figure 2: Landmarks Showing the Measured Phenotypic Traits

The measured morphometric traits were Total length (TL), 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), Caudal Peduncle depth (CPD), Fork Length (FL), Caudal Fin Height (CFH) Pre- pectoral (PPEL), Pre pelvic (PPL), Pre-Dorsal Distance (PDD), Pre-Anal Distance (PAD), Distance from dorsal fin to the occipital process (OPD), Total Anal Length (TAL), Adipose fin length (AFL), Dorsal spine length (DSL)

The measured Nine (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 was 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 as describe by Uruku *et al*. (2021). Meristic counts were repeated on the same specimens using hand-held magnifying lens to ensure accuracy.

3. 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 meristic are discrete and are fixed early during development (Oyebola, 2015). Data on each of the morphometric attributes were processed for phenotypic value determined as morphometric value divided by standard length, multiplied by 100%.

This is a preferred method for removing size variation characters among individuals as observed by Oyebola (2015). 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 (Murta, 2000). Therefore, raw meristic data was taken as phenotypic values and used for analysis.

The mean and respective standard deviation of each of the attributes (morphometric and meristic traits) were used to derive Coefficient of Variation (CV), expressed as standard deviation divided by mean phenotypic value, multiply by 100 percent.

4. 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 were 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.

5. 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); Oyebola (2015) and Uruku *et al*. (2021). The DR and AFR were also taken as important taxonomic factors, being the main identification keys for the species (Holden and Reeds, 1978; Teugels, 1986).

5.1. Statistical Analysis

For phenotypic variability data, Univariate statistics such as minimum, maximum, mean, mode and standard deviation was used to describe phenotypes. 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. Significant differences were taken at $p < 0.05$. Within and between subgroup member's relationships were established through cluster analysis while correctness of sub groupings as canonical units was tested by Discriminate Function Analysis (DFA). All correlations were tested using the bivariate correlation coefficients of Pearson. Then, linear and non-linear regression models were investigated using regression fits.

5.2. Results

Genetics of the phenotypic structure and analyses of the contributory factors responsible for heterogeneity of the sampled *Chrysichthys nigrodigitatus* population from River Taraba Tella Nigeria are presented in this section.

5.3. Structure of the Meristic Attributes of the Population

Descriptive statistics on phenotypic values and coefficient of variation in meristic characteristics of the studied *C. nigrodigitatus* populations are presented in Table 1. The mean value of meristic attributes varied from 5.98±0.68 in PELFR-L to 19.28±1.32 in CFR. Coefficient of variability of the population varied from 6.83 in DFR to 17.49 in PESES-L. A total of 77.78% of meristic attributes were heterogeneous (CV > 10%). All the meristic attributes except DFR and CFR have heterogeneous status (CV=6.83% and 6.85% respectively). Multiple modal was recorded in only PECFR-L.

Table 1: Phenotypic Values and Coefficient of Variation (CV) of Meristic Attributes of the Studied Sample Population (N = 60)

Phenotype	Minimum	Maximum	Mean±SD	CV (%)	Mode
DFR	5	7	6.00±0.41	6.83	6
PECFR-L	5	10	7.23±1.24	17.15	6 [a]
PECFR-R	5	9	7.20±1.13	15.69	7
PESES-L	8	20	12.12±2.12	17.49	12
PESES-R	8	20	12.10±2.10	17.36	12
PELFR-L	5	8	5.98±0.68	11.37	6
PELFR-R	5	8	6.03±0.66	10.95	6
AFR	8	12	10.48±1.40	13.36	10
CFR	15	22	19.28±1.32	6.85	20

Note: a: Multiple mode, DFR: Dorsal fin rays count, PECFR-L: Pectoral fin rays count on left side, PECFR-R: Pectoral fin ray count on the right side, PESES-L: Possession of anteriorly serrated spine on the left side, PESES-R: Possession of anteriorly serrated spine on the right side, PELFR-L: Pelvic fin rays count on left side, PELFR-R: Pelvic fin rays count on right side, AFR: Anal fin rays count, and CFR: Caudal fin rays count.

Table 2 shows that among the meristic attributes, DFR does not correlate significantly with any other attribute. PECFR-L correlated positively with PECFR-R, PESES-L, PESES-R, AFR and CFR at r = 0.80, 0.38, 0.36, 0.40 and 0.46

Table 2: Statistically Significant Correlations (r-Values) of Meristic Attributes of the Studied sample Population (N = 60)

	DFR	PECFR-L	PECFR-R	PESES-L	PESES-R	PELFR-L	PELFR-R	AFR	CFR
DFR	1	–	–	–	–	–	–	–	–
PECFR-L		1	0.80	0.38	0.36	–	–	0.40	0.46
PECFR-R			1	0.43	0.48	–	–	0.40	0.42
PESES-L				1	0.96	–	–	–	0.40
PESES-R					1	–	–	–	0.38
PELFR-L						1	0.87	0.26	0.30
PELFR-R							1	–	0.44
AFR								1	0.53
CFR									1

Note: – Indicates that correlation is not significant ($p > 0.05$).

respectively. PECFR-R positively correlated with PESES-L, PESES-R, AFR and CFR at r = 0.43, 0.48, 0.40 and 0.42 respectively. PESES-L correlated positively with PESES-R and CFR at r = 0.96 and 0.40 respectively. PESES-R positively correlated with CFR at r = 0.38. PELFR-L correlated positively with PELFR-R, AFR and CFR at r = 0.87, 0.26 and 0.30 respectively. PELFR-R positively correlated with CFR at r = 0.44. While AFR positively correlated with CFR at r = 0.53. In summary, 47.2% of the attributes correlated with at least one other attribute while 52.8% did not correlate with any other attribute. All the attributes that correlated with each were positive, no negative correlation among the attribute.

5.4. Genetic Structure of the Morphometric Attributes of the Population

The mean value of the morphometric attributes (Table 3) varied from 12.74±1.67 in TAL to 69.06±8.21 in PAD. Coefficient of variability of the population varied from 11.89 in PAD to 93.37 in PECFLL. A total of 100% of morphometric attributes were heterogeneous (CV >10%). Meanwhile, multiple modes were recorded in 61.90% of the attributes.

Table 3: Phenotypic Values (as %SL.) and Coefficient of Variation (CV) of Morphometric Attributes of the Studied Sampled Population (N=60)

Phenotype	Minimum	Maximum	Mean ± SD	CV (%)	Mode
HL	17.65	104.11	28.42±10.65	37.47	25.00
FL	10.71	40.23	23.04±5.58	24.22	24.19[a]
DFL	8.05	34.88	14.42±6.71	46.53	10.49[a]
DSL	9.52	46.43	19.51±5.03	25.78	17.24 [a]
PDD	27.59	54.03	35.62±4.66	13.08	35.71
AFL	6.98	23.85	12.96±2.88	22.22	12.50
PAD	46.56	104.84	69.06±8.21	11.88	68.55 [a]
TAL	8.33	16.94	12.74±1.67	13.11	12.50
CFH	15.63	58.14	36.81±9.29	25.24	32.39 [a]
CPD	0.00	37.41	16.96±8.03	47.35	13.33 [a]
PECSLL	10.69	22.58	16.72±2.64	15.79	16.00 [a]
PECSLR	10.69	22.58	16.50±2.58	15.64	14.29 [a]
PECFLL	5.60	155.84	19.54±18.44	93.37	18.55[a]
PECFLR	7.14	27.42	16.87±4.41	26.14	18.24 [a]
PPED	12.50	51.23	23.58±5.49	23.28	25.00
PELFLL	9.16	25.00	14.88±3.30	22.18	14.29
PELFLR	9.16	24.17	14.81±3.06	20.66	14.29[a]
PPD	22.07	82.31	52.37±8.96	17.11	50.00
BD MAX	15.59	30.61	20.80±2.87	13.80	17.86[a]
BD MIN	9.52	28.17	14.95±3.10	20.74	12.50[a]
OPD	11.41	29.03	17.94±4.26	23.75	15.00

Note: a = Multiple modes; Head length (HL), Fork length (FL), Dorsal fin length (DFL), Dorsal spine length (DSL), Pre-dorsal distance (PDD), Adipose fin length (AFL), Pre-anal distance (PAD), Total anal length (TAL), Caudal fin height (CFH), Caudal peduncle depth (CPD), Pectoral spine length left (PECSLL), Pectoral spine length right (PECSLR), Pectoral fin length left (PECFLL), Pectoral fin length right (PECFLR), Pre-Pectoral distance (PPED), Pelvic fin length left (PELFLL), Pelvic fin length right (PELFLR), Pre-pelvic distance (PPD), Maximum body depth (BD-MAX), Minimum body depth (BD-MIN), Occipital process distance (OPD).

Morphometric attributes have significant correlations (Table 4). The TL correlated positively with SL, PECFLR, BWT and GWT at r value of 0.96, 0.26, 0.96 and 0.70 respectively, while AFL, CPD and POD correlated negatively with TL at r value of -0.29, -0.45 and -0.31. The SL correlated positively with BWT and GWT at r value of 0.93 and 0.60 while negative correlation with SL occurred in DFL, PDD, AFL, CFH, CPD, PPED and POD at r value of -0.26, -0.27, -0.29, -0.29, -0.40, -0.30 and -0.35 respectively. The HL did not correlate either positively or negatively with any attribute. The FL correlated positively with DSL, TAL, PECSLL, PECSLR, PECFLR, PELFLL, PELFLR, PPD, and BD MAX at r = 0.30 to 0.48. The DFL correlated positively with CFH at r = 0.51. The DSL correlated positively with PECSLL, PECSLR, PECFLR, PELFLL, and PELFLR at r = 0.27 to 0.47. The PDD positively correlated with PAD, PECSLL, PPED, PELFLL and PELFLR at r = 0.28 to

Table 4: Statistically Significant Correlations (r-Values) of Morphometric Attributes of the Studied *sample* Population (N=60)

	TL	SL	HL	FL	DFL	DSL	PDD	AFL	PAD	TAL	CFH	CPD	PECSLL	PECSLR	PECFLL	PECFLR	PPED	PELFLL	PELFLR	PPD	BD MAX	BD MIN	POD	BWT	GWT
TL	1	0.96	–	–	–	–	–	-0.29	–	–	–	-0.45	–	–	–	0.26	–	–	–	–	–	–	-0.31	0.96	0.70
SL		1	–	–	-0.26	–	-0.27	-0.29	–	–	-0.29	-0.40	–	–	–	–	-0.30	–	–	–	–	–	-0.35	0.93	0.69
HL			1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
FL				1	–	0.30	–	–	–	0.34	–	–	0.43	0.45	–	0.48	–	0.39	0.38	0.31	0.30	–	–	–	–
DFL					1	–	–	–	–	–	0.51	–	–	–	–	–	–	–	–	–	–	–	–	–	–
DSL						1	–	–	–	–	–	–	0.27	0.29	_	0.47	–	0.33	0.39	–	–	–	–	–	–
PDD							1	–	0.35	–	–	–	0.28	–	–	–	0.34	0.29	0.33	–	–	–	–	–	–
AFL								1	–	–	–	0.45	–	–	–	–	–	–	–	0.45	–	–	0.49	–	–
PAD									1	–	–	–	0.26	–	–	–	–	0.31	0.34	0.26	–	–	0.27	–	–
TAL										1	–	–	0.35	0.34	–	0.30	–	–	–	–	0.43	0.30	–	–	–
CFH											1	–	0.33	0.35	–	–	–	0.36	0.38	–	0.42	–	0.28	-0.26	–
CPD												1	–	–	–	-0.45	–	-0.29	-0.28	0.30	–	–	0.34	0.33	0.36
PECSLL													1	0.95	–	0.50	–	0.42	0.46	0.35	0.36	0.26	–	–	–
PECSLR														1	–	0.51	–	0.47	0.51	0.35	0.37	0.33	–	–	–
PECFLL															1	–	–	–	–	–	–	–	–	–	–
PECFLR																1	–	0.52	0.52	0.31	0.31	0.37	–	–	0.28
PPED																	1	–	–	–	–	–	–	-0.27	_
PELFL																		1	0.91	–	–	–	–	–	–
PELFLR																			1	–	0.28	–	–	–	–
PPD																				1	0.45	0.36	0.33	–	–
BD MAX																					1	0.61	–	–	–
BD MI																						1	–	–	0.28
OPD																							1	-0.27	–
BWT																								1	0.66
GWT																									1

Note: – Indicates that correlation is not significant ($p > 0.05$).

0.35. The AFL correlated positively with CDP, PPD and POD at r = 0.45 to 0.48. The PAD positively correlated with PECSLL, PELFLL, PELFLR, PPD and POD at r = 0.26 to 0.34. The TAL correlated positively with PECSLL, PECSLR, PECFLR, BD MAX and BD MIN at r = 0.30 to 0.42. The CFH correlated positively with PECSLL, PECSLR, PELFLL, PELFLR, BD MAX and POD at r = 0.28 to 0.42. while negative correlation with CFH occurred in BWT PAL at r = -0.26. The CPD correlated positively with PPD, POD, BWT and GWT at r = 0.30 to 0.36 while negative correlation with CDP occurred in PECFLR, PELFLL and PELFLR at r = -0.28 to -0.45. The PECSLL positively correlated with PECSLR, PECFLR, PELFLL, PELFLR, PPD, BD MAX and BD MIN at r = 0.26 to 0.95. The PECSLR positively correlated with PECFLR, PELFLL, PELFLR, PPD, BD MAX and BD MIN at r = 0.33 to 0.51. Meanwhile, no attribute correlated with PECFLL. The PECFLR positively correlated with PELFLL, PELFLR, PPD, BD MAX, BD MIN and GWT at r = 0.28 to 0.52. The PELFLL positively correlated with PELFLR at r = 0.91. The PELFLR correlated positively with BD MAX at r = 0.28. The PPD correlated positively with BD MAX, BD MIN and POD at r = 0.33 to .045. BD MAX positively correlated with BD MIN at r = 0.61. BD MIN positively correlated with GWT at r = 0.28. CPD correlated negatively with BWT at r = -0.27 and BWT positively correlated with GWT at r = 0.66.

The meristic attributes have significant correlations with morphometric attributes as shown in Table 5. The DFR does not correlate with any of the morphometric attribute. The PECFRL correlated positively with PDD at r = 0.38. However, no attribute correlated negatively with PECFRL. The PECFRR correlated positively with CFH at r = 0.27. No attribute correlated negatively with PECFRR**.** The PESES-L correlated positively with TL, SL, PDD, PECFLR, BWT and GWT at r = 0.62, 0.56, 0.28, 0.34, 0.55 and 0.60 respectively while negative correlation with PESESL occurred in CPD at r = -0.28. The PESESR correlated positively with TL, SL, PECFLR, BWT and GWT at r = 0.64, 0.59 0.34, 0.58 and 0.59 respectively. However, no attribute correlated negatively in PESESR. The PELFRL does not correlate with any of the morphometric attribute. The PELFRR correlated positively with PECFLL at r = 0.35. However, no attribute correlated negatively in PELFRR. The AFR correlated positively with TAL at r = 0.28. However, no attribute correlated negatively in AFR. The CFR correlated positively with PDD, TAL, PECSLL, PECSLR, PECFLL and BDMIN at r = 0.28, 0.40, 0.28, 0.34, 0.32 and 0.34 respectively. However, no attribute correlated negatively in CFR.

Table 5: Statistically Significant Correlations (r-Values) of Morphometric and Meristic Attributes of the Studied Sample Population (N=60)

	TL	SL	HL	FL	DFL	DSL	PDD	AFL	PAD	TAL	CFH	CPD	PECSLL	PECSLR	PECFLL	PECFLR	PPED	PELFLL	PELFLR	PPD	BD MAX	BD MIN	POD	BWT	GWT
DFR	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
PECFRL	–	–	–	–	–	–	0.38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
PECFRR	–	–	–	–	–	–	–	–	–	–	0.27	–	–	–	–	–	–	–	–	–	–	–	–	–	–
PESESL	0.62	0.56	–	–	–	–	0.28	–	–	–	–	-0.28	–	–	–	–	0.34	–	–	–	–	–	–	0.55	0.60
PESESR	0.64	0.59	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.34	–	–	–	–	–	–	0.58	0.59
PELFRL	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
PELFRR	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.35	–	–	–	–	–	–	–	–	–
AFR	–	–	–	–	–	–	–	–	–	0.28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CFR	–	–	–	–	–	–	0.28	–	0.40	–	–	0.28	0.34	0.32	–	–	–	–	–	–	–	0.34	–	–	–

Note: – Indicates that correlation is not significant ($p > 0.05$).

6. Discussion

Genetics of quantitative traits, which are phenotypes that vary continuously such as height, length or weight as opposed to phenotypes and gene products that are discretely identifiable such as eye, colour or presence of a particular biochemical. Due to continuous distribution of phenotypic values, quantitative genetics must employ variance to link phenotypic attributes to genotypes (Anderberg, 1973).

6.1. Genetics of Phenotypic Variability of Chrysichthys nigrodigitatus *Population*

The results of the present study indicate an agreement with Oyebola (2015); Tosin *et al*., (2018) and Uruku *et al*., (2021) who observed that some morphological characters of fish were useful in generating heterogeneity in morphology. The

morphometric variability among the sampled *Chrysichthys nigrodigitatus* in this study was mainly due to the variation of characters related to fins, and body characteristics. It also signifies consonance 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 population, thus agreeing with the observation that phenotypes variability could vary within a single population (Oyebola, 2015). 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 river.

Wimberger (1992) have revealed that there is great phenotypic plasticity of fishes in response to changes in environmental factors. Bock (1990) reported that morphological features were adaptive; that is, they evolved and diversified 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.

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). Trend of compromising identity within river Taraba *Chrysichthys nigrodigitatus* population may signal an evolving trend of adaptation which could have taxonomic implications. This indicates a possible source of high coefficient of variation as observed in the population's haplotypes. A similar trend of phenotypic variation was observed to be related with morphological types of *Pangasianodon hypophthalmus*.

A further analysis of the population confirmed Presence of taxonomic subgroup in the population could be suspected because heterogeneity of a meristic attribute occurred concurrently with that of most of the morphometric attributes and especially, with multiple modes occurring in the DR attribute. Multiple modal values indicate heterogeneity of most morphometric traits and a meristic traits underlines need for delineating the population to morphotypes, this is necessary because, multiple modes may indicate presence of morphologic types in fish (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. Santos *et al*. (2011) reported that morphological changes among species reflected at least, in part, the differentiated use of resources and ecological differences. 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 contribute 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 rivers (Fletcher *et al*., 2014). Fish adapt to water current in Rivers condition by maintaining attached laminar flow as the ideal flow regime (Fish, 1998), or inducing and controlling turbulent flow (Bushnell and Moore, 1991).

This study reveals phenotypic diversity of *Chrysichthys nigrodigitatus*. This agrees with the reported work of Solomon *et al*. (2016) and Uruku *et al*. (2021), who reported high phenotypic plasticity of African catfish. 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 (Oyebola, 2015).

7. Conclusion

The studied *Chrysichthys nigrodigitatus* population was characterized by heterogeneity of phenotypic values and the population can be taxonomically discriminated by meristic and morphological types.

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