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Phenotypic features depict variability in *Clarias jaensis* wild populations in Cameroon

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Keywords

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Historic

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Abstract

This study was conducted to contribute to a better understanding of the phenotypic diversity of natural populations of *Clarias jaensis* in Cameroon, with the objective to harness the exploitation and conservation of this native catfish. A total of 269 native catfish (*Clarias jaensis*), including 139 males and 130 females, were sampled on 6 sites in Cameroon. One (1) phaneroptic observation, seventeen (17) biometric traits and four (4) meristic traits were evaluated. The main results showed that there are three colour patterns (brown, black and marbled) on the dorsal region and flanks in *Clarias jaensis*, with a predominance of brown (81.04%) and black (11.52%) patterns. The effect of sex on total weight (TW), snout length (SnL), prepelvic length (PPvL), total length (TL), standard length (SL), body depth (BD) and caudal peduncle depth (CPD) was significant ($p<0.05$). In general, biometric traits were significant ($p<0.05$) and positively correlated with total weight. The number of soft fin rays in dorsal fin (D) and anal fin rays (A) were negatively and weakly correlated with total weight ($r=-0.02$ and $r=-0.04$ respectively), while, the number of soft fin rays in pectoral fin was negatively and weakly correlated with total weight ($r=0.13$). The Principal Component Analysis (PCA) performed on all the biometric and meristic traits shows that the first two axes alone account for more than 50% of the total inertia. Hierarchical Ascending Classification (HAC) highlighted the existence of 3 morphotypes. The observed biodiversity suggests that the *Clarias jaensis* catfish is a natural genetic resource with the necessary variability to be exploited, though there is a need to develop population and habitats monitoring plan.

1. Introduction

Biodiversity conservation is one of the most important global challenges of this century. Biodiversity provides irreplaceable products that are indispensable to humanity [1]. It is essential for a sustainable food supply and the provision of many ecosystem services [2, 3, 4, 5]. However, many essential elements of this biodiversity, such as fish species, are threatened with extinction or overexploited by humans [6, 7, 8, 9, 10]. *Clarias jaensis* (family Clariidae) is one of the endemic fish species overexploited in Cameroon. It is an endemic fish species of sub-Saharan Africa that is highly valued in local cuisine, wedding celebrations and other customary considerations; indeed, it is easy to handle and highly valued by the local population [11]. According to Zango *et al.* [12], using this species for fish farming would reduce fishing pressure and conserve endogenous biodiversity. Some work has been done on this species in Cameroon; however, this work has focused on assessing its reproductive characteristics [13, 12] and growth [14, 15, 16]. According to FAO [17], good management of genetic resources requires knowledge of their intra-diversity. Indeed, proper identification of resources is crucial for appropriate fisheries assessment and management programs. With regard to the analysis of population dynamics, this work was initiated aiming at contributing to a better understanding of the phenotypic variability of natural populations of *C. jaensis*. More specifically, the objectives were to describe the variability of morpho-biometric and meristic traits of *C. jaensis* populations according of sites and to describe the structure and relationships between the different morphotypes.

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2. Materials and Methods

2.1 Study sites

Specimens of *Clarias jaensis* were collected from the Sanaga, Nyong, Nkam, Menoua, Mfouri and Magam Rivers (Figure 1). The study sites (Table 1) were selected based on their accessibility and the presence of this species.

2.2. Fish sampling

Morphological data were collected from December to March 2023. Each month, all sites were systematically sampled for *Clarias jaensis* specimens. *C. jaensis* were caught with cast nets and hooks with the participation of the fishermen. A total of 269 adult *C. jaensis* were sampled. Back and flank colour was recorded immediately after each capture; and morphometric, meristic and weight traits were recorded on each individual after sexing. Phanerotic descriptions were made by direct observation immediately after capture. For each individual, 16 measurements (Figure 2) were taken using a 20 cm calliper gauge with

Table 1: Location and number of individuals sampled per site

Sites	Localities	GPS location	Sample size
Menoua River	Nteingué	N5°21'9.68472'' E10°0'14.14956''	n=30
	Madagascar/Santchou	N5°16'50.8746'' E9°58'50.36628''	n=30
Nyong River	Akonolinga	N3°46'10.78968'' E12°14'46.46292''	n=21
	Ayos	N3°54'11.11428'' E12°31'35.81688''	n=17
	Mbalmayo	N3°30'39.0474'' E11°30'25.73784''	n=25
Nkam River	Fongwang	N5°16'11.45748'' E9°58'30.85248''	n=29
	Lélem	N5°12'55.63872'' E9°59437.41144''	n=27
Sanaga River	Edéa	N3°48'24.82524'' E10°7'12.62784''	n=30
Magam River	Nden-efoungwo	N5°17'12.45228'' E9°56'52.65744''	n=30
Mfouri River	Bamengui	N5°12'51.66432'' E10°4'23.64852''	n=30

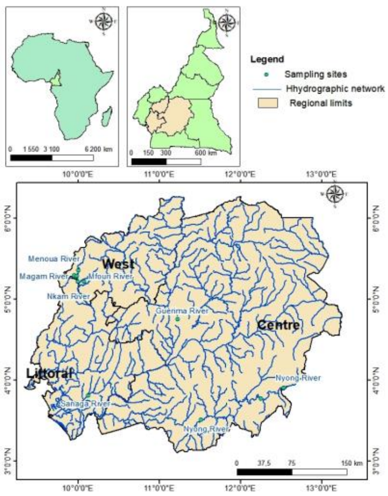
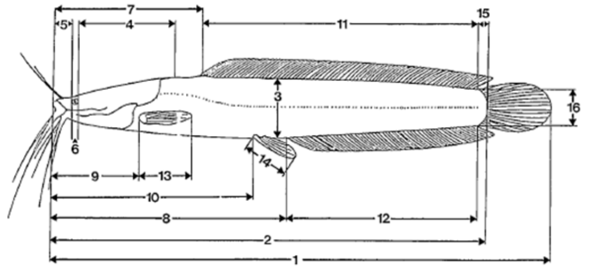


Figure 1 : *Clarias jaensis* sampling sites

a 0.02 mm graduation and an ichthyometer. These measurements were made for total length (TL), standard length (SL), body depth (BD), head length (HL), snout length (SnL), eye diameter (ED), predorsal length (PDL), preanal length (PAL), prepectoral length (PPL), prepelvic length (PPvL), dorsal fin base length (DFL), anal fin base length (AFL), pectoral fin length (PL), pelvic fin length (PVL), caudal peduncle length (CPL), caudal peduncle depth (CPD). A total of 4 meristic counts were made on each specimen. These included: the number of soft rays on the dorsal fin (D), the number of soft rays on the anal fin (A), the number of soft rays on the pectoral fin (P) and the number of soft rays on the pelvic fin (V). Sampled fishes were individually weighed using a Weiheng® 10 kg capacity electronic scale (accuracy of 0.5g).

2.3. Statistical analyses

Descriptive statistics (calculating mean, standard deviation, coefficient of variation) were calculated using the summary function of the R software. The chi-2 test was used to test the association between the qualitative factors. Means were compared in pairs using Student's t-test after checking the normality of the distribution and homogeneity of variances. Analysis of Variance (ANOVA) was used to compare the means of the morphometric and meristic data, and Tukey's test was used to separate the means when the differences were significant. Both



1: Total length; 2: Standard length; 3 : Body depth ; 4 : Head length ; 5 : Snout length ; 6 : Eye diameter ; 7 : Predorsal length ; 8 : Preanal length; 9 : Prepectoral length ; 10 : Prepelvic length ; 11 : Dorsal fin base length ; 12 : Anal fin base length ; 13 : Pectoral fin length ; 14 :Pelvic fin length; 15 : Caudal peduncle length ; 16 : Caudal peduncle depth.

Source: Lévêque *et al.* [18]

Figure 2: Standard Body Measurements on Catfish

morphometric and meristic measurements were submitted to multivariate analysis (PCA and HAC). All analyses were performed using R software 4.3.0 [19] and XLSTAT 2015.

3. Results

3.1 Colour of the flanks and back of *Clarias jaensis*

Table 2 shows the colour variability of the dorsal region and flanks of *Clarias jaensis* at different sites.

Table 2 shows that *Clarias jaensis* can have brown, black or marbled backs and flanks, with brown predominating. Brown individuals were mainly found in the Sanaga, Nkam, Nyong and Menoua Rivers. Black individuals were more common in the Magam River. The contingency test shows that the colour of the back and flanks of *Clarias jaensis* varied significantly from site ($p<0.05$). Figures 3 (a, b and c) shows the colour variability of the dorsal region and flanks of *C. jaensis* populations at the different sites.

Table 2: Colour variability of the dorsal region and flanks of *Clarias jaensis* at different sites

Sites	Body colour (back and flanks)						p-value
	Brown		Black		Marbled		
	n	%	n	%	n	%	
Sanaga River	30	100.00	0	0.00	0	0.00	
Nkam River	50	89.28	3	5.36	3	5.36	
Nyong River	56	88.89	7	11.11	0	0.00	
Menoua River	51	85.00	5	8.33	4	6.67	0.00
Magam River	14	46.67	16	53.33	0	0.00	
Mfouri River	17	56.67	0	0.00	13	43.33	
All sites	218	81.04	31	11.52	20	7.44	

n: number, %: percentage.

a : Brown Back and flanks **b** : Black back and flanks **c :** Marbled back and flanks

Figure 3: Back and flank colour in *Clarias jaensis: a) Brown; b) Black; c) Brown.*

3.2 Height and total weight

The variability of biometric and weight characteristics by study site is shown in Table 3.

Out of the 17 traits studied, 9 showed significant differences between rivers. No significant difference was observed between rivers for total length ($p=0.90$), standard length ($p=0.75$), pre pelvic length (0.06), predorsal length (0.35), preanal length ($p=0.06$), dorsal fin base length ($p=0.06$), anal fin base length ($p=0.06$) and caudal peduncle length

Table 3: Mean and coefficient of variation of *Clarias jaensis* biometric traits in each river

Features	Values	Sites						All sites
		Sanaga River	Nkam River	Nyong River	Menoua River	Magam River	Mfouri River	
TW (kg)	M± SD	0.48±0.08^{b}	0.48±0.18^{b}	0.48±0.13^{b}	0.54±0.11^{ab}	0.51±0.24a^{b}	0.60±0.14^{a}	0.51±0.15
	CV	16.66	37.50	26.08	20.37	47.05	23.33	29.41
TL (cm)	M± SD	39.21±3.85^{a}	39.53±5.88^{a}	39.91±4.68^{a}	39.45±3.97^{a}	38.86±4.54^{a}	38.99±4.55^{a}	39.43±4.67
	CV	9.82	14.87	11.73	10.06	11.68	11.67	11.84
SL (cm)	M± SD	34.98±3.52^{a}	34.70±5.62^{a}	35.51±4.50^{a}	35.41±3.86^{a}	34.37±3.76^{a}	34.45±3.69^{a}	35.01±4.36
	CV	10.06	16.19	12.67	10.90	10.94	10.71	12.45
HL (%SL)	M± SD	21.24±2.70^{a}	20.51±2.63^{ab}	19.39±2.63^{b}	20.98±3.07^{a}	21.61±2.75^{a}	22.00±3.05^{a}	20.72 ±2.91
	CV	11.71	12.82	13.56	14.63	12.72	13.86	14.04
SnL (%SL)	M± SD	1.41±0.47^{bc}	1.30±0.48^{c}	1.28±0.38c	1.61±0.32^{ab}	1.41±0.26^{bc}	1.80±0.36^{ab}	1.44±0.42
	CV	33.33	36.92	29.69	19.87	18.44	20.00	29.16
ED (%SL)	M± SD	1.22±0.27^{a}	0.99±0.23^{c}	1.00±0.18^{c}	1.22±0.21^{a}	1.14±0.27^{ac}	1.52±0.30^{b}	1.15±0.28
	CV	22.13	23.23	18.00	17.21	23.68	19.74	24.34
PPL (%SL)	M± SD	18.91±3.08^{a}	16.57±3.41^{b}	16.04±2.49^{b}	18.64±2.57^{a}	19.40±3.43^{a}	19.26±2.57^{a}	17.78±3.18
	CV	16.28	20.57	15.52	13.79	17.68	13.34	17.88
PPvL (%SL)	M± SD	41.71±6.59^{a}	40.82±6.57^{a}	40.25±6.53^{a}	41.25±5.18^{a}	43.39±4.10^{a}	43.67±4.31^{a}	41.48±5.88
	CV	15.80	16.09	16.22	12.56	9.45	9.87	14.17
PDL (%SL)	M± SD	33.85±3.01^{a}	34.57±5.58^{a}	34.40±3.02^{a}	35.51±4.39^{a}	33.97±2.00^{a}	34.23±2.20^{a}	34.56±3.88
	CV	8.89	16.14	8.78	12.36	5.88	6.43	11.22
PAL (%SL)	M± SD	51.44±3.91^{a}	50.15±4.86^{a}	50.14±4.70^{a}	52.15±3.47^{a}	52.18±3.48^{a}	52.70±4.23^{a}	51.02±4.28
	CV	7.60	9.69	9.37	6.65	6.67	8.03	8.39
PL (%SL)	M± SD	9.66±1.65^{ab}	10.40±1.99^{b}	9.78±1.50^{ab}	9.48±1.60^{a}	9.76±1.33^{ab}	9.40±1.44^{ab}	9.78±1.65
	CV	17.08	19.13	15.33	16.87	13.63	15.32	16.87
PVL (%SL)	M± SD	7.43±1.10^{ab}	7.91±1.12^{a}	7.31±1.08^{b}	7.43±1.09^{ab}	7.71±1.05^{ab}	7.30±1.23^{ab}	7.52±1.11
	CV	14.80	14.16	14.77	14.67	13.61	16.85	14.76
BD (%SL)	M± SD	18.09±2.18^{b}	16.86±2.64^{ab}	16.30±2.28^{a}	16.95±2.10^{ab}	17.26±1.82^{ab}	17.81±2.05^{b}	17.03±2.29
	CV	12.05	15.65	13.99	12.39	10.54	11.51	13.45
DFL (%SL)	M± SD	66.15±4.60^{a}	63.40±8.57^{a}	66.50±7.90^{a}	64.62±5.96^{a}	67.78±5.73^{a}	67.76±6.84^{a}	65.68±7.12
	CV	6.95	13.52	11.88	9.22	8.45	10.09	10.84
AFL (%SL)	M± SD	48.56±3.19^{a}	48.06±4.47^{a}	49.65±6.05^{a}	47.56±3.18^{a}	49.85±3.65^{a}	49.84±5.19^{a}	48.77±4.60
	CV	6.57	9.30	12.18	6.69	7.32	10.41	9.43
CPL (%SL)	M± SD	3.59±1.14^{a}	3.94±0.88^{a}	3.64±0.56^{a}	3.63±0.78^{a}	3.86±0.95^{a}	3.51±0.97^{a}	3.71±0.85
	CV	31.75	22.33	15.38	21.49	24.61	27.63	23.91
CPD (%SL)	M± SD	6.06±0.78^{a}	6.73±1.08^{b}	6.49±0.93^{ab}	6.13±0.95^{a}	6.32±0.91^{ab}	6.10±0.84^{a}	6.35±0.96
	CV	12.87	16.04	14.32	15.50	14.40	13.77	15.11

a,b,c: Means with the same letter in the same line indicate a significant difference at 5% level; M: mean; SD: standard deviation; CV: coefficient of variation; TW: total weight; TL: total length; SL: standard length; HL: head length; SnL: snout length; ED: eye diameter; PPL: prepectoral length; PPvL: prepelvic length; PDL: predorsal length; PAL: preanal length; PL: pectoral fin length; PVL: pelvic fin length; BD: body depth; DFL: dorsal fin base length; AFL: anal fin base length; CPL: caudal peduncle length; CPD: caudal peduncle depth

Tableau 4: Body metric and weight characteristics by sex

Features	Sex				T-test
	Females		Males		
	M ± SD	CV	M ± S	CV	
Weight (kg)	0.44±0.09[a]	20.45	0.57±0.17[b]	29.82	**
TL (cm)	37.54±3.90[a]	10.39	41.20±4.65[b]	11.29	**
SL (cm)	33.47±4.05[a]	12.10	36.46±4.15[b]	11.38	**
HL (%LS)	20.41±2.74[a]	13.42	21.01±3.04[a]	14.47	NS
SnL (%LS)	1.37±0.38[a]	27.73	1.51±0.44[b]	29.14	**
ED (%LS)	1.13±0.28[a]	24.78	1.16±0.29[a]	25.00	NS
PPL (%LS)	17.64±3.20[a]	18.14	17.91±3.18[a]	17.75	NS
PPvL (%LS)	40.63±5.82[a]	14.32	42.28±5.84[b]	13.81	*
PDL (%LS)	34.97±4.52[a]	12.92	34.16±3.12[a]	9.13	NS
PAL (%LS)	50.51±4.36[a]	8.63	51.51±4.16[a]	8.08	NS
PL (%LS)	9.67±1.86[a]	19.23	9.89±1.42[a]	14.35	NS
PVL (%LS)	7.56±1.15[a]	15.21	7.48±1.08[a]	14.44	NS
BD (%LS)	17.41±2.33[a]	13.39	16.69±2.21[b]	13.24	*
DFL (%LS)	65.61±7.00[a]	10.67	65.75±7.25[a]	11.03	NS
AFL (%LS)	48.75±4.75[a]	9.74	48.79±4.47[a]	9.16	NS
CPL (%LS)	3.75±0.85[a]	22.67	3.66±0.86[a]	23.50	NS
CPD (%LS)	6.61±0.95[a]	14.37	6.10±0.91[b]	14.92	**

a,b: Intra-class means of the same line followed by the same letter are not significantly different at the 5% level; ** : p<0.01; * : p<0.05; NS : p>0.05 ; M: mean; SD: standard deviation; CV: coefficient of variation; TL: total length; SL: standard length; HL: head length; SnL: snout length; ED: eye diameter; PPL: prepectoral length; PPvL: prepelvic length; PDL: predorsal length; PAL: preanal length; PL: pectoral fin length; PVL: pelvic fin length; BD: body depth; DFL: dorsal fin base length; AFL: anal fin base length; CPL: caudal peduncle length; CPD: caudal peduncle depth.

fish from the Mfouri River had greater head length and snout length, both of which were less in fish from the Nyong River. Pectoral fin length was greater in fish from the Nkam River and less in those from the Menoua River, while the height of the caudal peduncle was greater in fish from the Nkam River and less in those from the Sanaga River. Body depth was greater in fish from the Sanaga River and lower in those from the Nyong River. Pelvic fin length was greater in fish from the Nkam River and lower in those from the Mfouri River. Fish from the Magam River had long pre-pectoral lengths. Overall, 62.5% of the biometric traits had a coefficient of variation (CV) less than 15%.

Table 4 reveals the metric and weight traits according to sex.

Student's t-test shows that total weight differed significantly between the sexes (p<0.05). Male fish weighed more (0.57±0.17 kg) than female fish (0.44±0.09 kg). 37.5% of the biometric traits differed significantly (p<0.05) between the sexes. The biometric traits that stood out were: total length, standard length, body depth, snout length, prepelvic length and caudal peduncle depth. Coefficients of variation for male fish were relatively high for total weight and snout length. Females, on the other hand, had low to medium coefficients of variation for most of the traits studied, except for snout length, which showed a high coefficient of variation.

3.3 Meristics traits

Table 5 reveals the meristics traits according to sites.

The number of soft fin rays in anal fin (A) and pectoral fin rays (P) varied significantly (p<0.05) between sites. The number of soft fin rays in anal fin was higher in individuals from the Mfouri River than in individuals from the Nkam River while the number of soft fin rays in pectoral fin was significantly higher in individuals from the Mfouri River and lower in individuals from the Magam River Overall, 100% of the meristic counts had coefficients of variation (CV) less than 15%.

Table 6 shows the variability of meristic counts according to sex.

Student's t-test showed that all meristic counts were comparable (p>0.05) between sexes. All coefficients of variation remained low, for both sexes.

Table 6: Means, standard deviations and coefficients of variation of meristic traits of *Clarias jaensis* by sex

Features	Sex						T-test
	Female			Male			
	M ± SD	CV	Interval	M ± SD	CV	Interval	
D	76.93±4.79[a]	6.22	67- 87	77.20±4.87[a]	6.31	67- 88	NS
A	59.88±3.04[a]	5.08	53 - 67	59.98±3.69[a]	6.15	53- 67	NS
P	10.06±0.52[a]	5.26	9 - 11	10.19±0.63[a]	6.18	9 - 11	NS
V	6.00±0.00[a]	0.00	6 - 6	6.00±0.00[a]	0.00	6 - 6	-

a, Intra-class means of the same line followed by the same letter are not significantly different at the 5% level; M: mean; SD: standard deviation; CV: coefficient of variation D: dorsal fin ray count; A: anal fin ray count ; P: pectoral fin ray count; V: pelvic fin ray count.

3.4 Correlation between phenotypic traits

Table 7 displays the correlations between biometric and meristic traits. Biometric traits were significantly (p<0.05) and positively correlated with total weight. However, preanal length (PAL) and total length (TL) were positively and strongly correlated with total weight (r=0.73 and r=0.71 respectively). For meristic counts, the number of soft fin rays in dorsal fin (D) and anal fin rays (A) were negatively and weakly correlated with total weight (r=-0.02 and r=-0.04 respectively), while the number of soft fin rays in pectoral fin was significantly and weakly correlated with total weight (r=0.13).

3.5 Multivariate analysis

Figure 4 shows the distribution of variables across the factorial plans. The Principal Component Analysis (PCA) performed on all the biometric and meristic traits (Figure 4) shows that the first two axes alone account for more than 50% of the total inertia. The percentage of variance decreases sharply from the first to the second factor level. The first axis, which accounts for more than 40% of the total inertia, is weakly correlated with meristic counts (anal fin rays count, dorsal fin rays count and pectoral fin rays count).

Table 5: Mean and coefficient of variation for meristic traits of *Clarias jaensis* by sit.

Features	Values	Sites						
		Sanaga River	Nkam River	Nyong River	Menoua River	Magam River	Mfouri River	All sites
D	M ± SD	76.13 ±4.80^{a}	76.96±4.09^{a}	76.70±5.14^{a}	77.31±4.80^{a}	78.47±4.78^{a}	77.13±5.51^{a}	77.07±4.82
	Interval	67 - 86	69 - 87	69 - 88	70 - 87	67 - 87	70 - 87	67 - 88
	VC	6.30	5.31	6.70	6.21	6.09	7.14	6.25
A	M ± SD	59.10±4.06^{bc}	58.82±3.62^{b}	60.13±3.41^{ab}	59.68±3.36^{ab}	61.33±2.04^{ac}	61.57±2.11^{a}	59.94±3.39
	Interval	53 - 67	53 - 67	53 - 66	53 - 67	57 - 65	58 - 66	53 - 67
	VC	6.87	6.15	5.67	5.63	3.33	3.43	5.65
P	M ± SD	9.87±0.51^{b}	10.27±0.48^{ac}	10.28±0.45^{ac}	10.01±0.62^{ab}	9.77±0.77^{b}	10.40±0.50^{c}	10.13±0.89
	Interval	9 - 11	9 - 11	9 - 11	9 - 11	9 - 11	10 - 11	9 - 11
	VC	5.17	4.67	4.38	6.19	7.88	4.80	8.78
V	M ± SD	6.00±0.00	6.00±0.00	6.00±0.00	6.00±0.00	6.00±0.00	6.00±0.00	6.00±0.00
	Interval	6 - 6	6 - 6	6 - 6	6 - 6	6 - 6	6 - 6	6 - 6
	VC	0.00	0.00	0.00	0.00	0.00	0.00	0.00

a,b,c: Means with the same letter in the same line indicate a significant difference at the 5% level ; M: mean ; SD: standard deviation; VC: coefficient of variation ; D : dorsal fin ray count ; A : anal fin ray count ; P : pectoral fin ray count ; V : pelvic fin ray count

Table 7: Correlations between body weight and phenotypic traits in *Clarias jaensis*

Variables	W	TL	SL	BD	HL	SnL	ED	PDL	PPvL	PVL	PAL	DFL	AFL	PL	PVL	CPL	CPD	D	A	P
W	**1.00**																			
TL	0.71*	**1.00**																		
SL	0.67*	0.92*	**1.00**																	
BD	0.49*	0.47*	0.44*	**1.00**																
HL	0.57*	0.56*	0.51*	0.50*	**1.00**															
SnL	0.66*	0.48*	0.43*	0.43*	0.51*	**1.00**														
ED	0.49*	0.29*	0.25*	0.40*	0.45*	0.61*	**1.00**													
PDL	0.65*	0.70*	0.68*	0.40*	0.44*	0.49*	0.29*	**1.00**												
PPvL	0.48*	0.45*	0.40*	0.43*	0.68*	0.57*	0.47*	0.44*	**1.00**											
PVL	0.56*	0.60*	0.59*	0.46*	0.52*	0.45*	0.31*	0.54*	0.46*	**1.00**										
PA L	0.73*	0.80*	0.79*	0.48*	0.62*	0.56*	0.40*	0.65*	0.55*	0.65*	**1.00**									
DFL	0.63*	0.71*	0.67*	0.40*	0.51*	0.54*	0.35*	0.63*	0.41*	0.61*	0.75*	**1.00**								
AFL	0.64*	0.77*	0.74*	0.41*	0.50*	0.53*	0.33*	0.60*	0.42*	0.59*	0.76*	0.77*	**1.00**							
PL	0.45*	0.54*	0.48*	0.27*	0.45*	0.25*	0.11	0.37*	0.26*	0.49*	0.55*	0.52*	0.52*	**1.00**						
PVL	0.38*	0.45*	0.42*	0.33*	0.39*	0.20*	0.02	0.22*	0.17*	0.40*	0.42*	0.25*	0.35*	0.48*	**1.00**					
CPL	0.18*	0.32*	0.26*	0.27*	0.27*	0.28*	0.05	0.22*	0.29*	0.25*	0.34*	0.26*	0.36*	0.24*	0.23*	**1.00**				
CPD	0.15*	0.48*	0.41*	0.16	0.19	0.13*	-0.03	0.21*	0.12*	0.17*	0.29*	0.23*	0.35*	0.27*	0.22*	0.28*	**1.00**			
D	-0.02	-0.05	-0.07	-0.07	0.07	0.08	0.07	-0.02	0.11	0.05	0.05	0.06	0.07	0.00	-0.05	0.02	0.00	**1.00**		
A	-0.04	-0.15	-0.12	-0.14*	-0.05	0.03	0.05	0.00	0.13	0.03	-0.03	0.13*	-0.04	-0.14*	-0.30*	-0.10	-0.08	0.40	**1.00**	
P	0.13*	0.08	0.09	-0.10	-0.14*	0.09	-0.05	0.12	-0.24	0.03	0.01	0.01	0.04	0.08	0.06	-0.11	0.08	-0.14*	-0.03	**1.00**

*: significant ; TW : total weight ; TS :total length ; SL : standard length ; BD : body depth ; SnL :snout length ; ED : eye diameter ; PDL : predorsal length ; PPL : prepectoral length ; PPvL : prepelvic length ; PAL : preanal length ; DFL : dorsal fin base length ; AFL : anal fin base length; PL: pectoral fin length; PVL: pelvic fin length; CPL: caudal peduncle length; CPD: caudal peduncle depth; D: dorsal-fin rays count; A: anal fin rays count; P: pectoral fin rays count.

3.5 Multivariate analysis

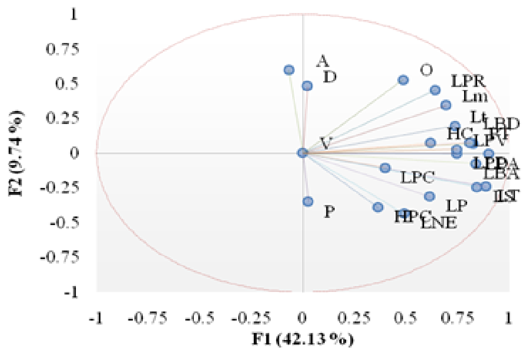


Figure 4: Distribution of *Clarias jaensis* variables on factorial plan

Dendrogram of *C. jaensis* populations

Figure 5 shows the dendrogram of *Clarias jaensis* populations

The dendrogram generated with all the individuals revealed the presence of 3 morphotypes.

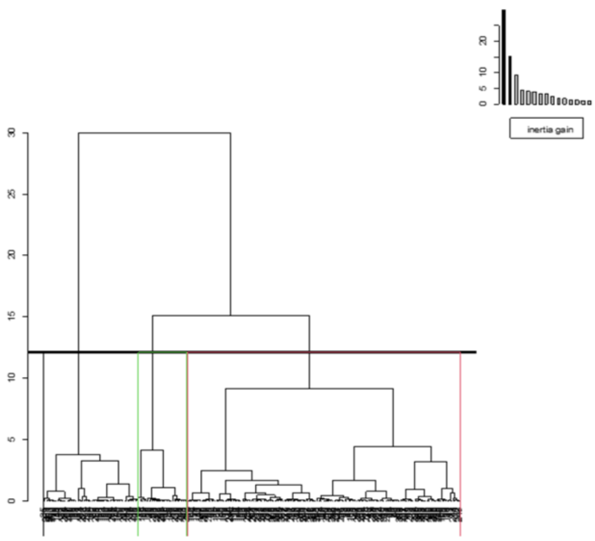


Figure 5: Dendrogram of *C. jaensis* populations

4. Discussion

Morphobiometric analysis of an animal species is a useful tool for describing variability within and between populations [20]. It has therefore been used to characterise several catfish species [21, 22, 23, 24, 25]. Based on a phaneroptic description carried out on *Clarias jaensis* in several sites in Cameroon, a colour variability of the back and flanks (brown, black and marbled) emerged. The same observations were made in the Nkam River by Geneva *et al.* (2019). In this study, brown individuals predominated black and marbled individuals. The colour variability found in the different sites indicates that there is genetic diversity within the *Clarias jaensis* population. In fact, as with other species, fish can have natural genetic variation that can result in different colours or patterns. The heaviest individuals were found in the Mfouri River, while the highest coefficient of variation for total weight was observed in the Magam River. This means that the variation around the mean was greater, which indicates a high degree of variability among individuals in this population.

Total weight was significantly higher in males than in females. This result contradicts the findings of Abanikannda *et al.* [26], who reported no significant difference between males and females in the *Clarias gariepinus* samples used in their study. This difference could be due to the population studied and the species. The authors used samples from the farm in their study.

Of the sixteen (16) measurements used in this study, 8 allowed significant differentiation between the different populations. Only head length (HL), snout length (SnL), eye diameter (ED), prepelvic length (PPvL), pectoral fin length (PL), pelvic fin length (PVL), body depth (BD) and caudal peduncle depth (CPD) varied significantly between sites. The significant variation in these metrics may be due to environmental variation, particularly temperature, food availability and water hardness. The highest total length and standard length were found in individuals from the Nyong River. Reduced fishing pressure would explain the presence of large individuals at this site. Many authors have used biometric measurements such as total length, eye diameter, predorsal length, etc. and measurements expressed as a percentage of the standard length are appropriate for characterising or describing fish species. The results of [24] on samples of *Clarias jaensis* from the Nkam River showed that the length of the base of the dorsal fin (DFL) was 65.13±1.35 %SL, anal fin length (AFL) 46.73±1. 35%SL, predorsal length (PDL) 34.41±0.79%SL, prepectoral length (PPL) 19.36±0.95%SL, prepelvic length (PPvL) 43.52±1.29%SL, preanal length (PAL) 48.26±1.00%SL and standard length (SL) 26.48±4.76. These results, although comparable to those of the present study (DFL=65.68±7.12; AFL=48.77±4.60; PDL=34.56±3.88; PPL=17.78±3.18; PPvL=41.48±5.88; PAL=51.02±4.28; SL=35.01±4.36), are still lower. The availability of food resources and the variability of environmental conditions from one site to another could explain these differences. The coefficients of variation (CV) of the male population were relatively high for total length, head length, snout length, dorsal fin base length, eye diameter, caudal peduncle length and caudal peduncle depth. Females, on the other hand, had high CVs for standard, predorsal, prepectoral, prepelvic, preanal, pectoral, pelvic, anal fin base length and body depth. The lowest coefficient of variation value observed in the male population was 11.03% for dorsal fin base length, while the female recorded 8.63% for preanal length. The results of this study show that total, standard, snout and prepelvic lengths were significantly higher in males, while, body and caudal peduncle depth were significantly higher in females. In general, the results for the different morphometric traits (except body depth, predorsal length, pelvic fin length and caudal peduncle length and depth) of *Clarias jaensis* showed that males were larger than females. This same observation of sexual dimorphism based on morphometric traits was reported in an experimental population of *Clarias gariepinus* by Abanikannda *et al.* [26].

In this study, several meristic counts were also considered and the results showed that the number of soft fin rays in anal fin (A) and the number of soft fin rays in pectoral fin (P) varied significantly ($p<0.05$) between sites. The number of soft fin rays in anal fin was higher in individuals from the Mfouri River (61.57±2.11) than in individuals from the Nkam River (58.82±3.62), while the number of soft fin rays in pectoral fin was significantly ($p<0.05$) higher in individuals from the Mfouri River (10.40±0.50) and lower in individuals from the Magam River (9.77±0.77). This significant difference observed for these traits reveals the heterogeneity of the populations studied. This heterogeneity could be due to environmental adaptation or genetic variation. It has been established that meristic traits are independent of fish size; consequently, they should not change during growth [27]. In their studies, Geneva *et al.* [24] observed 61-86 rays on the dorsal fin (D), 53-65 rays on the anal fin (A). Teugels [28] also described the number of rays on the dorsal fin (70-86) and the number of rays on the anal fin (54-71). These results are comparable with the results of this study (D=67-88; A=53-67), although there are slight variations.

Biometric traits were significant ($p<0.05$) and positively correlated with total weight. However, preanal length (PAL) and total length (TL) were positively and strongly correlated with total weight. This relationship shows that the longer the fish grows (PAL and TL), the better it grows in weight. It is important to know the correlations between the traits to either predict the changes induced in the other traits during the selection of the target trait, to select the target trait indirectly by measuring another trait, or finally to know if it is possible to select two traits simultaneously or not. Standard length (SL), head length (HL), snout length (SnL), predorsal length (PDL), prepelvic length (PPvL), dorsal fin base length (DFL) and anal fin base length (AFL) were positively and moderately correlated with total weight. Prepectoral length (PPL), pectoral fin length (PL), pelvic fin length (PVL), caudal peduncle length (CPL), caudal peduncle depth (CPD) and eye diameter (ED) were positively and weakly correlated with total weight. For meristic counts, the number of soft fin rays in dorsal fin (D) and the number of soft fin rays in anal fin (A) were negatively and weakly correlated with total weight, while the number of soft fin rays in pectoral fin (P) was significantly ($p<0.05$) and weakly correlated with total weight. Principal Component Analysis (PCA) and Hierarchical Ascending Classification (HAC) integrating biometric and meristic data in this study revealed the presence of three morphotypes.

5. Conclusion

This study describes the morphological variability of natural populations of *C. jaensis* in Cameroon. The results show that the colouration of the back region and flanks of *C. jaensis* varies from one site to another. Individuals with brown backs and flanks are more common in the Sanaga River, while individuals with black back; flanks and individuals with marbled backs and flanks are more common in the Magam and Mfouri Rivers. The largest specimens were found in the Mfouri River, while the smallest specimens were found in the Sanaga, Nkam and Nyong Rivers. Males were significantly larger than females. 37.5% of biometric characteristics varied significantly between sexes, while 50% varied between sites. Biometric traits were significantly and positively correlated with total weight, while meristic traits were weakly correlated with total weight. The population dendrogram showed the presence of three morphotypes.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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