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Phenotypic characteristics of native edible snails *Achatina fulica* and *Archachatina marginata* in equatorial region of Cameroon

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Abstract

Between February and May 2019, in the equatorial forest urbanized area of Cameroon (Mfoundi), a study was conducted and aimed to contribute on a better understanding of the biodiversity of edible snails for their genetic improvement and conservation. A total of 693 adult snails of two species: *Archachatina marginata* and *Achatina fulica* were collected in the various localities (Odza, Mbankolo, Biyem-assi, Nyom, Nkolbisson and Simbok). Information about biometric morpho characters was collected using a survey sheet, an electronic scale of 7000g capacity with accuracy of plus or minus 1g, a sliding foot with an accuracy of plus or minus 0.01 millimeter. A digital camera will be used for the subsequent morphological assessment of the animals. Results revealed significant influence of locality on all the morphobiometric characteristics. The shell color of *A. marginata* was black with yellowish stripes and the red tip was the most frequent (62.85%); while for the species *A. fulica* it was brown with white stripes and white tip (76.09%). The most common color of the foot in *A. marginata* was brown with white traces (41.70%) and in *A. fulica*, it was black (82.50%). The number of shell turns in *A. marginata* was higher in the localities of Mbankolo (5.36±0.12) and Odza (5.38±0.05) while in *A. fulica* it was higher in the locality of Simbok (7.41±0.49). Concerning body measurements (in mm), the total body length of *A. marginata* was higher in Nkolbisson (88.10±1.30) and that of *A. fulica* was greater in Simbok (112.25±12.16). The live weight (g) of *A. marginata* was higher in Mbankolo (70±0.00) on the other hand, that of *A. fulica* was higher in Simbok (80±0.02) and Nyom (80±0.12). The diversity observed suggests that edible snails constitutes rich natural genetic resources enough variability to envisage genetic improvement and develop preservation schemes for these snails mostly collected from wild.

Keywords: Phenotype, edible snails, metrics, urban area, equatorial forest, Cameroon

Introduction

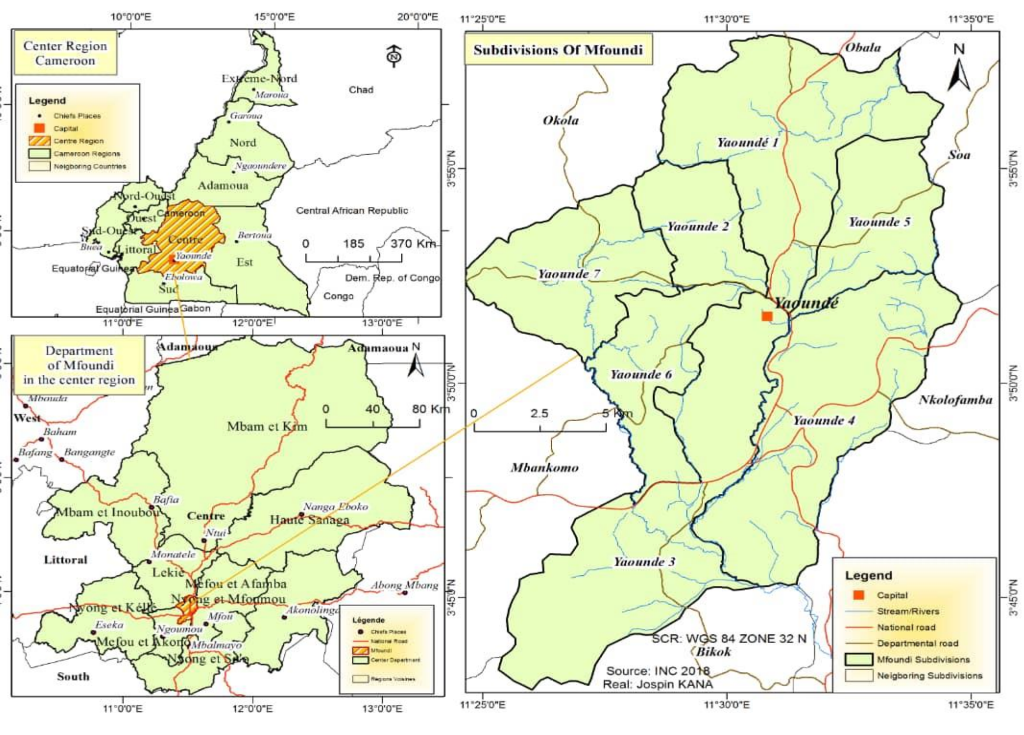
Communities in tropical Africa have developed a diversity of food systems based on collection of various biological resources. Among them, snails are exploited in all rainy African environment. It has been documented that the giant African snail has several attributes besides nutritive values. Its husbandry seems well established in West Africa. Its meat is rich in minerals (iron and calcium), and, compared to other protein sources (like poultry and pork), it is low in fat and cholesterol. The exploitation is mostly based on seasonal harvesting, mainly from wild. Because of habitats' destruction and uncontrolled collection, natural stocks are under threats (Zongo, 1996; Bouye et al 2017). Thus, snails' husbandry becomes an important opportunity though genetics of these resources have not yet been unraveled (Cobbinah et al 2008). The guidelines on phenotypic characterization established by FAO are in line with strategic priority 1 of the global action plan devoted to the characterization, inventory and monitoring of trends and associated risks (FAO, 2013). This action plan for zoo genetic resources (FAO, 2017) emphasizes that a good understanding of breed characteristics is necessary for decision-making in terms of development and breeding programs. There are several edible species of snails exploited in Cameroon, especially in the Equatorial coastal Cameroon region (Etchu et al 2008). *Achatina fulica* also called garden snail or crazy snail is a large snail that can be 20 cm long or more; its shell is 20 to 25 cm long and 12 cm in diameter for a live weight more than 50 g in adulthood. It has a shell with 6 to 9 turns on the adult shell. The shell is narrow conical or even pointed. It is generally reddish-brown in color with faint yellowish vertical marks but the coloration varies with environmental conditions and diet. An adult snail weighs approximately 250 g. Another species, *Archachatina marginata*, a large snail also called a giant African land snail, generally reaching a length of 20 cm and a weight of 500g is more or less farmed. *A. marginata* snails have an average size of 170 mm in adulthood in the wild (Kouadio, 2015). The shell is much less pointed than the one of *Achatina* species, its roundness being particularly accentuated in young snails. Vertical streaks, stripes, zigzag lines or spots, brown to light brown in color, on a yellow background. These snails' females (though they are all hermaphrodites) lay everyday about 2 to 5 eggs of around 5g (Hodasi, 1984).

Despites the tendencies of snails' products trade in Cameroon, there are gaps concerning genetics of edible snails in Cameroon (Nkwendem et al, 2019). Therefore, this study aims at contributing to a better understanding of the genetic diversity of snails exploited in the equatorial forest urbanized area for its genetic improvement and preservation. More specifically, the focus was to evaluate the effects of locations on morphological and biometric characteristics of snails according to the locality and the species on one hand, and on the other hand to analyze the genetic variability, structure and phylogenetic relationships of snail population.

Methodology

Survey site

The study took place between February and May 2019 in 6 localities of the Mfoundi Division (where Yaounde, the Cameroon capital city is located) , namely: Nyom in Yaoundé 1, Mbankolo in Yaoundé 2, Simbok in Yaoundé 3, Odza in Yaoundé 4, Biyem-assi in Yaoundé 6, Nkolbisson in Yaoundé 7; and the data were collected at the Nkolbisson IRAD Laboratory.



Sampling and choice of snails

The snails of were obtained from collectors in the various localities (Odza, Mbankolo, Biyem-assi, Nyom, Nkolbisson and Simbok). This sample consists of 693 adult snails of two species: *Archachatina marginata* and *Achatina fulica*. The distribution of the snails according to the localities is presented in table 2. These snails were selected according to the state of the shell, the appearance of the snail and the foot in a random manner (Hannah et al 2016) and were purchased subject to availability in the field. They were then subjected to identification by numbering using stickers (Aluko et al 2014).

Table 1. Distribution of samples according to localities

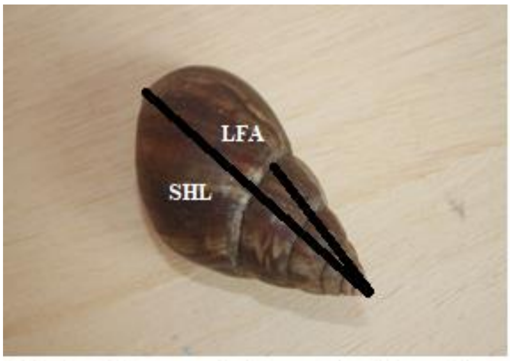
Localities	**Species**		**Total**
	A.fulica	***A.marginata***	
Nyom	63	34	**97**
Mbankolo	126	11	**137**
Odza	53	49	**102**
Biyem-assi	37	76	**113**
Simbok	32	95	**127**
Nkolbisson	32	85	**117**
All localities	**343**	**350**	**693**

Morphological data collection tools

The information concerning the morphological characters were collected using a survey form, an electronic scale with a capacity of 7000g with an accuracy of 1g, a caliper with an accuracy of 0.01 mm (FAO, 2011; 2012). A digital camera was used for the subsequent morphological appreciation of the animals. In this study, the determination of the shell color and the color of the foot were carried out by direct observation of the snails (Hannah et al 2016). Color patterns considered were as follows: b =black; B =brown; b_YS_BT= black yellowish stripe with brown tip; b_WS= black white stripe; b_YS_PT =black yellowish stripe pink tip; b_YS_RT= black yellowish stripe with red tip; b_YS_YT= black yellowish stripe with yellow tip; B_GWS_WT =brown greenish white black stripe with white tip; B_WS= brown white stripe; B_WS_WT =brown whitish stripe with white tip; Gb =Greyish black and W_bS =White black stripe.

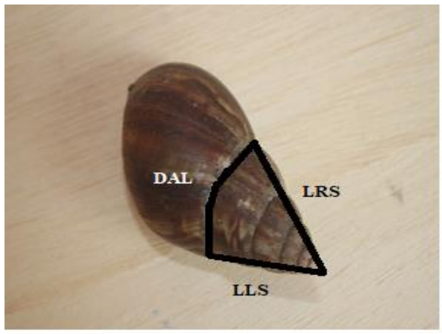
Biometric features

The body measurements were carried out using a caliper of more or less 0.01mm precision. The live weight was taken using precision scale more or less 1g. In this study, the biometric morphometric measurements were made according to the model of Nkwendem et al (2019), Memel et al (2017), Okon et al (2017) and (Hannah et al 2016). The various measurements were noted as follows: APL= Length of Aperture; APW= Width of Aperture; DAL= Diagonal length from right to left of the first spiral; LFA = Length between the first spiral and Apex; LLS =Length of left side; LRS=Length of Right side; NT =Number of turns; SHL= Shell length and SHW =Shell width.



LFA: length between the first spiral and Apex; **SHL:** Shell length

Figure 1: Measurement of the total lengths of the shell and the apex at the last turn

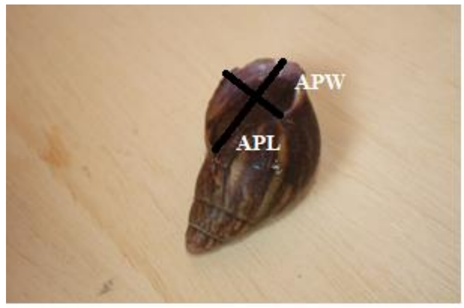


DAL: diagonal length from right to left of the first spiral; **LRS:** Length of Right side **LLS:** Length of left side

Figure 2: Measurement of the apex sides

SHW: Shell Width

Figure 3: Measuring the width of the shell



APW: Width of Aperture; **APL:** Length of Aperture

Figure 4: Measure the width and length of the shell opening

Statistical analyses

Descriptive statistics were used to describe the morphological characteristics; the Chi square (at 1%) test was used to test the association or independence between the factors (species and localities) and the qualitative characteristics; Pearson correlations were used to assess the degree and the sense of association between body measurements and live weight and the principal component analysis (PCA) based on 10 biometric characteristics was performed to assess the genetic variability of the population (FAO, 2013), the discriminant factor analysis (DFA) based on 10 body measurements was carried out to identify the characters that best discriminate snails, the dendrogram or the phylogenetic tree was designed to identify the morphotypes and the relationships between them (Roux, 2006); the analysis of variance (ANOVA) was performed to evaluate the influence of the locality on the different body measurements and live weight. When the effects were significant, Duncan's test was used to separate the mean. The data were processed using SPSS version 21.0 and XLSTAT-Pro 2014 software.

Results

The Chi square test showed that the locality had an influence on the color of the shell of *A.fulica* and *A.marginata* ($p < 0.01$)

Table 2. Distribution of the shell color of *A.fulica* and *A.marginata* according to localities in equatorial forest region of Cameroon

Shell color *species*	**Localities**												**Total**	
	Nyom		**Mbankolo**		**Odza**		**Biyem-assi**		**Simbok**		**Nkolbisson**			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
A.marginata														
b_YS_YT	6	1.71	0	0.00	3	0.85	5	1.42	2	0.56	3	0.85	19	5.42
b_YS_BT	0	0.00	2	0.57	0	0.00	9	2.57	3	0.85	7	2.00	21	6 .00
b_YS_RT	28	8.00	9	2.57	23	6.57	56	15.99	52	14.85	52	14.85	220	62.85
b_YS_PT	0	0.00	0	0.00	23	6.57	6	1.71	38	10.85	23	6.56	90	25.71
Total	**34**	**9.71**	**11**	**3.14**	**49**	**14**	**76**	**21.71**	**95**	**27.14**	**85**	**2.42**	**350**	**100**
p Value	0.00													
X2	**													
A.fulica														
B_WS_WT	63	18.36	74	21.57	23	6.70	37	10.78	32	9.32	32	9.32	261	76.09
B_GWS_WT	0	0.00	52	15.16	30	8.74	0	0.00	0	0.00	0	0.00	82	23.90
Total	**63**	**18.36**	**126**	**36.73**	**53**	**15.45**	**37**	**10.78**	**32**	**9.32**	**32**	**9.32**	**343**	**100**
p Value	0.00													
X2	**													

n: Number of individuals per locality; %: Percentage; b_YS_YT: black yellowish stripe with yellow tip; b_YS_BT: black yellowish stripe with brown tip; b_YS_PT: black yellowish stripe pink tip; b_YS_RT: black yellowish stripe with red tip. B_GWS_WT: brown greenish white black stripe with white tip. B_WS_WT: brown whitish stripe with white tip

Table 2 shows that regardless of the locality, for *A. marginata*, the following colors, black, yellowish stripe with red tip is the most frequent; this pattern is more observed in Biyem-assi; for *A.fulica*, the brown greenish white black stripe with white tip is the most frequent. It is more represented in the locality of Mbankolo and Nyom.

Figures 5 and 6 show the color of the shell of A. *marginata* and A. *fulica.*

b_YS_YT: black yellowish stripe with yellow tip; b_YS_BT: black yellowish stripe with brown tip; b_YS_PT: black yellowish stripe pink tip; b_YS_RT: black yellowish stripe with red tip

Figure 5: Color of the shell of *A. marginata* in the equatorial region of Cameroon

B_GWS_WT: brown greenish white black stripe with white tip, B_WS_WT: brown whitish stripe with white tip

Figure 6: Color of the shell of *A. fulica* in the equatorial region of Cameroon

Table 3. Distribution of the foot color of *A.fulica* and *A.marginata* according to the locality in equatorial forest region of Cameroon

Foot color *species*	**Localities**												**Total**	
	Nyom		**Mbankolo**		**Odza**		**Biyem-assi**		**Simbok**		**Nkolbisson**			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
A.marginata														
B-WS	12	3.42	12	3.42	32	9.13	40	11.42	12	3.42	47	13.42	146	41.70
W_Bs	3	0.85	3	0.85	10	2.84	15	4.27	40	11.42	11	3.14	87	24.75
b_WS	19	5.42	19	5.42	7	2.00	21	5.99	43	12.28	27	7.70	117	33.42
Total	**34**	**9.71**	**11**	**3.14**	**49**	**14**	**76**	**21.71**	**95**	**27.14**	**85**	**24.28**	**350**	**100**
P value	**0.00**													
X2	**													
A.fulica														
Gb	11	3.20	25	7.28	0	0.00	0	0.00	0	0.00	3	0.87	39	11.37
b	42	12.24	90	26.23	53	15.45	37	10.78	32	9.32	29	8.45	283	82.50
B	10	2.91	11	3.20	0	0.00	0	0.00	0	0.00	0	0.00	21	6.12
Total	**63**	**18.36**	**126**	**36.73**	**53**	**15.45**	**37**	**10.78**	**32**	**9.32**	**32**	**9.32**	**343**	**100**
P value	**0.00**													
X2	**													

*n: Number of individuals per locality; %: Percentage; **: significant at α = 1%; W_bS: white black stripe; B: brown; B_WS: brown white stripe; b: black; b_WS: black white stripe; Gb: greyish black*

Table 3 shows that regardless of the locality, for *A. marginata*, the brown coloration, white stripe is the most frequent; it is more widespread in Nkolbisson (13.42%); for *A.fulica*, black coloration is the most frequent (82.50%). It is more present in the locality of Mbankolo (26.23%). Figure 7 and 8 shows the foot color of *A.marginata* and *A.fulica.*

W_bS: white black stripe; B_WS: brown white stripe; b_WS: black white stripe

Figure 7: Foot color of *A. marginata* in the equatorial region

B: brown; b: black; Gb: greyish black

Figure 8: Foot color of *A.fulica* in in equatorial region

Table 4. Biometric parameters (NT, SHW, APW) by locality of A. marginata and A. fulica in equatorial forest region of Cameroon

	NT			**SHW**		**APW**	
Species	n	$\bar{X} \pm$ E.S	**cv(%)**	$\bar{X} \pm$ E.S	**cv(%)**	$\bar{X} \pm$ E.S	**cv(%)**
A.marginata							
Nyom	34	5.20 ± 0.07^{bc}	7.70	51.93 ± 1.25^{c}	27.14	36.69 ± 1.18^{cd}	33.43
Mbankolo	11	5.36 ± 0.12^{c}	8.90	47.87 ± 2.21^{b}	13.52	34.51 ± 2.07^{bcd}	15.08
Odza	49	5.38 ± 0.05^{c}	0.10	43.79 ± 1.04^{a}	9.73	32.49 ± 0.98^{ab}	14.03
Biyem-assi	76	5.06 ± 0.04^{ab}	8.60	44.60 ± 0.84^{ab}	11.62	29.73 ± 0.79^{a}	20.21
Simbok	95	5.23 ± 0.04^{bc}	8.00	47.93 ± 0.75^{b}	14.01	33.65 ± 0.70^{bc}	16.84
Nkolbisson	85	4.89 ± 0.04^{a}	6.20	52.94 ± 0.79^{c}	13.07	37.36 ± 0.74^{d}	18.58
p Value	0.00						
Total	**350**	**5.19±0.02**	**8.60**	**48.18±0.51**	**16.74**	**34.07±0.48**	**21.78**
A.fulica							
Nyom	63	7.00 ± 0.18^{b}	2.5	52.00 ± 10.11^{c}	19.29	35.41 ± 8.28^{c}	23.2
Mbankolo	126	7.00 ± 0.00^{b}	0	41.13 ± 5.18^{a}	12.55	27.65 ± 4.51^{a}	16.27
Odza	53	7.00 ± 0.27^{b}	3.9	44.96 ± 5.82^{b}	12.83	31.94 ± 5.35^{b}	16.6
Biyem-assi	37	6.84 ± 0.50^{a}	7.2	47.34 ± 4.92^{b}	10.25	29.93 ± 5.91^{ab}	19.48
Simbok	32	7.41 ± 0.49^{c}	6.6	61.06 ± 6.18^{d}	9.97	46.19 ± 6.19^{d}	13.2
Nkolbisson	32	6.81 ± 0.47^{a}	6.8	50.48 ± 5.59^{c}	10.89	34.39 ± 4.51^{c}	12.9
p Value	0.00						
Total	**343**	**7.00±0.32**	**4.6**	**47.12±8.94**	**18.94**	**32.34±7.88**	**24.32**

a. b. c. df in the same column. the values bearing the same letter are not significantly different ($p > 0.05$); $\bar{X} \pm$ ES: average plus or minus standard error; CV: coefficient of variation; SHW: shell width. APW: Width of Aperture . NT: Number of Turns

Table 5. Biometric parameters (SHL, LLS, LRS) by locality of A. marginata and A. fulica in equatorial forest region of Cameroon

Species	**SHL**			**LLS**		**LRS**	
Localities	n	$\bar{X}$ ± E.S	**CV(%)**	$\bar{X}$ ± E.S	**CV(%)**	$\bar{X}$ ± E.S	**CV(%)**
A.marginata							
Nyom	34	86.58±2.05^{bc}	20.90	30.63±2.36^{ab}	38.51	42.69±1.28^{b}	30.57
Mbankolo	11	80.67±3.61^{ab}	16.90	24.18±4.15^{ab}	13.15	37.31±2.26^{a}	14.70
Odza	49	76.20±1.71^{a}	8.90	24.60±1.96^{ab}	15.53	37.35±1.07^{a}	13.11
Biyem-assi	76	75.63±1.37^{a}	10.90	23.68±1.58^{a}	18.37	33.96±0.86^{a}	17.28
Simbok	95	81.03±1.22^{ab}	16.10	28.01±1.41^{ab}	85.36	37.19±0.77^{a}	19.37
Nkolbisson	85	88.10±1.30^{c}	13.60	31.25±1.49^{b}	22.03	42.50±0.81^{b}	17.18
p Value	0.00						
Total	**350**	**81.37±0.83**	**15.80**	**27.06±0.96**	**50.86**	**38.50±0.52**	**22.3**
A.fulica							
Nyom	63	99.28±20.37^{d}	20.3	44.11±12.06^{c}	27.13	57.16±13.90^{e}	24.12
Mbankolo	126	82.62±10.36^{a}	12.4	32.33±5.85^{a}	18.01	44.64±7.34^{a}	16.39
Odza	53	87.03±11.18^{ab}	12.7	35.02±6.33^{ab}	17.9	48.89±7.88^{c}	15.97
Biyem-assi	37	91.85±9.60^{bc}	10.3	37.72±8.08^{b}	21.13	47.62±8.31^{ab}	17.21
Simbok	32	112.25±12.16^{e}	10.6	50.01±5.24^{d}	10.31	66.04±7.30^{f}	10.89
Nkolbisson	32	96.05±12.78^{cd}	13	40.97±6.91^{c}	16.61	53.07±8.55^{d}	15.85
p Value	0.00						
Total	**343**	**91.38±16.02**	**17.5**	**37.95±9.64**	**25.38**	**50.70±11.32**	**22.3**

a. b. c. d. e. f in the same column. the values bearing the same letter are not significantly different (p> 0.05); $\bar{X}$ ± ES: average plus or minus standard error; CV: coefficient of variation; SHL : shell length. LRS : Length of Right side . LLS: Length of left side.

Table 6. Biometric parameters (LFA, APW, DAL, live weight) by locality of A. marginata and A. fulica in equatorial forest region of Cameroon

Species	**LFA**			**APW**		**DAL**		live weight **(g)**	
	n	$\bar{X}$ ± E.S	**CV(%)**	$\bar{X}$ ± E.S	**CV(%)**	$\bar{X}$ ± E.S	**CV(%)**	$\bar{X}$ ± E.S	**CV(%)**
A.marginata									
Nyom	34	34.93±1.14^{b}	35.52	49.18±1.11^{ab}	12.26	30.15±0.89^{a}	15.10	70±0.005^{bc}	44.76
Mbankolo	11	28.57±2.00^{a}	13.86	53.52±1.95^{c}	11.51	31.61±1.56^{ab}	14.24	70±0.008^{c}	46.22
Odza	49	29.37±0.95^{a}	14.36	46.79±0.92^{a}	10.14	30.83±0.74^{a}	12.10	50±0.004^{a}	28.22
Biyem-assi	76	28.39±0.76^{a}	16.69	48.47±0.74^{a}	10.45	30.26±0.59^{a}	14.29	50±0.003^{a}	34.89
Simbok	95	30.38±0.68^{a}	19.97	52.03±0.66^{bc}	13.82	33.78±0.53^{b}	16.31	50±0.003^{ab}	50.71
Nkolbisson	85	36.23±0.72^{b}	18.36	56.74±0.70^{d}	13.33	38.03±0.56^{c}	16.57	70±0.003^{bc}	32.82
p Value	0.00								
Total	**350**	**31.31±0.46**	**23.10**	**51.12±0.454**	**14.27**	**32.44±0.364**	**18.05**	**60±0.002**	**43.08**
A.fulica									
Nyom	63	48.04±12.66^{b}	26.1	53.71±9.32^{d}	17.21	39.65±8.99^{d}	22.51	80±0.12^{b}	136.1
Mbankolo	126	36.21±6.10^{a}	16.79	44.53±4.93^{a}	11.03	30.26±4.39^{a}	14.46	50±0.01^{a}	33.47
Odza	53	40.12±8.05^{b}	19.89	47.19±5.46^{b}	11.46	33.47±4.89^{b}	14.48	50±0.01^{a}	28.22
Biyem-assi	37	41.49±7.90^{b}	18.78	50.17±5.15^{c}	10.13	34.67±6.34^{b}	18.05	50±0.01^{a}	28.63
Simbok	32	58.76±6.54^{d}	10.96	64.77±7.27^{e}	11.05	48.37±4.00^{e}	8.14	50±0.02^{b}	30.69
Nkolbisson	32	46.05±7.49^{b}	16.01	52.46±6.00^{cd}	11.26	38.92±4.77^{c}	12.07	60±0.02^{a}	31.43
p Value	0.00								
Total	**343**	**42.58±10.73**	**25.1**	**49.86±8.70**	**17.43**	**35.45±7.98**	**22.48**	**60±0.05**	**83.8**

a. b. c. d. e. f in the same column. the values bearing the same letter are not significantly different (p> 0.05); $\bar{X}$ ± ES: average plus or minus standard error; CV: coefficient of variation; APW :Width of Aperture . DAL : diagonal length from right to left of the first spiral and LFA: length between the first spiral and Apex.

Table 7. Pearson's Correlation between weight A. fulica and A. marginata measurements in the equatorial region

Variables	live weight	NT	SHL	LFA	LRS	LLS	SHW	APW	APL	DAL
live weight	**-**	**0.2**	**0.47**	**0.37**	**0.42**	**0.38**	**0.31**	**0.27**	**0.34**	**0.3**
NT	**0.38**	**-**	**0.37**	**0.36**	**0.37**	**0.34**	**0.28**	**0.32**	**0.31**	**0.3**
SHL	**0.83**	**0.35**	**-**	**0.92**	**0.95**	**0.92**	**0.86**	**0.79**	**0.87**	**0.86**
LFA	**0.61**	**0.23**	**0.87**	**-**	**0.95**	**0.94**	**0.9**	**0.87**	**0.9**	**0.92**
LRS	**0.66**	**0.32**	**0.9**	**0.94**	**-**	**0.94**	**0.88**	**0.84**	**0.87**	**0.9**
LLS	**0.26**	**0.06**	**0.4**	**0.44**	**0.44**	**-**	**0.88**	**0.83**	**0.87**	**0.89**
SHW	**0.65**	**0.17**	**0.87**	**0.89**	**0.88**	**0.41**	**-**	**0.92**	**0.95**	**0.95**
APW	**0.59**	**0.21**	**0.83**	**0.86**	**0.9**	**0.44**	**0.9**	**-**	**0.92**	**0.92**
APL	**0.64**	**0.21**	**0.78**	**0.68**	**0.71**	**0.3**	**0.75**	**0.74**	**-**	**0.94**
DAL	**0.57**	**0.21**	**0.77**	**0.75**	**0.76**	**0.34**	**0.76**	**0.76**	**0.87**	**-**

The correlations of A marginata are under the diagonal while those of A fulica are above the diagonal. *SHW: shell width. APW: Width of Aperture . NT: Number of Turns . SHL : shell length. LRS : Length of Right side . LLS: Length of left side. APW :Width of Aperture . DAL : diagonal length from right to left of the first spiral and LFA: length between the first spiral and Apex. The bolden values are different from 0 when alpha is equal to 0.05.*

Table 7 shows that for *A. fulica* the correlations between live weight and measurements are not important and range from 0.20 to 0.47. The highest coefficient of correlations is observed between LRS and LFA, between SHL and LRS, APL and SHW, DAL and SHW (r - 0.95). On the other hand, for *A. marginata*, the correlations between live weight and measurements range from 0.26 to 0.83. The highest correlation coefficient is observed between the LRS and the LFA (r - 0.94). These correlations reflect variability in its edible species and the obligations to take them into account during their genetic improvement.

Discussion

The diverse colors of the shell opening observed in the edible snail populations of the equatorial region surveyed in this study indicate that there is genetic variability. These colors would be influenced by the effects of genes, the action of the environment and the different interactions between genes and environment.

The black coloration with yellowish stripes and red tip observed in *A.marginata* is different of observations made by Nkwendem et al (2019) in the Moungo (Cameroon) and those of Mbetid et al (2006) in the Central African Republic which had shown that the black color with whitish stripes was the most observed. On the same line, the brown color with white stripes observed in *A.marginata* is not what Nkwendem et al (2019) in the Moungo (Cameroon) who found that the brown color was predominant. The brown color with white stripes plus white tip observed in *A.fulica* is also mentioned by Nkwendem et al (2019) in the Moungo (Cameroon), Hannah et al (2016) in Nigeria and Mbetid et al (2006) in the Central African Republic. It appears also that color pattern observed in *A.fulica* (black) corroborates with that found by (Nkwendem et al 2019). These edible snails display interesting phenotypic variation across humid equatorial Africa.

For body measurements, the significant variation between localities would be the result of the effect of the genes, the environment and the interaction between the genotype and the environment. The mean values of the length of the right side and the length of the left side obtained are greater than those observed by Memel et al (2017) who found 33.8 mm and 24.3 mm respectively for the length of the right side and the length of the left side of *A. ventocida*, a close snail species. These are also superior to the results found by Nkewndem et al (2019) who reported that for *A. marginata*, the length of the left and right side is 23.18 mm and 32.78 mm respectively and for *A. fulica* it is 28.56 mm and 39.09 mm. These variations are probably due to environmental conditions, the genetic material studied, and the food resources available (CUVC, 2018) or the effect of genes (Okon et al, 2012).

Concerning the width of the shell opening, the average value in *A. marginata* is 34.07 mm and in *A.fulica* it is 32.34 mm. These results are superior to those reported by Aluko et al (2014) which was 23.80 mm for *A.*

marginata. Also to those Okon et al (2012) who found 29.90 mm and 28.50 mm for *A. marginata* and *A.fulica* respectively in the snails population in Nigeria. These are also superior to those of Okon et al (2017) here this measurement was 10.60 mm for *A.fulica*. Likewise, Hannah et al (2016) in Nigeria found that this measurement is 29.90 mm for *A.fulica* and 31.84 mm *A.marginata*. Likewise, Nkewndem et al (2019) found that this measurement is 21.06 mm for *A.marginata* and 18.62 mm *A.fulica*.

As for the length of the shell opening, the average value in *A.marginata* is 56.12 mm and in *A.fulica* it is 49.86 mm. These results are superior to those reported by Aluko et al (2014) which was 50.70 mm for *A. marginata*. Also to those Okon et al (2012) who found 53.00 mm and 50.40 mm respectively for *A.marginata* and *A.fulica* in the snail population in Nigeria. These are also superior to those of Okon et al (2017) where this value was 32.40 mm for *A.fulica*. Likewise, Hannah et al (2016) in Nigeria found that this measurement is 52.91 mm for *A.fulica* and 53.68 mm *A.marginata*. Likewise, Nkewndem et al (2019) reported that this measurement was 41.26 mm for *A.marginata* and 37.59 mm *A.fulica*. This could be explained by environmental and specifically feeding conditions as well as the effect of genes.

The average weight of *A. marginata* is 60g and 60g for *A.fulica.* These results are lower than those found by Hannah et al (2014), who found that *A.fulica* had a live weight of 137.5 g and *A.marginata* had a live weight of 135.2 g. Similarly, for Okon et al (2012) who obtained a live weight of 115.80g for *A.marginata* and 138.60g for *A.fulica*. However, these results are superior to those of Nkenwdem et al (2019) who found a weight of 37.69 g for *A.marginata* and 33.59g for *A.fulica*. When raised in an artificial environment, Olesugun et al (2011) in Nigeria obtained 111.11 g for *A. marginata* subjected to a diet based on soy milk and cassava sievate at 30%, the same results were obtained by Babalola et al (2016) in immature species of *A. marginata*, whereas, Aman et al (2011) in Ivory Coast obtained 183.1 g for *A.marginata* subjected to a diet based on snail powder at 10 %, Kouassi et al (2016) in Ivory Coast obtained 358g for *A.marginata* subjected to a diet based on compost plus calcium carbonate at 30%.

Conclusion

The shell colors of edible snails encountered in the equatorial region urbanized area are black plus yellowish stripes and red tips more encountered in *A. marginata* and more widespread in some sites; for *A.fulica*, the whitish white stripe brown coloring is the most widespread in some sites. The most widespread color of the foot was brown plus white traces for *A.marginata* and the black color is more frequent for *A.fulica*. The locality significantly influenced all morphological and biometric characteristics. As for *A.fulica's* correlations between bodyweight and body measurements are weak. On the other hand, for *A. marginata*, the correlations between bodyweight and body measurements are average. The phenotypic diversity observed in *A. marginata* and *A. fulica* populations of the equatorial region suggests their adaptation to environmental conditions. Thus, they constitute natural genetic resources which the variability opens opportunities for further domestication actions, genetic improvement and surely preservation to harness their potentials for local food systems.

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Author’s Contributions

Meutchieye designed and monitored the whole study; **Tsayo and Etchu** the data collection and primary data analysis; contributed to statistical analyses and paper write-up; **Ngoula**, **Djiotsa** and **Nkewndem,** contributed each to the paper write-up at different levels.

Ethics

Authors declare that there are ethical issues that may arise after the publication of this manuscript.

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