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MANDIBLE IN THE AFRICAN RODENT *Cricetomys gambianus* (WATERHOUSE, 1840) IS LOW SEXUALLY DIMORPHIC

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ABSTRACT

The aim of this study was to compare mandible forms in adult males and females of African giant rat (or Gambian pouched rat) (*Cricetomys gambianus*Waterhouse, 1840). For this purpose, 9 lateral mandibular landmarks were analysed by means of geometric morphometrics in 12 males and 13 females. Males and females appeared poorly discriminated according to mandible shape analysis, being major differences localized on mental foramen position and on alveolar height at first premolar. This fact suggested to be functionally related to diet preference and pattern of food handling. The results obtained from this research can be useful in rodent ration formulation and captive species management. This is the first time to the best of our knowledge that geometric morphometric comparison of mandible morphology in this African rodent is described.

KEYWORDS: African giant rat, comparative morphometry, Gambian pouched rat, sex assessment, *Nesomyidae*

INTRODUCTION

African giant rat (*Cricetomys gambianus*, Waterhouse, 1840), also known as Gambian pouched rat, is among the largest muroids in the world (Allen, 1877). It belongs to the subfamily *Cricetinae*, family *Nesomyidae*. This species is found in central Africa, in regions south of the Sahara desert as far south as Zululand. This includes countries such as Nigeria among others (Ajayi *et al*., 1978; Ali *et al*., 2011). The rodents inhabits a variety of habitats ranging from tropical to temperate areas and live in sub-surface interconnected warrens, in hollow trees, rock outcroppings, or burrows made by other animals (Kingdon, 1989; Ali *et al*., 2011). Males and females are usually similar in body size, with minimal sexual dimorphism, reaching maximum body weights of approximately 2.8 kg in bucks and 1.39 kg in does (Olude *et al*., 2011).

Cheek pouches exist in other families of *Rodentia*, such as the African hamster and members of the subfamily *Cricetinae* (Landry, 1970; Ryan, 1989) with omnivoral mandible architecture structured for mixed diet (Cooper, 2006). Mandibular size and shape study in*C. gambianus* is justified by observed characteristics demonstrated by the large cheek pouches in food processing; these are capable of expansion to great sizes, allowing massive transport/storage of food quantities when necessary especially in females (Ajayi, 1977).

Agood understanding of the nature and factors of expression of sexual dimorphism is fundamental for the study on its growth, development, and evolution (Rohlf, 1996; 2010). In fact, the isolation, interpretation, and quantification of data representing manifestations of sex bias traits are essential parts of skeletal analytic process. Recent related research focused on cranial characters dimorphisms without mandibles (Parés-Casanova*et al*., non published data) thereby justify the study on gender differences in form (size + shape) of their mandibles. Moreover, existing literary information on sex comparative mandible morphology of *C. gambianus*is rare despite an abundance of similar works in other rodent species. Vinogradov and Argiropulo (1941) studied the mole rat, Dursun and Tipirdamaz (1989) worked on minks, Janzen (1967) on morphometry of lagomorphs with no comparisons, Matina *et al*. (2010) on vocalization differences in wild laboratory mice (*Peromyscus californicus*), Olude *et al*. (2001) on the African giant rat, and Yazdi and Adriaens (2013) investigated *Meroines tristami and Meroines persicus*.

This study was performed using geometric morphometrics (GM) technique. GM employs the Cartesian coordinates of a set of topographically corresponding landmarks to compare the form of organisms and their organs. In two-dimensional analyses, the landmarks are usually digitized on images of organisms under study. To remove differences due to specimen orientation and position during data collection, and to separate the size and shape components, landmark configurations are first scaled to the same size, centered at their origin and rotated to minimize the distances among the corresponding landmarks (Generalized Procrustes Analysis or GPA) (Rohlf, 2010). GPA superimposes specimen landmark configurations by translating them to a common origin, scaling them to unit centroid size (the square root of the sum of squared distances of all landmarks to the centroid of the object), and rotating them according to a best-fit criterion. This procedure eliminates ''size'' as a factor (although size-related shape differences may remain) and ''shape'' can therefore be analysed separately from ''size''**.**After the GPA, each landmark configuration corresponds to a point in a curved shape space and needs to be projected in a tangent Euclidean space to perform standard multivariate statistical analyses: this process is analogous to a flat map approximation of a small region of the earth's surface. The coordinates of the tangent space provide a set of shape variables that describe only those morphological features that do not change with scale, position and orientation. To the best of our knowledge literary information on *C. gambianus* mandible morphology using 2-D geometry is scarce.

MATERIALS AND METHODS

A mandible sampling of *C. gambianus* (n=25, 12 males and 13 females) was used. It comprised animals collected from south-western Nigeria between January to March and between July and October of 2014. Initial maceration procedure of harvested heads was done immediately after cervical decapitations were done according to Onar *et al*. (2001). Mandibles were posteriorly disarticulated and the two hemi-mandibles were separated. No edentulous mandible appeared in the sampling.

Pictures of the right hemi-mandibles (lateral aspect) were taken using a digital camera Canon EOS1200D (Canon Inc. Tokyo Japan) equipped with an EFS 18-58mm telephoto and Hama tripod with stabilizer. Images were taken at an aperture of 5.6, DIN of 200 and speed of 1/500. Nine type 1 landmarks were digitalized on each picture (Figure 1 and Table 1). Landmarks used in this study were primarily chosen to describe major mandibular regions, and points of particular morpho-functional interest. The *x* and *y* co-ordinates of all landmarks for the photographed views were then obtained using TpsDig, v. 2.16 software (Rohlf, 2010) and processed with MorphoJ, v. 1.06c (Klingenberg, 2011).

For the smallest shape variation around the point of tangency, the best point of tangency is the sample mean form. TpsSmall, v.1.29 software (Rohlf, 2014) was utilized in correlation evaluations between the 2D Procrustes distances and Euclidean distances in that tangent space. This correlation came close to linear for all data (r=0.999; slope, b=0.997), suggesting that tangent space was an adequate approximation to Kendall and that no specimens deviated appreciably from the linear regression line. Though the lateral view of mandibles is not a flat object, authors considered that the two-dimensional approach implies a limited loss of information, and proceeded with the morphometric analyses. Landmark coordinates were superimposed using GPA. Multivariate analyses based on Procrustes-aligned specimens were found to have higher statistical power than alternative geometric morphometric approaches (Hammer, 2001). A discriminant analysis (with a 1,000 permutation runs) was applied to detect differences between genders. Then, a Principal Component Analysis (PCA) from covariance matrix was used for analysis. PCA; a data-reduction exploratory technique summarizes the total variance in a data set by rotating it so that the principal components explain progressively smaller amounts of the total variance (Klingenberg, 2011) and their contributions. Principal component axes function as shape variables, the first of which represents the major axis of variation among the objects. A cross-validation analysis was finally used to determine how well the principal components classified both sexes.

Ethics statement

The studied species is not endangered or protected. All protocols according to the Veterinary decree 1962, animal welfare, game hunting and handling edict of the Federal Republic of Nigeria (1978) were rigorously observed.

RESULTS

There were significant gender shape differences (p=0.047). The proportion of correctly classified sex from cross-validation analysis showed an accuracy of less than 50% (Table 2). First two Principal Components in PCA explained a 74.9% of the total observed variance (PC1+PC2=55.9+19.0%) (Figure 2, Table 3) It must be acknowledged that both genders were widely distributed on the first and second plane of the PCA. Major differences were observed on mental foramen (8) and on alveola of first premolar (9) (Figure 3) which demonstrates the division of components based on relative feeding habits and other ecologic considerations observed more profound in *C. gambianus.* Mandibles with more negative scores are concave and shorter with more effective leverage moments arm for the *temporalis* and *masseter* muscles (Figueirido *et al*., 2009) while the less concave with less negative score values are comparatively less adapted for such mandibular functions as seen in this species mandibles

DISCUSSION

Our comparative mandible shape analysis detected slight shape differences between the sexes of African giant pouched rat or Gambian pouched rat (*Cricetomys gambianus*). The anatomical diversity of mandibulo-dental complexes of mammals is large and probably reflects some adaptation to diet and fauna quality (Vinogradov *et al*., 1941; Kingdon, 1989), although there has been reports of diet and morphology non-correlations (Langenbach and Eidjen, 2002; Samuel, 2009). The relative development (size, strength, and angulation) of the muscles of mastication is known to influence the expression of mandibular dimorphism as masticatory forces exerted are different for males and females, as reported in humans (Mulder *et al*., 2006). Similar biologic trends have been reported in other rodents (Pergams and Lawler, 2009;Yazdi and Adriaens, 2013), hence mandible condyle and ramus would be the most sexually dimorphic structures as they are sites associated with the greatest morphological changes in size and remodeling during growth (Gibson and Wagner, 2000). This is not the case in *C. gambianus* where, due to reasons of its total percentage variance observed in the current investigation is postulated that feeding habit is a subsidiary consideration to strong phylogenic *Cricetidae* family mandible character evidenced by a more profound genealogic affinity constraint in the species (Franklin *et al*., 2008; Rohlf, 2014). A relatively more highly placed and posteriorly oriented coronoid process to the articular condyle level in this species is similar to ruminant's mandible (Olopade, 2006) located well above the level of the cheek tooth row. The possible predictive accuracy of mandibular shape as a single indicator of sexual dimorphism in *C. gambianus* can be queried and it may be a suggested caveat when applying the GM technique in the absence of other morphological and osteometric indicators, especially in the case of fragmentary forensic or possible fossil remains. In comparing rodents diet compositions (Samuel, 2009; Matina *et al*., 2010; Ali *et al*., 2011) reported that African Giant rat survives more on domestic waste and less fiber diet, this is perhaps corroborated by its curved and long mandibular architecture (long *buccinators* and *masseter* muscle attachments), for food stowaway in cheeks. Overall, there is less mandible pasticity in this species evaluated with more conservative evolutionary adherence.in architecture (Franklin *et al*., 2008). But further studies on more geographical populations to assess the significance of the mandibular shape are recommended.

CONFLICT OF INTEREST STATEMENT

No conflicts of interests nor financial obligations/commitment to any institution exist.

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Table 1. Nine landmarks studied on lateral view of each mandible for *Cricetomys gambianus*.

Landmark no.	Right lateral view of mandible
1	Dorsal point of incisor alveolus
2	Ventral point of incisor alveolus
3	Most ventral point of mental foramen on mandible body
4	Caudal angle point of mandible
5	Most dorsal point on mandible condyle
6	Most nuchal on coronoid process
7	Point on last cheek tooth alveolus
8	Dorsal point of mental foramen
9	Alveolus of first premolar

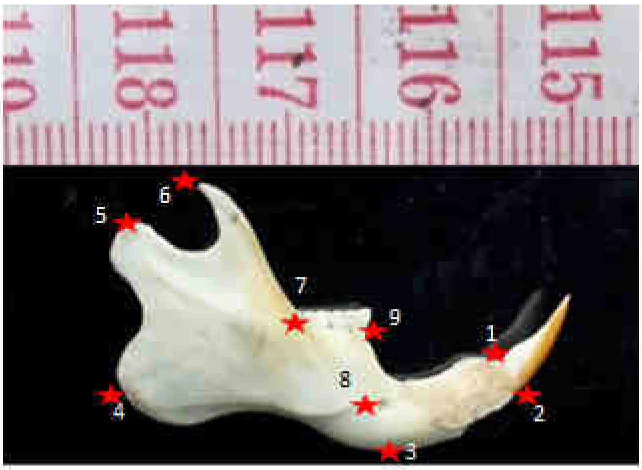

Figure 1.Right lateral mandible view of *Cricetomys gambianus* with 9 studied landmark points. Numbers correspond to definitions given in Table 1.

Table 2. Cross-validation analysis for *Cricetomys gambianus*. It showed an accuracy of less than 50%.

	Correctly assigned	Incorrectly assigned	Total
Females	6	7	13
Males	4	8	12

Table 3. Principal Component (PC) eigenvalues for mandibles of *Cricetomys gambianus* (n=25, 12 males and 13 females).First two Principal Components in PCA explained a 74.95% of the total observed variance.

PC	Eigenvalue	% observed variance	Cumulative variance %
1	0.00638217	55.950	55.95
2	0.00216758	19.003	74.95
3	0.00150638	13.206	88.15
4	0.00043567	3.819	91.97
5	0.00024180	2.120	94.09
6	0.00021123	1.852	95.95
7	0.00016637	1.459	97.40
8	0.00010977	0.962	98.37
9	0.00006350	0.557	98.92
10	0.00004302	0.377	99.30
11	0.00003685	0.323	99.62
12	0.00002600	0.228	99.85
13	0.00001109	0.097	99.95
14	0.00000537	0.047	100

Table 4. Values for PC1 and PC2 coefficients for sexual mandibular differences in (*Cricetomys gambianus*) (n=25, 12 males and 13 females). First two Principal Components in PCA explained a 74.95% (PC1+PC2=55.95+19.00%) of the total observed variance. Most discriminative values (>[0.2]) appear in bold.

	PC1	PC2
x1	0.053955	-0.230666
y1	0.071716	-0.564544
x2	-0.000903	-0.046936
y2	-0.096662	0.314700
x3	-0.068628	0.149901
y3	-0.022745	0.333752
x4	0.025770	0.077695
y4	-0.010229	0.133420
x5	0.064123	-0.135645
y5	-0.012825	-0.056113
x6	0.032720	-0.337590
y6	-0.062639	0.238362
x7	-0.106961	0.187521
y7	0.068810	-0.145663
x8	**0.439197**	**0.258478**
y8	**-0.498383**	**-0.214763**
x9	**-0.439273**	0.077242
y9	**0.562956**	-0.039151

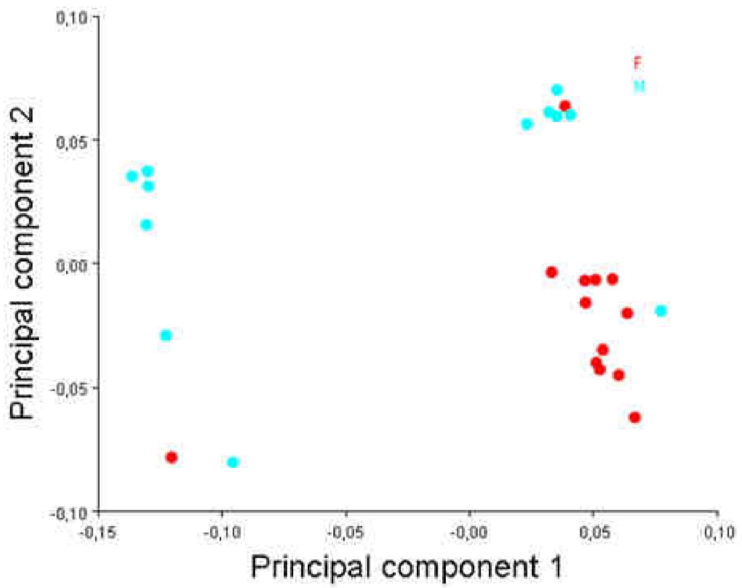

Figure 2. Principal Component Analysis for males and females of *Cricetomys gambianus* (n=25, 12 males and 13 females). First two Principal Components in PCA explained a 74.95% (PC1+PC2=55.95+19.00%) of the total observed variance. In the morphometric space described, both species were significantly distinguished from each other (p=0.047). It must be acknowledged that both genders were widely distributed on the first and second plane of the PCA.

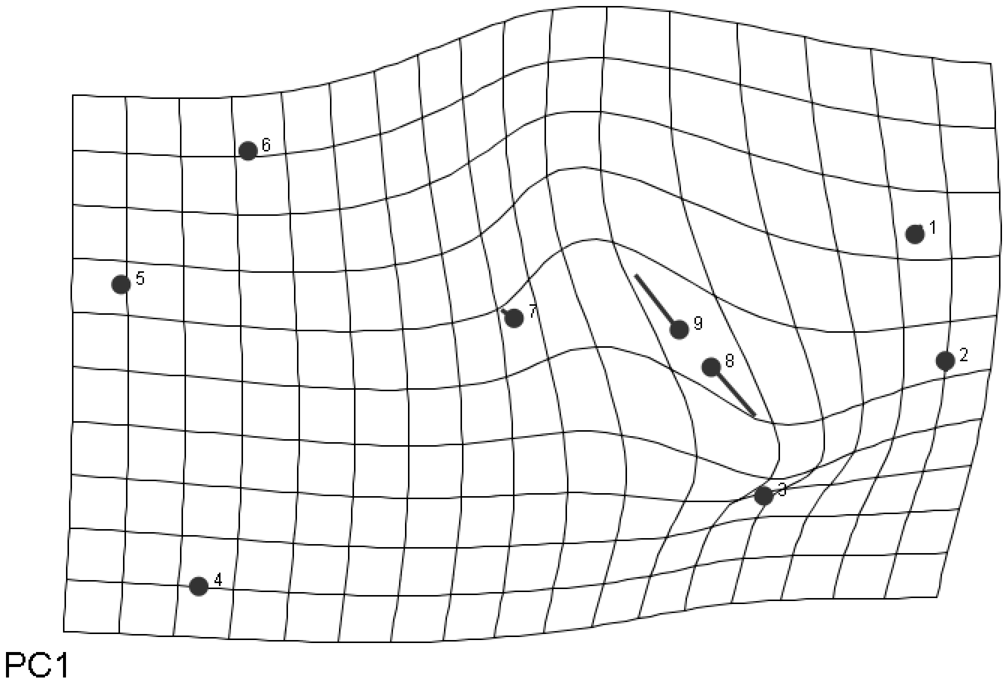

Figure 3. Deformation grid of *Cricetomys gambianus.* Main differences can be observed on mental foramen (8) and on alveolus of first premolar (9).