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# Cranial and External Morphology of Tree Squirrels (Heliosciurus. rufobrachium) in selected locations of savannah forest in Nigeria

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**Abstract**
*This study examined the differences in cranial morphology of tree squirrel species (Heliosciurus rufobrachium) from three different locations in Savannah vegetation zone of Nigeria. Locally fabricated live traps made of wire- mesh and steel was used to capture the squirrels. Trapped tree squirrels were immediately transferred to the laboratory in captivity cages, where they were euthanized by placement in a bell jar containing chloroform-soaked cotton wool. Specimens were then preliminarily identified to the generic level, using an identification key. 176 skulls were prepared (55 male and 121 female) using Long Island Natural History Museum guide and the sex of the specimens was determined by visual inspection of the external genitalia. The skull and other body parameters were measured using digital venire calliper. The results showed that the body parameters (HBL, TL, TBL, EL, HFL and BW) measured were slightly different from one location to another with specimen from Ilorin having the highest HBL (241.50 mm) and BW (299.50 mm). Also, the cranial measure showed some similarities and slight differences among the locations (Asejire, Ilorin and Ogbomosho). In conclusion, the body morphology and cranial parameters of the tree squirrels from the three locations (Asejire, Ilorin and Ogbomosho) showed that despite the tree squirrels are from different locations, they were of the same genus (H. Rufobrachium), which indicated that locations might not have effect on the specimen.*
**Keywords:** Tree squirrel, Crania parameter, Morphology, Forest, Abundance

## 1.0 Introduction

The mammalian fauna of the forests of West Africa, which is about 320 species, constitute about a quarter of mammalian diversity in Africa (Myer et al., 2000). Rodents (Order: Rodentia) are the world's most diverse mammals, constituting 42% of global mammal diversity (Musser et al., 1997). Among members of the Order Rodentia, squirrels of the family Sciuridae, is one of the largest. The family contains an abundant and diverse group of species which have been the subject of numerous and important studies with reports on behaviour, ecology, reproductive biology, and morphology well documented, hence the sciurid are among the best-understood mammals in these regards (Archana and Ashutosh, 2013).

The family Sciuridae includes tree squirrels, ground squirrels, and flying squirrels. Tree squirrels have long, bushy tails, sharp claws and large ears, with some having well developed ear tufts (Thorington and Ferrell, 2006). Trees squirrels have been used to measure the structure and richness of forest because they depend on mature forest for nest site, food, cover and their daily activities (Steel and Koprowski, 2001). Disturbance of such forest condition in any way always create a problem for tree squirrels, which sometimes lead to permanent habitat loss.

The major threats to squirrel persistence are habitat loss, fragmentation, overexploitation, persecution, and invasive species (Steel and Koprowski, 2001). The report of IUCN (International Union for Conservation of Nature) Red alert list database showed most squirrel species are of least concern with respect to their conservation status. However, about one in five species is either of elevated conservation risk or is so poorly known that an assessment cannot be rendered (Thorington et al., 2012) due to loss of habitat during deforestation.

Red-legged sun squirrel (*H. rufobrachium*) is a species of rodent in the family Sciuridae, also commonly known as the crab-eating mangoose (Grubb & Ekue, 2008). Red-legged sun squirrel (*Heliosciurus rufobrachium*) is a native to tropical western and central Africa where its range extends from Senegal in the west, through Nigeria. The natural habitats of Red-legged sun squirrels are subtropical and moist savannah (Grubb & Ekue, 2008). It is found in habitats with large trees in which it can climb, in moist primary and secondary forests (Jonathan et al., 2013).

The field of morphometric is concerned with methods for the description and statistical analysis of shape variation within and among samples of organisms and of the analysis of shape change because of growth, experimental treatment or evolution. Morphometric methods are needed whenever one needs to describe and to compare shapes of organisms or of particular organs. The samples may represent geographic localities, developmental stages, genetic effects and environmental effects (Rohlf and Marcus, 1993). Cranium measurement of the same species or different species from the same location or different location can also be used to differentiate between species (Voss and Jansa, 2009).

The cranium is a peculiar area of phylogenetic research for assessing mammalian relationships and it serves as the major skeletal component from which morphological measurements are taken (Voss and Jansa, 2009). According to Zelditch *et al.* (2012), subtle cranial differences can be shown by measurements and quantitative comparisons of the skull among rodents. Corti *et al.* (2000) reported that since the skull contains the major sensory organs, the brain and the feeding apparatus, it also contains a lot of information on the phylogeny, ontogeny and adaptation of rodents. It is thus not surprising that skull characters have been the primary source of study in rodent morphology.

Happold (1987) was able to identify different species of tree squirrels in Nigeria after which there is little or no report on three squirrels in Nigeria. Due to deforestation and urbanization in Nigeria, there is need to carry out study on tree squirrels especially Red-legged sun squirrel in some part of savannah vegetation zone in Nigeria. Hence, this study aims to compare the body and cranial morphology of tree squirrel (*H. rufobrachium*) in some part of savannah vegetation zone in Nigeria to establish effect of urbanization and deforestation on tree squirrel.

## 2.1 Materials and Methods

### 2.1.1 Study area

Squirrel samples were collected within the savannah vegetation zones of Nigeria. The squirrel samples were collected from Asejire, Ilorin, and Ogbomosho.

### 2.1.2 Sample collection

The specimens were collected using locally fabricated live traps made of wire-mesh and steel of 18 x 18 x 45 cm for a 19 months period (November 2011 – May 2013) to cover both rainy and dry seasons. The traps were baited with palm kernel, fresh corn, and groundnuts and were checked every morning and evening for trapped specimens by the hunters in the locations. The trapped specimens were immediately transferred to the laboratory in captivity cages, where they were euthanized by placement in a bell-jar containing chloroform- soaked cotton wool. Specimens that could not be examined immediately were preserved by immersion in jars containing 96% ethanol solution (Olayemi, 2006).

### 2.1.3 Specimen identification

Specimens were preliminary identified to the generic level, using an identification key prepared by Happold (1987) and the sexes were determined by visual inspection of the external genitalia.

### 2.1.4 Skeletal Preparation

The skull of the sacrificed specimen was severed from the neck skinned and the surrounding musculature was removed with the aid of knife and scissors. Skeletal preparation was carried out using the Long Island Natural History Museum guide (2000) on how to prepare skeletal material.
The skull was soaked in water, inside a plastic container, for two weeks to ensure that the remaining attached flesh was degraded through bacteria maceration. The skull was then cleared with a fine-tooth brush; the skull, which was completely devoid of flesh, was then degreased by placing it in a solvent (kerosene) contained in a sealed glass container for two weeks. The skull was then bleached by soaking in 20% hydrogen peroxide for two days, removed and allowed to dry in a Petri dish at room temperature, over a period of five days.

## 2.2 Cranial and External Measurements

27 cranial and 6 external measurements were taken on each of the specimens according to the method of Rasmussen and Thorington (2008), and Song *et al.* (2012) using digital calliper (RUPAC, Italy), and digital weighing balance for the body weight with values allowed to be in 2 decimal places. The cranial measured parts include: Length of Nasals (NL), Breadth of Nasals (NB), Interorbital Breadth (IOB), Zygomatic Breadth (ZB), Breadth behind Postorbital Process (POB), Breadth of Braincase (BCB), Greatest Length of skull (GLS), Depth of Incisor (ID), Depth of Braincase (BCD),

Occipitonasal Length (ONL), Length of Auditory Bulla (BL), Rostrum Breadth (ROB), Rostrum Length (ROL), Length of Diastema (DL), Length of Bony Plate (BPL), Breadth of Bony Plate (BPB), Postpalatal Length (PPL), Interseptal Breadth (ISB), Mastoid Length (MTL), Breadth across Occipital Condyle (OCB), Length of Incisive Foramen (IFL), Breadth across the Incisive Foramina (IFB), Breadth of First Upper Molar (M1B), Length of Maxillary Toothrow (TRL), Mandibular Toothrow Length (LMT), Mandible Length (ML), Height of Mandible (THM) (Figure 2) while the Body weight and external measurement include: Head body length (HBL), Tail length (TL), Total body length (TBL), Ear length (EL), Hind Foot length (HFL) as shown in Figure 3.

### 2.2.1 Sampling Locations

The study was carried out in two different locations in South Western Nigeria.

a. Asejire: 07° 21´ N - 07°22´ N and 004° 08´ E - 004° 10´ E
b. Ilorin: 08°29´ N- 08° 31´ N and 004 °21´ E- 004° 22´ E
c. Ogbomosho: 08° 08´ N- 08° 10´ N and 004° 13´ E- 004° 14´ E

### 2.3 Statistical Analysis

Data generated from this work were subjected to descriptive statistics such as mean, and standard deviation. One-way analysis of variance (ANOVA) was used to determine the significant differences between the means while the significant means were separated at $P < 0.05$, using Duncan multiple Range Test from System Analysis Software (1997). The inferential statistics employed were correlation and Principal Components Analysis (PCA) computed using Paleontological Statistics (PAST) version 1.75.

### 3.1 Results

The pelage of *Heliosciurus rufobrachium* caught in all the locations were rufous-grey or brown black. There was speckled rufous on the head with the extent of rufous colouration varying and absent in some individuals. The vental pelage was creamy-white while tail has similar colour to the back pelage.

### 3.1.1 Composition and Abundance

One hundred and seventy-six (176) of *Heliosciurus rufobrachium* were collected across the studied locations (Asejire, Ilorin and Ogbomosho) (Table 1). In Asejire location, the highest number (69) were collected which make about 39.21% of the total of sample collected. In Ogbomosho location, 60 specimens were collected, and this make about 34.05% of the specimen. In Ilorin location, the least specimen was collected (47) and it was about 26.71% of the total collection. The amount collected for this duration of study was lower than what was expected.

In all locations, higher numbers of females of *H. rufobrachium* were collected (Table 1). The sex ratios (M: F) in the various locations were: Asejire 1:2, Ilorin 1:4, and Ogbomosho 1:2. Overall comparison showed that the sex ratio in the savannah zone was 1:2. Higher numbers of males of *H. rufobrachium* specimens were collected from two locations (Asejire and Ogbomosho), when compared to the number of male sample in Ilorin.

The measured morphometric parameters of *H. rufobrachium* sample in three locations (Asejire, Ilorin and Ogbomosho) are shown in Table 2. The Head body length (HBL) of the specimens sample from different locations differs accordingly. Specimens from Ilorin had the highest HBL mean value (241.50 mm) and ranged between 233 – 250 mm. Specimens from Ogbomosho followed specimen from Ilorin with mean value of HBL of 236.67 mm and ranged from 212 to 241 mm. Specimen from Asejire had the least mean value of HBL of 217.00 mm and ranged between 207 to 244 mm.

The Tail length (TL) values of specimen from Ilorin was the highest (282.50 mm), followed by TL of specimen from Ogbomosho (255.50 mm) and Asejire having the least value of TL (215.00 mm). The TL values for all the specimens ranged between 202 to 295 mm. Total body length (TBL) of the specimens followed the same path as HBL and TL. Specimen from Ilorin have the highest mean value of 524.00 mm, followed by Ogbomosho with mean value of TBL of 492.17 mm and Asejire (432.00 mm). The TBL range value for all the specimens caught in all the locations were 396 to 555 mm.

The Ear length (EL) value of specimen from Asejire was the highest (17.00 mm), followed by specimen from Ogbomosho (15.17 mm) and 14.50 mm from Ilorin. The range of values for all the specimens were from 13 to 19 mm. The Hind foot length (HFL) and Body weight (BW) mean value of all the *H. rufobrachium* sample in all the locations (Asejire, Ilorin and Ogbomosho) are in line with mean value of HBL, TL, & TBL. The HFL & BW mean values of specimen from Ilorin was the highest (50.50 & 299.50 mm). Specimen from Ogbomosho have mean value of 48.00 mm for HFL and 282.17 mm for BW. The least mean value of HFL and BW was from specimen sample in Asejire (44.00 & 210.00 mm).

### 3.1.3 Variations in the measured cranial parameters across locations

The measurement of cranial parameters across the three sampled locations (Asejire, Ilorin and Ogbomosho) are shown in Table 3. NL (Length of Nasal), NB (Breadth of Nasal), BCB (Breadth of Brain case), ID (Depth of Incisor), BCD (Depth of Braincase), ROB (Rostrum Breadth) and TRL (Length of maxillary toothrow) were found to be similar between specimens from Asejire and Ogbomosho but significantly different ($P < 0.05$) in specimen from Ilorin.

The value of IOB (Interorbital Breadth), PPL (Postpalatal length) and ZB (Zygomatic Breadth) of specimen from Asejire and Ilorin was similar but significantly different at $P < 0.05$ in specimen from Ogbomosho. The values of GLS (Greatest length of skull), ONL (Occupational Length), BPL (Length of Bony Plate) and ML (Mandible Length) were significantly difference at $P < 0.05$ in the specimen from all the locations (Asejire, Ilorin and Ogbomosho). The DL (Length of Diastema) value of specimen from Ilorin and Ogbomosho was similar and significantly different ($P < 0.05$) in specimen from Asejire.

The remaining cranial parameters measured, POB (Breadth behind postorbital process), BL (Length of Auditory Bulla), ROL (Rostrum length), BPB (Breadth of Bony Plate), ISB (Inter-septal breadth), MTL (Mastoid Length), OCB (Breadth across occipital condytle), IFL (Length of incisive foramen), IFB (Breadth across the incisive foramina), MIB (Breadth of First Upper Molar), LMT (Mandibular toothrow length) and THM (Height of mandible) showed no significant difference at $P > 0.05$ in all the specimen from all the three locations (Asejire, Ilorin and Ogbomosho).

Cranial parameters subjected to a Principal Component Analysis (PCA) showed correlations and variance occurred among the specimens collected from the three locations in this study. The Principal Component Analysis divided the cranial parameter measured into three (3) namely the PC (1, 2, 3) representing each location (Asejire, Ilorin and Ogbomosho) respectively which have an Eigen value each and percentage variance in Table 4a. From this table, only PC1 (Asejire) of Eigen value 3369.03 and percentage variance of 99.80 were most significant being higher than the Joliffe cut- off 85.76.

In addition, in Table 4b, it is observed that PC1 (Asejire) had the highest Eigen value of 2.99402 and percentage correlation of 99.80 compared to all other parameters. Here in correlation the Joliffe cut-off is 0.7. The loading plot in Figure 4 showed the variance that occurred in the cranial parameters measured.

A scatter plot diagram in Figure 4 showed a cluster eclipse of all the cranial parameters of the locations (Asejire, Ilorin and Ogbomosho) represented. The plotting showed that all the cranial parameters measured categorised the specimens caught in all the locations to belong to the same homogeneous population, though there might be a very little variation which is statistically insignificant. The Eigen value shows that specimens sample from Asejire might be slightly different from specimens from Ilorin and Ogbomosho, which the scatter plot diagram was also show with few measured cranial parameters (ZB, ONL, and GLT) being out of the plot.

### 3.2 Discussions

The abundance and the composition of *H. rufobrachium* collected in various locations (Asejire, Ilorin and Ogbomosho) showed the effect of urbanization on three squirrels in Nigeria. Development in various states and urban areas in Nigeria due to increase in population poses threat to tree squirrels. Grimm et al. (2008) reported that urban development leads to an overall loss of native biodiversity and Evans et al. (2015) reported that the species of animal that are in areas subjected to anthropogenic disturbance a divergent set of abiotic and biotic selective forces that considerably alter their population dynamics. Many trees with fruits which serves as food and habitation for trees squirrels have been cut down to make wood for building houses, cooking and other various purposes. Koprowski and Steele (1998) reported that urbanization and deforestation were one of the major risk factors of tree squirrels across the globe. In addition, Mansur (2017) also reported similar findings on biodiversity and species extinction in Nigeria that deforestation could cause a great danger to wild animals if not regulated or controlled.

The increase in the number of female tree squirrel (*H. rufobrachium*) collected in each location (Asejire, Ilorin and Ogbomosho) may be due to competition among male squirrel due to territorial behaviour (Schwanz et al., 2016). Female squirrel has been reported to be dominant in various location by some researchers due to reproduction and nursing of their young ones (Palombit, 2015). This finding is similar to the report of Bamidele and Kowobari (2019) on the ratio of male to female black rat (*Rattus rattus*) collected in Obafemi Awolowo University student residence.

Local hunters and various prey (Snake) may also be responsible for the decrease in number of tree squirrel caught in various locations during the period of this study. Squirrel meat is one of the meat delicacies in most part of the country (Falola, 2004); such meat is called "Bush meat". Also, killing and selling of tree squirrel serves as source of income for some local hunters (Falola, 2004).

Various variation exhibited by different vertebrate (rodents) in measured morphometric parameters have been reported to be hypothetically due to climate factors, metabolism rate, competition and mating success (Brunner et al., 2013). However, size variation is generally considered more liable to environmental gradients than shape (Wei et al., 2013). There is positive correlation (0.78) exhibited among the measured morphometric parameters in this study. This is in line with the report of Wheatley. (2007) on ground squirrels. They reported that, the morphometric parameters of ground squirrel caught at different locations was positively correlated (0.86) because of climate changes and their feeding habit. Higher values of body weight, tail length and body length reported for the specimens caught in Ilorin may be due to availability of food in the sampled location when compared to other locations (Asejire and Ogbomosho). Also, the effect of the local hunters and various predators may be responsible for decrease in morphometric parameters measured in other locations mainly in Asejire. It is possible that most of the old and matured tree squirrel has served as meat (food) to both local hunters and prey, while it was the younger ones that were collected in this study.

The cranial parameters measured showed that the tree squirrel (*H. rufobrachium*) collected in various locations (Asejire, Ilorin and Ogbomosho) were not different, although there were slight differences ($P > 0.05$) among some few cranial parameters measured. The cranial parameters of specimens collected in Ilorin stand out among other specimens collected from other two locations (Asejire and Ogbomosho). This may be due to age and sex of the specimens caught in Ilorin, which may be higher than other two locations. Although this study did not consider the age of the specimens. This finding is in line with the report of Goheen et al. (2003) who reported craniometrics differences among red squirrel obtained in region that is characterised by vastly different biotic community.

The similarity among the cranial parameters measured may be due to same specie (*H. rufobrachium*) of the tree squirrel sampled in this study. There are lots of overlap in the cranial parts measured and this may be due to the closeness of the vegetation zones sampled for the collection of specimens. Canady et al. (2015) reported overlap in some of the cranial part measured among the Eurssian Red Squirrel (*Paraxerus palliatus*) from Slovakia and the overlap was reported to be due to location of the squirrels.

## Conclusion

The body morphology of tree squirrel (*H. rufobrachium*) from the three locations (Asejire, Ilorin and Ogbomosho) is similar which confirm that they are of the same species. The cranial parameters also confirm that the tree squirrels are of the same species. This shows that rural and urban development may not affect the genus (*H. rufobrachium*) in savannah vegetation zone but it may affect the populations.

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## Conflict of Interest

The authors declared that there is no conflict of interest on this publication.

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**Table 1: The abundance of tree squirrel (*H. rufobrachium*) caught in various locations in savannah forest in Nigeria**

| Location | Male | Female | Total | Percentage (%) |
|---|---|---|---|---|
| Asejire | 21 | 48 | 69 | 39.21 |
| Ilorin | 9 | 38 | 47 | 26.71 |
| Ogbomosho | 25 | 35 | 60 | 34.09 |
| Total | 55 | 121 | 176 | 100 |

Table 2: **The Mean ($\bar{X}$) and Range (R) values of the Morphometric Parameters for *H. rufobrachium* during the period of Study**

| Locations | HBL | | TL | | TBL | | EL | | HFL | | BW | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Asejire | $217.00^{a}\pm2.5$ | 207-244 | $215.00^{a}\pm1.2$ | 202-264 | $432.00^{a}\pm4.6$ | 396-523 | $17.00^{c}\pm0.3$ | 15-19 | $44.00^{a}\pm0.5$ | 40-48 | $210.00^{a}\pm1.6$ | 196-220 |
| Ilorin | $241.50^{c}\pm8.50$ | 233-250 | $282.50^{c}\pm4.5$ | 281-284 | $524.00^{c}\pm7.1$ | 517-531 | $14.50^{a}\pm1.5$ | 13-16 | $50.50^{c}\pm0.3$ | 46-55 | $299.50^{c}\pm14.5$ | 265-294 |
| Ogbomosho | $236.67^{b}\pm6.56$ | 212-241 | $255.50^{b}\pm11.7$ | 206-295 | $492.17^{b}\pm6.5$ | 435-555 | $15.17^{b}\pm0.3$ | 13-17 | $48.00^{b}\pm0.3$ | 44-52 | $282.17^{b}\pm6.3$ | 207-427 |

**Column mean with the same super script are not significantly different ($P > 0.05$) from each other.*
*HBL – Head Body Length; TL – Tail Length; TBL – Total Body Length; EL – Ear Length; HFL – Hind Foot Length; BW – Body Weight*

**Table 3: Variations in the Means (mm) of Cranial Parameters of *H. rufobrachium* across the three Sampled Locations**

| Skull Parameters | Asejire | Ilorin | Ogbomosho |
|---|---|---|---|
| NL | $13.82^{a}\pm0.3$ | $14.10^{b}\pm0.2$ | $13.53^{a}\pm0.3$ |
| NB | $6.75^{a}\pm0.1$ | $7.09^{b}\pm0.4$ | $6.64^{a}\pm0.5$ |
| IOB | $11.55^{a}\pm0.5$ | $11.60^{a}\pm0.5$ | $12.48^{b}\pm0.2$ |
| ZB | $25.12^{b}\pm0.2$ | $25.49^{b}\pm0.4$ | $24.85^{a}\pm0.4$ |
| POB | $15.60^{a}\pm0.3$ | $15.50^{a}\pm0.3$ | $15.20^{a}\pm0.3$ |
| BCB | $19.60^{a}\pm0.4$ | $21.60^{b}\pm0.5$ | $19.80^{a}\pm0.2$ |
| GLS | $46.60^{b}\pm0.5$ | $48.59^{c}\pm0.4$ | $45.63^{a}\pm0.4$ |
| ID | $2.36^{a}\pm0.2$ | $3.26^{b}\pm0.1$ | $2.40^{a}\pm0.1$ |
| BCD | $16.49^{a}\pm0.3$ | $17.84^{b}\pm0.2$ | $16.08^{a}\pm0.4$ |
| ONL | $44.82^{b}\pm0.8$ | $45.65^{c}\pm0.6$ | $43.64^{a}\pm0.3$ |
| BL | $8.23^{a}\pm0.3$ | $8.05^{a}\pm0.1$ | $8.45^{a}\pm0.2$ |
| ROB | $6.60^{a}\pm0.1$ | $7.23^{b}\pm0.2$ | $6.94^{a}\pm0.4$ |
| ROL | $9.40^{a}\pm0.1$ | $9.40^{a}\pm0.5$ | $9.76^{a}\pm0.2$ |
| DL | $11.75^{a}\pm0.5$ | $12.18^{b}\pm0.3$ | $12.12^{b}\pm0.2$ |
| BPL | $12.26^{b}\pm0.2$ | $13.21^{c}\pm0.4$ | $11.64^{a}\pm0.3$ |
| BPB | $10.60^{a}\pm0.1$ | $10.65^{a}\pm0.3$ | $10.40^{a}\pm0.2$ |
| PPL | $16.30^{b}\pm0.3$ | $16.49^{b}\pm0.7$ | $15.85^{a}\pm0.4$ |

| | | | |
|---|---|---|---|
| ISB | $4.43^{a}\pm0.2$ | $4.36^{a}\pm0.6$ | $4.43^{a}\pm0.5$ |
| MTL | $8.61^{a}\pm0.1$ | $8.13^{a}\pm0.2$ | $8.52^{a}\pm0.3$ |
| OCB | $9.99^{a}\pm0.5$ | $9.91^{a}\pm0.4$ | $9.73^{a}\pm0.4$ |
| IFL | $3.81^{a}\pm0.2$ | $3.91^{a}\pm0.3$ | $3.84^{a}\pm0.5$ |
| IFB | $2.24^{a}\pm0.1$ | $2.43^{a}\pm0.1$ | $2.06^{a}\pm0.3$ |
| MIB | $2.34^{a}\pm0.2$ | $2.45^{a}\pm0.3$ | $2.44^{a}\pm0.4$ |
| TRL | $8.94^{a}\pm0.2$ | $9.14^{b}\pm0.4$ | $8.79^{a}\pm0.3$ |
| LMT | $8.38^{a}\pm0.3$ | $8.50^{a}\pm0.5$ | $8.22^{a}\pm0.4$ |
| ML | $20.43^{a}\pm0.7$ | $25.80^{c}\pm0.6$ | $24.62^{b}\pm0.5$ |
| THM | $15.77^{a}\pm0.5$ | $15.89^{a}\pm0.5$ | $15.46^{a}\pm0.7$ |

*Column mean with the same super script are not significantly different ($P > 0.05$) from each other.*

**Table 4:** The Eigen value and percentage (a) variance (Joliffe cut-off of 85.76) and percentage (b) correlation (Joliffe cut-off of 0.7) of each Principal Component of cranial parameters of *H. rufobrachium* across the three sampled locations with a Joliffe cut-off of 0.7

| | a | | b | |
|---|---|---|---|---|
| PC | Eigenvalue | % variance | Eigenvalue | % correlation |
| 1 | 3369.03 | 99.801 | 2.99402 | 99.801 |
| 2 | 0.57499 | 0.15642 | 0.00472 | 0.15734 |
| 3 | 0.15516 | 0.04220 | 0.00126 | 0.04211 |

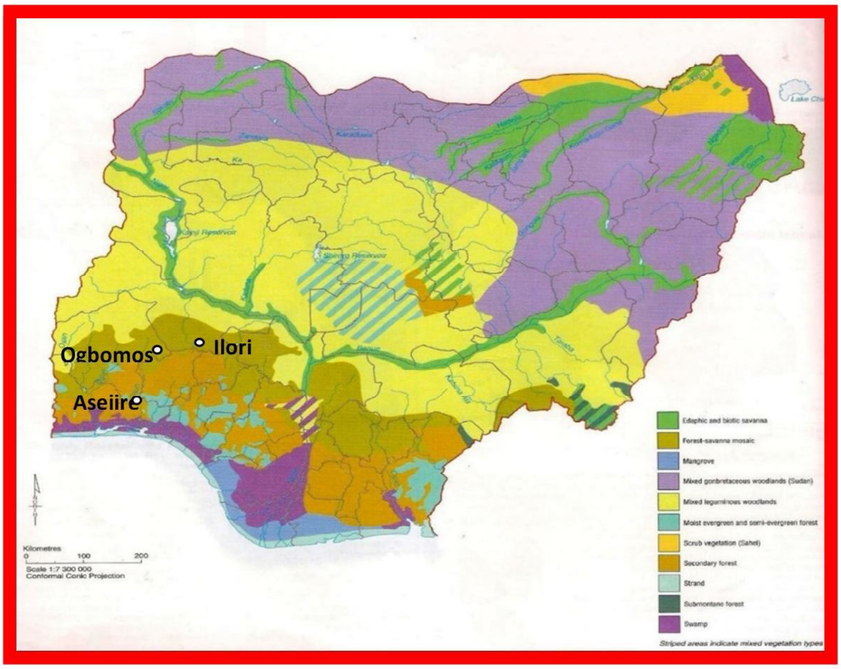
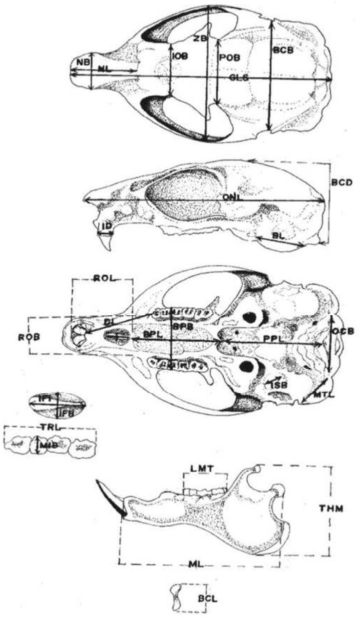


**Figure 1**:Map of Nigeria Showing the Sampling Locations with Respect to the Vegetation Zones. *Source:* Atlas, Macmillian Nigeria Secondary (18) modified.




**LEGEND**
**A.**
**NL = Length of Nasals**
**NB = Breadth of Nasals**
**IOB = Interorbital Breadth**
**ZB = Zygomatic Breadth**
**POB = Breadth behind Postorbital Process**
**BCB = Breadth of Braincase G**
**LS = Greatest Length of skull**
**B.**
**ID = Depth of Incisor**
**BCD = Depth of Braincase**
**ONL = Occipitonasal Length**
**BL = Length of Auditory Bulla**
**C.**
**ROB = Rostrum Breadth**
**ROL = Rostrum Length**
**DL = Length of Diastema**
**BPL = Length of Bony Plate**
**BPB = Breadth of Bony Plate**
**PPL = Postpalatal Length**
**ISB = Interseptal Breadth**
**MTL = Mastoid Length**
**OCB = Breadth across Occipital Condyle**
**C.1**
**IFL = Length of Incisive Foramen**
**IFB = Breadth across the Incisive Foramina**
**C.2**
**M1B = Breadth of First Upper Molar**
**TRL = Length of Maxillary Toothrow**
**D**
**LMT = Mandibular Toothrow Length**

**Figure 2**: Localization of the 27-craniodental measurements recorded in this study. Diagrammatic representation of Measurements taken from a generalized Tree Squirrel Skull and Mandible; (A) Skull, dorsal view (B) Skull lateral view (C) Skull ventral view (C1) Incisive foramina (C2) Maxillary check-teeth and (D) Left mandible, lateral view. Adapted from 16 & 17. Plate 1, 2 & 3 showed the measurement of the cranial characters

**Measurement of the cranial characters**

Plates 1, 2, and 3 show the different views of the *H. rufobrachium* skull.

**Plate 1: Dorsal View of *H. rufobrachium* skull**

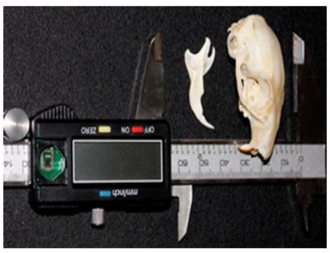


**Plate 2: Lateral View of *H. rufobrachium* skull**

**Plate 3: Ventral View of *H. rufobrachium* skull**

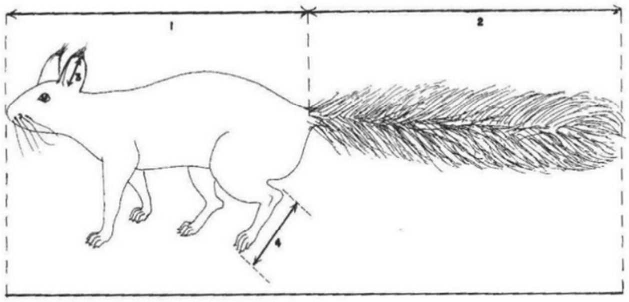


**Figure 3:** **Diagrammatic representation of External Measurements that were taken from a generalized Tree Squirrel (lateral view)** (*Source: Happold, 13 modified*) Keys: 1. Head Body Length (HBL), 2.Tail Length (TL), 3. Ear Length (EL), 4. Hind foot Length (HFL), 5. Total body length (1 + 2)

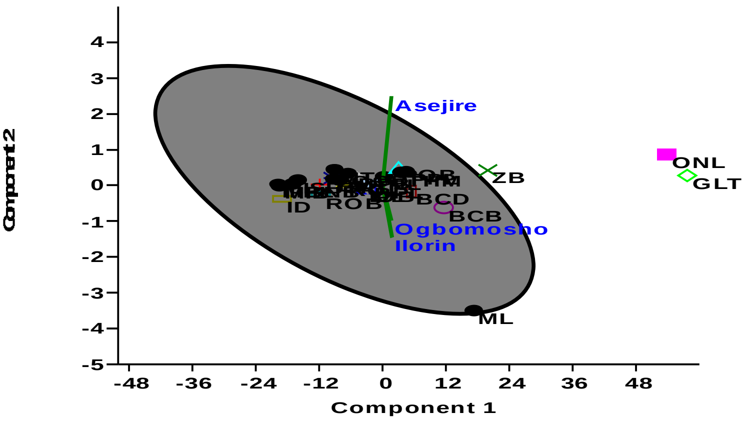



**Figure 4:** Principal Component Analysis (PCA) Scatter Plot showing Morphometric relationship in cranial parameters of *H. rufobrachium* across the three sampled locations (Asejire, Ilorin and Ogbomosho)