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Comparison of Cranial and External Morphology of Tree Squirrels (*Funiscurus leucogenys*) in Selected Locations of Rainforest in Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author AIA designed the study and author AOB performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AOB and AIA managed the analyses of the study and the literature. Both authors read and approved the final manuscript.

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ABSTRACT

This study looked at the differences in cranial morphology of tree squirrel species (*F. leucogenys*) from four different locations in Rainforest part of Nigeria. The squirrels were captured through the use of locally fabricated live traps made of wire-mesh and steel. Trapped specimens were immediately transferred to the laboratory in captivity cages, where they were euthanized in a bell-jar containing chloroform-soaked cotton wool. Specimens were then preliminarily identified to the generic level, using an identification key. The skull of 131 tree squirrels were prepared 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 venier caliper. The results showed that the body parameters (HBL, TL, TBL, EL, HFL and BW) measured were slightly different from one location to another. Also, the cranial measure showed some similarities among some locations (Ile-Ife, Emure-Ekiti and Ado-Ekiti), while measurement on squirrels from Sekona was different from other three locations. In conclusion, the cranial measurements of the tree squirrels shows there was no new species of F. leucogeny from the sampled locations.

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1. INTRODUCTION

Squirrel, one of the largest members of the order Rodentia belong to the family Sciuridae which contains an abundant and diverse group of species [1].

In the study of Nigeria squirrels, Happold [2] reported 4 genera (*Heliosciurus* [3], *Funisciurus* [3], *Protoxerus* [3] and *Xerus* comprising of seven species. Coker [4] however reported three species namely; *F. amerythus, F. pyrrlopus* and *H. gambianus* from two selected locations in Southwestern Nigeria. Taxonomic ambiguities have been associated to geographical occurrence of the various species delineated by several isolating mechanisms as well as to reliability of the identification tools utilized.

Morphometric analyses have been reported to be a viable tool for extracting information about the biological materials, quantitative characterization, and comparison of biological form by several authors [5,6]. Several studies have also shown that evolutionary history is paramount to shaping morphological variation at lower taxonomic levels under conditions of ecological homogeneity [7,8].

Morphometric analysis may contribute to the re-evaluation of specimen that have in the past been misidentified possibly due to external similarities, been unintentionally ascribed to already known species [9]. Cranial and external body measurement of two different species of Tree squirrels (*Helosciurus rufobrachium* and *Funisciurus leucogeny*) were used to examine if there was a new species from different locations in Savannah forest in Nigeria [10,11]. They reported no new species due to method used (cranial and external body measurement).

However, to the best of our knowledge, there has been no documented study available on the Tree squirrels apart from the report of Happold [2] on trees squirrels in Nigeria. This study therefore aimed at comparing tree squirrel (*Funisciurus leucogeny*) skulls and external morphology in some part of rain forest Nigeria (Ile-Ife, Sekona, Ado-Ekiti and Emure-Ekiti) in Southwestern Nigeria in other to determine if there is different species.

2. MATERIALS AND METHODS

Squirrel samples were collected within the rainforest zones of Nigeria. The specimens were collected using locally fabricated live traps made of wire-mesh and steel of 18 x 18 x 45 cm (Fig. 1) for a 19 months period (November 2011 – May 2013) to cover for both raining and dry seasons (Supplementary Table 1). The traps were baited with palm kernel, fresh corn, and groundnuts and were checked every morning and evening for trapped specimens. One animal was trapped in a trap (This occurred when the animal attempt to eat he bait which was attached to the trap door with a light metal) and ten (10) traps were set per time. 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 [9]. Specimens were preliminarily identified to the generic level, using an identification key prepared by Happold [2] and the sexes were determined by visual inspection of the external genitalia.

Fig. 1. The locally fabricated trap made of wire-mesh and steel

2.1 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 [12] 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 Rosevear [13], Happold [2], Rasmussen and Thorington [14] and Song, et al. [15] using digital caliper (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) (Fig. 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 Fig. 3. Fig. 4 shows map of Nigeria and the map of various states where the samples were collected.

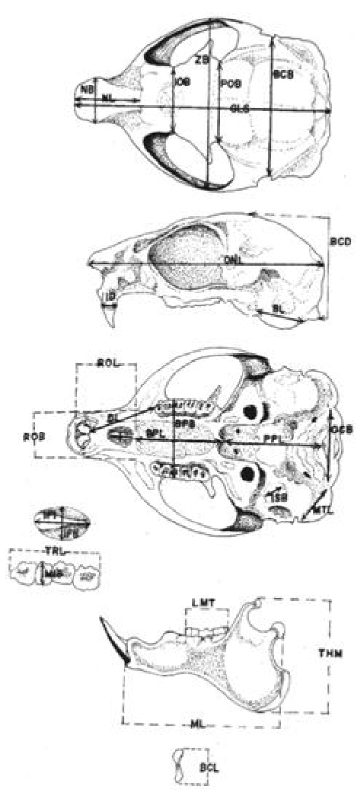

Fig. 2. Localization of the 27-craniodental measurements recorded in this study

Abbreviations for variables are defined in materiel and methods. 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 Rasmussen and Thorington [14] Song, et al. [15]

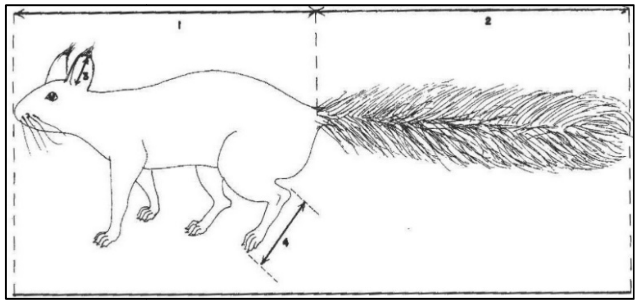

Fig. 3. Diagrammatic representation of external measurements that were taken from a generalized tree squirrel (lateral view)

Source: [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)

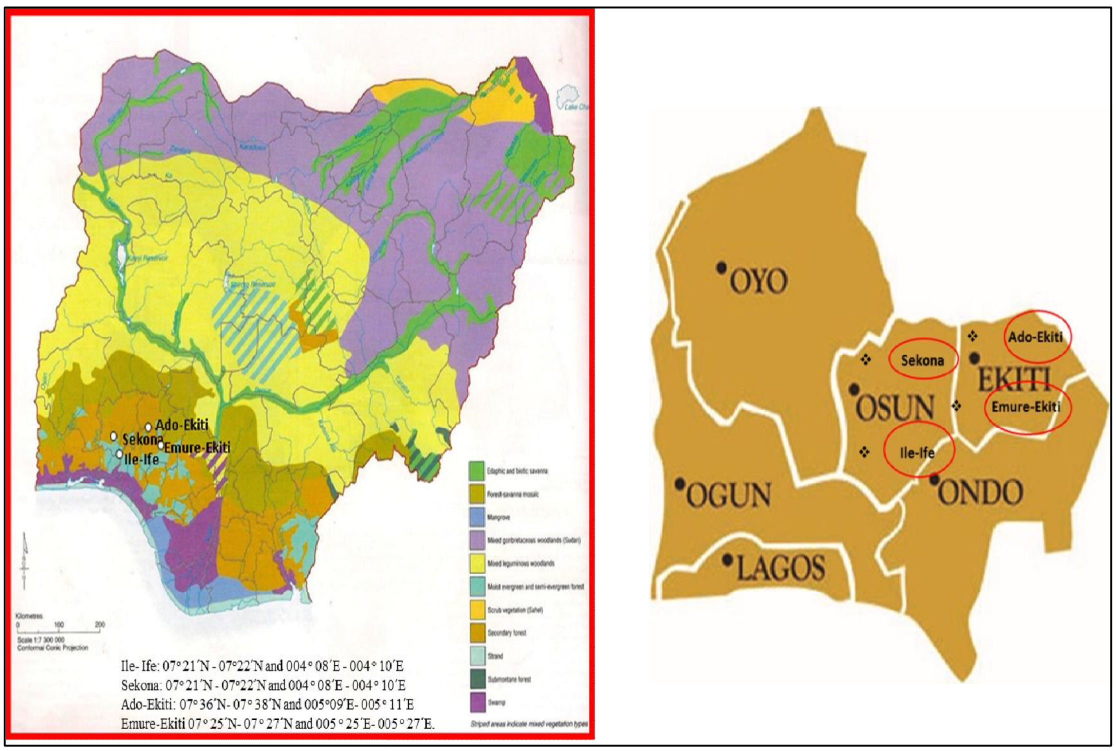

Fig. 4. Map of Nigeria and South West showing the sampling locations with respect to the vegetation zones

[16]

2.3 Statistical Analysis

One-way analysis of variance (ANOVA) was used to determine the significant difference between the means, while the significant mean was separated at $p \leq 0.05$ using Least Significant Difference (LSD) test from System Analysis Software [17]. Principal Component Analysis (PCA) was carried out with IBM SPSS 20th version [18].

3. RESULTS

3.1 Abundance and Distribution of Tree Squirrel

The tree squirrel specimens caught in all locations were identified as *Funiscurus leucogenys.* In all locations, higher numbers of females of *Funisciurus leucogenys* were collected (Table 1) . The sex ratios (M: F) in the various locations were: Ile-Ife 1:3, Sekona 1:3, Ado-Ekiti 1:5, and Emure-Ekiti 1: 4. Overall comparison showed that the sex ratio in the Rainforest zone was 1:3. Ado-Ekiti has the least number of specimen (*Funisciurus leucogenys*), while Ile-Ife had the highest collection (51). Emure-Ekiti followed Ile-Ife with 49 number of specimen while Sekona followed Emure-Ekiti (25).

3.2 Squirrel External Morphometric

The measured morphometric parameters of *F. leucogenys* caught in the four locations are shown in the Table 2. The Head Body Length (HBL) of the specimens caught in all the locations have no significant different ($p > 0.05$), although they have different ranges. The Tail Length (TL) also showed no significant difference at $p > 0.05$, for specimens from Ile-Ife and Ado-Ekiti, and there was no significant difference for specimens from Sekona and Emure-Ekiti at $p > 0.05$. The specimens from Emure-Ekiti have significant difference ($p < 0.05$) for the Ear Length, while there was no significant difference for the specimens from other locations. There was slight difference in Total Body Length (TBL) and Hind Foot Length of the specimens in all the four locations. *F. leucogenys* from Ile-Ife and Ado-Ekiti showed no significant difference at $p > 0.05$ for TBL and HFL, while the specimens from Sekona and Emure-Ekiti have no significant difference at $p > 0.05$ for the same parameters.

The Body Weight (BW) for all the specimens caught in all locations were different with significant difference at $p > 0.05$. Specimens from Ile-Ife have the least value of BW (186.9 g) while specimens from Emure-Ekiti have the highest (199.6g). Specimen from Sekona and Ado-Ekiti have similar values (190.2 and 192.4 g).

3.3 Variations in the Measured Cranial Parameters across Locations

Analyses of measured cranial parameters across the four sampled locations are shown in Table 3. POB (Breadth behind Postorbital Process), BCB (Breadth of Braincase), ID (Depth of Incisor), BCD (Depth of Braincase) and IFB (Breadth across the Incisive Foramina) were the five (5) parameters which were found not to be significantly different ($P > 0.05$) in the population of *F. leucogenys* across the four locations. The mean length of nasals (NL) in specimens collected from Ado-Ekiti and Sekona locations were found to be significantly different ($P < 0.05$) from each other. There were overlaps however in the mean NL of specimens collected from Ile-Ife and Emure-Ekiti population.

The mean breadth of nasals (NB) in the specimens collected from Ado-Ekiti location was significantly different ($P < 0.05$) from those of Sekona. The mean interorbital breadth (IOB) in the *F. leucogenys* specimens collected from Ado-Ekiti location was significantly different ($P < 0.05$) from those of specimens from other locations. The means of IOB of specimens from Sekona, Ile-Ife and Emure-Ekiti locations were found not to be significantly different ($P > 0.05$) from each other.

The mean ZB in specimens collected from Sekona and Ile-Ife locations was found not to be significantly different ($P > 0.05$) from each other. However, the mean ZB of specimens collected from Emure-Ekiti was found not to be significantly different ($P > 0.05$) from those of populations collected from other locations. The means of greatest length of skull (GLS) were found to be significantly different ($P < 0.05$) in specimens collected from Ado Ekiti locations. The mean GLS from the Ado-Ekiti populations was found to be significantly different ($P < 0.05$) from those of specimens collected from Emure-Ekiti locations. GLS in the specimens collected from Sekona location was however found not to be significantly different ($P > 0.05$) from those collected from Ile-Ife, and Emure-Ekiti locations.

The mean occipitonasal length (ONL) in *F. leucogenys* specimens was found to be significantly different ($P < 0.05$) between the populations of the species collected from Ado Ekiti and Sekona locations. Also, the mean ONL of specimens of the species collected from the Ile-Ife locations were found not to be significantly different ($P > 0.05$) from Ado-Ekiti and Emure-Ekiti locations.

Table 1. Composition and abundance of *F. leucogenys* caught during the period of study

Locations	Male	Female	Total
Ile-Ife	12	39	51
Sekona	6	19	25
Ado-Ekiti	1	5	6
Emure-Ekiti	9	40	49

Table 2. Comparison of measured morphometric parameters of *F. leucogenys* caught in four different location during the period of study (mm)

Locations	HBL		TL		TBL		EL		HFL		BW (g)	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
Ile-Ife	$200.6^{a}\pm1.8$	172-224	$193.5^{a}\pm2.4$	142-226	$394.1^{a}\pm2.5$	362-435	$15.6^{a}\pm0.1$	14-18	$43.5^{a}\pm0.3$	37-48	$186.9^{a}\pm3.3$	118-236
Sekona	$199.8^{a}\pm2.1$	175-215	$197.1^{b}\pm2.7$	171-245	$401.9^{ab}\pm7.2$	352-555	$15.1^{a}\pm0.3$	11-17	$44.1^{ab}\pm0.3$	42-47	$190.2^{b}\pm5.2$	118-238
Ado-Ekiti	$199.2^{a}\pm2.1$	142-204	$194.5^{a}\pm2.1$	152-212	$396.2^{a}\pm3.3$	320-444	$15.2^{a}\pm0.3$	14-18	$43.9^{a}\pm0.4$	39-49	$192.4^{c}\pm5.1$	117-236
Emure-Ekiti	$197.9^{a}\pm2.5$	155-217	$198.5^{b}\pm3.1$	124-226	$398.8^{ab}\pm3.4$	311-424	$16.0^{b}\pm0.2$	14-18	$44.3^{ab}\pm0.3$	41-47	$199.6^{d}\pm4.2$	119-243

**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. Comparison of cranial parameters of *F. leucogenys* across the four locations of the study

Parameters	Ile-Ife	Sekona	Ado-Ekiti	Emure-Ekiti
NL	$13.89^{b} \pm 0.2$	$13.30^{a} \pm 0.1$	$14.27^{c} \pm 0.2$	$13.60^{b} \pm 0.2$
NB	$6.90^{a} \pm 0.2$	$6.99^{a} \pm 0.2$	$7.74^{b} \pm 0.2$	$7.25^{b} \pm 0.2$
IOB	$11.75^{a} \pm 0.2$	$12.07^{b} \pm 0.3$	$12.84^{b} \pm 0.3$	$11.66^{a} \pm 0.1$
ZB	$25.63^{a} \pm 0.5$	$25.64^{a} \pm 0.5$	$26.24^{b} \pm 0.1$	$25.55^{a} \pm 0.5$
POB	$15.70^{a} \pm 0.1$	$15.10^{a} \pm 0.2$	$15.20^{a} \pm 0.2$	$15.30^{a} \pm 0.2$
BCB	$19.70^{a} \pm 0.3$	$19.50^{a} \pm 0.3$	$20.30^{a} \pm 0.5$	$19.80^{a} \pm 0.3$
GLS	$47.61^{b} \pm 0.9$	$47.03^{bc} \pm 0.3$	$48.90^{c} \pm 0.3$	$46.64^{a} \pm 0.4$
ID	$2.48^{a} \pm 0.1$	$2.41^{a} \pm 0.3$	$2.51^{a} \pm 0.3$	$2.43^{a} \pm 0.3$
BCD	$16.06^{a} \pm 0.1$	$16.25^{a} \pm 0.3$	$16.45^{a} \pm 0.3$	$16.33^{a} \pm 0.3$
ONL	$44.94^{a} \pm 0.5$	$46.53^{b} \pm 0.7$	$47.19^{c} \pm 0.6$	$44.35^{a} \pm 0.7$
BL	$8.22^{ab} \pm 0.1$	$8.10^{a} \pm 0.3$	$8.84^{b} \pm 0.2$	$8.27^{ab} \pm 0.3$
ROB	$6.31^{a} \pm 0.3$	$6.76^{ab} \pm 0.3$	$6.89^{b} \pm 0.3$	$6.49^{ab} \pm 0.3$
ROL	$9.56^{ab} \pm 0.3$	$9.21^{a} \pm 0.3$	$9.70^{b} \pm 0.1$	$9.58^{ab} \pm 0.3$
DL	$11.94^{a} \pm 0.3$	$11.88^{a} \pm 0.2$	$12.49^{b} \pm 0.3$	$12.16^{ab} \pm 0.3$
BPL	$13.14^{a} \pm 0.2$	$13.31^{ab} \pm 0.3$	$13.77^{b} \pm 0.3$	$13.10^{a} \pm 0.3$
BPB	$10.66^{a} \pm 0.2$	$10.76^{a} \pm 0.1$	$10.94^{a} \pm 0.4$	$10.66^{a} \pm 0.1$
PPL	$16.46^{ab} \pm 0.5$	$16.20^{a} \pm 0.3$	$17.28^{b} \pm 0.3$	$16.15^{a} \pm 0.3$
ISB	$4.41^{a} \pm 0.1$	$4.80^{b} \pm 0.1$	$4.96^{b} \pm 0.3$	$4.64^{a} \pm 0.3$
MTL	$8.71^{ab} \pm 0.3$	$8.21^{a} \pm 0.3$	$9.37^{b} \pm 0.3$	$9.27^{b} \pm 0.3$
OCB	$9.74^{ab} \pm 0.3$	$9.81^{b} \pm 0.2$	$10.60^{b} \pm 0.2$	$9.60^{a} \pm 0.3$
IFL	$4.01^{a} \pm 0.3$	$3.93^{a} \pm 0.1$	$4.20^{a} \pm 0.3$	$3.89^{a} \pm 0.1$
IFB	$2.18^{a} \pm 0.1$	$2.39^{a} \pm 0.3$	$2.18^{a} \pm 0.3$	$2.71^{a} \pm 0.3$
MIB	$2.58^{ab} \pm 0.1$	$2.35^{a} \pm 0.2$	$2.55^{ab} \pm 0.3$	$2.41^{ab} \pm 0.1$
TRL	$8.77^{a} \pm 0.3$	$8.75^{a} \pm 0.3$	$9.27^{b} \pm 0.3$	$8.87^{a} \pm 0.3$
LMT	$8.22^{a} \pm 0.1$	$8.21^{a} \pm 0.3$	$8.70^{b} \pm 0.3$	$8.40^{ab} \pm 0.3$
MLT	$25.31^{b} \pm 0.4$	$26.07^{bc} \pm 0.6$	$27.36^{c} \pm 0.5$	$24.96^{a} \pm 0.5$
THM	$15.66^{a} \pm 0.3$	$15.61^{a} \pm 0.3$	$16.89^{b} \pm 0.3$	$15.81^{a} \pm 0.3$

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

The means of the Length of Auditory Bulla (BL) in F. leucogenys populations collected from Sekona and Ile-Ife locations were found not to be significantly different from each other (P > 0.05) but were significantly different (P < 0.05) from those specimens collected from the Ado Ekiti area.

The Rostrum Breadth (ROB) was also found to be variable in F. leucogenys specimens collected across the locations. The mean ROB in specimens collected from Ado Ekiti was found to be significantly different (P < 0.05) from those of specimens collected from Ile-Ife location. Also, the means of ROB of specimens collected from Emure-Ekiti was found to be significantly different (P < 0.05) from specimens collected from Ado Ekiti.

Analyses of the rostrum length (ROL) in *F. leucogenys* showed that the means of ROL in specimens of the species collected from Ado-Ekiti and Sekona locations were significantly different (P < 0.05) from each other. However, the ROL means in the species collected from Ile-Ife and Emure-Ekiti, locations were not significantly different (P > 0.05) from those of specimens from Ado-Ekiti and Sekona locations.

The Length of Diastema (DL) in *F. leucogenys* populations from the four locations varied. The means of DL in populations collected from Sekona and Ile-Ife locations were found not significantly different (P > 0.05) from each other but were significantly different (P < 0.05) from those specimens collected from Ado-Ekiti location. Analyses of the means of Length of Bony Plate (BPL) showed that in *F. leucogenys* populations collected from Sekona, Ile-Ife, and Emure-Ekiti locations, the mean BPL were not significantly different (P > 0.05) from each other. However, the means of BPL from these locations were found to be significantly different (P < 0.05) from those of specimens collected from Ado-Ekiti.

The means of Breadth of Bony Plate (BPB) of specimens collected from Ado-Ekiti and Sekona locations were not significantly different (P > 0.05) from each other but were significantly different (P < 0.05) from those specimens collected from Ile-Ife and Emure-Ekiti locations.

The mean Postpalatal Length (PPL) of specimens of *F. leucogenys* collected from Ado Ekiti location was significantly different from those from other three locations. However, the means of PPL from the other locations were found not to be significantly different (P > 0.05) from each other. Analyses revealed that the means of Interseptal breadth (ISB) of specimens of the species collected from Ado-Ekiti and Sekona locations were significantly different (P < 0.05) from those from Ile-Ife and Emure-Ekiti Locations.

In *F. leucogenys* specimens, the means of the Mastoid Length (MTL) and Breadth of Occipital Condyles (OCB) of the populations collected from Ado-Ekiti and Sekona locations were significantly different (P < 0.05) from those of specimens collected from Ile-Ife and Emure-Ekiti locations. However, the means of IFL of specimens from these locations were found not to be significantly different (P > 0.05) from those of specimens collected from Sekona, Ile-Ife, and Emure-Ekiti.

The means of Length of Maxillary Toothrow (TRL) of specimens across the locations are shown in Table 3. Analyses showed that the mean TRL of specimens collected from Ado-Ekiti location was significantly different (P < 0.05) from those collected from Sekona and Ile-Ife locations. However, the mean TRL of specimens from these locations were found not to be significantly different (P > 0.05) from those of *F. leucogenys* populations collected from Emure-Ekiti.

Specimens of *F. leucogenyns* collected from Ado-Ekiti location had a significantly different (P < 0.05) mean Mandibular Toothrow Length (LMT) from those of specimens collected from Sekona and Ile-Ife. However, the means of LMT from these locations were found not to be significantly different (P > 0.05) from those of specimens collected from Emure-Ekiti locations. The means of Mandible Length (MLT) of specimens of *F. leucogenys* caught from Sekona were significantly different (P < 0.05) from those of specimens collected from Ado-Ekiti location. However, the means of ML from specimens caught from the above locations (Sekona and Ado-Ekiti) was not significantly different (P > 0.05) from those collected from Ile-Ife and Emure-Ekiti locations.

Analyses of the means of Height of Mandible (THM) of *F. leucogenys* populations across the sampled locations showed that the THM means of specimens collected from Sekona, Ile-Ife, and Emure-Ekiti locations were not significantly different (P > 0.05) from each other. However, the THM means from these locations were significantly different (P < 0.05) from those specimens collected from Ado-Ekiti locations.

4. DISCUSSION

The variation in the number of specimen caught in in the Rainforest zone (Ile-Ife, Sekona, Ado-Ekiti and Emure-Ekiti) may be attributed to so many factors such as, type of trap used, the location of collection, types of foods in the location and type of predators [19]. The highest collection from Ile-Ife was due to the location where the specimen was collected. They were collected at the Obafemi Awolowo University staff quarters where there was abundant of foods and less predators. Emure-Ekiti specimen was also collected in the rural area where the people leaving in the village has bigger animals to hunt than tree squirrels. The decrease in the amount of *F. leucogenys* collected in Sekona may be attributed to the presence of predator like human and other animals like snake that feed on tree squirrel, and that of Ado-Ekiti may be due to deforestation due to urbanization. The location where the specimen was collected was around Ado-Ekiti University where all the bush had been cut leaving very little bushes around [19]. These findings have been supported by Koprowski and Steele [20] who reported that population of tree squirrels across the globe are at risk due to changes in food abundance, increasing inter- and intra-species competition, urbanization and predation by humans.

The variation in the measured external body parameters of the specimens may be attributed to feeding and availability of food. Also, age and sex can be other factors which may cause variation in the external body measurement of the specimens. These were not taken into consideration in this study. The specimen from Ile-Ife have the least body weight (186.9 g), while the specimen from Emure-Ekiti have the highest body weight (199.6 g). Specimens from Sekona

(190.2 g) and Ado-Ekiti (192.4 g) were found to have higher body weights than specimen from Ile-Ife. Tree squirrel feeds on seed (including nuts), fruits, leaves and fungi growing on trees. They (tree squirrels) are also, known to gnaw on bones and eat soil, to obtain minerals which are deficient in seeds and nuts [21]. The deficiency or lack of food may result in low body weight which may occur due to change in season and deforestation. Wauters and Dhondt [22] reported a variation in length and body weight of the red squirrels (*Sciurus vulgaris* Linnaeus, 1758) in two different habitats. The absence of significant difference at p > 0.05 for the parameter (HBL) measured for all the specimens caught in all the locations may be attributed to the mean value used which may reduce the difference from all the specimens. The significant difference observed in the Tail Length (TL), Total Body Length (TBL), Ear Length (EL), Hind Foot Length (HFL) and Body Weight (BW) may be due to combination of sexes (male and female). Selonen, et al. [23] reported higher body measurement in female flying squirrel than male. Selonen, et al. [23] also reported that age difference affected the body parts of flying squirrels which may also affect the tree squirrels.

The measured cranial parameters showed some variation across the locations, and the variations may be attributed to climate change, sex, mating success and metabolism rate [10,11]. The report of Bamidele and Akinpelu [10,11] of *F. leucogenys* in some part of Savannah forest in Nigeria (Asejire, Ogbomoso and Ilorin) showed differences in cranial parameters of the specimens from those locations (Asejire, Ogbomoso and Ilorin). The difference in the cranial parameters were attributed to sex, where female specimens have higher values of some measured cranial parts than male specimen. Although, there was similarities in some cranial parts of the specimens from different locations (POB, BCB, ID, BCD & IFB), the remaining 22 measured parameters showed significant difference or overlapped due to factors mentioned above.

Although the tree squirrels were of the same genus (*F. leucogenys*) and from the same Rainforest in Nigeria. The cranial measurement showed some similarities and difference in the parts measure. In most of the parts measured, specimens from Ado-Ekiti tends to stand out when compared with the remaining locations (Ile-Ife, Sekona and Emure-Ekiti). This is similar to the report of Li, et al. [24] reported craniometric differences among the four species of giant flying squirrels in China. For further confirmation of the differences, *F. leucogenys* specimens collected from all the locations were pooled and subjected to PCA to determine whether the recorded variations were significant.

Table 4. PCA loadings showing the discriminatory characters in *F. leucogenys* populations across the four locations

Factor	PC 1	PC 2
NB	-0.7872	
IOB	-0.9960	
ZB	-0.9771	
GLS	-0.9147	
ONL	-0.8974	
BL	-0.8596	
ROB	-0.8107	
ROL		0.9417
DL	-0.7253	
BPL	-0.9955	
BPB	-0.9860	
PPL	-0.9257	
ISB	-0.7892	
MTL		0.8839
OCB	-0.9906	
IFL	-0.9178	
TRL	-0.8273	
LMT	-0.7728	
ML	-0.9895	
THM	-0.8976	

The discriminatory cranial characters between the sexes were: IOB (Interorbital Breadth), ZB (Zygomatic Breadth), GLS (Greatest Length of Skull), ID (Depth of Incisor), BCD (Depth of Braincase), ONL (Occipitonasal Length), ROB (Rostrum Breadth), ROL (Rostrum Length), DL (Length of Diastema), BPB (Breadth of Bony Plate), PPL (Post Palatal Length), MTL (Mastoid Length), OCB (Breadth across Occipital Condyle), IFL (Length of Incisive Foramen), IFB (Breadth across Incisive Foramina), LMT (Mandibular Toothrow Length), ML (Mandible Length) and THM (Height of Mandible)

4.1 Multivariate Analyses of the Craniometrics Data

The Eigen values on the PCA loadings (Supplementary Table 2) showed that PC1 contributed 78.428% of the variation while PC2 contributed 16.220% of the variance. The PCA loadings (Table 4) showed that twenty (20) cranial characters were discriminatory between the populations from the various locations.

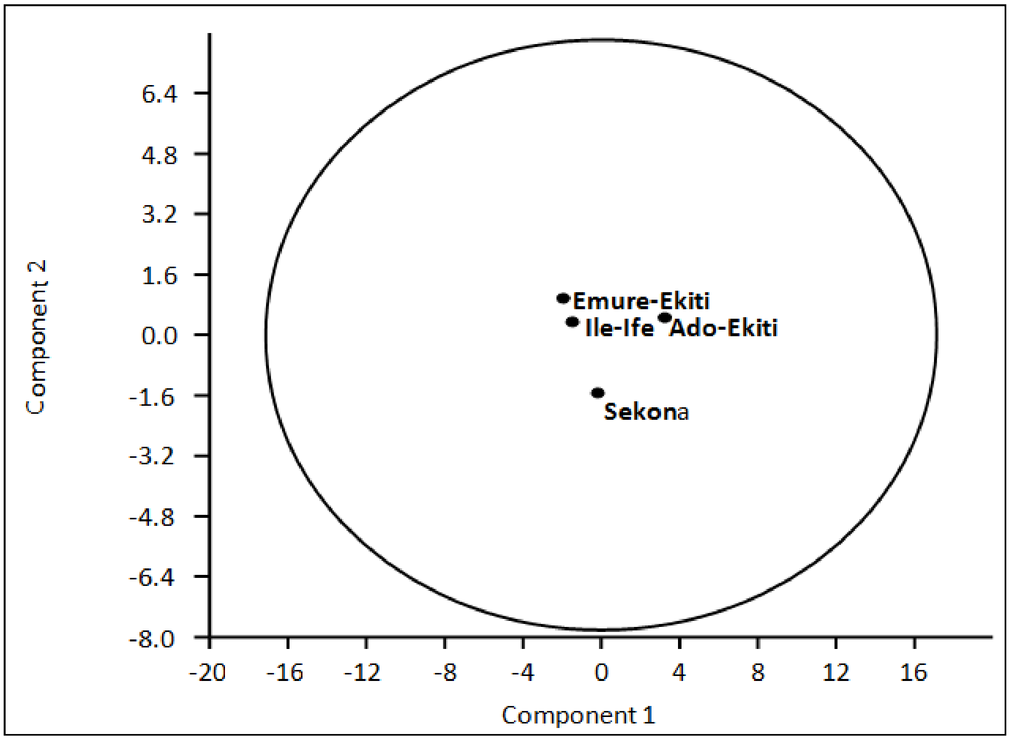

Fig. 5. PCA scatter plots for *F. leucogenys* specimens showing the relationship among the populations across the four locations

The discriminatory characters were: NB (Breadth of Nasals), IOB (Interorbital Breadth), ZB (Zygomatic Breadth), GLS (Greatest Length of Skull), ONL (Occipitonasal Length), BL (Length of Auditory Bulla), ROB (Rostrum Breadth), ROL (Rostrum Length), DL (Length of Diastema), BPL (Length of Bony Plate), BPB (Breath of Bony Plate), PPL (Postpalatal Length), ISB (Interseptal Breath), MTL (Mastoid Length), OCB (Breath across Occipital Condyle), IFL (Length of Incisive Foramen), TRL (Length of Maxillary Toothrow), LMT (Mandibular Toothrow Length), ML (Mandible Length) and THM (Height of Mandible).

All these cranial characters showed the discrimination among the locations. This was also similar to the report of, Li et al. [24] on the cranial measurement of giant flying squirrels in China.

Fig. 5 shows the PCA scatter plots for *F. leucogenys* specimens showing the relationships between the means of cranial features of populations from the different locations. The scatter diagram showed that populations from Ile-Ife, Emure-Ekiti, and Ado-Ekiti clustered and were different from those from Sekona location.

The differences observed may be attributed to the urbanization of the location where specimens in Ado-Ekiti was collected which influence the type of life style tree squirrels were living. Also, the age may be another factor that may cause the difference since age, food urbanization and predation has been factors reported to influence reproduction and body mass of squirrels [19].

5. CONCLUSION

Tree Squirels (F. leucogenys) in some parts of the Rainforest in Nigeria (Ile-Ife, Sekona, Ado-Ekiti and Emure-Ekiti) have similar properties. The cranial and the External body parameters measured show no significant difference among the specimen from the four locations. It can be concluded base on the parameters used in this study that there may be no new species related to *F. leucogeny*, but there is ongoing work using the combination of the method used in this study and the DNA of the specimens to determine if there are new species.

ETHICAL APPROVAL

Animal ethic Committee approval has been collected and preserved by the author.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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