Differences in the Mandibular Centroid Size of Squirrels in the Family Sciuridae

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**Introduction**

A black and white drawing of a hand holding a chain

Description automatically generated with low confidence Squirrels are the small animals found in the trees of many forests that are part of the Sciuridae family. Squirrels can be different sizes and colors. Not only can squirrels bodies be different shapes and sizes, but their jaws can differ in shape and size as well. Many factors can determine the size of a squirrel’s jaw including their body size and diet. There are other factors that can affect the size and shape of a squirrel’s jaw. The mandible is used to process food, but depending on the size and shape the process can differ. A study done by Swiderski and Zelditch examined how the differences in food processing effects the mandible shape. There are two diet groups, the granivores and the folivores. The granivores are individuals that eat nuts, seeds, and sometimes plant parts. The folivores eat mainly leaves and sometimes seeds (Swiderski & Zelditch, 2022). It would be much easier for an individual to process grass than to chew up a nut or seed. This would mean the granivores would have differently shaped mandibles than the folivores due to their diets.

Figure : Landmarks and semi-landmarks of a squirrel mandible. Retrieved from Zelditch et. al, 2017

An article written by Casanova-Vilar and van Dam suggested that the size of the mandible is inherited and passed down in species. Closely related species may have more related jaw sizes than those that are very distantly related (Casanovas-Vilar & van Dam, 2013). This means if you randomly pick two species from a phylogenetic tree, there is a chance they could be closely related and have very similar structures, but the chance is small. Genetics could play a big role in this research because the size and shape of the mandible could be passed down from parent to offspring. However, inherited traits can adapt and evolve to the environment for survival purposes.

The article written by Zelditch et. al compared how the different diets between species can affect the mandibular centroid size. They categorized their data into squirrels that eat nuts, hard nuts, bark, seeds, grass, soft, browse1, and browse2. They hypothesized that the optimal size of the squirrel’s jaw would be dependent upon the diet, but the shape for that diet would be dependent on the size (Zelditch et al., 2017). Niche partitioning could also be a factor in this study because if different species of squirrels eat different types of food in the same population, this can cause the mandible shape and size to change to the diet. Louise Roth proposed that the differences could be in individual parts of the bone rather than the mandible or the skull as a whole. She found that the mandible and skull differed in covariance but there was no clear line separating the skull into subunits (Roth, 1996).

A study done by Mazzamuto et. al looked at how migration into new environments can cause changes in the mandible shape and size in different squirrel species. The study found that there was no significant difference between males and females, and the variation in size was similar between the populations. However, the authors found a small divergence in the closely related species (Mazzamuto et al., 2021). This article examined the centroid size in different species of squirrels to identify if there is a statistically significant difference between the genera. There is a statistically significant difference in the mandibular centroid size among the 184 genera of squirrels from the Sciuridae family.

**Methods**

The data used in this research was collected from an article by Zelditch et.al. This data was used in a previous study done in 2015 which they had morphological and molecular data for the species. They observed the species in multiple seasons to look at the diets. Information about the dies was obtained from literature written by Thorington et. al (2012). To avoid any bias in the sampling, the diets that they observed were variable meaning there were multiple different diets observed at different locations and different seasons for the species.

The data was downloaded from dryad and uploaded to RStudio for analysis. The only variables used out of the dryad set is the species and the mandibular centroid size. Using the dryad data provided from their research, a plot showing the average centroid sizes of each species as well as a graph showing the frequencies of the average centroid sizes was created using Microsoft Excel. There were multiple packages used in RStudio to complete the statistical analysis. Those packages include: readxl, ggplot2, readr, kruskal.test, and dunn.test.

For statistical analysis, a Kruskal-Wallis Rank Sum test and a Dunn test was completed in RStudio. The Kruskal-Wallis tests is a nonparametric test that is used to compare two or more independent groups of ordinal or continuous data. This test is the nonparametric equivalent of the ANOVA and is used when the data does not meet the assumptions of normality and homogeneity of variance. This test is used to determine whether there are significant differences between the groups. It is a rank-based test that takes the medians of the groups and compares them to each other. A post hoc test is usually performed with the Kruskal-Wallis test to determine which group or groups are significantly different from each other. In this paper, a Dunn test was used which is a pairwise comparison. It takes all the groups and compares then and calculates a p-value from each comparison. To avoid false positives in this test the p-values are adjusted for multiple comparisons. The Kruskal-Wallis test was used for this paper because it is comparing 184 species to determine a significant difference. The Dunn test was used to determine which groups were different from each other. There were 1677 squirrels measured for the study from 184 genera. For this paper the only variables used are the species and the mandibular centroid size.

**Results**

The Kruskal-Wallis Rank Sum test showed that the p-value was <2.2e-16. Since this is below 0.05 the test shows there is a statistically significant difference between genera in the mandibular centroid size. Table 1 shows the average centroid sizes for all squirrel species that were gathered. There are many fluctuations in the graph that are visible showing that there are differences between the species. In some species, you can’t tell that there are differences. This is why the Dunn test was performed. However, the results of the Dunn test were inconclusive.

Table 1: Average mandibular centroid size in each of the squirrel species

Table 2 shows the frequencies of the different centroid sizes. Larger centroid sizes are not seen very often compared the smaller and medium sized mandibular centroids. Most of the data falls into the 58.516mm to 138.516mm size range. The majority of the data falls into the 78.516mm to 98.516mm data range. There were very few species that had an average centroid size over 138.516mm.

Chart type: Histogram. Frequency of 'CS(Average)'

Description automatically generated

*Table 2: Frequencies of the average centroid size*

**Discussion**

The data showed that there was a statistically significant difference in centroid sizes between the genera. The are many factors that could have swayed the results. One that was very prevalent in this data set was inadequate sample sizes. There were many species that had only one or two data points to examine however, there were some species that had ten or more. This could drastically affect the results of the study. If the sample size is too small, the test may not be able to detect if there are real differences. Small sample sizes can also show higher variability and the measurements will be less precise which makes the results unreliable.

Casanovas-Vilar and van Dam proposed that the reason for these differences could be an adaptation to the environment or a specific function it needs to perform and not just the diet of the squirrel (Casanovas-Vilar & van Dam, 2013). This could mean that the squirrel is changing its jaw shape or size because it has to change the way it performs certain functions in the environment. The environment may not be hospitable, and the species may have to move to a new area causing it to change its eating habits to a new food type which could change the shape and size. Adaptation can shape evolution because as they evolve, they acquire new traits that allow them to survive and reproduce more. There are also selective pressures that can favor certain traits over others.

The results from the Zelditch study showed that only 40% of the variance in the data could be explained by the different diets of the squirrels meaning there has to be more than just diet to explain the differences (Zelditch et al., 2017). Swiderski and Zelditch found that the diet of the squirrel does affect the size and shape of the mandible. They also found that the difference in function and muscles for processing the different diets is the mechanical difference in the jaw shape for each species (Swiderski & Zelditch, 2022). Mazzamuto found that invasive species going into new populations can cause the species to adapt to the new environment. They also found that environmental stress such as not being able to find specific food types could cause the differentiation as well as genetic drift. Another reason given to explain the variation is an independent origin (Mazzamuto et al., 2021). If the differences have an independent origin of each other, the species will show different shapes and sizes because there would be multiple origins of those shapes and sizes.

There are many evolutionary forces affecting the mandible size in squirrels. If squirrels with larger mandibles have an advantage in gathering and processing food, then natural selection may favor larger jaws. This can lead to larger mandibles evolving over time. This can also happen from sexual selection. Larger jaws may be favored in some species of squirrels meaning those with smaller mandibles may not get picked for mating. This will cause the larger mandibles to be more common. Even in the absence of natural and sexual selection, genetic drift can cause the alleles for large or small jaws to evolve overtime with one becoming more common. Migration brings new alleles in and out of populations. If a new allele affecting jaw sizes comes into a population, there can be evolutionary changes in the jaw size. The last evolutionary force that can affect the jaw sizes of squirrels is mutations. Mutations can change alleles that code for larger jaws to smaller jaws by changing one piece of genetic material. This change can get passed down and the mutation will evolve overtime and can become more common.

**Conclusion**

Many factors can affect and change the mandibular shape and size in a squirrel’s jaw. In this study there was a statistically significant difference in the mandibular centroid size in the genera of squirrels from the family Sciuridae. One factor is the diet of the squirrel. The diet can affect how the food is mechanically processed which can use different muscles and require the mandible to be a different shape than other diets. Other factors can include inheritance of specific mandible shapes and sizes. Genetics can be an important factor because if a specific jaw shape and size is passed down, the squirrel will have to keep the same diet as the parent, or the offspring will have to adapt its jaw to a different diet. The size and shape could simply have different origins in different species. There is not one factor causing the difference between genera or species, but a combination of multiple factors.

**References**

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