BATS MAY HAVE ORIGINATED IN THE WESTERN HEMISPHERE

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ABSTRACT: Although bats (order Chiroptera) make up one of the largest extant groups of mammals, second only to rodents, their location of origin remains a mystery. The fossil record of any genetically linked group of species can be a valuable tool to determine the location of origination of that group, and from there serve as a foundation towards further study of that group. This paper describes an analysis of the bat fossil record made to narrow the location of origination for bats to either the Western Hemisphere or the Eastern Hemisphere. The average age of fossils found within the Western Hemisphere was found to be greater than the average age of fossils found in the Eastern Hemisphere (27.66 million years old vs. 17.99 million years old respectively; $p<0.001$). This result would indicate that bats most likely originated in the Western Hemisphere. However, the poor quality of the bat fossil record has limited the data available which could potentially affect the accuracy of the analysis.

Keywords: Bats, Western Hemisphere, Eastern Hemisphere, Origin, Fossil Record

Introduction

Bats, order chiroptera, make up one of the largest groups of extant animals. They can be found in nearly all different habitats and environs across the Earth, and have been one of the most successful mammalian orders since their origin (Gunnell & Simmons, 2005). Given their wide dispersal and diverse abundance, they are of great importance to ecosystems the world over. To understand bats and their evolution is to understand a great portion of the evolution of mammals.

Gunnel & Simmons (2005) report that the location of bat origination remains unknown. While some of the oldest fossils on record have come from North America (Gunnel & Simmons, 2005) some molecular evidence has pointed towards an Eastern Hemisphere origination (Gunnel et al., 2017). Additionally, genetic studies have been used to create additional potential evolutionary trees for bats. For example, using genetic information Teeling et al. (2005) has argued for a possible origination in North America while Eick et al. (2005) argues for an African origination. While molecular studies are a valid and rich alternative approach to the study of bat origins, studies based upon bat fossil evidence is still of major importance as fossils are the only direct physical evidence that can display the expanding geographic range and increase in bat species over time (Eiting, 2009).

Paleobiologic data was used in this study to test the hypothesis that bats originated in the Eastern Hemisphere. It was predicted that the oldest fossils on record would not only be found in the Eastern Hemisphere, but that most of the oldest fossils would be found in the Eastern Hemisphere. This would imply that bats first appeared within the Eastern Hemisphere before they diversified and extended their influence nearly world-wide. To test this hypothesis, a comparison of the mean ages of Eastern Hemisphere and Western Hemisphere fossils was performed.

Materials and Methods

The data for this research was downloaded from the Paleobiology Database on 21 October 2017, using chiroptera as the only taxon to include. This data was exported as a Microsoft Excel file. The data encompassed all chiroptera fossils present in the database along with the locations they were found. The geographic information included the latitude and their furthest identified taxonomic rank and name. The oldest fossils were found in both the Western Hemisphere and Eastern Hemisphere and dated 56.8 million years ago (mya) to the early Eocene while the most modern fossils were dated to the current epoch at 0.0117 mya and found in the Eastern Hemisphere.

Fossils where divided into two categories; Eastern Hemisphere and Western Hemisphere. To do this, all fossils found at a longitude of -40 or lower (more West) were treated as Western Hemisphere fossils, and any longitude greater (more East) than -40 as Eastern Hemisphere fossils. The dependent variable is the age of the fossils, in mya. The prediction was that the average age of the Eastern Hemisphere fossils will be statistically greater (that is, older) than the average of the age of fossils found in the Western Hemisphere. To test this, a one-tailed t-test with a significance level of α=0.05 was used. Analyses were conducted in Microsoft Excel.

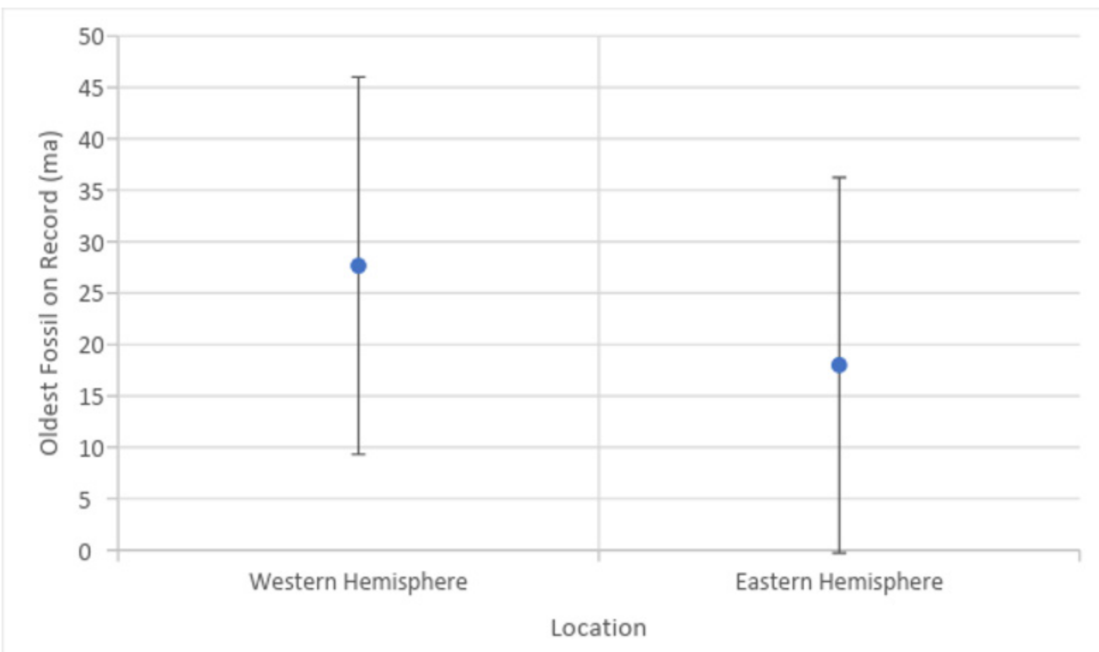

Figure 1. The differing ages of the known fossils of bats found in the Western and Eastern Hemispheres. Statistical error is shown through error bars. The mean age of Western Hemisphere Chiroptera fossils was higher than the mean age of Eastern Hemisphere Chiroptera fossils. The standard error of the mean for Western Hemisphere fossils is 18.26, and the standard error of the mean for Eastern Hemisphere fossils is also 18.26. P-value = 0.0006

Results

A one-tailed t-test was performed to determine if there is a significant statistical difference between the mean ages of the oldest known bat fossils found in the Western and Eastern Hemispheres respectively. The t-test gave a p-value < 0.001 which indicates the chance of getting the results obtained by coincidence or random chance is quite low, and that the null hypothesis, because there is no difference between the means of fossil ages, must be rejected. The mean age of the fossils found in the Western Hemisphere was found to be 27.66 mya with a standard deviation of 18.26 mya. The mean of the age of the fossils found in the Eastern Hemisphere was 17.99 mya with a standard deviation of 18.26 mya. Although a significant difference was found between the two means, the research hypothesis that the mean age of the fossils in the Eastern Hemisphere would be older than those in the Western Hemisphere could not be accepted. This is because the mean age of the fossils found in the Western Hemisphere is greater. Instead, the data indicates that the fossils found in the Western Hemisphere are older than those in the Eastern Hemisphere. Figure 1 displays the ages of the oldest known bat fossils found in the Western and Eastern Hemispheres respectively.

Discussion

As the mean age of Western Hemisphere Chiroptera fossils was shown to be significantly different than the mean age of Eastern Hemisphere Chiroptera fossils, the null hypothesis must be rejected. However, the mean age of fossils in the Western Hemisphere was found to be 9.67 mya older than the mean age of the fossils in the Eastern Hemisphere. This means the research hypothesis that placed the mean age of the fossils found in the Eastern Hemisphere to be older must also be rejected. Instead, the mean age of the fossils found in the Western Hemisphere are greater than those found in the Eastern Hemisphere.

If the location of origination for bats was within the Western Hemisphere, we would expect the oldest bat fossils would be deposited in the Western Hemisphere where the earliest ancestors lived. We would also expect that as the earlier ancestors have had more time to deposit fossils, their location would have a greater number of older fossils. This conclusion is compatible with the findings made by the analysis of the available fossil data.

The oldest bat fossil on record was found in Wyoming by Simmons et al. (2008) and was dated to the early Eocene. This would seem to also imply origins in North America. However, other fossils from the early Eocene also appear in the Eastern Hemisphere (Gunnell & Simmons, 2005). This could point to an ancestor that was able to diversify before the separation of the Eastern Hemisphere from the Western Hemisphere. Since as Hamilton et al. (2012) described, bats from the Western Hemisphere may occasionally be found in parts of the Eastern Hemisphere, it is also possible that very early migration may have occurred.

The data gathered would imply that bats originated in the Western Hemisphere and spread out from there to eventually encompass much of the world. The relative closeness in the mean age of Western Hemisphere fossils to the mean age of Eastern Hemisphere fossils (less than 10 mya) would also seem to imply a rapid diversification after origination, which is supported by Gunnel et al. (2017) when they reported on the appearance of many fossils representing differentiated groups of bats early in their evolutionary history.

Future Work and Limitations

Although all the available fossil data was used in the statistical analysis, it is possible that there are missing fossils or data from species that were not preserved that could alter the results. The fossil record for bats is highly incomplete, with much lower completeness estimates than the fossil records of other comparable groups (Eiting & Gunnel, 2009). Genetic sampling from extant bats still indicates an origination in the Western Hemisphere (Teeling et al., 2005) and this data is independent of the fossil record.

A large statistical error was present through the analysis. This is troublesome, especially as the statistical error is larger than the mean age of Eastern Hemisphere fossils. This would signify that the difference in age between fossils found in both the Eastern Hemisphere and Western Hemisphere is large, and that the ages do not tend to be close to their individual means. This assessment is conclusive with the data used in this study, as the 157 fossils available had ages ranging from 0.0117 mya to 56.8 mya with no clear common age. A greater sampling of bat fossils would likely lower the standard deviation and return a more reliable statistic.

While the results of the statistical test imply origination of bats in the Western Hemisphere, the data is not definitive. If a greater amount of bat fossils were to be unearthed and accurately dated, it would be possible to more accurately predict the region of origination for bats with greater accuracy. As concluded by Eiting & Gunnel (2009), historically under-sampled regions should be targeted for examination. Currently, fossil sampling of bats is poor due to less than ideal circumstances such as the nature of bat skeletons (Gunnell & Simmons, 2005). Rather than use the poor fossil record, many studies have instead looked at the molecular genetics of bats to relate them to each other and to map their ancestry (Ammerman & Hillis 1992, Teeling et al., 2005, Almeida et al., 2011). Although this method does not provide physical proof it can provide significant genetic evidence. Ideally, a combination of new fossil evidence along with greater genetic evidence via greater taxonomic sampling would be the way forward to discovering more information about this diverse and important mammalian order.

Acknowledgements

I would like to thank Magdalena Brooks and James J. Crowley for their respective reviews of my results section draft. I would like to thank Gavin Basuel for his insightful critique of this paper. I would like to thank the University of Washington library, without whom I would have been unable to access many of the papers cited in this work below. I would also like to thank Dr. Becca Price for her help analyzing and cleaning my data, providing advice, and for giving me the opportunity to write this paper.

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