Title
Body Size and Taxonomic Influence on Bee Wing Vein Density

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Data Availability
The data associated with this publication are available at: https://github.com/LeoEisner/Body-Size-and-Taxonomic-Influence-on-Bee-Wing-Vein-Density

Body Size and Taxonomic Influence on Bee Wing Vein Density

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Abstract

In this study, I investigated bee forewing vein density as it relates to body size and taxonomic group. Using dorsal and slide-plated wing images, wing vein density (WVD) and intertegular span (ITS) was measured for bee species within different genera and families. The study found that both taxonomic level and body size influence WVD, of which the taxonomic level of genus has the most significant effect, regardless of body size.

Introduction

All winged insects have wing veins that form unique patterns. A strong correlation between wing size and body size has been established in the insect order Hymenoptera, including bees (Bullock 1999). The number of wing veins is also known to increase with body size in Hymenoptera (Danforth 1989). However, how this pattern relates to the density of veins observed in the wing has not previously been studied and the overall relationship between wing vein number and body size has not been evaluated in bees in the absence of other hymenopteran taxa. Vein pattern in bees is also an important trait for identification at the genus level.

The objective of this project is to determine if wing vein density (WVD) is more strongly correlated with body size or taxonomic group. By utilizing the images of bee specimens taken as part of the Big Bee Project (http://big-bee.net), further insight can be gained regarding the impact body size has on the WVD of a bee, as well as how much of it is influenced by taxonomic level, regardless of body size.

Methods

48 female specimens from 29 species (5 families, 17 different genera) were measured for WVD, body size, forewing size, and forewing width. The pinned bees were analyzed for intact right forewings and two specimens per species were imaged dorsally using a 100mm Canon Macro lens top-down setup. Species were selected based on the total number of that species available in the UCSB Invertebrate Zoology Collection as well as the inclusion of a broad range of families and genera. The intertegular span was measured from images to determine body size, and the right forewing was removed and photographed. Additional specimens were obtained through the Bee Library online bee and trait image portal (https://library.big-bee.net).

The images were cleaned up in Adobe Photoshop and two wing images were created. One entire wing fully blacked out and another of just the veins thresholded in black and the rest of the wing in white. Intertegular span (ITS) and the wing width and length were measured from images using ImageJ. ITS is known to be an approximate calculation for dry body weight in bees (Cane, 1987). The wing area was measured using the black version of the wing and the vein area was measured using the vein-thresholded version (Fig. 2). The two measurements were used to calculate the area of the entire wing and the proportion of wing veins to wing, or wing vein density.

The Pearson Correlation Coefficient was used to determine the relationship between WVD and ITS. One-way and two-way ANOVA tests were used to examine WWD for each taxonomic level (family, genus). These tests were used to determine the relationship between taxonomic level and WVD, as well as which taxonomic level had the strongest influence, both in the context of and regardless of body size. All analyses were conducted in the programming language R after confirming random variance (linear model and residual plot) and a normal distribution of the data (Q-Q plot and Shapiro-Wilks Test).

Results

The Pearson Correlation Coefficient resulted in a moderate positive correlation between WVD and ITS (R value = 0.431; p-value = 0.00226). As shown in Figure 3, as ITS increases the WVD also increases. The coefficient of determination (R^2 value) was 0.1853, indicating that the data was scattered in relation to a linear relationship between WVD and ITS.

When determining the statistical significance of the relationships between species, genus, and family to WVD regardless of ITS, one-way ANOVA tests showed p-values of 0.0131, 3.12×10^{-5}, and 0.00845, respectively. Accounting for body size by conducting two-way ANOVA tests, however, the tests showed p-values of the relationships between species, genus, and family to WVD of 0.0136, 1.68×10^{-5}, and 0.00507, respectively. In addition, the p-values reported for ITS in relation to taxonomic group and WVD were 0.26, 0.0647, and 0.02368, with respect to species, genus, and family. As shown, in Figure 4 and 5, WVD was plotted against each genus and each family studied. The family *Apidae* had the most specimens with the highest WVD overall and the family *Andrenidae* had the most specimens with the lowest WVD overall. All of the interquartile ranges of each family overlap each other significantly. The outlier, *Megachilidae*, is not significant since that family only included one specimen. In terms of genus, *Xylocopa* had the highest WVD with a ratio of vein area to wing area of around 0.175, and *Perdita* had the lowest WVD with a ratio of around 0.11.

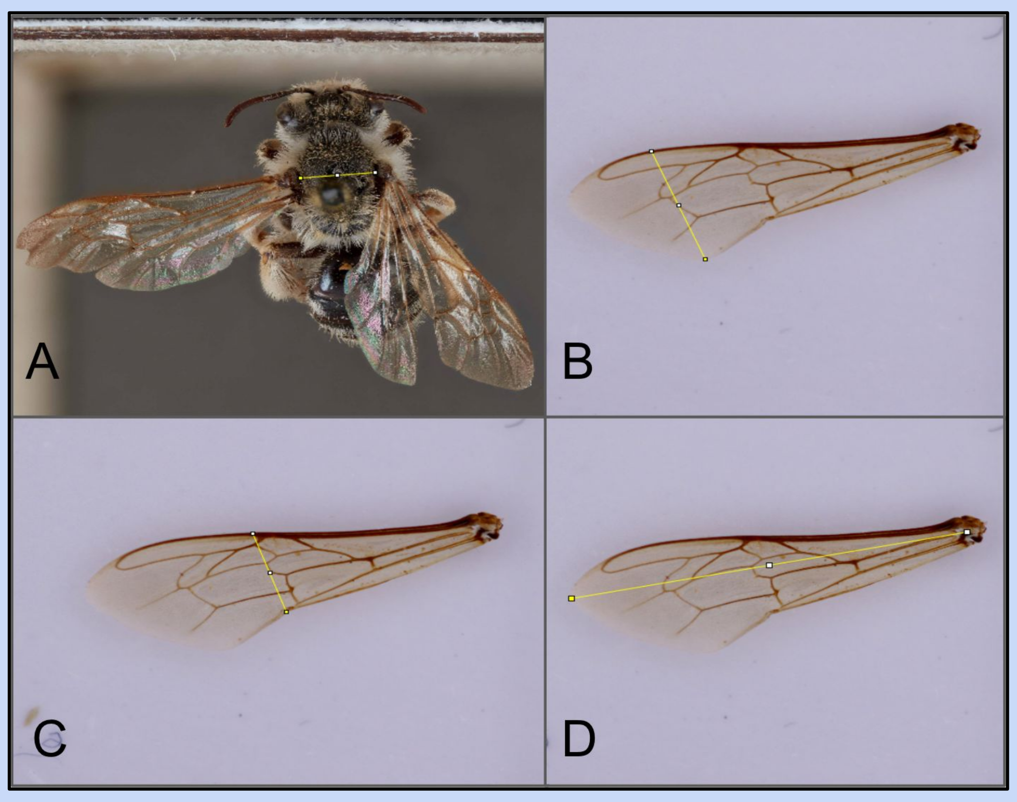

Fig. 1 Measurements using ImageJ – A: Intertegular Span, B: Distal Wing Width, C: Proximal Wing Width, D: Wing Length.

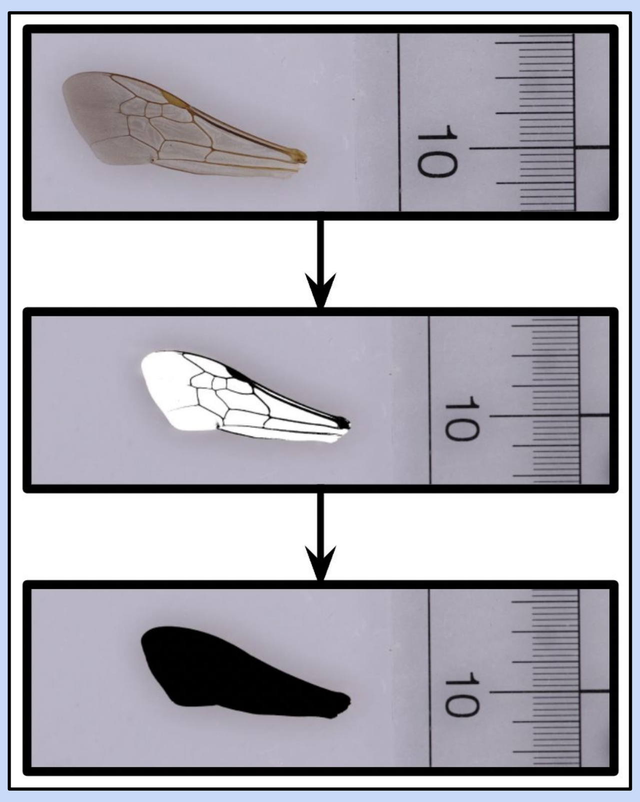

Fig. 2 (Top) Original image, (Middle) Veins thresholded, (Bottom) Whole wing blacked out.

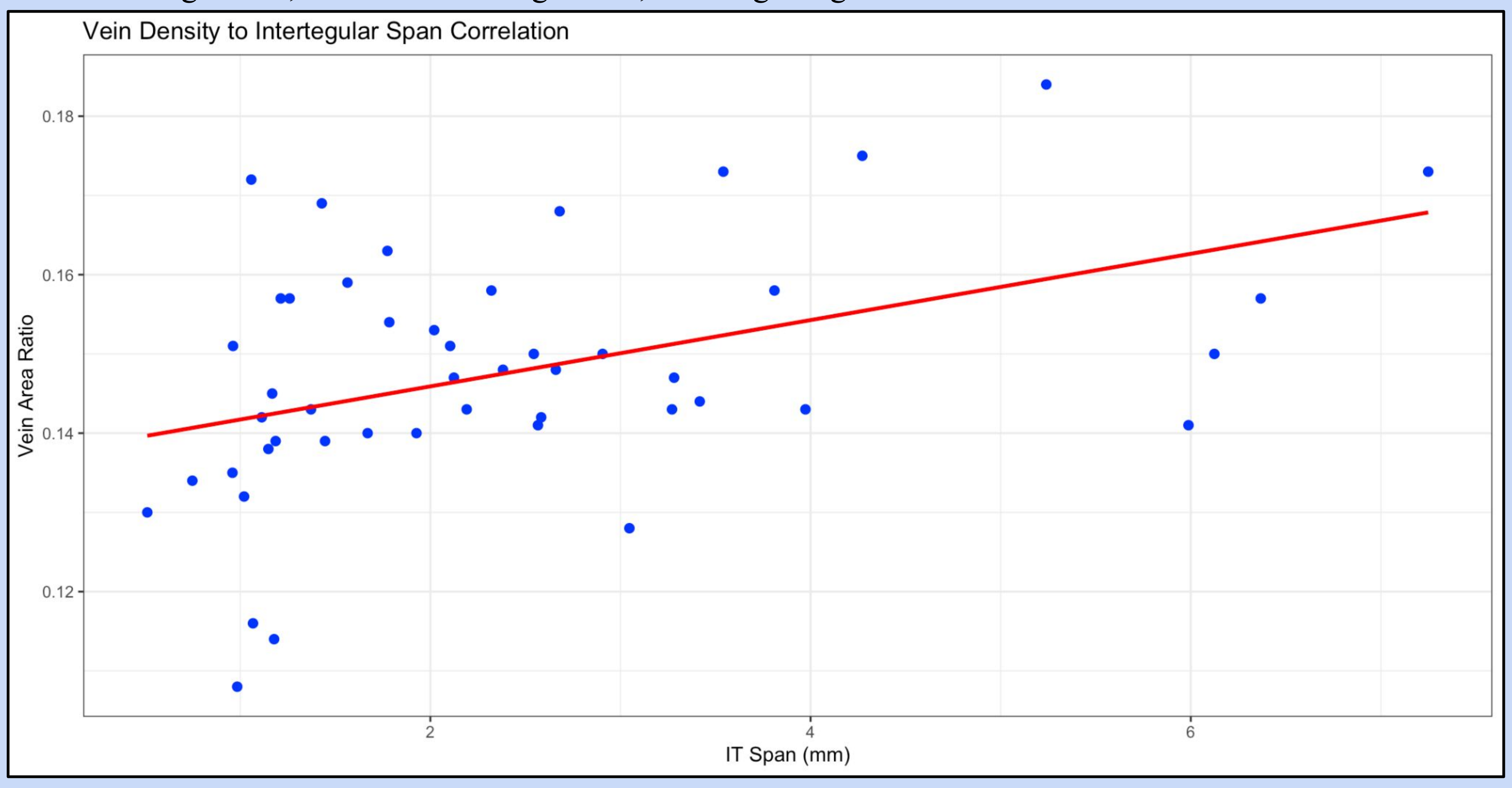

Fig. 3 Scatter plot with linear regression showing the correlation between wing vein density ratio and body size.

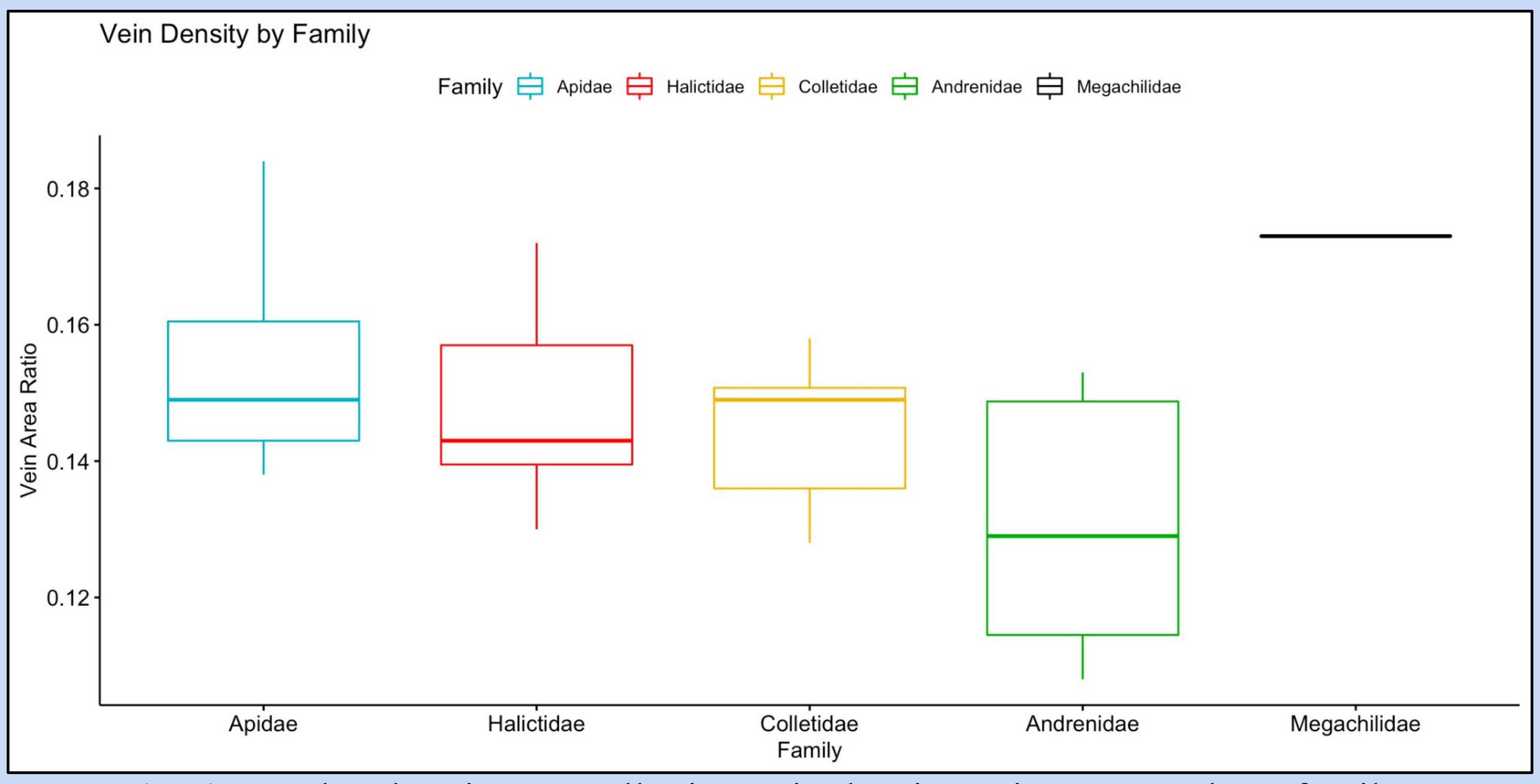

Fig. 4 Boxplot showing overall wing vein density ratio measured per family.

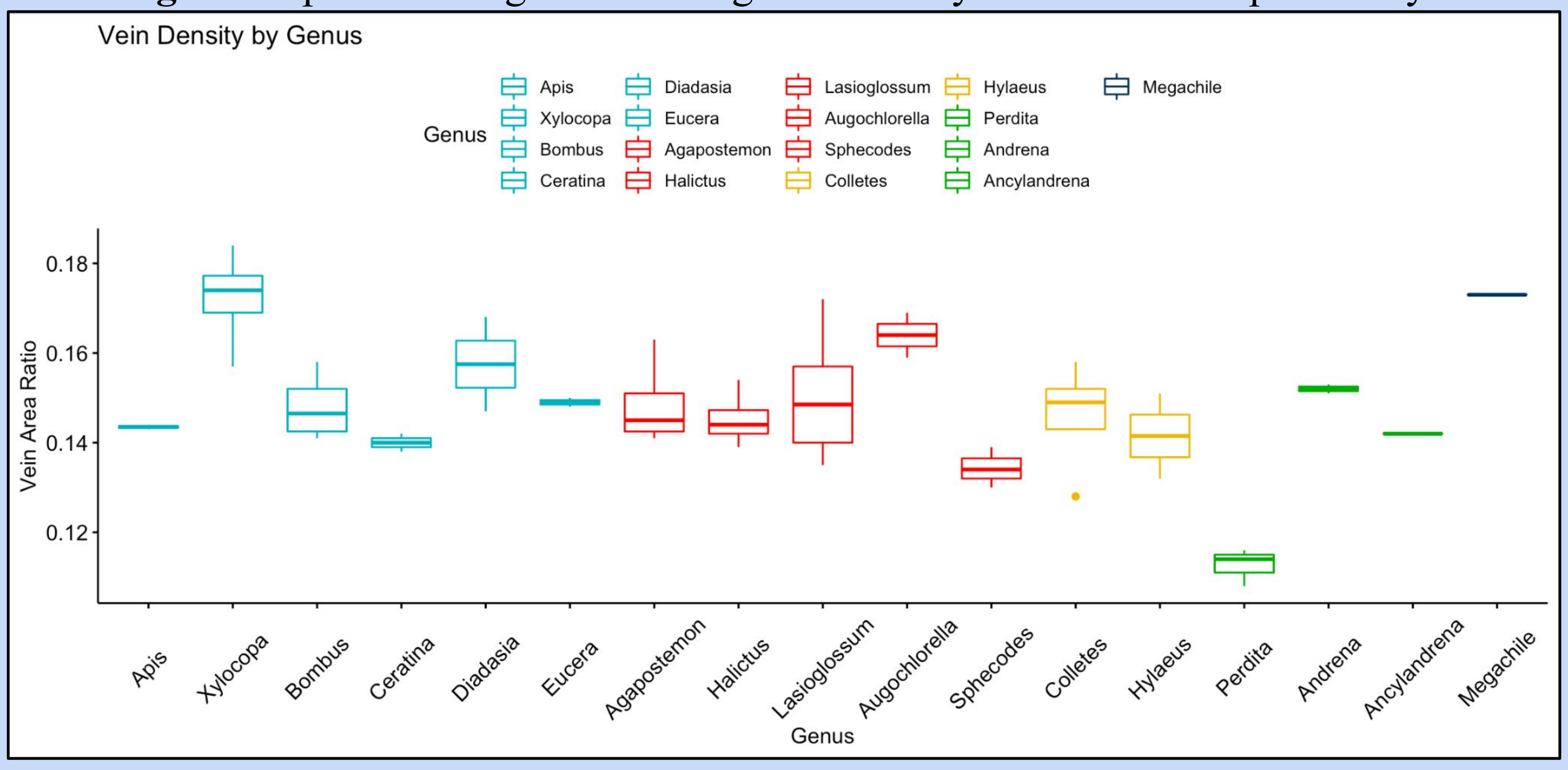

Fig. 5 Boxplot showing overall wing vein density ratio measured per genus. Refer to figure 4 for color key by family.

Discussion

The moderate positive correlation between WVD and intertegular span indicates that bee body size is a factor that influences the density of bee wing veins. Even though the Pearson Correlation Coefficient test resulted in a statistically significant p-value, the coefficient of determination was low indicating that there are additional factors besides body size (as determined by ITS) influencing the WVD.

Our results indicate that wing vein density is conserved at the genus level and that the genus a bee is found determines WVD more than its designated family. It should be noted, however, that their was more data at the genus level than family, and even fewer for species.

Looking at both body size and taxonomy together, it appears that they both have some level of significance in determining WVD. Nonetheless, the results indicate that the genus has a much greater impact on predicting WVD than body size alone. There are a few examples illustrating this point in the dataset. When looking between genera in the family Apidae, the WVD differs quite significantly and the genus with the highest WVD, *Xylocopa*, is also a genus of relatively large bees. Yet, another genus within Apidae, *Diadasia*, also had a high WVD, but is actually less than half the body size of the *Xylocopa*. Furthermore, the genera *Sphecodes* and *Hylaeus* both had smaller ITS than the genus *Perdita*, but *Perdita* ended up having the lowest WVD by far.

The results and findings of this study increase our understanding of the relationships between WVD, body size, and taxonomic group. Further data collection would be beneficial to reduce the weight that any one taxonomic group has on the overall relationships. This study aimed to include at least two specimens of each species and an equal number of specimens per family and genus, but that goal proved to be more challenging than anticipated. However, given more time and resources, further research should be conducted in order to include a larger variety and number of genera and species, as well as a wider range of body sizes.

Literature Cited

Bullock, S. H. 1999. Relationships among Body Size, Wing Size and Mass in Bees from a Tropical Dry Forest in México. Journal of the Kansas Entomological Society 72: 426–39.
Danforth, B. N. 1989. The Evolution of Hymenopteran Wings: The Importance of Size. Journal of Zoology 218: 247–276.
Cane, J. H. 1987. Estimation of bee size using intertegular span. Journal of the Kansas Entomological Society 60: 145-147.