Title

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Identifying the Impact of Body Measurements on Dry Weight Across and Within Bee Species

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UC SANTA BARBARA Cheadle Center for Biodiversity & Ecological Restoration

Smithsonian Institution

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Background

Bee body size affects their foraging behaviors, carry pollen, and adapt to environmental conditions. Body size is influenced by environmental factors such as food availability and temperature. As global temperature continues to increase, body size tends to shrink, influencing foraging behavior by decreasing foraging range [1] and affects the flowering community which affects bees with a narrower diet [2]. It is crucial to accurately measure body size and determine **whether particular body measurements can predict size variation across and within species**. Because we are using a museum's collection, as many researchers do for ecological and evolutionary studies, the process of measuring body size is challenging as bees are often small and may be missing body parts.

Fig. 1. Damaged and undamaged specimens

Fig. 2. Missing body parts in specimens' boxes

Experimental Design/Methods

In this study, we examined ten different bee species across three different families from the UCSB Invertebrate Zoology Collection. We compared body and wing measurements as proxies for dry weight for both damaged and non-damaged bees. We removed the labels from all the dry specimens and weighed them (Fig. 2). The true weight of the bee was then obtained by deducting the average pin weight from the overall weight. All specimens' head width was measured by measuring the widest part of the head using a microscope. We measured intertegular distance, wing length, costal vein, marginal cell, radial cell, and wing width using ImageJ version v1.54g. To understand the relationships between dry weight and the measurements, we used fitted vs. residuals and QQ plots to test for normality and linearity, along with performing simple linear regression using R version 4.4.0. In order to perform significance tests within species, we only conducted on a sample size of females greater than 10 (n > 10).

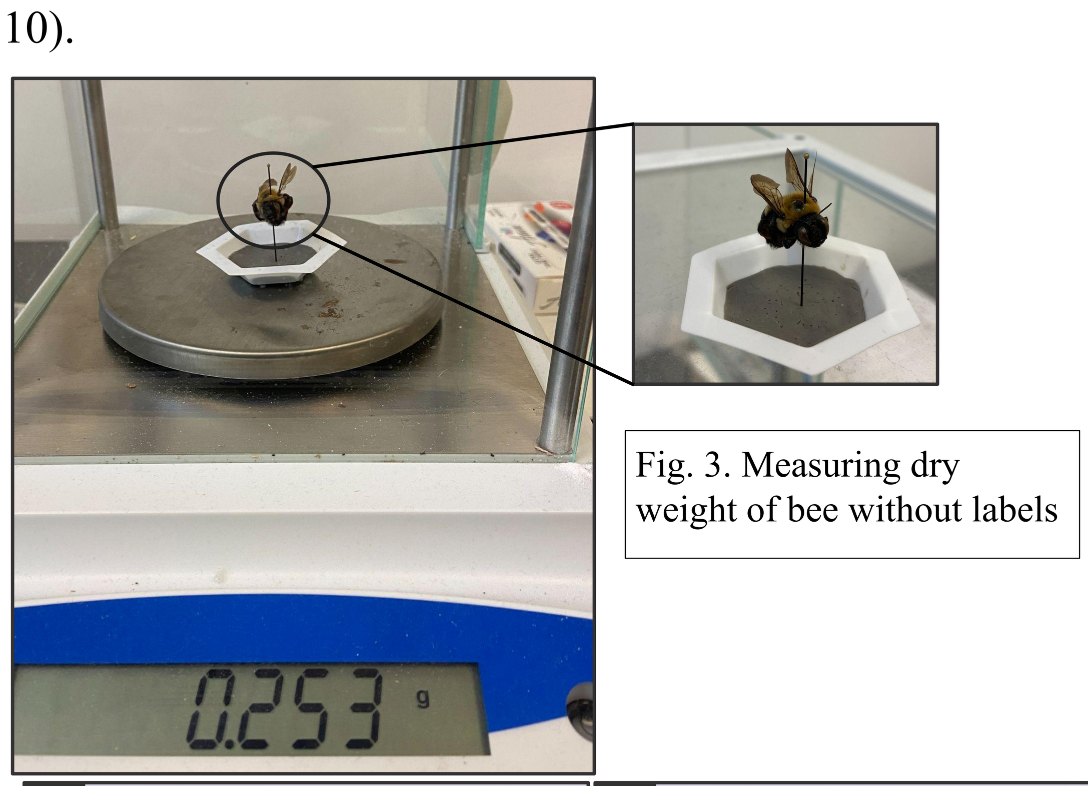


Fig. 3. Measuring dry weight of bee without labels

Fig. 4.
a. Measuring head width
b. Measuring intertegular distance

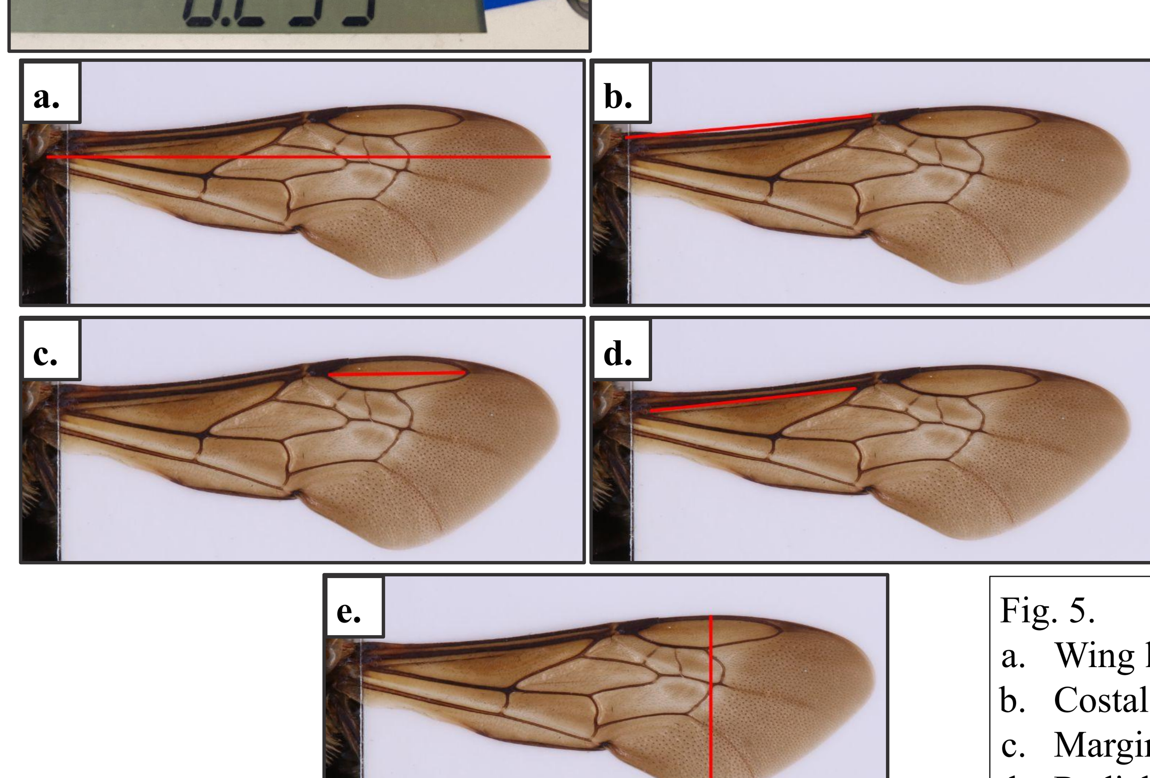


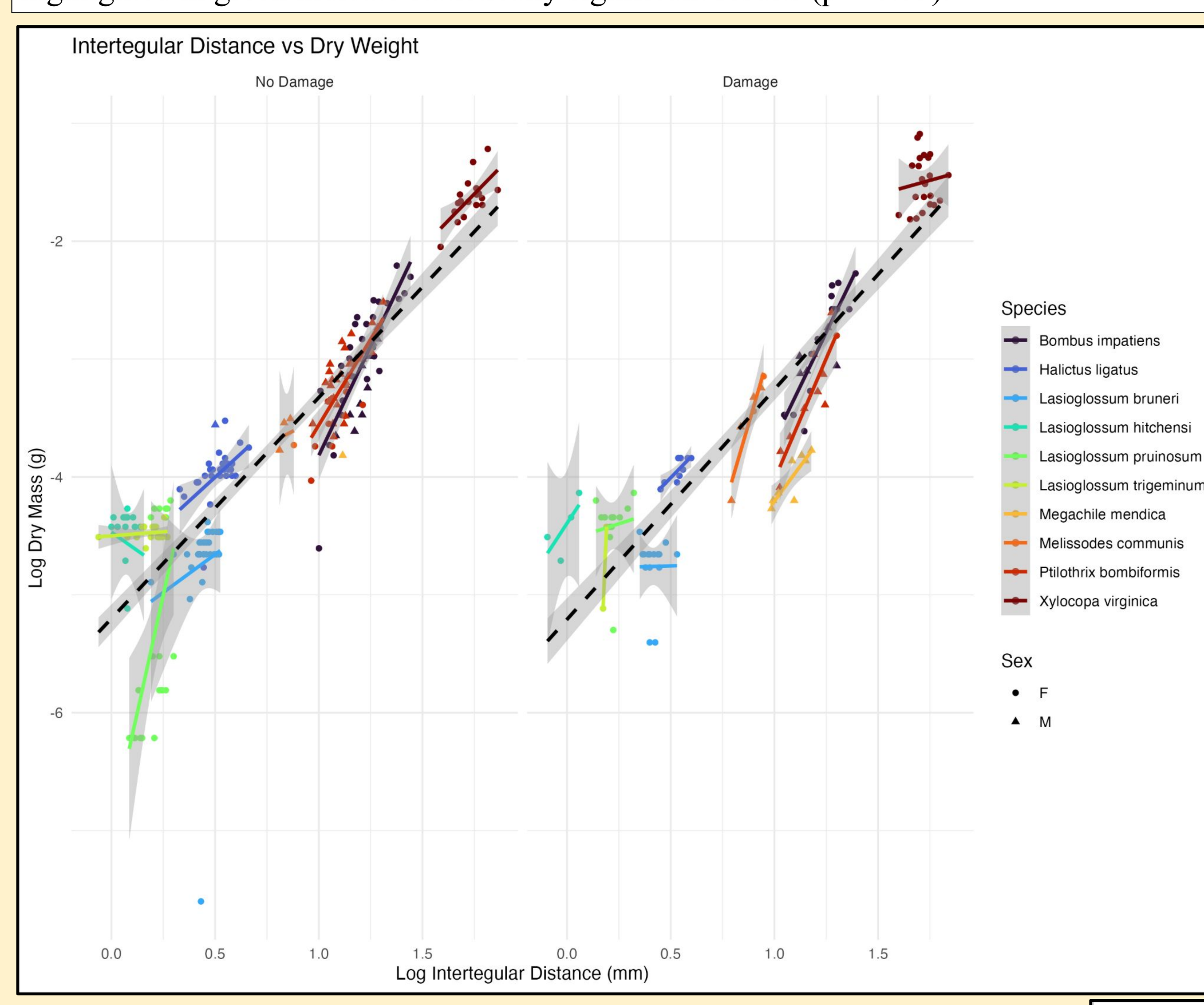
Fig. 5.
a. Wing length measurement
b. Costal vein measurement
c. Marginal cell measurement
d. Radial cell measurement
e. Wing width measurement

Results

Body measurements are inconsistent predictors of body size within species as seen in Fig. 6.

Measurement/Species	Xyl. vir.	Bom. imp.	Pti. bom.	Hal. lig.	Las. hit.	Las. tri.	Las. pru.	Las. bru.
ITD p-value	0.0552	1.23E-12	0.00191	0.0003083	0.7327	0.6876	0.01113	0.3826
Head Width p-value	0.01042	1.46E-15	0.003289	0.0001161	0.281	0.9288	0.149	0.3889
Wing Length p-value	0.1624	0.3627	0.0001834	0.1182	0.7898	0.1826	0.1508	0.8384
Costal Vein p-value	0.5429	0.5927	0.06135	0.4532	0.6792	0.3064	0.3595	0.8421
Radial Cell p-value	0.1328	0.883	9.18E-05	0.07894	0.5311	0.211	0.3397	0.8815
Wing Width p-value	0.6983	0.7421	0.3832	0.367	0.6745	0.1981	0.4061	0.7451
Marginal Cell p-value	0.2746	0.7627	0.0006345	0.4418	0.7248	0.5678	0.1315	0.8579
Body Size p-value	0.5456	0.002909	0.6731	0.259	0.7409	0.2926	0.6795	0.004394
Wing Size p-value	0.784	0.9585	0.3468	0.3392	0.6586	0.1151	0.6177	0.854
Marginal Cell/ Costal Cell	0.9055	0.8432	0.3265	0.9264	0.9054	0.8368	0.7449	0.4733
Radial Cell / Costal Cell p-	0.5498	0.9686	0.4242	0.6922	0.4813	0.4062	0.9878	0.4774
Width / Length p-value	0.2253	0.3183	0.01581	0.1947	0.1706	0.5261	0.0238	0.8185

Fig. 6. Summary of p-values, Adjusted R^2, & R^2 for each measurement within species. Species are represented by their abbreviated names: Xyl. vir (*Xylocopa virginica*), Bom. imp. (*Bombus impatiens*), Pti. bom. (*Ptilothrix bombiformis*), Hal. lig. (*Halictus ligatus*), Las. hit. (*Lasioglossum hitchensi*), Las. tri. (*Lasioglossum trigeminum*), Las. pru. (*Lasioglossum pruinosum*), Las. bruh. (*Lasioglossum bruneri*). Cells highlighted in green indicate statistically significant results ($p < 0.05$).



Damaged and undamaged specimens are both linear across and within species as seen in Fig. 7

Fig. 7. Comparison of Species Across Damage & No Damage Groups: The graph on the left illustrates the relationship between log intertegular distance (x-axis) and log dry mass (y-axis) for undamaged species, with each point color-coded for species. The graph on the right mirrors the same relationship for damaged species. The lines within each color represent the within-species relationships.

ITD and Head Width are the same significance level for damaged and undamaged bees as seen in Fig. 8.

	p-value	Adjusted R^2	R^2
No damage (HW)	< 2.2e-16	0.8052	0.8061
Damage (HW)	< 2.2e-16	0.7997	0.8018
No damage (ITD)	< 2.2e-16	0.7840	0.7850
Damage (ITD)	< 2.2e-16	0.8379	0.8394

Fig. 8. Summary of p-values, Adjusted R^2, & R^2 for damage and no damage species, focusing on head width and intertegular distance measurements.

Body measurements are strong predictors of body size across species as seen in Fig. 9.

Measurement	p-value	Adjusted R^2	R^2
ITD	< 2.2e-16	0.8096	0.8101
Head Width	< 2.2e-16	0.81	0.8106
Wing Length	< 2.2e-16	0.6625	0.6659
Costal Vein	< 2.2e-16	0.709	0.7119
Radial Cell	< 2.2e-16	0.6537	0.6687
Wing Width	< 2.2 e-16	0.6913	0.6945
Marginal Cell	< 2.2e-16	0.7122	0.7151
Body Size	0.0109	0.03242	0.03818
Wing Size	0.7464	-0.01821	0.002154
Marginal Cell/ Costal Cell	0.0001776	0.1254	0.1342
Radial Cell / Costal Cell	0.006194	0.06517	0.07471
Width / Length	0.1045	0.01691	0.02694

Fig. 9. Summary of p-values, Adjusted R^2, & R^2 for each measurement across species. Cells highlighted in green indicate statistically significant results ($p < 0.05$).

Conclusions

We determined that intertegular distance (ITD) and head width (HW) to be the most significant predictors of dry weight across species and within most species, suggesting that these measurements may be used to accurately estimate dry weight. We also found that intertegular distance significantly predicted dry mass even in specimens missing body parts, suggesting that this measurement is somewhat robust to specimen damage. Furthermore, we observed that across species, body size, marginal cell/costal cell, and radial cell/costal cell are similarly significant. Within species, we observed ITD, and HW to be significant within half the species. *Ptilothrix bombiformis* is significant in half of the measurements, *Bombus impatiens* and *Lasioglossum bruneri* are significant in body size, and *Lasioglossum pruinosum* is significant in width/length. Overall, this research helps us better understand which body measurements can predict size variation in across and within species and for future projects focused on identifying which bee species may be more vulnerable to environmental changes based on their body parts and size.

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Big-Bee LATINO CENTER Smithsonian NSF

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