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Title
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Utilizing Surface Area to Volume ratios and Thermal Tolerance of Various Bee Species to Predict their Performance under Rising Global Temperatures

UC SANTA BARBARA Cheadle Center

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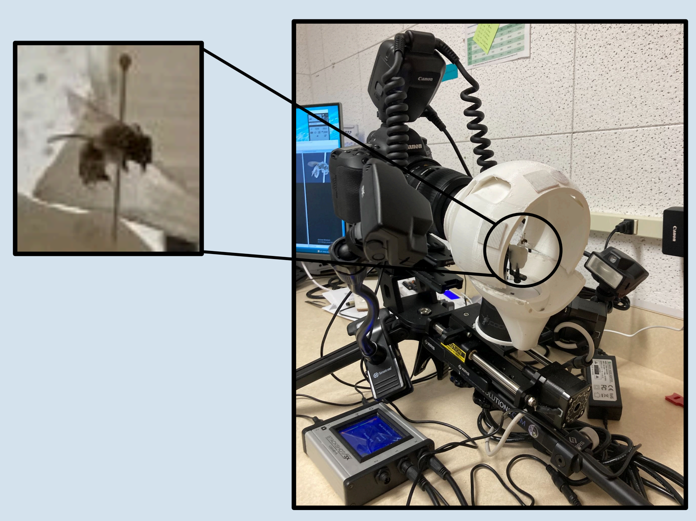
Abstract

The purpose of this research project is to investigate how rising temperatures, for instance climate change, can affect bees of various body sizes given their essential role in the global food supply through pollination of agricultural crops. To achieve this I utilized 3D imaging and 3D modeling techniques to calculate surface area-to-volume (SA/V) ratios of the bees that otherwise cannot be obtained using conventional methods. SA/V ratios were calculated for 4 different families (Halictidae, Colletidae, Apidae, and Megachilidae) in the order Hymenoptera and were analyzed alongside the bee's Critical Thermal Maximum (CT Max) data, the maximum heat a bee can withstand before losing mobility, to gain insight on the bee's ability to survive in extreme hot temperatures. It is evident from the data that larger bees, characterized by smaller SA/V ratios, presented a higher CT Max suggesting their greater chance of survival in higher temperatures than smaller bees due to less heat exchange relative to their body size. This data implies that with earth's rising global temperatures larger bees will likely perform better than smaller bees.



Methods

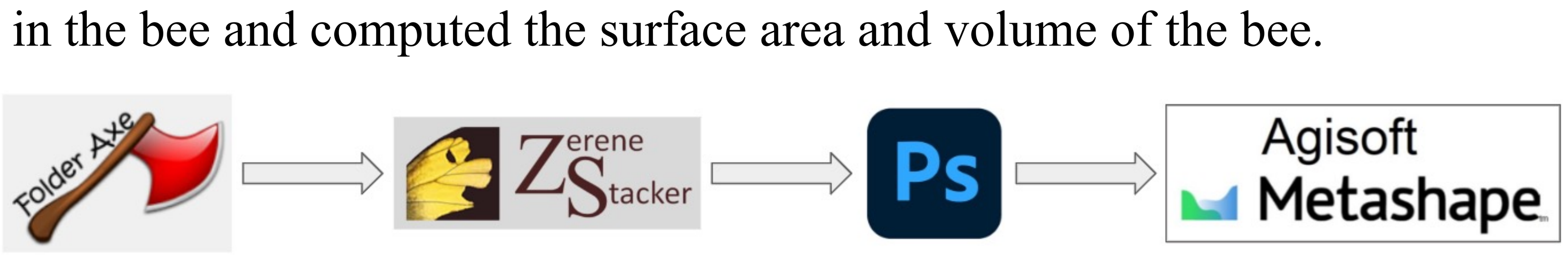
All 21 bee species underwent a consistent methodology and were chosen at random from the collection box

CT Max:

- Dr. Madeleine Ostwald conducted controlled thermal ramping experiments to assess the bees CT Max

3D-imaging and 3-D modeling:

- Equipment: Canon EOS 6D camera, MP-E 65mm lens, Quantum AC Turbo flash and flash arms, Macroscopic solutions light diffuser
- Camera captured photographs of specimens at 30-80 different depths and 120 different angles, rotating every 3 degrees
- Carried out photogrammetric processes by employing multiple software applications. Used Agisoft Metashape: Professional Edition to remove the pin in the bee and computed the surface area and volume of the bee.



Processing the data:

- R programming language was executed in RStudio Cloud browser
  - tidyverse package
  - ggplot command for scatter plots

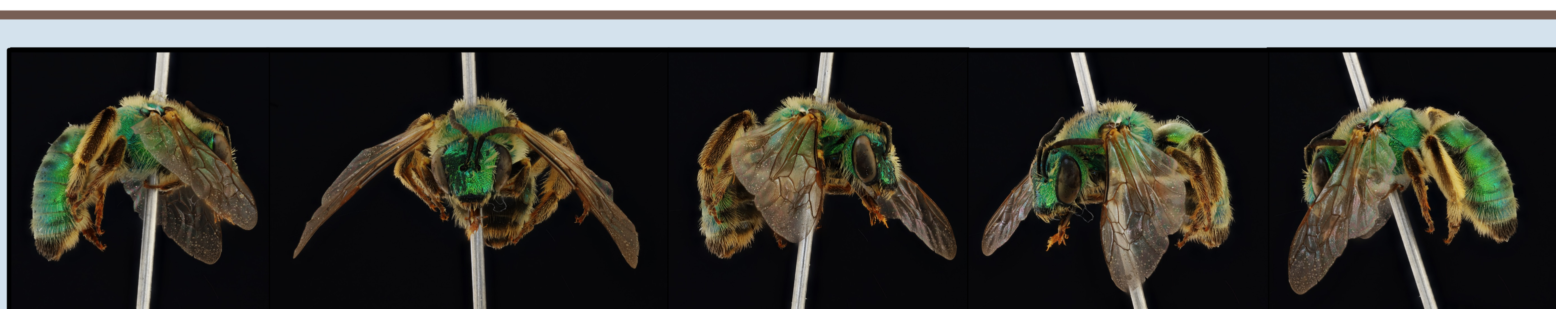


Fig 1: focal stacked photograph of *Agapostemon texanus*

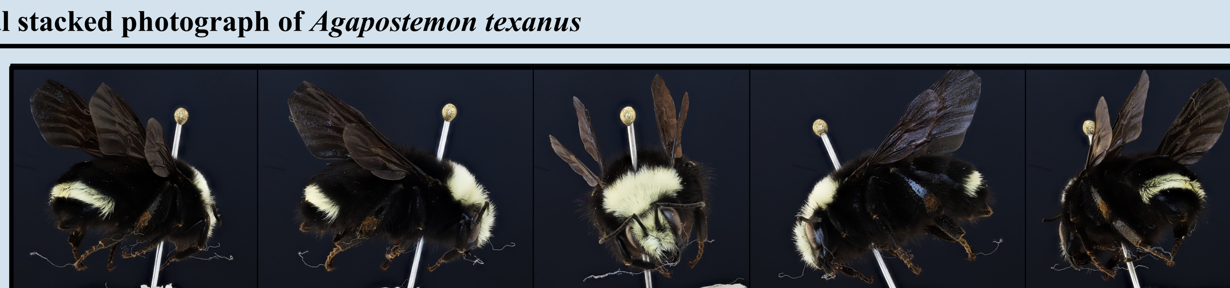


Fig 2: focal stacked photograph of *Bombus vosnesenskii*

Literature Cited

- Kühsel, Sara, et al. "Surface Area-Volume Ratios in Insects." *Insect Science*, vol. 24, no. 5, 15 Aug. 2016, pp. 829–841, https://doi.org/10.1111/1744-7917.12362.

Results/Discussion

- Analysis of the data revealed larger bees, characterized by a smaller SA/V ratio, have a greater capacity at tolerating higher temperatures while smaller bees, characterized by a larger SA/V ratio, cannot withstand such high temperatures
- No significant trend is observed when analyzing individual measurements with their corresponding CT Max
- Considering bees are ectotherms and heat exchange is constantly occurring with the organisms and their outside environment we can make sense that smaller bees, lacking volume and having more surface area, do not have as much heat resistance and heat inertia as a bigger bee would have.

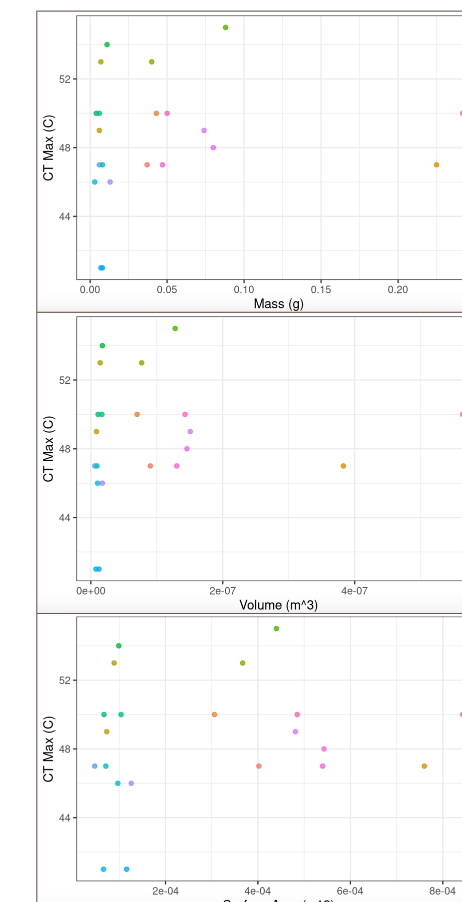


Fig. 3: No significant relationship was observed between these individual measurements and their CT Max for the bee species

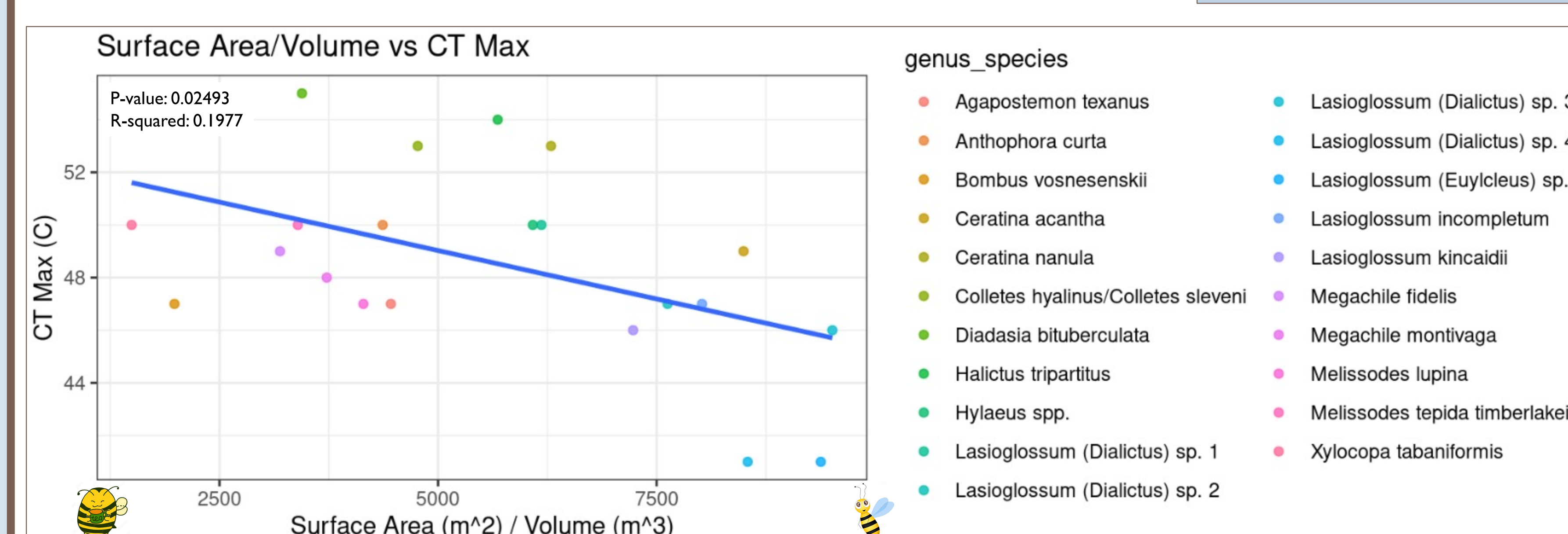


Fig 4: As bees decrease in overall size, larger surface area to volume ratio, the amount of heat they can tolerate decreases as well

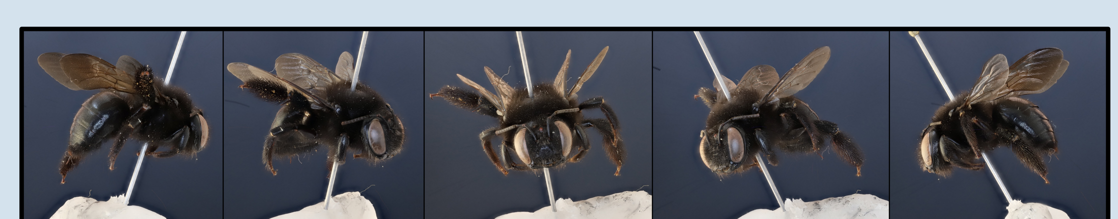
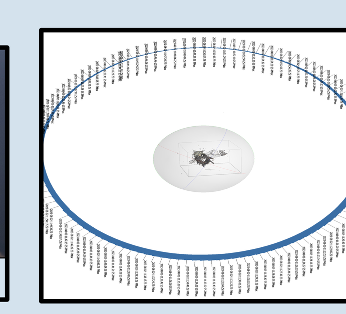


Fig 5: focal stacked photographs of *Xylocopa tabaniformis*



Conclusions/Future Research

- Given the complex relationship between bee body size and heat tolerance, with mixed data for this analysis across taxonomic groups, our study shows a significant correlation between SA/V ratios and heat tolerance, something that is rarely measured. These results indicate that integrating SA/V measurements can improve our understanding of heat tolerance across taxa. While many conservation efforts focus on large charismatic bee taxonomic groups (such as bumble bees), we identified that smaller bees might be at a greater threat under future climate scenarios. We can identify groups of conservation concern by analyzing such traits to predict bee's vulnerability to climate change.
- This regionally focused data set could be further expanded to a larger scale to predict performance of bees in other climates
- This method of 3D-modeling could also be used to test cold thermal tolerance of bees

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