Title

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Publication Date

2024-08-13

Variation in Bee Body Size Due to Anthropogenic Land Use

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Introduction

This study investigated the impacts of land use on bee body size across 18 different species. Adult body size can be impacted by many aspects of an individual's environment, especially during development; a crucial factor is the diversity and abundance of food resources (1). Collection sites were sorted into 3 categories – developed, agricultural, and forest – depending on its land use. **Developed land often has reduced floral diversity and density, and is hypothesized to produce smaller bees due to limited food resources.** To determine body size we took 3 measurements: head width, distance between the wing pads (intertegular distance, or ITD), and dry mass; these are commonly used metrics for bee body size (2). The information from this study can highlight the influence of a changing landscape on bee functional traits, providing essential insights into the ecological consequences of land use on bee health. Considering the amount of pollen a bee can carry and its foraging range is correlated to the bee's body size (1), if bees are decreasing in size due to available habitats, pollination has the potential to decrease as well.

Methods

Head width (Fig. 6) was measured under a microscope and dry mass was measured on a scale (Fig. 3). Dorsal images of the bees were taken and analyzed using ImageJ to determine ITD (Fig. 5). All measurements were converted to z-scores to remove any skewing of results based on differences in relative bee size across species. One-way ANOVA tests (Fig. 8) were performed to determine significance, followed by Tukey's HSD test (Fig. 9). Type of land use was determined using the USGS National Land Cover Database (Fig. 1).

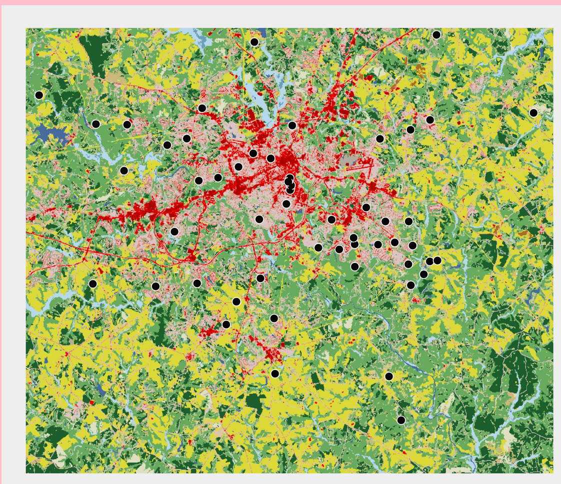

Fig. 1 Black dots represent collection sites centered around Athens, GA and color represents habitat type.

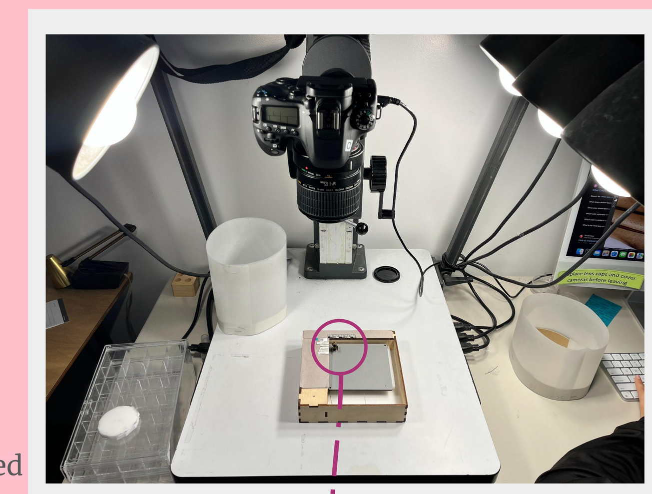

Fig. 2 Set up for dorsal images, analyzed for ITD

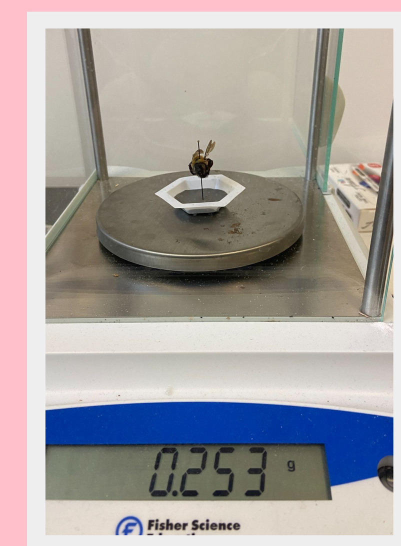

Fig. 3 Measuring dry mass

Fig. 7 X axis represent the type of z-score measurement being analyzed based on habitat type and the y axis represent the z-score value.

Fig. 6 The white line represents the head width measurement taken at the widest point of the head, *Xylocopa virginica* for reference.

^ **Fig. 5** White line across the thorax represents ITD measurement taken between the tegula
> **Fig. 4** Enlarged dorsal imaging set up for bee specimens from Fig.3, *Bombus impatiens* used as example

Results

We found that bees from agricultural habitats were significantly larger than bees from both forest and developed habitats in all metrics – ITD, head width, dry mass, and body size index.

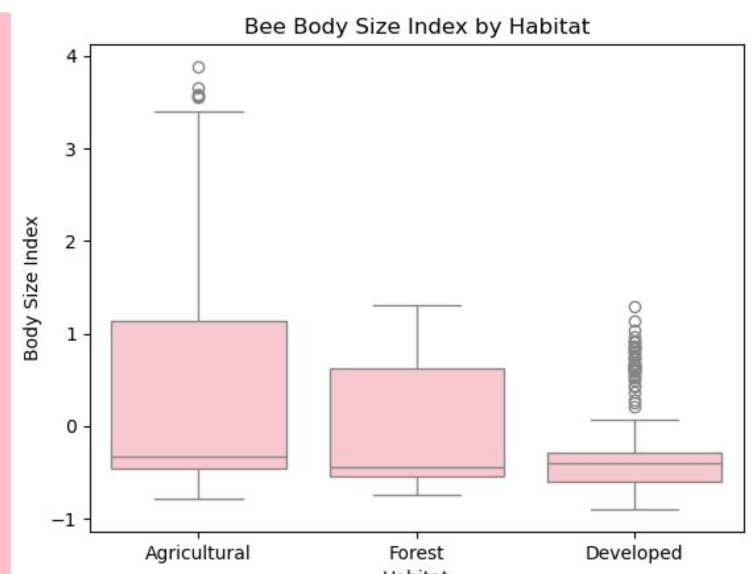

Fig. 10 Boxplot of body size index z-scores on y axis separated by habitat type on x axis

ANOVA Results Testing Body Size Measurements Against Habitat Type

Measurement	p-value	Significant?
Head width	<0.001	Yes
ITD	<0.001	Yes
Dry mass	<0.001	Yes
Body size index	<0.001	Yes

Fig. 8 Table of p-values from ANOVA tests comparing body size metrics against habitat type, and whether they are significant; significance level = 0.0.5

Tukey's HSD Test of Body Size Index between Habitat Types

Habitat Pairing	P-value	Significant?
D & F	0.0189	Yes
D & A	<0.01	Yes
F & A	<0.01	Yes

Fig. 9 Tukey's honest significant difference (HSD) test to determine significant difference between body index z-scores of the 3 habitat types (A = agricultural, F = forest, D = developed); significance level = 0.05

Discussion

In this study we saw that agricultural land use plots produced larger bees while bees from forest and developed plots were smaller. From the ANOVA and post hoc tests, we can see that the type of habitat the bee was collected from did affect its size. From this information, we can garner that anthropogenic land use does have the potential to alter bee populations by affecting the size of the individuals. Since smaller bees are not able to carry as much pollen or forage as far (1), if anthropogenic land use in developed areas continue to not provide sufficient floral resources to bee populations, there is a chance of decreased pollination in those areas.

To advance this study, we could investigate the collection sites further to identify any other aspects that could have affected the results. These features could be abundance of flowering plants in bloom during the collection season, type of flora available, and average temperatures and climate during collection. Considering the specimens were collected up to nearly 9 years ago, this could prove difficult; however, it could provide valuable insight about how underlying environmental conditions can affect the development of different bee species. To counteract this difficulty, we can also repeat the experiment with an emphasis on local plants surveys to determine how local flora influences bee size.

References

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Acknowledgements

This project was supported by the National Science Foundation project Extending Anthophila research through image and trait digitalization (Big-Bee, #DBI2102006). The UCSB-Smithsonian Scholars received federal support from the Latino Initiatives Pool, administered by the National Museum of the American Latino. Thank you to S.K. Braman and the University of Georgia, College of Agricultural and Environmental Sciences for providing the specimens used for this study.