Title
Body Size-Mediated Wing Wear: Analyzing Wing Damage in Native Bee Species Using Image Segmentation Model

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Body Size-Mediated Wing Wear: Analyzing Wing Damage in Native Bee Species Using Image Segmentation Model

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Introduction

Damage to bee wings commonly occurs during ecologically-essential foraging and flight activities of bees. Interactions and collisions with native environmental conditions such as wind and vegetation leave wings exposed to potential wear and tear[1]. Morphological traits influence bee flight performance, as bees with larger bodies show increased flight distance capacity and foraging range[2].

In this study, we analyze degree of wing wear predicting that larger bees will accumulate more wing damage from extended exposure to environmental wear. This was done by imaging wings across bee species native to Santa Barbara County and manually creating image masks to isolate the wing from its background. This was used to train a computer vision model with ground-truth data to automate this scoring. This image segmentation model allows for comparison of degree of wear in the wing margin across species and analysis of variation between body sizes, and was compared against a manual wing wear scoring index to assess accuracy. Comparing wear patterns across species could offer insight on species resilience in native habitats.

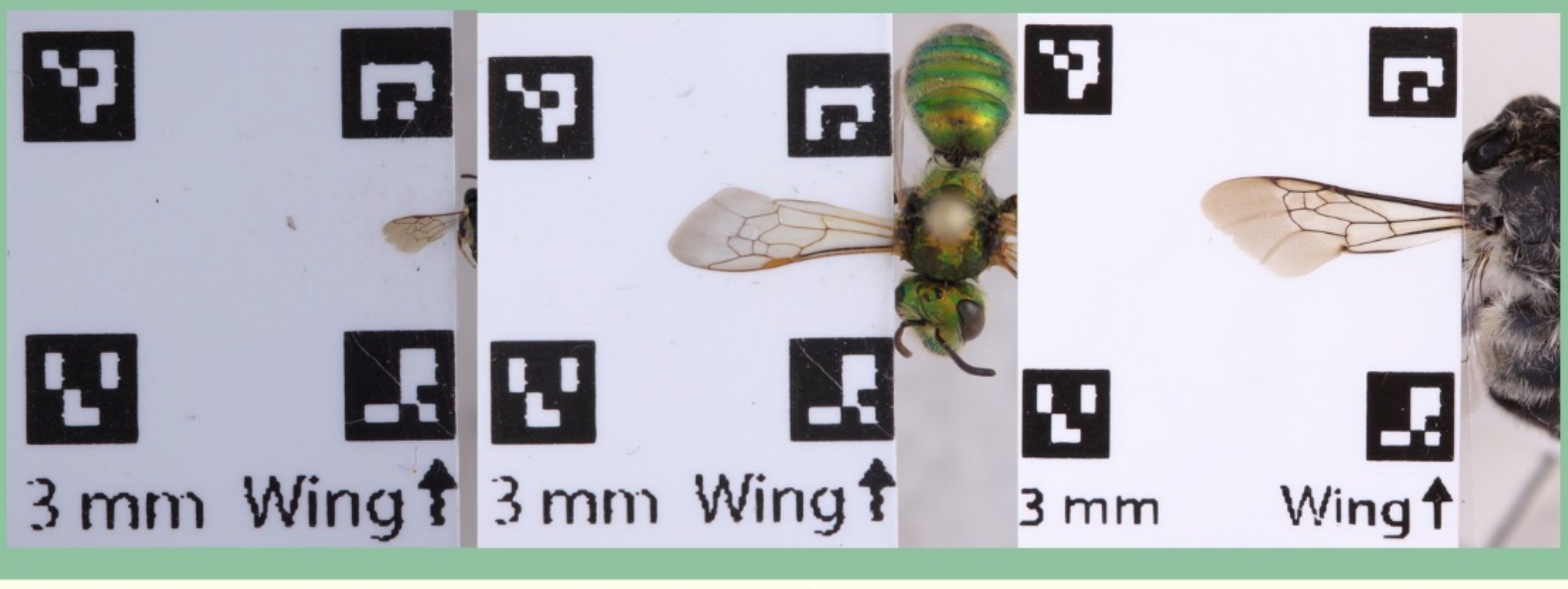

Figure 1: Various Body Sizes in *Ceratina arizonensis* (left), *Agapostemon texanus* (middle), *Anthrophora edwardsii* (right)

Methodology

The computer vision model was trained to classify pixels in bee wing images as either wing or background, using a training dataset composed of 159 pairs of wing images and their ground truth masks created in Adobe Photoshop. After raising segmentation accuracy to 92.9%, the model was given 465 new images spanning 53 various native bee species to perform this autonomous segmentation, producing wing wear scores as an area:perimeter ratio of the predicted masks generated from the input images.

A wing wear scoring index (Figure 5) was created to manually score the degree of wing wear for each of the 465 images on a scale of 0-6, and was assessed against the computer vision model to test the accuracy and efficiency of manual vs automated methods of data analysis. The images were manually scored by 2 researchers in this project, averaged, and analyzed through a Spearman Correlation Plot (Figure 3) and Mann-Whitney U Test using the R package "ggplot2."

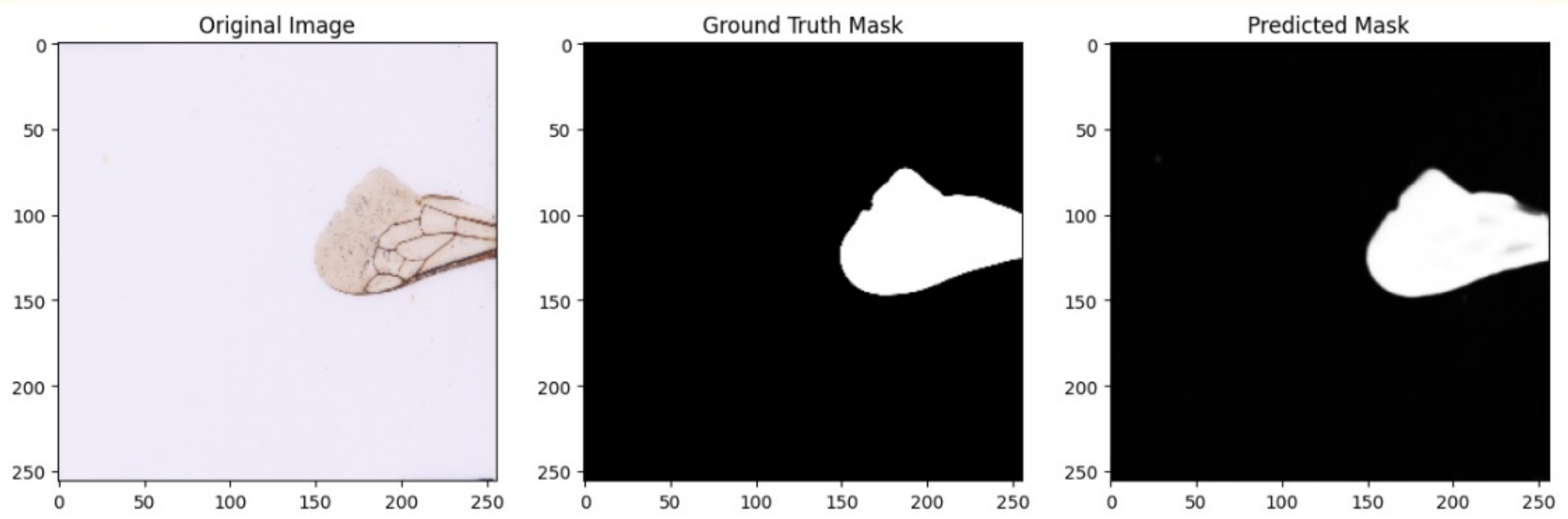

Figure 2: Original Wing Image and Manual Image Mask (Input), Predicted Mask (Output)

Discussion

The computer vision model exhibited a weak statistically significant correlation with the manual wing wear scores (S = 16622009, p-value = 0.008027, sample estimates: rho 0.120369), as demonstrated in Figure 3's variation from the linear trend. This result indicates a lack of accuracy in the method of manually scoring compared with the computer vision model, which had a 92.9% segmentation accuracy. The model's ability to predict results, being trained from a large dataset of bee wings with diverse phenotypic traits and degrees of wear, offers potential in future research applications by quickly and accurately automating results for large-scale sets of quantitative data.

No statistically significant difference was found between the average body size of each species and the degree of wing wear (F-stat = 2.015, p-value = 0.1635, r2 = 0.02416) in performing a linear regression test. Bees with larger body size did show some tendency to have larger average degrees of wing wear (Figure 4), but there may be some confounding variables alongside body size such as sex or lifespan in order to accurately predict degrees of wing wear, on which further research can be conducted. However, this correlation of larger body size and increased degree of wing wear suggests that larger bees may be more vulnerable to environmental stresses such as through stronger or increased number of collisions with the native topology, or through larger body sizes correlating with more demanding flight and foraging efforts. With further research on bee phenotypic diversity in their native climate and in further refining the use of area to perimeter ratio as an indicator of degree of wear, these correlations and model could offer insight on species resilience in their native habitats and have potential implications bioindicators of the local foraging ecology and environmental stress/fragmentation.

Results

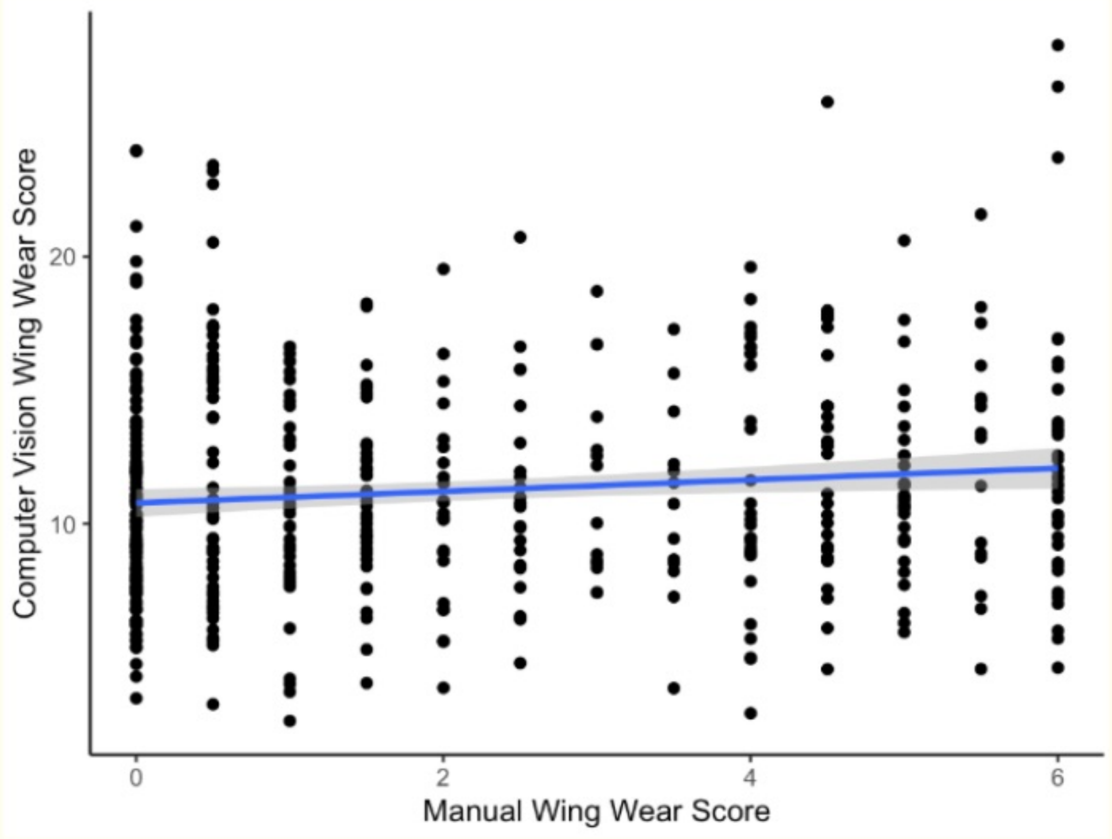

Figure 3: Spearman Correlation Plot of Manual vs Computer Vision Wing Wear Scores

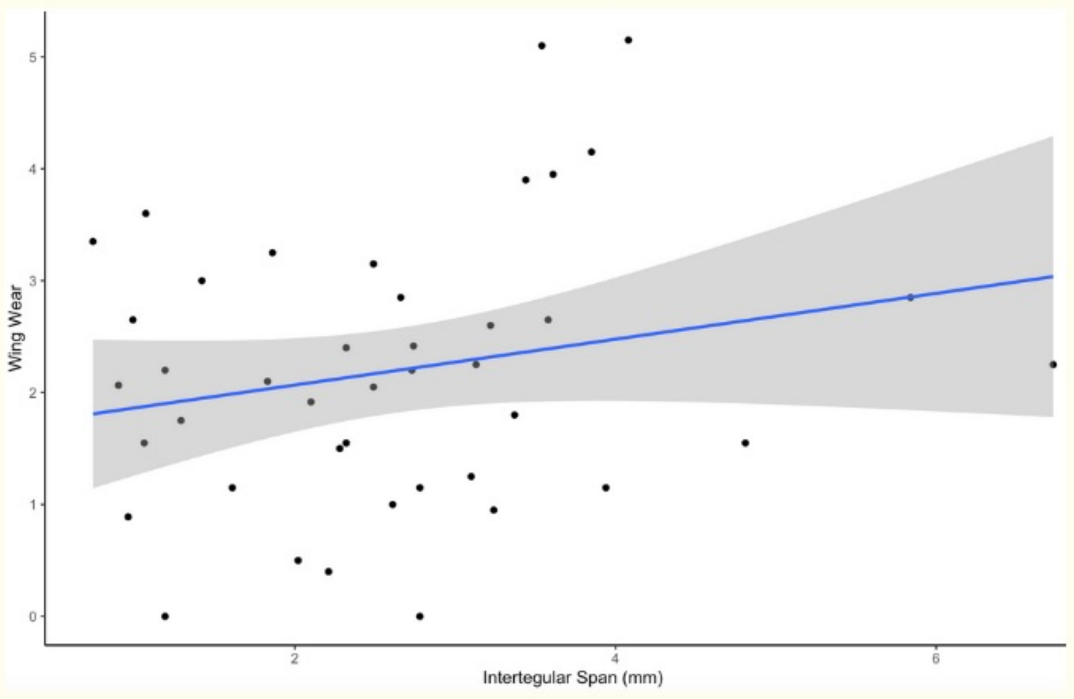

Figure 4: Scatterplot of Species Average Body Size vs Degree of Wing Wear

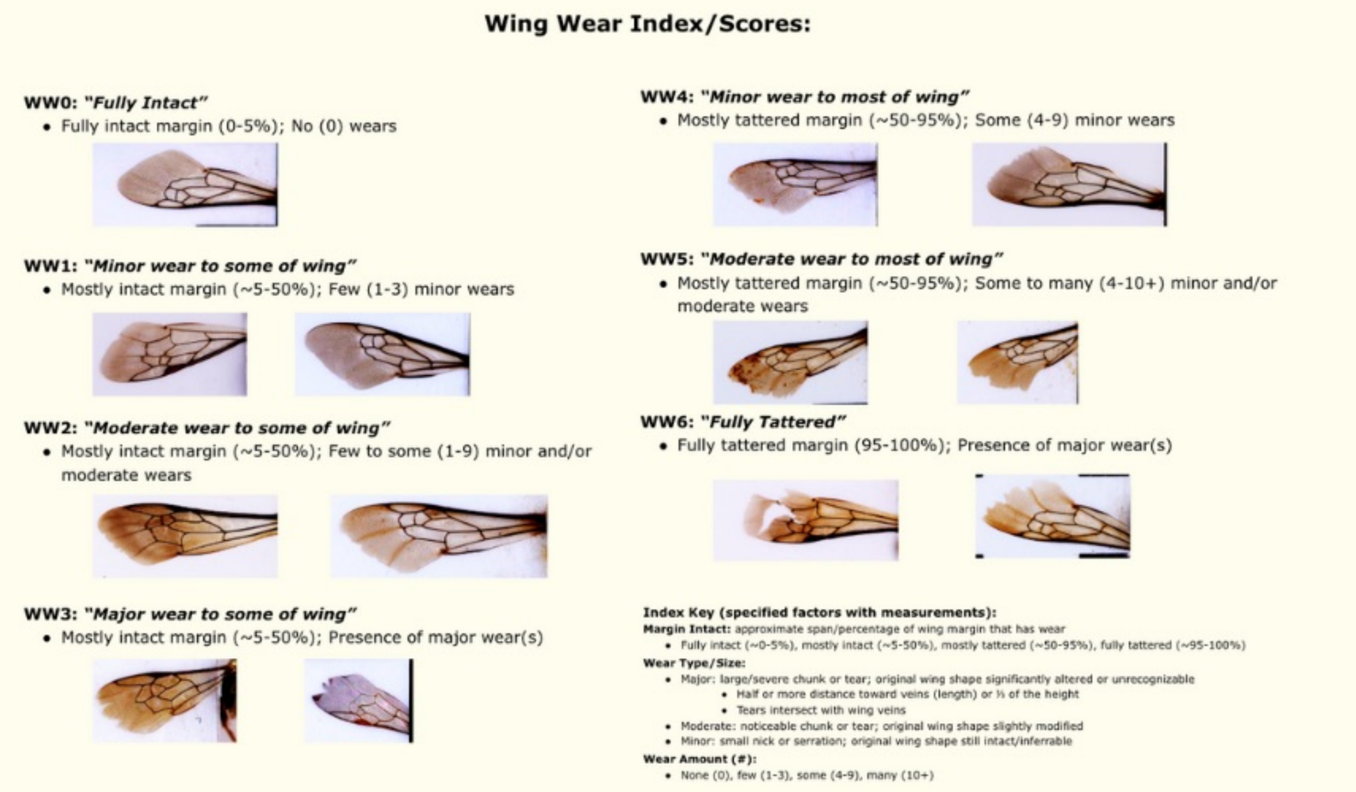

Figure 5: Index and Key of Manual Wing Wear Scores

References

1. Foster DJ, Cartar RV. What causes wing wear in foraging bumble bees? J Exp Biol. 2011 Jun 1;214(Pt 11):1896-901. doi: 10.1242/jeb.051730. PMID: 21562177.
2. Mueller, U.G., Wolf-Mueller, B. A method for estimating the age of bees: Age-dependent wing wear and coloration in the Wool-Carder bee*Anthidium manicatum* (hymenoptera: Megachilidae). *J Insect Behav* 6, 529–537 (1993). https://doi.org/10.1007/BF01049530

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