Demographics of an Emergent Neotropical Ant-Plant Symbiosis

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Introduction

Ant-plant symbioses are ecological interactions that often result in coevolutionary dynamics. In many of these associations, ants defend their host plants from herbivores and parasites, which can enhance host plant fitness. In return, host plants typically provide preformed nesting structures (domatia) and nutritional rewards. However, not all symbioses conform to this pattern. In some systems, such as the *Myrmelachista* ant and Lauraceae plant associations, host plants offer limited structural or nutritional rewards to their tenant ants, suggesting this symbiosis is still in its primordium. The genus *Myrmelachista* is comprised of obligately arboreal ants that nest within both dead and live plant stems. Some live-stem nesters are specialists, exhibiting associations with specific host plants; whereas most are generalists, occupying a broader range of host plant species. In the absence of direct nutritional rewards from their host, specialist *Myrmelachista* species associate with sap-feeding hemipterans (Coccoidea: mealybugs and soft scales) that inhabit the nest (Figure A). These hemipterans produce an exudate called honeydew, an exudate which serves as a nutritional resource for the ants. This forms a tritrophic symbiosis, in which ants rely on the host plant for nesting and Coccoidea for food. Because Lauraceae hosts do not provide domatia, *Myrmelachista* colonies are excavated within plant stems.

Objectives

The goal of our study is to assess whether host plant size and specialist *Myrmelachista* colony size are related, how adults, brood, and Coccoidea are distributed within excavated stem cavities, and how Coccoidea populations within those cavities relate to colony size in hosts lacking direct rewards.

Figure A. Exterior view of Lauraceae treelet in the Costa Rican understory, occupied by *Myrmelachista* ants.

Figure B. Cross section of a host plant, highlighting cavity with *Myrmelachista* queen, brood mass, and workers.

Methodology

Sampling and Quantification

Colonies of specialist *Myrmelachista* were collected from Lauraceae treelets in Costa Rica during December 2019 to March 2020. For three host plants, whole colonies were quantified; individual branches of ten additional plants were sampled to assess colony demographics. Height, stem diameter, and branching architecture were recorded for all samples. Stem sections were dissected and contents were removed and examined under a stereomicroscope. Individuals were sorted into adults (alate queens, males, workers), brood (larvae and pupae), and Coccoidea.

Volume Estimation and Data Analyses

A population model was developed and uses complete Lauraceae hosts to derive constants (Ω and τ). Effective stem length was calculated from treelet height and branch length using Ω. Population estimates were calculated by first determining the density of a sample, then multiplying that density by the host plants effective length, with a taper correction (τ) added to account for vertical decline in population. Estimates were generated in Python (≥3.13) and validated against whole-plant counts. R (>4.3) was used to generate descriptive statistics and to analyze the relationships between effective length, colony size, and Coccoidea populations.

Results

Treelet heights ranged from 0.93-5.5 m (mean = 3.1 ± 1.4 m). After calculating our model constants (Ω = 1.48 and τ = 0.72), we applied our population model to complete host plant samples (n = 3) finding that estimates were 9.8 % higher than true colony size on average. Estimated populations ranged from 1,072-30,751 individuals (mean = 11,362 ± 10,091). Colony composition was relatively uniform across tree height, with adults comprising 59% ± 15% and brood 41% ± 17%. Associated Coccoidea populations ranged from 0-1,316 individuals (mean = 346 ± 406). Local colony density was on average higher near outer stem regions with a mean branch to main stem ratio of 1.24 (± 0.33).
Effective length was positively correlated with overall colony size (r = 0.822, p < 0.001) and total brood (r = 0.762, p = 0.002). Coccoidea populations were positively correlated with effective length (r = 0.630, p = 0.021) but showed a poor correlation value with overall colony size (r = 0.241, p = 0.428).

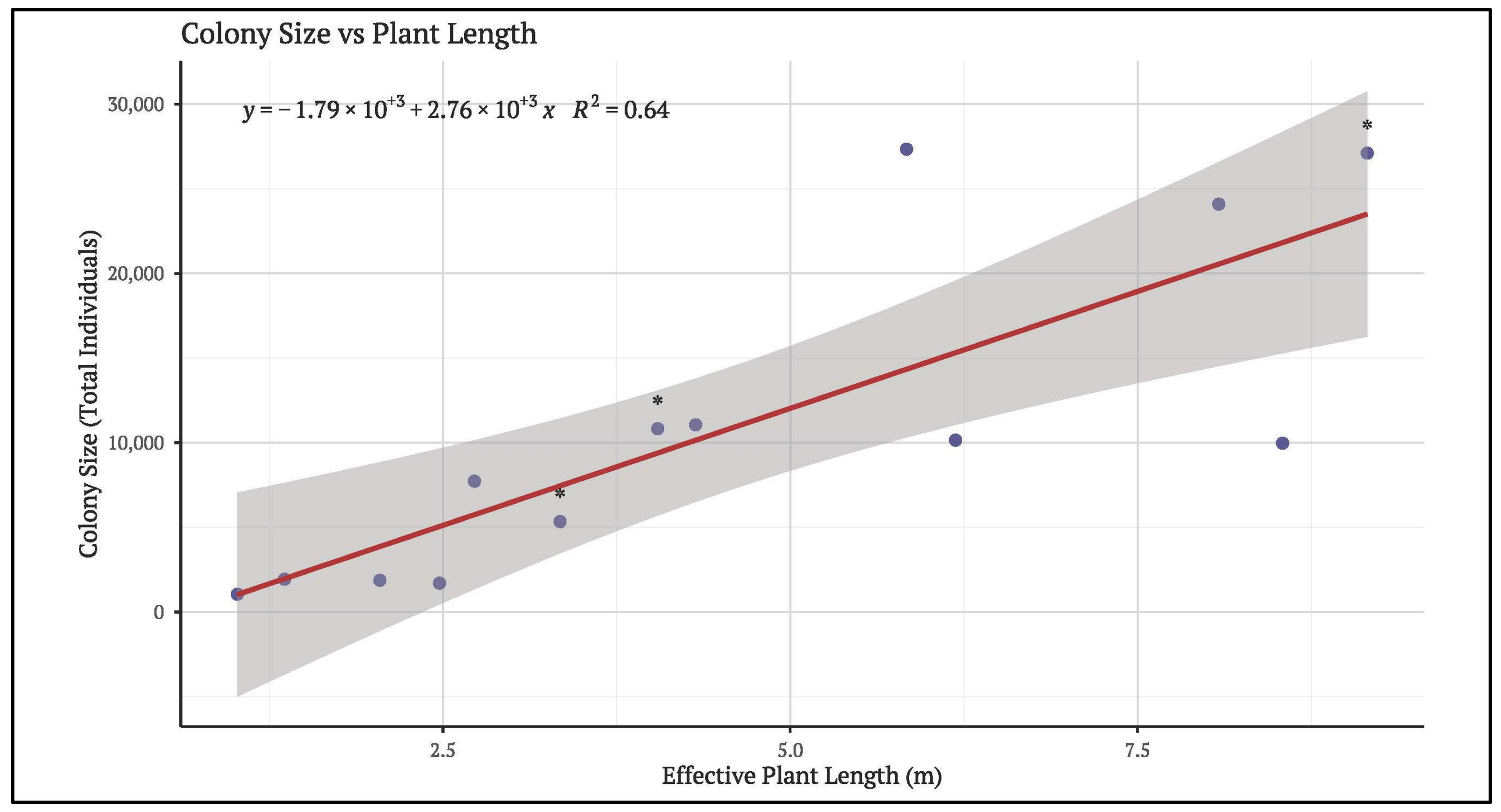

Figure C. Scatter plot of colony size versus effective plant length. The solid line shows the linear regression, with shading indicating the 95% confidence interval. Goodness-of-fit analysis indicated a moderate association (R^2 =0.64).

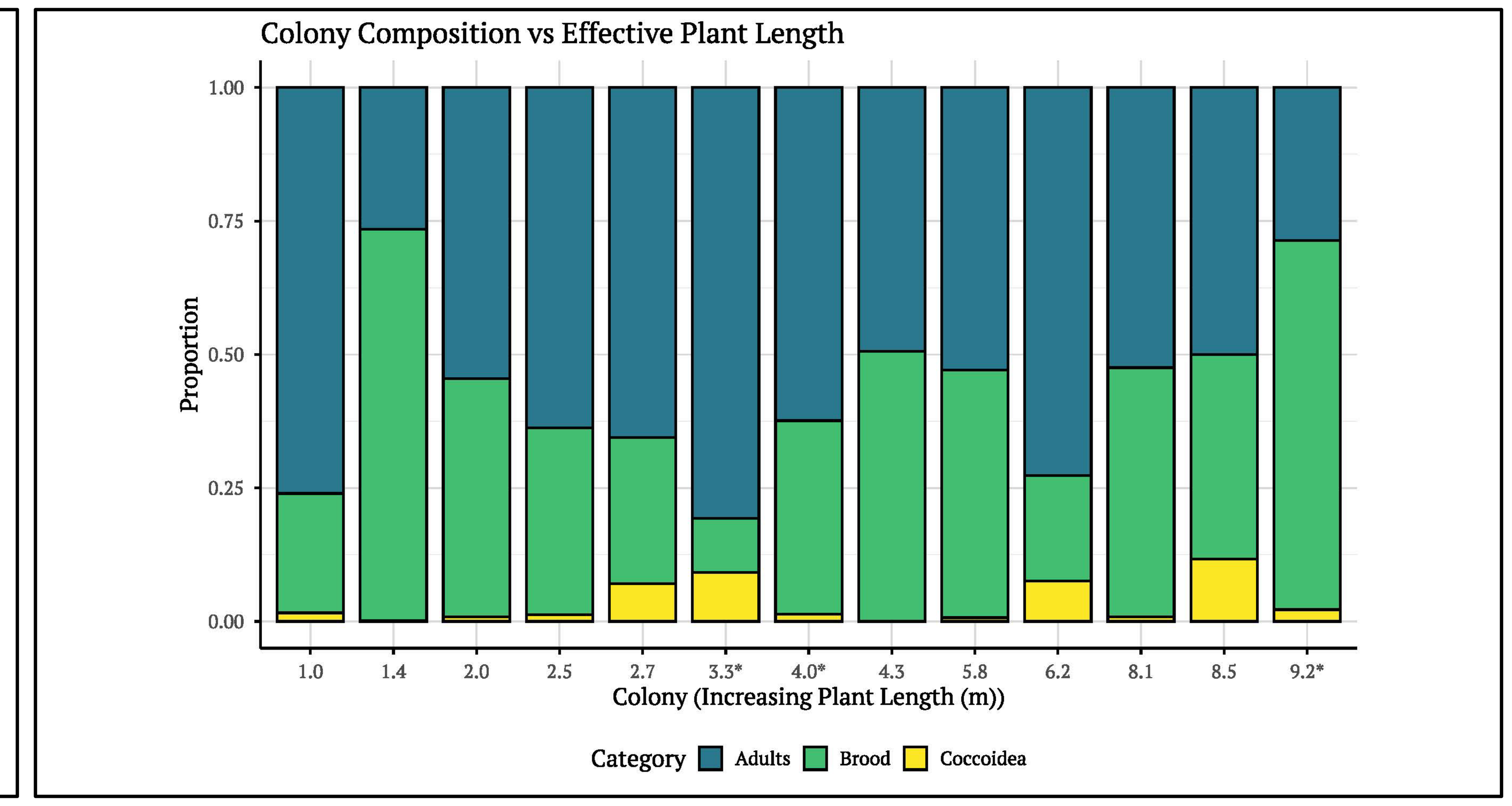

Figure D. Stacked bar plot representing proportional composition (adults, brood, Coccoidea) for each colony (n=12). Colonies are ordered by increasing effective plant length, with the true effective length values labeled.

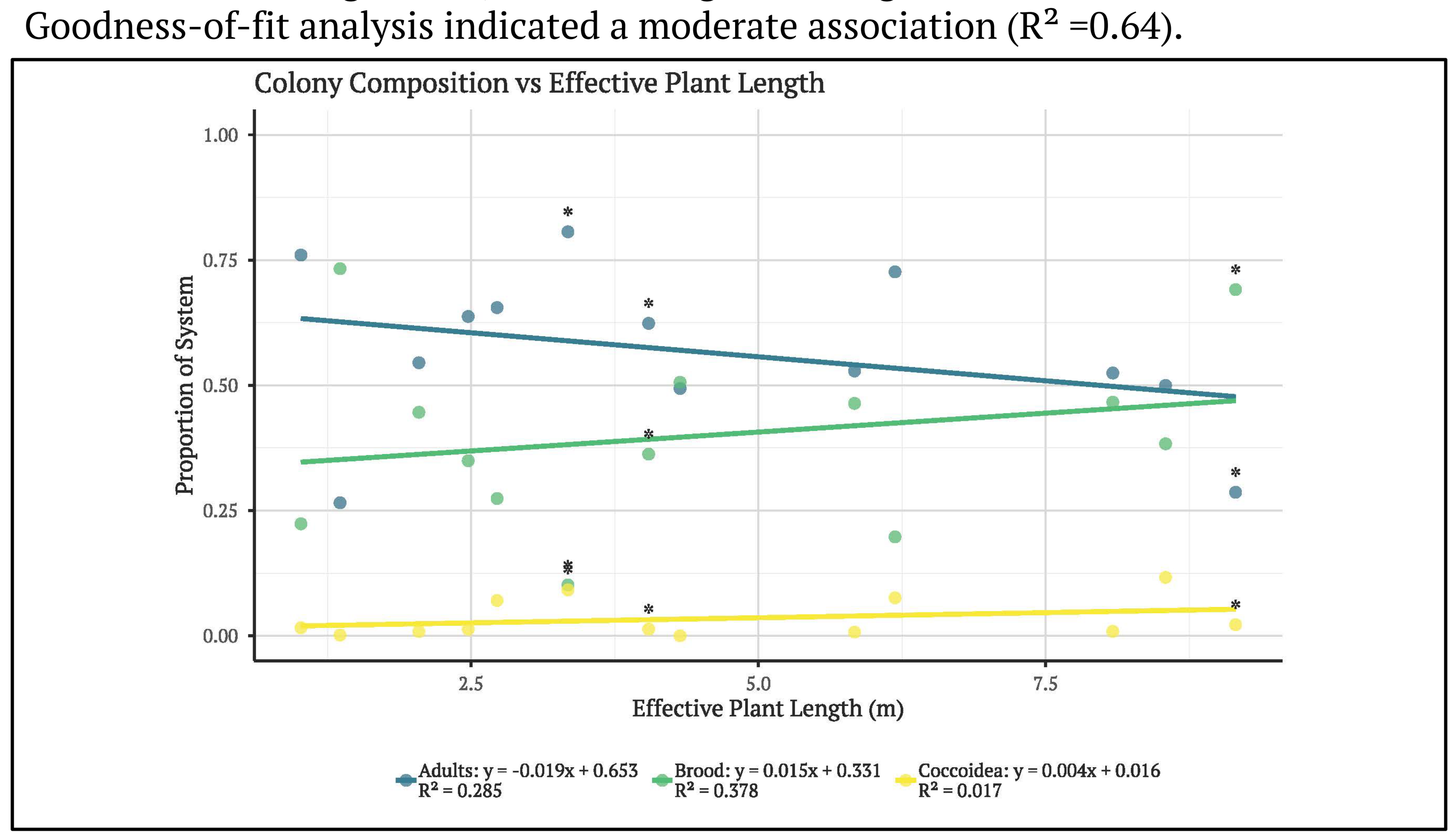

Figure E. Scatter plots for three categories (adults, brood and Coccoidea), representing the proportional change in colony composition as host plant's effective length increases. Lines indicate category-specific linear regressions.

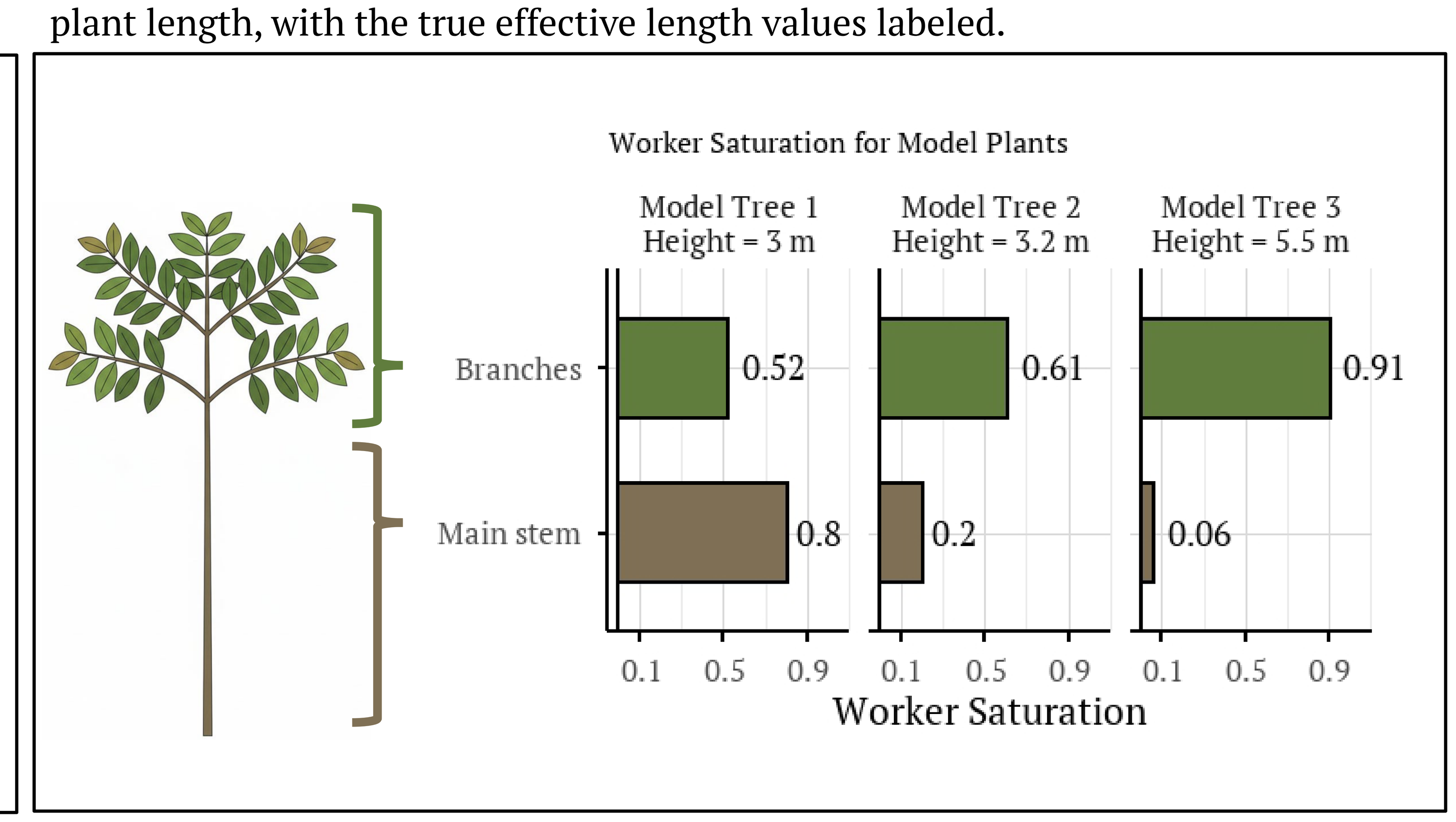

Figure F. Model plant (n=3) worker saturation values. Represents allocation of workers across host plant structures, distinguishing between main stem and branch allocation. Tree visual aid was generated with the use of AI (Adobe Firefly).

Discussion

Larger treelets hosted larger *Myrmelachista* colonies (Figure C), indicating a positive relationship between effective length and colony size. The strong correlation between effective length and colony size suggests that colony growth scales directly with structural capacity. Colony density was found to be higher in peripheral stem regions (Figure F), indicating that colonies are not uniformly distributed within hosts.
Colony demographic composition was similar across host plants of different sizes (Figures D and E), with adult and brood proportions remaining within comparable ranges. As colony size increased, these proportions changed little, indicating proportional growth with available nesting space. The stability of adult and brood proportions across hosts of varying size suggests that colony expansion occurs without major shifts in demographic structure, reflecting consistent scaling of caste composition as colonies increase in size. Coccoidea populations were positively correlated with effective length, though the strength of this relationship was weaker than that observed between effective length and overall colony size. In contrast, no meaningful correlation was detected between Coccoidea populations and colony size.
Myrmelachista colony size was positively correlated with Lauraceae host plant size, colonies were more concentrated toward peripheral stem regions, and colony demographic proportions were similar across hosts. These results describe a consistent relationship between colony size, colony distribution within hosts, and host plant size.

Population Estimation Model

$$N_{\text{total}} = \frac{N_{\text{subset}}}{\pi r_1^2 L_{\text{subset}}}\left(\pi r_1^2 L_{\text{main stem}} + \pi r_2^2 L_{\text{branch}}\right) = \frac{N_{\text{subset}}}{L_{\text{subset}}}\left(L_{\text{main stem}} + \Omega\, L_{\text{branch}}\right)\tau$$

Acknowledgements

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