Development and application of an index of condition in *Acacia collinsii*

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Abstract: The relative condition of *Acacia collinsii* trees in PaloVerde National Park, Costa Rica, was assessed using an index based on the physiology of trees. We assumed that individuals with a greater leaf area per unit stem volume are in better condition than trees with less leaf area per unit stem volume. We hypothesized that high-index trees would exhibit characteristics suggestive of a healthy resident *Pseudomyrmex* colony, particularly the presence of a large cleared area around the base of the tree. Data did not support this hypothesis. However, condition index was associated with stem form; trees in better condition had lower basal area to height ratio. The index of condition may have further application as a predictor of performance attributes of *A. collinsii* and other tree species.

Key Words: Acacia, *allometry, leaf area* , Pseudomyrmex, *Palo Verde, stem volume*

Introduction

Rapid assessment of the condition of an individual tree can be valuable in physiological and ecological investigations. We developed and implemented an index of tree condition for *Acacia collinsii* in Palo Verde National Park, Costa Rica. The logic of this index is based on allometric relationships and simple physiological principles. Individuals with a greater amount of photosynthetic tissue (leaf area) per unit volume of support tissue (as assessed by stem volume) should be in better condition than individuals with less leaf area per unit of stem volume. Because allometric relationships between stem volume and leaf area may be of various functional forms, we suggest using the residuals from the best-fit relationship between these variables as an index of condition. A positive residual above the fit line represents a tree with a greater leaf area (given its stem volume) and therefore better than average condition. Conversely, negative residuals represent trees with less leaf area (given their stem volume) and thus poorer condition.

In addition to developing this index, we hypothesized that *A. collinsii* individuals with a higher index would exhibit characteristics suggestive of good tree condition. The most convenient attribute to assess was the presence or absence of Beltian bodies (high protein structures harvested by *Pseudomyrmex* ants). However, we recognized that production of Beltian bodies may be balanced by ant consumption of them, thus weakening the relation between plant condition and presence of Beltian bodies. We also hypothesized that high-index trees would exhibit characteristics suggestive of a healthy resident *Pseudomyrmex* colony, specifically the presence of a large cleared area around the base of the tree.

Methods

A. collinsii trees were selected based on two criteria. Trees had to be 2m or less in height (for practicality) and at least twice as tall as any *A. collinsii* trees within 3m to ensure that the tree measured was the main host of its ant colony. To estimate individual leaf area, we designated a standard "leaf unit." The "leaf unit" we used was a healthy *A. collinsii* compound leaf approximately 12cm x 6cm. Moving systematically over the branches and assessing equivalent units on the subject tree, we estimated the total number of units present. To reduce potential bias among samplers, we standardized our assessments. All 6 samplers (authors plus D. R. Peart) independently estimated leaf area on several

branches on different trees using the standard "leaf unit" until all six individual estimates of leaf area (ranging from 8 to 20 units on the various branches) were within 1-2 units.

An index of stem volume for each *A. collinsii* tree was calculated by multiplying stem height by the square of stem diameter (measured 10cm above the ground using calipers). If there was a well-defined clearing around the base of the tree (as judged by the removal of ground vegetation, not simply removal of dead leaves), its diameter was measured. For each tree, ant species (black, red) and the presence of Beltian bodies were recorded.

Results

Leaf area of *A. collinsii* increased significantly with stem volume ($r^2 = 0.93$, df = 1,43, $P < 0.0001$). We log transformed both axes to meet the assumptions of linear models, and the allometric relationship appeared linear on the log-log scale (Fig. 1). As discussed above, the residuals from this regression were used as an index of *A. collinsii* condition; they were normally distributed.

The area cleared by ants increased significantly with stem volume ($r^2 = 0.69$, df = 1,19, $P < 0.0001$, Fig. 2), although there was no clearing around the five smallest trees. However, contrary to our hypotheses, condition was not significantly associated with either cleared area ($r^2 = -0.02$, df = 20, $P = 0.48$) or the presence of Beltian bodies (ANOVA, $F = 0.21$, df = 43, $P = 0.65$). To explore the relationship between tree condition and stem shape, we also plotted the condition index against the ratio of basal area to height (log scale). Trees with a higher index were taller relative to their basal areas than trees in poorer condition ($r^2 = 0.074$, df = 44, $P = 0.039$, Fig. 3).

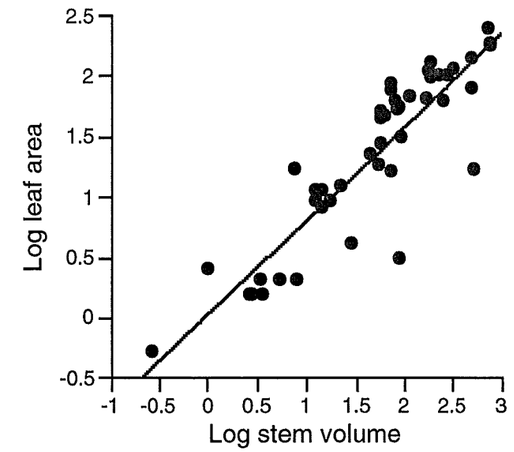

Fig. 1. Relation between *A. collinsii* leaf area and stem volume at Palo Verde National Park, Costa Rica. Leaf area was estimated in standard units (see text). An index of stem value was calculated as the product of basal area and stem height. For each tree, a condition index was calculated as the residual from this regression line.

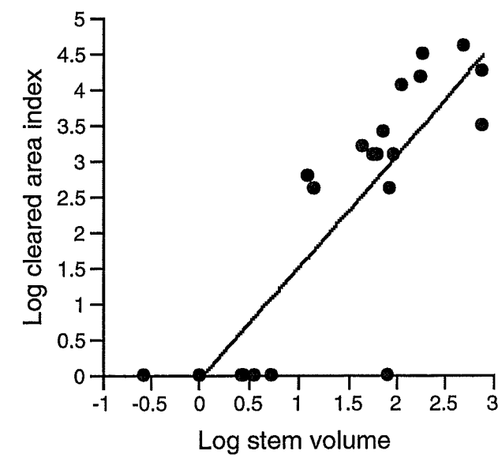

Fig. 2. Relation between area of cleared ground at the base of *A. collinsii* and log stem volume. An index of cleared area was calculated by squaring the diameter. See Fig.1 for calculation of stem volume.

Discussion

We developed and applied an index to *A. collinsii* in order to determine relative tree condition. Fig. 1 confirms that there is a strong underlying allometric relation between stem volume and leaf area such that individual variation from the best-fit line likely represents

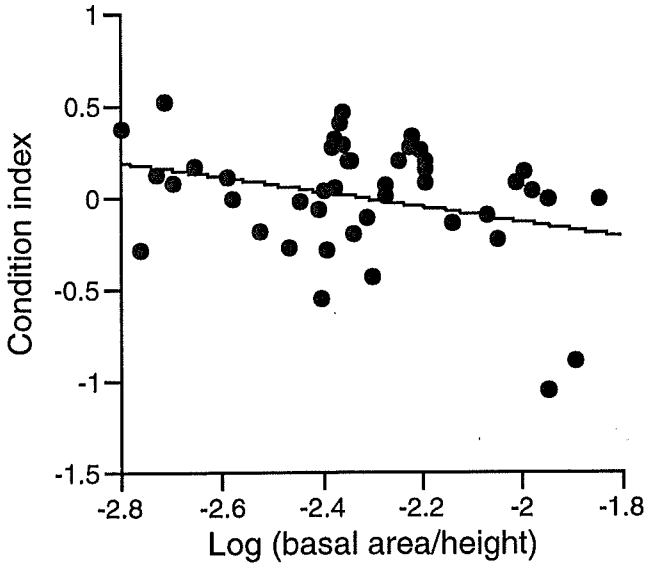

Fig. 3. Relationship between the relative condition of *A. collinsii* and tree shape, as quantified by basal area to height ratio. See Fig. 1 for calculation of tree condition index.

variation in tree condition.

Data did not show that Beltian bodies or cleared area beneath the tree were associated with tree condition. Beltian bodies are produced by trees and may be consumed by *Pseudomyrmex* at the rate of production, resulting in little to no standing abundance. Our data on cleared area was limited to a small subset of our sample, and the criteria for what constitutes "cleared" must be better defined for future study. Fig. 2 suggests that stem volume may be a more important factor in determining cleared area than tree condition. Further research should apply the index to a broader scope of *A. collinsii* performance attributes, such as *Pseudomyrmex* population size.

We found a significant correlation between tree condition and tree shape, or allometry (Fig. 3). Trees with a greater height to basal area ratio tended to be in better condition, though we cannot infer the causal mechanisms involved. Numerous factors affect tree shape and resource allocation, such as resource availability, habitat structure, and herbivory. The relative contribution of each factor is not well understood. Although the adjusted r^2 value from Fig. 3 is low (0.07), tree morphology is such a fundamental attribute that any factor contributing significantly to it is worthy of note.

Though we had mixed success in the application of this index, the fundamental physiological assumption and the observed significant allometric relationship suggest that the index may be a convenient and powerful tool.