# A taxonomic reevaluation of the genus *Ostrya* (Betulaceae) in the Southwestern United States based on leaf morphology


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## BACKGROUND AND INTRODUCTION

*Ostrya* is a genus of small deciduous trees in the birch family, Betulaceae, commonly known as hop-hornbeam. The genus represents an ancient Holarctic plant distribution and occurs in deciduous forests of Asia and Europe as well as in eastern North America in abundance with isolated populations found in the dryer mountains of the southwestern United States and NW Mexico, extending south as a cloud forest endemic through central Mexico to Honduras (Furlow, 1990). The number of species within North American *Ostrya* is small (3-5) and has been debated by systematists. *Ostrya* populations in the eastern U.S. have been commonly recognized as *Ostrya virginiana* (Mill.) K. Koch (Brain and Spamer, 2000) however, the grouping of populations in the southwest has not been so easily agreed upon.

The isolated and disjunct occurrences of *Ostrya* across the SW US have led to the recognition of one to three distinct species (Figure 1 & 2). Some botanists group the southwestern populations under the single species *Ostrya knowltonii* Coville. The genus has been further segregated, however, by some researchers based primarily on geographic location and variation in fine-scale leaf morphology. Populations of the Guadalupe Mountains have been referred to as *O. baileyi* Rose and populations restricted to the Chisos Mountains in Texas and the Sierra del Carmen in Coahuila as *O. chisosensis*. Under this segregated view *O. knowltonii* is restricted to the Colorado River drainage in northern Arizona and southern Utah. No systematic study has been conducted to consider the distinction of each population in relation to each other and evaluate the validity of the proposed taxonomic delineation (Furlow, 1990).

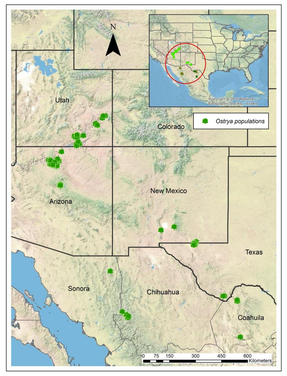


**Figure 1.** Distribution of *Ostrya* in the SW United States and NW Mexico based on herbarium records.

The purpose of this study was to examine the distribution and morphological variation of *Ostrya* in the southwestern United States to gain a clear understanding of the taxonomic delineation of the species. This work represents a contribution to an ongoing systematic revision of the genus across North America and consisted of morphometric analyses of leaf form across ten populations of *Ostrya.*

## METHODS

- Ten populations representing all known areas of occurrence and each putative taxon were sampled in the field during the summers of 2012 and 2013. Ten branches, each from a separate tree, were collected from each population and were pressed and dried for preservervation in the Fort Lewis College Herbarium (FLD).
- Morphological measurements were recorded for the largest leaf of each sample. The following morphological characteristics were measured: petiole length (mm), leaf lamina length (mm), leaf lamina width at widest point (mm), lamina width +30° (mm), lamina width +60° (mm), lamina width -30° (mm), lamina width -60° (mm), number of primary leaf veins (one side of leaf), stipitate glands on petiole (no=0, yes=1), stipitate glands on leaf lamina (no=0, yes=1), abaxial pubescence desity (lite=0, moderate=1, dense=2), adaxial pubescence density (lite=0, moderate=1, dense=2), number of margin teeth (between the 3rd and 4th secondary veins on one side of leaf), depth of largest measured tooth (mm), depth of smallest measured tooth (mm). To eliminate gross size differences ratios were calculated between total lamina length and width and lamina length and width at +30°, +60°, -30°, and -60°.
- Univariate analyses were conducted by constructing box plots representing variation within individual populations using SigmaPlot Ver. 12. Differences among the means of populations were determined using a One-way Analysis of Variance followed by a Tukey Post hoc test to determine significant differences using SPSS Ver. 18.
- Three multivariate analyses were conducted using MVSP (MultiVariate Statistical Package) Ver. 3.22: 1) Principal Components Analysis (PCA) of all continuous data. Data was centered and log10 transformed. 2) PCA of ratio data. Data was centered and log10 transformed and 3) Principal Coordinates Analysis (PCoA) including all continuous and discrete data (minus ratios) using the Gower General Similarity Coefficient.

## RESULTS

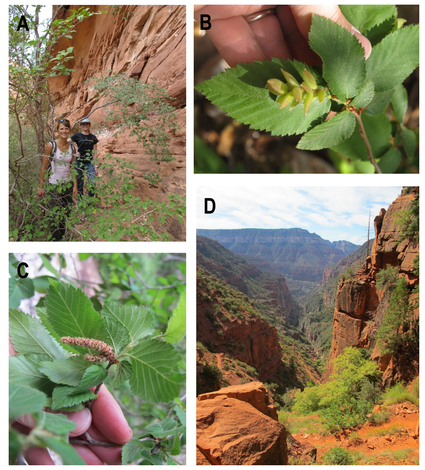


**Figure 2.** Species of *Ostrya* illustrating habit, leaf morphology, and reproductive structures. **A.** Collecting *O. knowltonii* near Moab, UT **B.** Infructescence *O. knowltonii,* Alamo Canyon, NM **C.** *O. baileyi* with staminate catkin at type locality in Dog Canyon, Guadalupe Mountains National Park, TX **D.** *O. knowltonii* in Roaring Springs Canyon, Grand Canyon National Park, AZ.

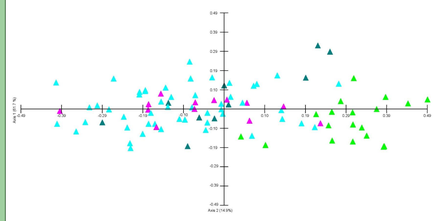


**Figure 3.** Multivariate analysis of ratio data. PCA. Centered data. Log10 transformed. No pattern is apparent with the SW populations but the *O. virginiana* of WV and OH show distinct segregation.

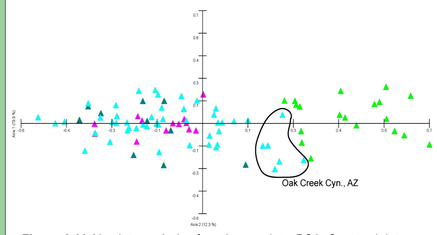


**Figure 4.** Multivariate analysis of continuous data. PCA. Centered data. Log10 transformed. *O. virginiana* of the Eastern states shows clear segregation. *O. knowltonii* of Oak Creek Canyon, AZ trends toward variation of *O. virginiana* segregating from the remaining SW populations.

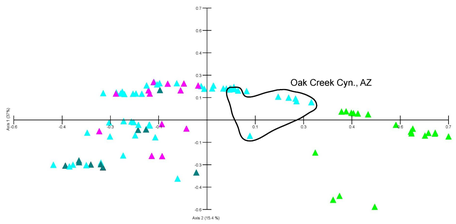


**Figure 5.** Multivariate analysis of continuous and discrete data. PCoA. *O. virginiana* of OH and WV is distinctly segregated. The Oak Creek Canyon, AZ population shows variation but is still united with the rest of the SW populations.

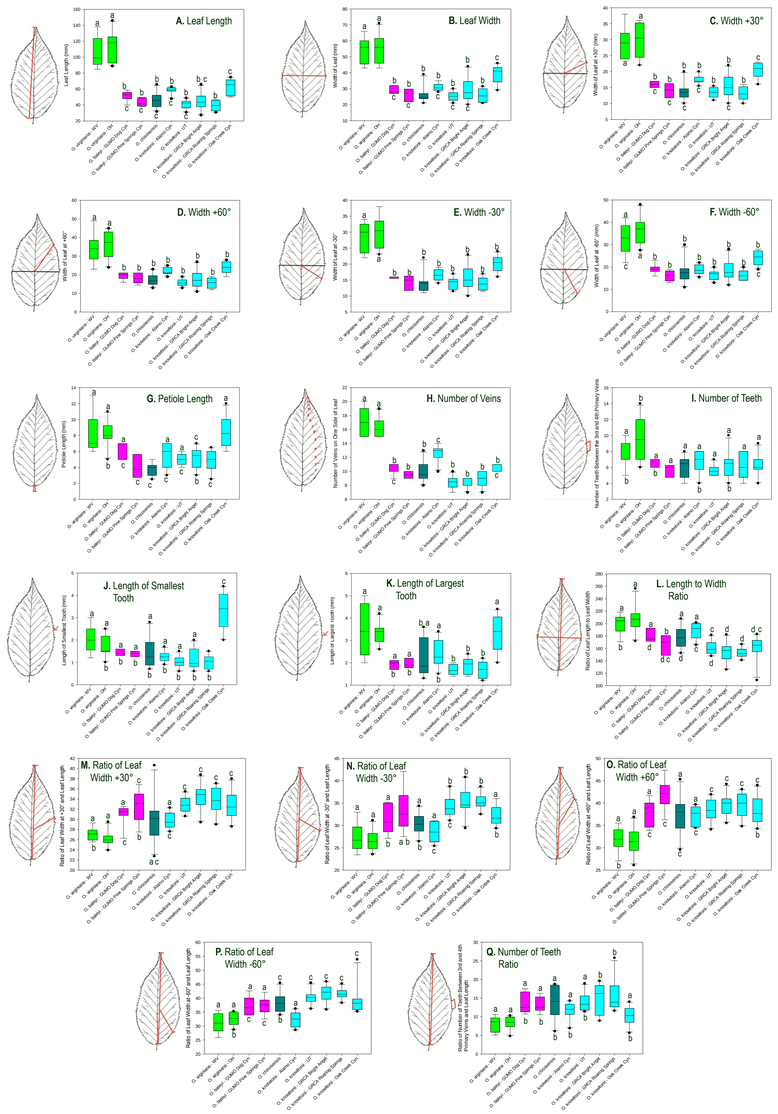


**Figure 6.** Results of univariate morphometric analyses using 11 measured variables and 6 composite ratio variables on leaf morphology in 10 populations of *Ostrya*. Shaded areas indicate the mean and 25th and 75th percentiles of the data with whiskers representing the 10th and 90th percentiles. Letters associated with boxes indicate groupings of similar values determined through a Tukey Post Hoc Test ($P<0.001$). Several characteristics show variation only between the Eastern populations and the Southwestern populations however the WV and OH populations are significantly similar to most of the SW populations for the majority of the measured characteristics. Variation between the Eastern *O. virginiana* and the Grand Canyon populations as well as the Utah population can be seen for many of the characteristics. The Oak Creek Canyon, AZ population is significantly different from the rest of the SW populations but similar to the Eastern populations for petiole length and length of largest tooth and is significantly different from all other populations for length of smallest tooth.

## DISCUSSION

Morphometric analyses of *Ostrya* in the SW US provides evidence that one variable species likely exists in this region (Figure 3-6). Though several taxa have been proposed for the SW US our data indicates that insignificant morphological variation exists among populations across the region to support the segregation of species. The distinction of *O. baileyi* in the Guadalupe Mountains and *O. chisosensis* in the Chisos Mountains was based principally off of differences in the expression of stipitate glands on the twigs and petioles with *O. baileyi* showing prominent glands and *O. chisosensis* lacking these glands (Rose, 1905; Correl 1965). Additional variations in leaf shape, leaf margin characteristics, and pubescence were also suggested (Furlow 1990) however, these characteristics were merely observed in few collected specimens. Our field observations and morphological analysis indicated that these characters are in fact variable within populations and thus do not serve as a means for segregating taxon groups.

Phenotypic plasticity is likely responsible for much of the morphological variation observed across the sampled populations. One particular example was the consistent divergence of the Oak Creek Canyon, AZ population from the remaining *O. knowltonii* populations. The ecosystem where this population grows is more moist and highly vegetated than the open environments more commonly inhabited by *Ostrya* in the SW (Figure 7). The larger trees and larger leaves are likely a physiological response to lower light levels in this ecosystem which approaches the understory habitat of *O. virginiana* and represents an inherent adaptability within the genome of the species.

This study supports the view that the SW US populations of *Ostrya* represent a single taxon which should be referred to as *Ostrya knowltonii* Coville. Additional molecular phylogenetic data for these populations inferred from four independent gene regions additionally showed only minor nonspecific variation across the region (Bielz and McCauley, 2013). Likely these isolated and disjunct occurrences represent relictual habitat islands representing the remnants of a wider continuous distribution contracted by long-term climatic changes.

Future investigations of morphological variation in North American *Ostrya* are needed to test the hypothesis that isolated occurrences of *Ostrya* in the Madrean Sky Islands and Copper Canyon region of NW Mexico represent a southern extension of *O. knowltonii.* Additionally the circumscription and affinities of the cloud forest occurrences across the Sierra Madre Occidental, Sierra Madre Oriental, and Southern Cordillera of Mexico currently viewed as conspecific with *O. virginiana* need to be evaluated.

**Figure 7.** *Ostrya* habitat in Oak Creek Canyon, AZ

## LITERATURE CITED


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