

A Preliminary Description of the Mogollon Highlands Ecoregion

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In this paper, we describe and present the results of our effort to establish a spatial delineation of the Mogollon Highlands region—an ecologically fascinating North American transition zone of continental importance. This dramatic landscape of escarpments, canyons, mesas, deserts, and high conifer forests—where the Sonoran Desert of the Basin and Range Province meets the redrock country of the Colorado Plateau and the Southern Rocky Mountains, where the northern limits of some species coexist with the southern limits of others—is a land of high biological, ecological, and cultural diversity. This area of dramatic elevational gradients, at a continental-scale biogeographic crossroads, is especially well-suited for studies that can provide understanding of global climate change and the capacity of species and ecological communities to adapt.

The Region

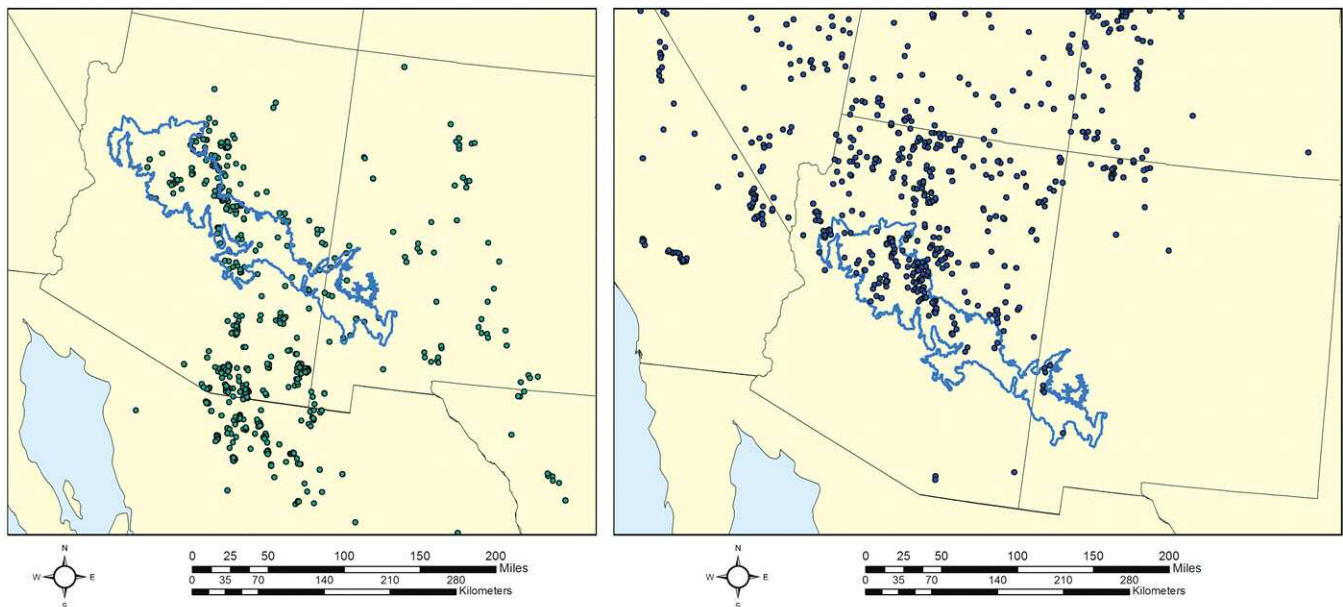
Portions of this area have been referred to, inconsistently, by many names (e.g., “Arizona Central Highlands”), yet the area remains relatively ill-defined and unknown in respect to its

southern counterpart, the Sonoran Desert, and its northern neighbor, the Colorado Plateau. This region roughly follows the interface of two great physiographic provinces of the American West — the Basin and Range and the Colorado Plateau (Hunt 1967). Due to great geologic diversity (Nations and Stump 1996), it presents dramatic topographic diversity—varying several thousand feet in elevation and including a series of deep canyon systems that drain off the Colorado Plateau and emerge into the low Sonoran Desert.

The region’s positioning at a continental-scale biogeographic crossroads contributes to its tremendous ecological diversity. The southern extent of the Rocky Mountains intersects the eastern portion of the Mogollon Highlands. All four of North America’s deserts connect directly with the region: the Great Basin Desert to the north, the Mojave to the west, and the Sonoran and Chihuahuan to the south. From an ecological perspective, this region is where Mexico meets Canada. Some species (e.g., *Juniperus osteosperma* and *J. scopulorum*) reach their southern extent here, while Sierra Madrean species (e.g., *J. deppeana*) reach their northern boundaries (Figures 1a and 1b). Some Great Plains graminoids (e.g., *Bouteloua gracilis*)

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Left to right: **Figure 1a.** Distribution of *Juniperus deppeana*, with northern extreme in Mogollon Highlands.
Figure 1b. Distribution of *Juniperus osteosperma* with southern extremes in Mogollon Highlands.

Mogollon Highlands Ecoregion *continued*

reach their western extent here while the eastern extent of some shrubs (e.g., *Rhus ovata*) lies in this region.

The Mogollon Highlands represents an interfingering of 11 of the 26 biotic communities in the southwestern United States and northwestern Mexico (southern Utah to northern Sinaloa, Pacific Coast to New Mexico), as described by Brown (1994). It supports five of the North American life zones described by Merriam (Lowe 1964, Phillips et al. 1989). Arizona has the third highest plant species richness of any state (Stein et al. 2000), and because of the broad ecotonal nature of the Mogollon Highlands, much of this plant diversity can be found here. The regional diversity is amplified even more due to punctuation by linear ribbons of riparian forest—one of the highest productivity habitats in North America. These lush green corridors concentrate wildlife, and include some of the highest biodiversity sites in North America (Johnson et al. 1977, Ohmart and Anderson 1982, Fleischner 1999).

In the Mogollon Highlands, the mega-diversity of Meso-America, and the Sierra Madre in particular (DeBano et al. 1995), has direct access into North America. As Felger and Wilson (1995) pointed out two decades ago, this Apachian/Madrean region is a “neglected center of biodiversity.” More recently, it has been referred to as a “biodiversity hotspot” in reference to herpetology (Bezy and Cole 2014). Davis et al. (1997) highlighted the region as a notable center of endemism in North America.

The core of this region is what the World Wildlife Fund (WWF) (Ricketts et al. 1999) named the “Arizona Mountain Forest.” WWF concluded this region had regionally outstanding biological distinctiveness due to relatively high species richness and endemism. The Mogollon Highlands largely coincides with The Nature Conservancy’s “Arizona-New Mexico Mountains” ecoregion (Marshall et al. 2006), although, as defined here, extends beyond these montane forests to include parts of adjacent, interwoven communities (the “Madrean Sky Islands Montane Forests” of WWF, the “Apache Highlands” of The Nature Conservancy).

Yet, this grand ecotonal band has been surprisingly neglected by scientists. Research institutions in Arizona tend to focus on the Colorado Plateau and Sonoran Desert, but have largely neglected the high diversity ecotonal region that connects them. In the recent analysis of herbarium records for the western U.S., all counties of the Mogollon Highlands region

were “under-collected” (Taylor 2014). Moreover, some of these ecosystem types are imperiled. In a report by the National Biological Service (Noss et al. 1995), two habitat types in the Mogollon Highlands region were identified as “endangered ecosystems,” defined as those in 85-95% decline: Old-growth Ponderosa pine (*Pinus ponderosa*) forest and Southwest riparian forests.

Delineating the Region

Spatial delineation of the Mogollon Highlands ecoregion was determined by GIS techniques, using two primary criteria: a) elevation, and b) geographic distribution of indicator species, focusing on the range overlap of closely related species. The ArcGIS program was used for these analyses. The boundary of the Mogollon Highlands is illustrated in Figure 2.

As a “highlands,” one primary delineator of this region is elevation. An elevational zone between 3,500 and 7,000 feet above sea level was isolated from a digital elevation model (DEM). As a transitional zone between high deserts and mountains of the Colorado Plateau to the north, and the low deserts and basins of the Sonoran Desert to the south, it is exemplified along the Mogollon Rim—an abrupt escarpment of 2,000-3,000 feet that defines the southern boundary of the Colorado Plateau. The Rim reaches approximately 200 miles from just west of Sedona, Arizona, well into New Mexico. Sites

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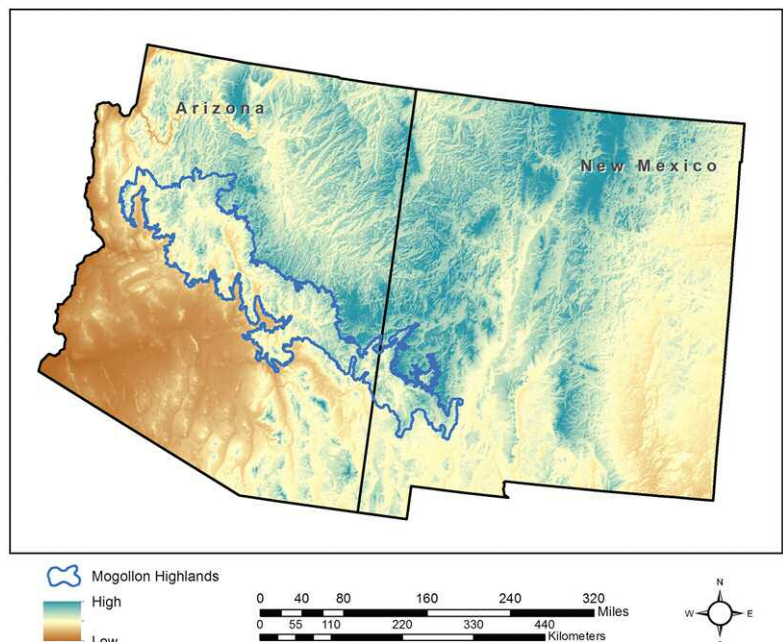


Figure 2. Outline of Mogollon Highlands.

Mogollon Highlands Ecoregion *continued*

that fit our elevation zone, but were north of the Mogollon Rim were eliminated from consideration.

The elevational boundary was further modified through the addition or elimination of areas based upon representative ecoregions defined by the U.S. Environmental Protection Agency (EPA) and ecologically significant watershed boundaries. The EPA Level IV ecoregions (Griffith et al. 2014) are defined by characteristic vegetation associations and our boundary was modified to include areas where these ecoregions were thought to be inclusive in the Mogollon Highlands (e.g., the Lower Mogollon Transition and the Mogollon Transition Conifer Forests).

A key element of the ecological distinctiveness of the Mogollon Highlands region is that it represents a broad zone of sympatry for closely related species in many taxa, including conifers, butterflies, lizards, and occasionally, birds. In many cases, species richness was higher within the Mogollon Highlands than in regions north and south. For example, Figure 3 illustrates the overlap between species of piñons (*Pinus* spp.) and junipers (*Juniperus* spp.). Also, many Madrean shrubs (e.g., *Garrya wrightii*, Figure 4) reach their northern edge in the Mogollon Highland; such species may form pure shrub forms (interior chaparral) or dense understory in Ponderosa pine forests. As such, the transitional Ponderosa pine forests are structurally unique from those of the north because perennial shrubs provide ladder fuels that support stand-replacing fires.

Locations of selected species occurrences were downloaded from the Southwest biodiversity “SEINet” collections and from the Global Biodiversity Information Facility (GBIF). These locations were plotted in ArcGIS and directional ellipses were calculated that describe the spatial trend of the species ranges. These ellipses were combined and areas of high species diversity were identified. Figure 5 depicts the overlap of key lizards. We hope to extend this diversity analysis to additional taxa to define further the unique biological characteristics of this ecoregion.

Conclusion

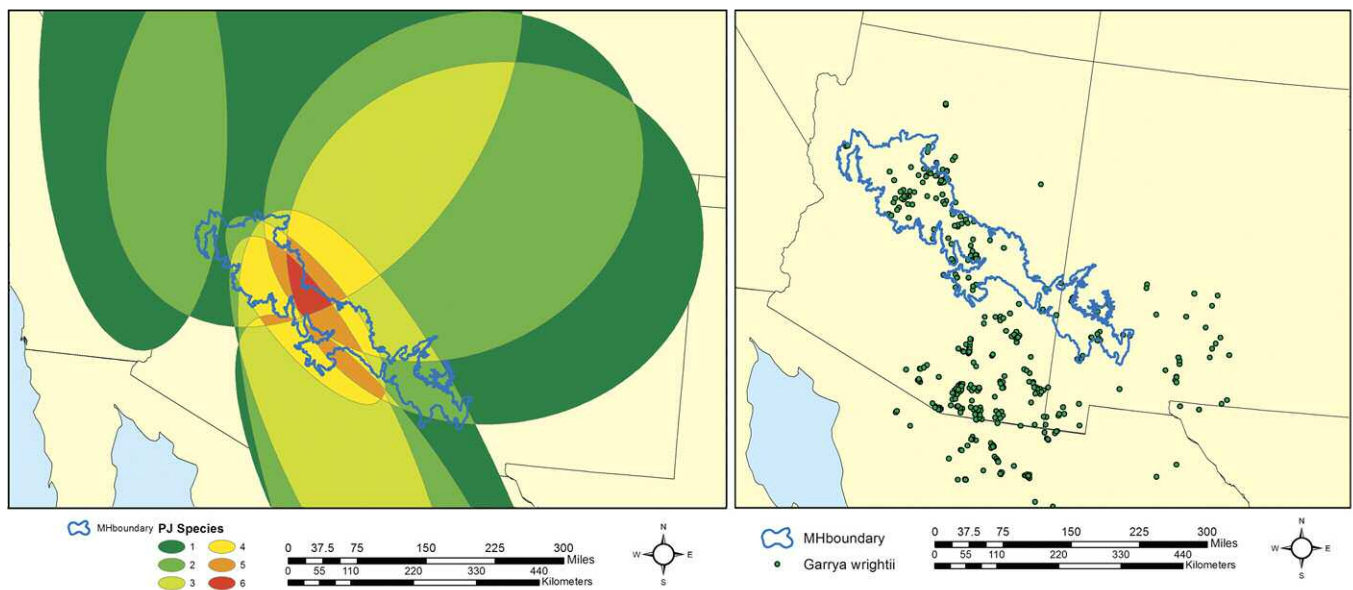
The Mogollon Highlands region merits consideration as a prominent, unique, high biodiversity transition zone of North America—not merely as the neglected edges of other provinces. Moreover, regions with significant elevational gradients, and with broad interpenetration of numerous ecological communities, represent living laboratories for how to deal with ecological and climatic change. The Mogollon Highlands ecoregion is ideally suited for ongoing studies of adaptation to a changing Earth.



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Left to right: Figure 3. Ellipses representing the range + 1 standard deviation of distribution of piñons and junipers in the Southwest. Figure 4. *Garrya wrightii* exemplifies how many madrean shrub species reach their northern edge in Mogollon Highlands.

Mogollon Highlands Ecoregion *continued*

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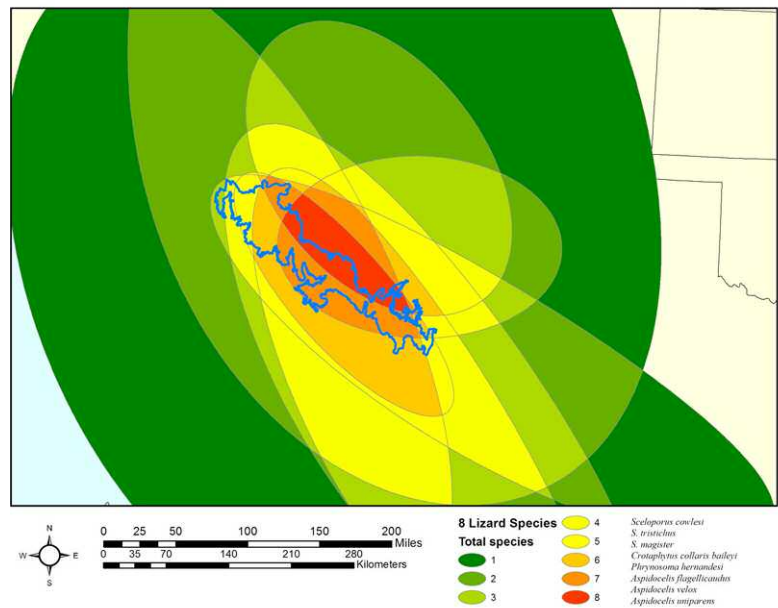


Figure 5. Overlap of 8 lizard species in Mogollon Highlands.

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