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Courthouse Butte, south of Sedona. *Photo courtesy Ries Lindley.*

In this Issue

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Plus

With Regular Features

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The Mogollon Highlands

From an ecological perspective, the Mogollon Highlands is where Mexico meets Canada. This area is intersected by the southern extent of the Rocky Mountains and the northern reaches of the Sierra Madre. 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. The Mogollon Highlands is a biodiversity hotspot and the region has been highlighted as a notable center of endemism in North America. We know that Arizona has the third highest plant species richness of any state, and because of the broad ecotonal nature of the Mogollon Highlands, much of this plant diversity can be found there. Despite all this, the Apachian/Madrean region is a neglected center of biodiversity, and therefore worthy of further study. The 2017 Arizona Botany Meeting, held in cooperation with Prescott College and the Natural History Institute, celebrated and explored this remarkable zone of diversity. The papers that follow immediately were presented at the meeting and provide a perspective on current botanical research in this special region of Arizona.

President's Note *by Douglas Ripley* jdougripley@gmail.com

I hope members of the Arizona Native Plant Society enjoyed a botanically rewarding summer. Although many parts of Arizona received exceptionally high initial monsoon rainfall, extremely dry conditions were the norm for the remainder of the season. But, of course, rain or shine, the Arizona Native Plant Society continues to serve as an advocate for Arizona's native plants, as evidenced in our various ongoing native plant conservation and habitat restoration programs, chapter meetings and field trips, sponsorship of various research and publication grants, and, of course, the semi-annual publication of our journal *The Plant Press*, which provides a forum for presenting a wide range of topics relative to Arizona's native flora.

As usual, a highlight of the year was our annual botany conference, which was held in May 2017 in cooperation with the Natural History Institute and Prescott College. The conference, which was attended by approximately 120 people, was entitled: "The Mogollon Highlands — Where Mexico meets Canada" and provided an opportunity to learn more of the biology and ecology of this remarkable zone of diversity. We decided to use the conference subject as the main theme for this issue of *The Plant Press* and are presenting here a number of papers from the conference.

In keeping with our desire to present the annual botany meeting in different regions of the state, we will hold the 2018 meeting at the Cochise College campus in Sierra Vista on 28–29 July 2018. While the program has not yet been developed, the theme of the conference will focus on the biology and ecology of the Madrean Sky Islands and will offer numerous field trips to the many interesting and beautiful nearby destinations.

We have added a new feature to this issue of *The Plant Press*, "Botanist Spotlight," in which we honor a member of the Arizona Native Plant Society who has made a significant contribution to the Society over the years. Please suggest members of your acquaintance who we could honor in future issues. And, of course, we welcome members' ideas for future topics of *The Plant Press*.

I believe that the Arizona Native Plant Society continues to be on a good footing; but, of course, we will continue to look for ways to improve. We hope to keep our membership level at a satisfactory level and encourage current members to renew their membership when notified. We encourage recruitment of new members by current members as that will be a very important contribution to the Society.

Thank you all for your support in the past year to the Arizona Native Plant Society and to the conservation, appreciation, and enjoyment of Arizona's priceless native flora.

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A Preliminary Description of the Mogollon Highlands Ecoregion

by Thomas Fleischner[1], David Hanna[1], and Lisa Floyd-Hanna[2]

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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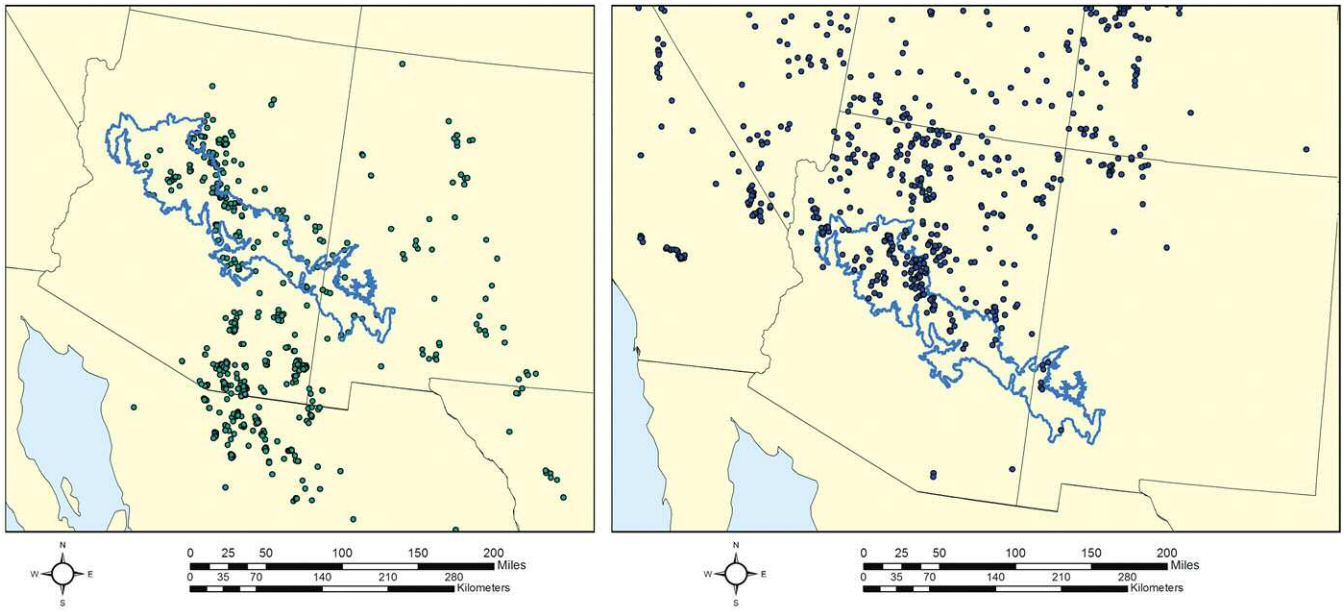

Left to right: Figure 1a. Distribution of *Juniperus deppeana*, with northern extreme in Mogollon Highlands.
Figure 1b. Distribution of *Juniperus osteosperma* with southern extremes in Mogollon Highlands.

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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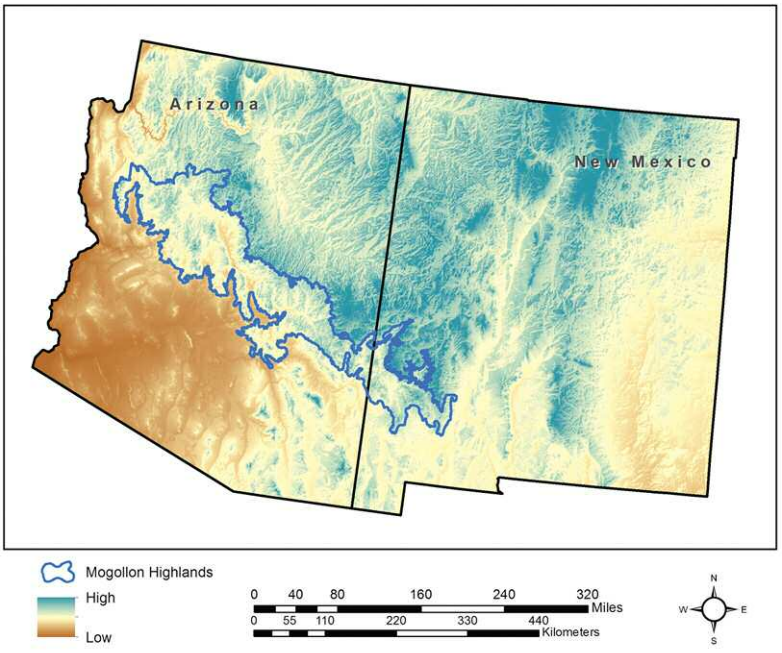

Figure 2. Outline of Mogollon Highlands.

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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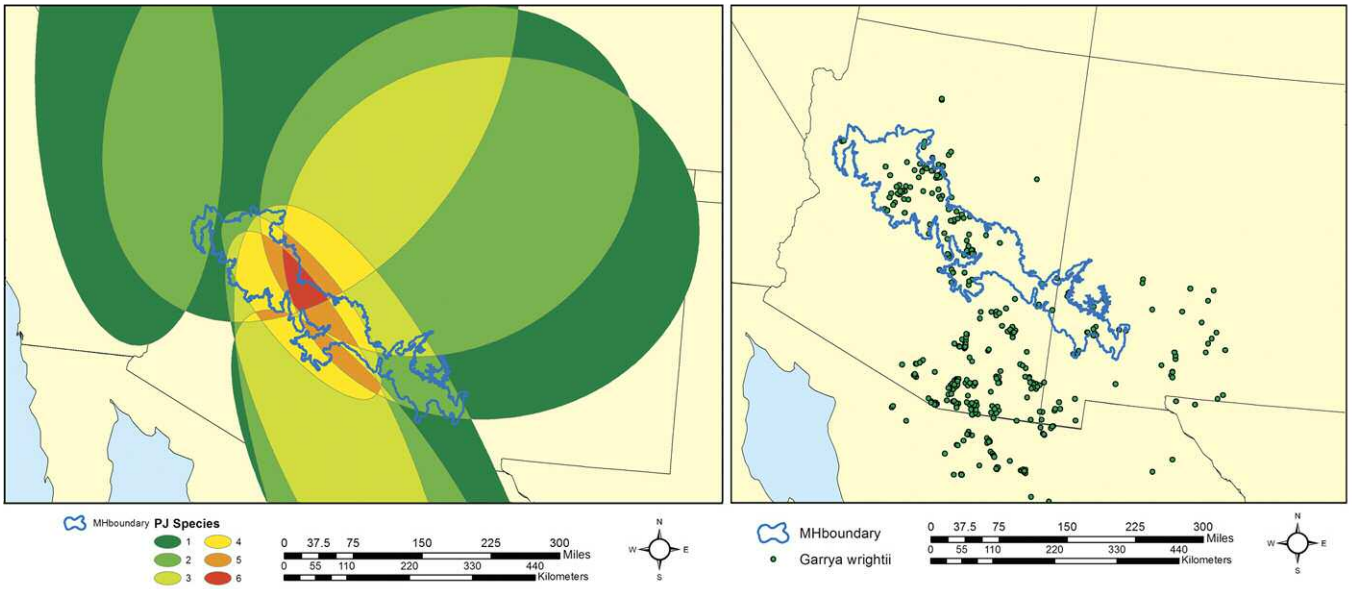

Left to right: Figure 3. Ellipses representing the range + 1 standard deviation of distribution of piñons and junipers in the Southwest. Figure 4. *Garrya wrightii* exemplifies how many madrean shrub species reach their northern edge in Mogollon Highlands.

Mogollon Highlands Ecoregion *continued*

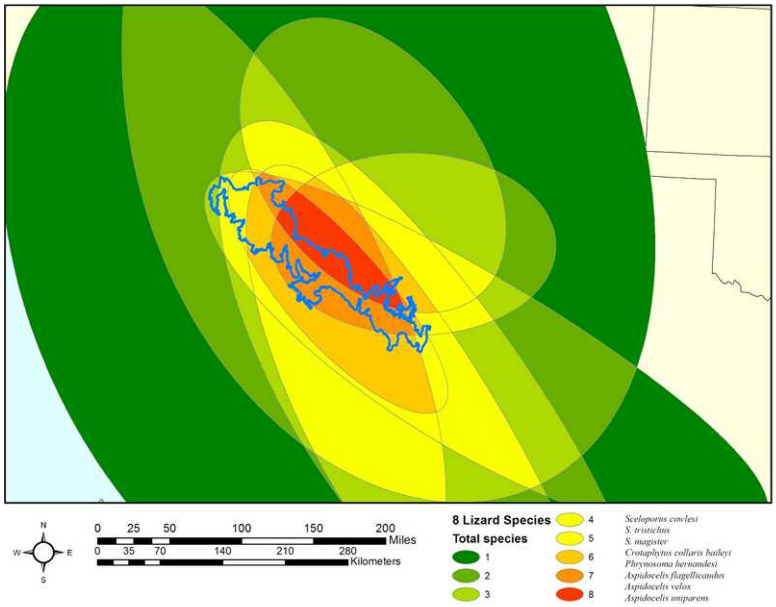

Figure 5. Overlap of 8 lizard species in Mogollon Highlands.

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Edaphic Endemism and the Mogollon Highlands

by John Anderson[1]

The Mogollon Highlands represent an overlap of the Mexican Madrean pine-oak-juniper woodlands floristic province with the Central Mountains/Transition Zone geological province across central Arizona (Figure 1). It is an area characterized topographically by closely spaced mountain ranges and narrow basins lying between the Southern Basin and Range and the Colorado Plateau geological provinces (Damon et al. 1984; Peirce 1984). Floristically, it is an anomalous area that is more characteristic of the Madrean vegetation of the Sonoran Sky Islands far to the southeast; but, it lies between the Arizona Sonoran Desert of the Southern Basin and Range to the south and the Cold Temperate Forest, Woodland, and Desert of the Colorado Plateau (Brown 1982) to the north.

A simple floristic transition could be expected between these two vegetation types in central Arizona. What accounts for the seeming floristic anomaly in central Arizona? Answering this question involves the factors of the geological and climatic history of the Southwest. During the Miocene epoch (33-5 mya), central Arizona had a more mesic climatic regime which was characterized by fewer temperature extremes and more summer rainfall. This more equable climatic regime favored the Madrean pine-oak-juniper woodland that extended across southern and central Arizona. Later, in the Pliocene epoch (5-2.6 mya), the Mid-Tertiary Basin and Range Disturbance saw basin subsidence along with an uplift of the Sierra Nevada to the west, forming a rain shadow across central Arizona. These topographic changes resulted in a less equable continental climate regime of more extreme temperatures and less summer rainfall (Axelrod 1979). In response to this climatic deterioration, the Madrean pine-oak-juniper woodland species — for example, *Quercus arizonica* Sarg., *Q. emoryi* Torr., *Juniperus deppeana* Steud., *Garrya wrightii* Torr., and *Desmanthus grahamii* A. Gray — were forced to migrate to remaining areas that still had a more equable climatic regime. This migration was either southeast into the Sky Islands of Arizona and Sonora or northward to the Central Mountains/Transition Zone where these species are now squeezed between the subtropical Sonoran Desert to the south and the cold temperate Colorado Plateau to the north. Desert-adapted species, for example *Allium bigelovii* Wats. and *Thamnosma texana* (Gray) Torr., migrated eastward to the current summer-rainfall characterizsed Chihuahuan Desert. Just as the desert in southwestern Arizona is called the Sonoran Desert like its counterpart desert in Sonora, perhaps the Central Mountains of Arizona could be called the Madrean Highlands after its vegetative counterpart in the Sky Islands of Sonora.

During the late Pliocene epoch, the closed basins formed in and on the edge of the Transition Zone by the Mid-Tertiary Basin and Range Disturbance were filled by sedimentary deposits of interbedded lacustrine and volcanic ash deposits called limy tuffs. Later, the increased precipitation during glacial periods caused increased basin lake fill with resulting

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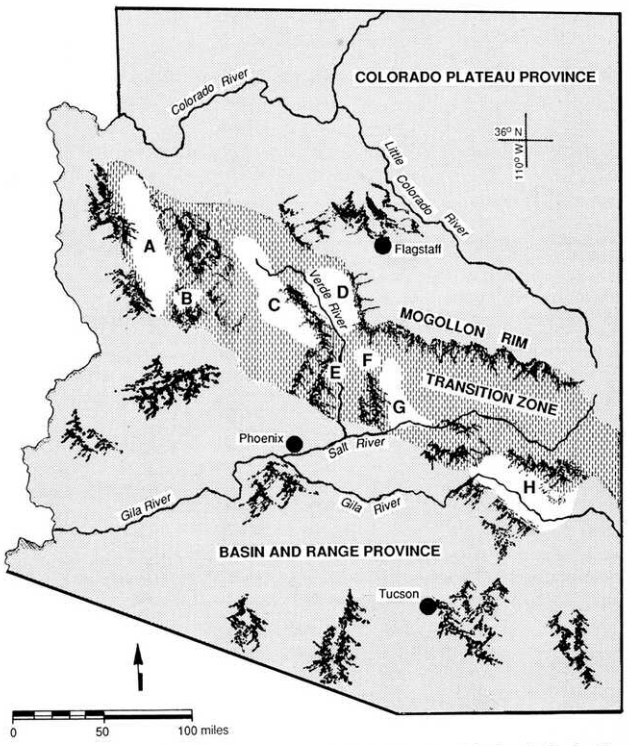

FIG. 1. Transition Zone Basins across central Arizona. A—Big Sandy Basin, B—Burro Creek, C—Chino Valley, D—Verde Valley, E—Lower Verde River (Horseshoe Reservoir), F—Payson Basin, G—Tonto Basin, and H—San Carlos Basin.

Figure 1. Transition Zone Basins across central Arizona (Anderson 1986).

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Edaphic Endemism *continued*

Figure 2. White lacustrine soil of the Verde Formation in the Verde Valley with thicket of *Quercus havardii* in deciduous condition (Anderson 2011).

flow of rivers through the basins and subsequent exposure of these deposits in basins like the Verde Valley. Presently, these basins lie floristically within the *Larrea tridentata-Canotia holocantha* Series of the Arizona Upland Subdivision of the Sonoran Desert (Brown 1982) and lie along the northern edge of the Sonoran Desert. These lacustrine soils are infertile compared to surrounding "normal" soils due to very low levels of nitrogen and phosphorus. This infertility provides a sharp edaphic contrast with the typical volcanic and alluvial desert soils surrounding the limy tuff deposits. It excludes the regionally dominant Sonoran Desert species — creosote bush (*Larrea tridentata* [DC.] Coville) and foothill palo verde (*Parkinsonia microphylla* Torr.) — that are not adapted to the infertile lacustrine soils. The absence of the dominant Sonoran Desert species on the lacustrine deposits results in less species competition for limited desert soil moisture and thus provides an ecological opening. The deposits act as refugia, specialized edaphic islands within the typical desert soils (Kruckeberg 1969, 1986) for disjunct occurrences of relict species of previous floristic regimes that require more soil moisture. Disjunct occurrences are populations which are widely separated geographically from the normal range of the species. Their only occurrences within the Sonoran Desert are on these edaphic islands (Anderson 1996, 2011); and, they would not be able to survive the present dry harsh conditions without this edaphic refugium. In *Autumn Across America*, Teal (1956) refers to disjunct, relict species as "trapped plants."

In addition to unusual soils, there are two other environmental factors favoring the relicts' survival in the Transition basins: climate and ecological "positioning." In order for relict species to survive in what would otherwise be an unsuitable climatic regime, they must occupy what Cain (1944) called "...regions of compensation where the local conditions of microclimate or soils allow them to resist, for a time at least, the climatic pressure and the competition from the surrounding vegetation...relicts are likely to occupy the most favorable sites in a region at least with respect to temperature and moisture conditions." As discussed above, the climate in the Transition Zone is a narrow band of more equable climate than that of the hotter, drier Sonoran Desert to the south and the colder, drier Colorado Plateau to the north. In essence it is a relict microclimate. The geographic positioning of the Transition Zone at the northern edge of the Sonoran Desert places it at an ecotone where the dominant competitive advantage of the regional vegetation is being lessened. Raven and Axelrod (1979) have described such areas as "...an ecotonal region of equable climate that [is] inhabited by many endemics, both ancient and recently derived." The Transition Zone in central Arizona comprises a unique combination of environmental parameters that together support edaphic endemics in the valleys (Table 1) and Madrean woodland species in the mountains.

Relict species like these edaphic endemics represent remnants from previous floristic types that were previously the dominant regional flora before changing environmental conditions caused them to retreat and migrate to remaining areas of suitable habitat (Gankin and Major 1964). During this floristic retreat, edaphic islands provide small refugia sites for relicts to survive. In an ecological twist, disjunct relicts on edaphic refugia sites may exhibit substrate switching and occupy an edaphic habitat opposite the normal habitat of their dominant range to take advantage of this ecological opening (Raven 1972). It would appear that the relict species growing on the calcareous lacustrine deposits in the Transition Zone basins are calciphiles, species that prefer calcareous soils; but, in their normal geographic range and habitat, most of them are not calciphiles and grow on non-calcareous soils (Anderson 1996). For example, *Quercus havardii* Rydbg. which has a disjunct population on the Verde Formation in the Verde

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Edaphic Endemism *continued*

Valley (Figure 2) normally grows on sandy, coppice-formed dunes in the Colorado Plateau (Anderson 2011).

Because over time different floras may have successively occupied the same region and left behind relicts on edaphic islands, anomalous floristic combinations may result on edaphic islands of species that would currently occur hundreds of miles apart and be from different floristic regimes. In the case of the Transition Zone basins, there are relicts from a northern migration into the Colorado Plateau and from an eastern migration into New Mexico and Texas growing together. For example, in the Verde Valley on the Verde Formation there are twenty relict species from the north in the Colorado Plateau (reflecting the more recent glacial periods) and four relict species from the southeast in the Chihuahuan Desert of New Mexico and Texas (Table 1).

Acknowledgments

This research is dedicated to Dr. Donald Pinkava who first recognized the disjunct pattern of relict species between the central Arizona basins. I thank Liz Makings from the Arizona State University Herbarium for her careful review of the draft manuscript.

Table 1. Relict species on the lacustrine Verde Formation in the Verde Valley listed by floristic affinities.

Colorado Plateau

Astragalus calycosus Torr. var. *scaposus* (A. Gray) M.E. Jones

Astragalus newberryi A. Gray var. *newberryi* A. Gray

Astragalus praelongus Sheldon

Cordylanthus parviflorus (Ferris) Wiggins

Erigonum ericifolium T. & G. var. *ericifolium* T. & G.

Eriogonum heermannii Dur. & Hilg. var. *argense* (M.E. Jones) Munz

Eriogonum ripleyi J.T. Howell

Eriogonum microthecum Nutt. var. *simpsonii* (Benth.) Reveal

Frasera albomarginata S. Watson

Glossopetalon spinescens A. Gray var. *aridum* M.E. Jones

Pediomelum verdiense S.L. Welsh & M. Licher

Penstemon thompsoniae (A. Gray) Rydb.

Petradoria pumila (Nutt.) Greene

Polygala rusbyi Greene

Quercus havardii Rydb.

Salvia dorrii (Kell.) Abrams var. *mearnsii* (Britt.) McClintock

Stanleya pinnata (Pursh) Britton

Streptanthus cordatus Nutt.

Tetraneuris acaulis (Pursh) Greene var. *arizonica* K.F. Parker

Townsendia incana Nutt.

Chihuahuan Desert

Allium bigelovii S. Watson

Anulocaulis leisolenus (Torr.) Standl.

Polygala scopariodes Chodat.

Thamnosma texana (A. Gray) Torr.

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Figure 1. Fossil Creek Watershed Area. *Photo courtesy Joni Ward.*

Fossil Creek Watershed PAPAZ Flora Project

by Joni Ward[1]

Introduction

In the spring of 2012, a group of volunteers, trained as part of the Plant Atlas Project of Arizona (PAPAZ), began working on the Flora of the Fossil Creek (or FC) Watershed and Planning Area. Collection efforts in the Fossil Creek site initially focused on the 10,000-plus acre Fossil Springs Wilderness and the 50-acre Botanical Area, both situated just south of the Mogollon Rim. The plant communities range from Desert Scrub to Riparian and Ponderosa Pine/Gambel Oak. Collection efforts have extended along the numerous hiking trails following the Creek, the Flume Trail, Fossil Springs Trail, and along FSR 708. The efforts included seasonal collecting in early spring, late spring, and summer/post-monsoon (Hodgson and Ward 2012).

The location of the Fossil Creek Watershed within the greater Verde River Watershed, connecting the Mogollon Rim with the Verde River, played an important role in the decision to begin the Flora of the Fossil Creek Watershed. The designation of Fossil Creek as a Wild and Scenic River in 2009 affirmed the timeliness of the Flora in assisting USDA Forest Service personnel as they began working to identify the outstanding, remarkable values (ORVs) of Fossil Creek, as this becomes the basis for managing the Wild and Scenic River corridor.

Location, Boundaries and Ownership

Fossil Creek in a major perennial tributary of the Verde River, both of which are located within the Central Arizona Highlands or Mogollon Highlands. It is an intermittent stream from its headwaters at the convergence of Sandrock and Calf Pen Canyons at an elevation of 7,200 feet until it reaches an area of over 60 springs collectively known as Fossil Springs. These springs emanate from limestone in an area spread out over approximately 900 feet and discharge a near constant temperature of 72° making it one of Arizona's rare warm water streams. The Creek flows perennially in a southwesterly direction for about 17 miles before entering the Verde River at an elevation of about 2,500 feet. Fossil Creek and the watershed area are located almost entirely within the jurisdiction of the USDA Forest Service and form

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Fossil Creek *continued*

the boundaries between Coconino and Tonto National Forests and between Yavapai and Gila Counties (Northern Arizona University 2005).

The Fossil Creek Watershed Flora Project covers over 36,000 acres and includes the FC Wilderness on the Coconino National Forest, the Fossil Springs Botanical Area, and numerous hiking trails along the Creek and surrounding areas. The area resides in the Mogollon Highlands and is expected to be one of moderate to high endemism based on previous DBG research (Hodgson et al. 2013).

Figure 2. Fossil Creek Wild and Scenic River Corridor. *Photo courtesy Joni Ward.*

History

Human occupation in the Fossil Creek watershed area related to the prehistoric Hohokam and Southern Sinagua cultural traditions dates back about 600 years. There are sites reflecting use by Yavapai and Apache hunter/gatherers as well as by farmers and stockmen. In 1909, in response to the increasing energy needs of the mining towns in the nearby Bradshaw Mountains and Black Hills, the Childs Power Plant was constructed and most of the flow of Fossil Creek was diverted at the historic Irving Power Plant site into a series of flumes, siphons, penstocks, turbines, and a reservoir (Stehr Lake). The Irving Power Plant was constructed and came online in 1916 (Northern Arizona University 2005).

In 2005, Arizona Public Service (APS) decided to decommission the dams and return full flow to Fossil Creek. In preparation for this, the staff at NAU compiled and published online the *Fossil Creek State of the Watershed (SOW)* report. This report summarized the information available at the time about the physical, biological, social, and human environment within the Watershed (University of Northern Arizona 2005).

With the return of the flow to the creek in 2005, and the designation of Fossil Creek as a Wild and Scenic River in 2009, the creek and the waterfall area became a very popular destinations for people to escape the heat. Initial efforts to mitigate the impact of human activity on the area included limiting the number of cars allowed to enter. In 2012, the Forest Service closed FS Road 708 from the Fossil Springs trailhead on the Strawberry side to the Waterfall parking area in a further effort to reduce human impact. In 2016, the Forest Service established a parking permit requirement from April through September for day use only, with no camping allowed in the permit areas (Fossil Creek Adaptive Management and Monitoring Workshop Report 2017).

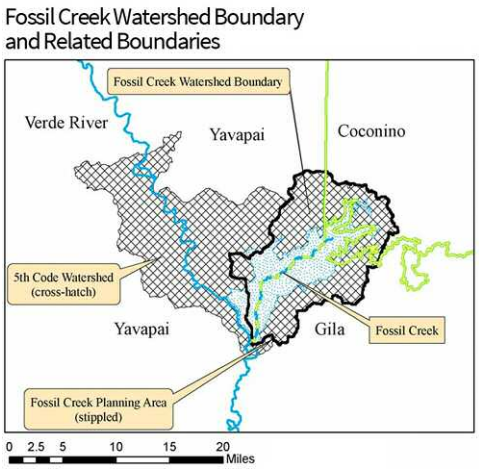

Figure 3. Map of the Fossil Creek Watershed Boundary and Surrounding Area. *Map courtesy Northern Arizona University.*

Outstanding and Remarkable Values of Fossil Creek Wild and Scenic River Corridor and Watershed

Yavapai/Apache Culture: The Yavapai-Apache Nation has strong cultural ties to the Fossil Creek area (USDA Forest Service 2017).

Water: Fossil Creek is the only intact perennial system in Arizona with continuous flow and no diversions. The free-flowing quality and quantity of the water, in addition to the super saturation of the water with calcium carbonate, contributes to the outstanding value of this remarkable waterway. (USDA Forest Service 2017).

Geology: Travertine deposits form when $CaCO_3$ precipitates from the spring-fed, heated and/or ambient-temperature waters. These deposits form dams, which can alter stream

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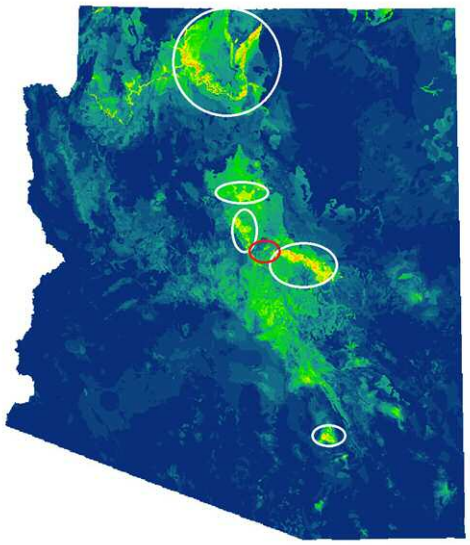

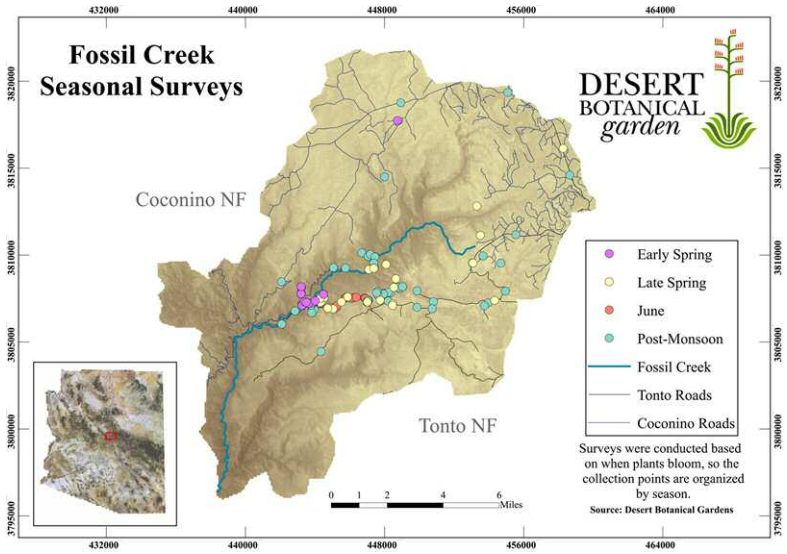

Left to right: Figure 4. The Fossil Creek Watershed (red circle) is located between the Verde River and the Mogollon Rim, predicted areas of AZ plant endemism (Hodgson et al. 2013). Figure 5. Seasonal Surveys to date. *Map by Melissa McGehee and Holly Winscott, ASU graduate students, GIS.*

Fossil Creek *continued*

morphology and create large pools in Fossil Creek (USDA Forest Service 2017).

Biology: Fossil Creek is home to a diverse native fish community including nine endangered and/or sensitive species. Common Black Hawk nesting sites found around Fossil Creek are being monitored as an indication of a healthy ecosystem (USDA Forest Service 2017). In 2010, the staff at the Desert Botanical Garden generated a map which shows the base of the Mogollon Rim and Verde Valley as predicted areas of high plant endemism, which may also indicate biodiversity hotspots (Hodgson 2013). The Fossil Creek watershed is located between two of these areas (Figure 3).

Recreation: Fossil Creek provides outstanding opportunities for a variety of recreational activities and it attracts numerous visitors, many of whom return year after year. Opportunities include swimming, camping, hiking, fishing, wildlife and nature observations, photography, bird watching, and potential cultural and historical site interpretation (USDA Forest Service 2017).

Flora Rational, Timing, and Progress

Considering the location and history of the Fossil Creek watershed, the designation of Fossil Creek as a Wild and Scenic River Corridor, the management needs, and the predicted biodiversity of this area, we saw an opportunity to build on valuable baseline data and information that can assist in managing Fossil Creek. We also saw an opportunity to further explore the predictions of endemism presented in the model mentioned.

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Left to right: Figure 6a. Endemics collected in the Fossil Creek Watershed Area. *Echinocereus yavapaiensis. Eremogone aberrans. Photos courtesy Joni Ward.*

Fossil Creek *continued*

The plant communities of Fossil Creek range from Desert Scrub to Ponderosa Pine/Gambel Oak and include riparian areas. The collection efforts covered this range of plant communities through three seasons, early spring, late spring/early summer, June and post monsoon/late summer.

What Plants Have We found?

As of March 2017, approximately 775 collections have been made, with 500 fully processed, representing 76 families and over 350 taxa (Table 1). Several Arizona endemics documented include *Agave chrysantha, Mentzelia longiloba* var. *yavapaiensis, Echinocereus yavapaiensis, Peritylе ciliata, Eremogone aberrans, and Galium collomiae* (Figure 6a and 6b).

Table 1. Plant collections to date.

	Prior to 2012	2012-2016
Families	60	73
Genera	118	197
Taxa	151	320
Collections	208	560

What is Next?

The Botanical Area, upper canyons (including Sandrock and Calf Pen Canyons), hanging gardens, and recreational areas downstream have yet to be thoroughly explored for additional plant discoveries and will be the areas of focus for the next few years.

On-going challenges to the ecosystem include water quality and flow in Fossil Creek, stability of the travertine deposits, recreational use, and grazing impacts. This flora project will continue to help inform decisions made to protect and maintain the biotic communities that provide the basis for this unique treasure in the Mogollon Highlands.

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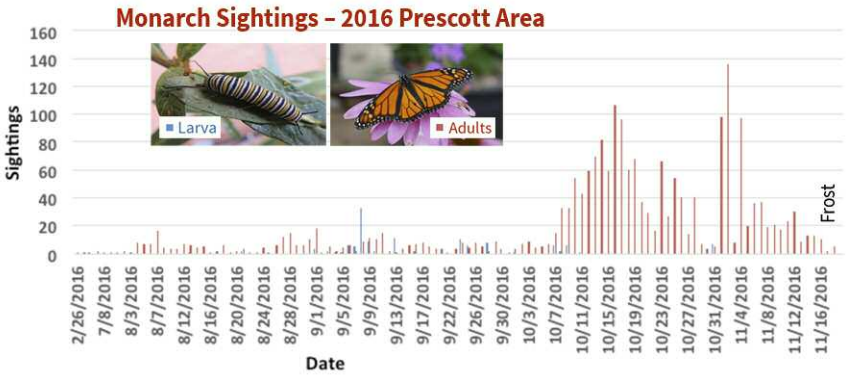
Left to right: Figure 6b. Endemics collected in the Fossil Creek Watershed Area. *Galium collomiae. Photo courtesy Kris Schloemer. Agave chrysantha. Photo courtesy Wendy Hodgson.*



From left: Figure 1. Tagged Monarch butterfly on horsetail milkweed. Figure 2. Number of Monarch butterfly larvae and adults observed by date during 2016.

Monarch Butterfly Plant Utilization, Migration, and Habitat Enhancement in the Prescott Area

by Bob Gessner and Cathy Palm-Gessner[1]

Introduction

Monarch butterflies utilize nectar and reproduce on plants from Mexico to Canada and migrate through the Mogollon Highlands of Arizona (Morris et al. 2015). Their migration is one of the longest for insects in the biological world (Oberhauser and Solensky 2004) and their decline in numbers during the past 20 years has been a cause of international concern (worldwildlife.org, monarchwatch.org, Oberhauser et al. 2015). Numbers in overwintering areas in Mexico and California still remain low (monarchjointventure.org). Monarch butterflies were not reported from Arizona until the 1970s (see Morris et al. 2015) and only recently have been included on the migration maps for North America (monarchwatch.org). Despite the relatively recent recognition of the presence of Monarchs in Arizona, the numbers reported are higher than previously realized (swmonarchstudy.org). The host plants and migration patterns for Monarchs in the Southwest are distinct from those of eastern populations (Morris et al. 2015) and additional research is needed to understand the unique biology of southwestern populations.

Materials and Methods

For the past three years (2014–2016), we have been recording sightings and tagging monarch butterflies (*Danaus plexippus*) from plants in the Prescott, Arizona, area with a team of citizen scientists. Observers are given training to distinguish Monarch butterflies from Queen, Painted Lady, and other butterflies in the area (swmonarchstudy.org, Oberhauser and Kuda 1997). They initially send in a picture for confirmation of a correct identification of a Monarch and then become part of the reporting team. Monarchs are caught with butterfly nets and tagged with a standard sticky tag developed by Monarch Watch and customized by Southwest Monarch Study (SWMS). The tag is placed on the mitten-shaped discal cell of the wing (Figure 1) and each tag has a unique code that is used for future identification. Basic data are recorded for each butterfly which include observer, date, location, gender, and host plant. The data are then sent to the SWMS data base. Spotters and tag collectors in California and Mexico report sightings and tag number recoveries back to SWMS.

Results and Discussion

Number of observers, locations, host plant species and season length in Prescott area — 2014–2016

Significant numbers of Monarch butterflies are typically seen in the Prescott area from June to the last killing frost (Figure 2). In 2016, the number of observers, locations where Monarchs were found, and number of plant host species was the highest of the three years of the study (Table 1). The numbers of Monarch larvae and adults spotted were also the highest (Table 2). This primarily relates to 2016 being a very good year for Monarch reproduction and migrants moving

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Monarch Butterfly *continued*

through the area. The year 2016 was the ninth wettest on record for Prescott (National Weather Service, Flagstaff) and good for plant growth and plant condition because of moisture levels from the summer monsoon. The last killing frost was not until November 17, but Monarchs were still reported up to November 19 (Table 1). The median frost date is October 11 for Prescott (University of Arizona Yavapai County Cooperative Extension Bulletin #25). Another contributing factor was having experienced spotters, especially for caterpillars on milkweed plants.

Over the three-year period, large numbers of native milkweeds have been made available to local citizens in the Prescott area at plant sales by the Highlands Center for Natural History and the Yavapai Master Gardeners Association. The plants were primarily supplied by SWMS and Arizona Milkweeds for Monarchs (**azmilkweedsformonarchs.org**). Local nurseries have also made available tropical milkweed, horticultural cultivars of butterfly milkweed, and occasionally native milkweed plants. The combination of more milkweeds available in gardens, and homeowners willing to report their observations, are other factors that contribute to the higher reported numbers.

Most utilized milkweed plants for reproduction

Ten of the 29 milkweed species found in Arizona (xerces.org) have been reported from Yavapai County (Seinet). The most utilized native plant for egg-laying and larval feeding is horsetail milkweed (*Asclepias subverticillata*) (Table 3). Tropical milkweed (*A. curassavica*), a Mexican species that has naturalized along the Gulf Coast and in some other moist mild winter areas in the U.S., is the second-most reported host for larvae and adults (Table 3). Only a small number of plants were probably grown in the past in Prescott area gardens. A local farm grew tropical milkweed plants in larger numbers for cut flower arrangements and these plants were found to host many Monarch larvae and adults. With the current interest in Monarchs, nurseries are selling milkweed plants grown in Arizona, California, and possibly other locations. Sometimes Monarch larvae and eggs are also imported with the plants. The increased number of Monarch sightings on tropical milkweed may relate to more plants being available for Monarchs. The number of tropical milkweed plants is still a very small percentage of the total compared to the available native milkweed species but Monarchs seem to have a strong preference for tropical milkweed. There is concern about the *A. curassavica* that has naturalized in the Gulf Coast states and its link to infections in Monarchs by the protozoan, *Ophryocystis elektroscirrha (*OE). That isn't a concern here in Arizona since the plants die back to the ground in the winter (Morris et al. 2015).

Table 1. Number of observers, locations, different plant host species, and season length, 2014–2016.

Year	Observers	Locations	Plant species	Season
2016	41	53	19	6/25–11/19
2015	33	39	11	7/9–11/1
2014	26	25	18	7/16–11/12

Table 2. Number of Monarch butterfly larvae and adults observed and tagged, 2014–2016.

Year	Larvae	Adults	Total Observed	Total Tagged
2016	137	1988	2125	667
2015	58	356	414	122
2014	25	469	494	123

Table 3. Number of Monarch butterfly larvae and adults observed on different milkweeds species, 2014–2016.

Plants	2014	2015	2016	Total
Asclepias subverticillata	21	149	174	344
Asclepias curassavica	11	35	117	163
Asclepias speciosa	0	0	41	41
Asclepias tuberosa	0	0	10	10
Asclepias asperula	10	0	7	7
Asclepias syriaca	0	0	7	7
Asclepias latifolia	0	0	1	1

Table 4. Number of Monarch butterfly larvae and adults observed on different nectar plants, 2014–2016.

Plants w/Adults/Larvae	2014	2015	2016	Total
Rubber rabbitbrush	80	47	1275	1402
Horsetail milkweed	21	149	174	344
Butterfly bush	21	112	76	209
Annual sunflower	176	11	19	206
Tropical milkweed	11	35	117	163
Mexican sunflower	49	11	16	76
Showy milkweed	1	0	41	42
Spider milkweed	10	0	0	10
Butterfly milkweed	0	0	10	10

Most utilized plants for nectar

Monarch butterflies have been reported from 19 different plant species during the past three years. The most preferred nectar plants include rubber rabbitbrush (*Ericameria*

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Table 5. Migration of adult Monarch butterflies from the Prescott and Prescott Valley to California.

Tag #	Gender	Date Tagged in AZ	Location Tagged	Date Spotted in CA	Location Spotted
AN741	Female	9/26/2016	Prescott, AZ	12/28/2016	Halcyon, CA
AR770	Female	10/16/2016	Prescott Valley, AZ	12/21/2016	Nipomo, CA
AQ070	Female	10/17/2016	Prescott Valley, AZ	11/16/2016	Cayucos/Villa Creek, CA
AQ743	Male	10/17/2016	Prescott Valley, AZ	11/23/2016	La Quinta, CA

Monarch Butterfly *continued*

nauseosa), horsetail milkweed, butterfly bush (*Buddleja* spp.), tropical milkweed, annual sunflower (*Helianthus annuus*), Mexican sunflower (*Tithonia* spp.), and three other milkweeds (Table 4). Monarch plant choices for reproduction and feeding appear to relate to plant condition (Morris et al. 2015, Agrawal 2017). During the migration, rubber rabbitbrush, butterfly bush, and Mexican sunflower are among the few plants still flowering which are sources of nectar. The rubber rabbitbrush plants primarily reported to be utilized by Monarchs in the Prescott area are from home and subdivision plantings that have naturalized into vacant land and drainages. It is believed that rubber rabbitbrush is not a native plant in most of the Prescott area but does occur as a native to the north and west of Prescott (Sue Smith, Prescott Chapter, Arizona Native Plant Society, personal communication).

Tagging during the migration

Tagging is usually done during the migration. During 2016, some tagging was done before the migration to monitor monarch movement, but no tags were recovered. Many more Monarchs were tagged in 2016 than the previous two years (Table 2). Having a much longer migration period based on the delay of a killing frost, as well as finding new locations for stands of rubber rabbitbrush contributed to the higher numbers tagged.

We are not aware of the source of the substantial number of Monarchs that migrate through the Prescott area. We have not yet recovered a Monarch with a tag from another location. Monarchs are tagged north of Prescott in Utah, Grand Canyon National Park, Sedona, Camp Verde, and other areas, and migrate south. The Monarchs that migrate south from the above locations may not travel through Prescott or we have not been at the right location when they are moving through the area. Only a small percentage of the population can be tagged, so the probability of observing one of the tagged butterflies is potentially low. It is also possible that the migrators we see have come from the local fields and gardens in the Prescott area. More research is needed on the movements of Monarchs in the state of Arizona and how it relates to the Prescott area.

Migration to California

Four monarchs that were tagged in the Prescott area during 2016 made it to California winter roosting areas (Table 5). These are the first reports of Monarchs, as far as we know, making it to these winter roosting sites from the Prescott area. The distance traveled by the four Monarchs was at least 237–463 miles. The wind direction at 1,000 ft. is an important determinate if Monarchs travel to California or Mexico for the winter (Morris et al. 2015).

Importance of citizen scientists and gardens in monarch conservation

With the help of many volunteers, we have been able to observe the behavior of Monarchs in the Prescott area. We now know approximately when Monarchs arrive in the Prescott area, when the migration to California and Mexico takes place, the preferred milkweed plants for reproduction, and the preferred nectar plants. The areas that Monarchs have been reported from include: residential gardens and subdivisions, plantings around commercial and public buildings, nurseries, and various private and public lands that have useable milkweed and/or nectar plants, trees for roosting, and possibly a water source (swmonarchstudy.org).

Most of the enhancement of Monarch habitats in the Prescott area is from the planting of milkweeds and nectar plants in private and public gardens. Four years ago, on our own property, we had never seen a Monarch and did not believe they even occurred in Prescott. After meeting with Gail and Bob Morris of SWMS, visiting the Monarch wintering sites in Mexico and California, and planting plants that Monarchs prefer in our yard, we now see a Monarch almost every day after the monsoon starts, have many eggs and larvae on the milkweeds, and see adults on the nectar plants.

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Clockwise from left: Close-up of the "beard" and "lip" of Beardlip Penstemon (*Penstemon barbatus*). Male Rufous Hummingbird feeding at Parry's Penstemon (*Penstemon parryi*). Female Broad-billed Hummingbird feeding at *Agastache* sp. *Photos courtesy Robert A. Behrstock.*

BOOK REVIEW *Karen LeMay, Founder of Pollinator Corridors SW, Sierra Vista; Cochise Chapter, Arizona Native Plant Society, KarenLeMay@cox.net*

Hummingbird Plants of the Southwest

by Marcy Scott. Rio Nuevo Publishers, Tucson, 2015. 344 pages.

The Cochise County Chapter of AZ Native Plant Society was fortunate to have Marcy Scott speak to us in April 2017. Discussing her move from the Midwest to New Mexico, she explained how she quickly became captivated by the fourteen species of hummingbirds inhabiting the Southwestern United States (versus one species in the Midwest). Fascinated by these amazing birds, she immediately wanted to learn more about them. Being a native plant nursery grower, she also wanted to provide gardeners with information on the plants that the Southwest's migrating hummingbirds evolved with and depended on for food and shelter along their long migration routes. She soon realized that few publications on Southwestern native plants for hummingbirds had been written, so she set out to expand the information that was available. After many years of research, photographing, and writing, *Hummingbird Plants of the Southwest* was published.

For me, so fortunate to live at the base of the Huachuca Mountains in southeastern Arizona, one of the many joys of spring is to see migrating hummingbirds. After a long winter, one of the first signs of spring in our habitat garden is migrating Rufous hummingbirds. They are a reminder of the changing seasons. Using the author's words, hummingbirds instantly "animate a garden."

Each of the 14 species of hummingbirds that migrate or nest in the Southwest is profiled in the second chapter. Every account includes a stunning photo, life history information, and current research data collected by the author.

One of the ways to attract these birds to gardens is to learn more about what type of food and shelter they need along their migration route and at their nesting areas. In the book's chapter entitled "Creating a Hummingbird Habitat," the author describes how gardeners can make a meaningful difference by enhancing natural areas of the Southwest that have been degraded by humans, drought, and wildfires. Residential gardens are the perfect place for a migrating hummingbird to rest and refuel for a week, as long as gardeners keep in mind that their yard must be safe from non-native predators (e.g., domestic cats) and pesticides. These safeguards are a small price to pay for having the pleasure of hummingbirds in our lives, and at the same time, providing a stopover along their migration routes. As the author points out, hummingbirds have great memories and will rely on and return to the same flower patch or resting area year after year.

For Southwest habitat gardeners, especially gardens focused on pollinators, this book is an excellent resource for

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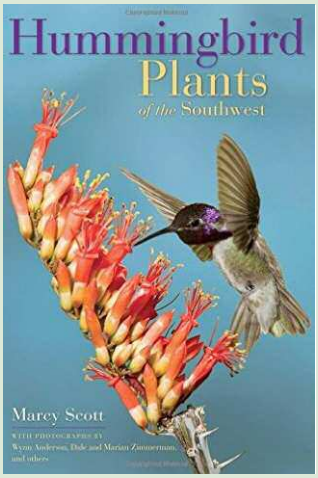
Book Review *continued*

attracting hummingbirds. The author discusses how hummingbirds are great pollinators since they feed all day, reliably visit flowers year-round, and travel great distances which enhances the genetic variability in the seeds of the plants they visit.



In the chapter entitled "Gardening with Native Plants, Southwestern Style," the author describes and includes beautiful images of the classic hummingbird flowering plants, typically those with bright red flowers that are tubular in shape. The author also profiles many other flowering plants visited by hummingbirds, adding interesting information such as the flower's nectar content, blooming periods, tips on garden design, and growing challenges, as well as the standard plant characteristics in an at-a-glance inset. In all, 120 plants native to different Southwest areas are described, including many familiar species such as penstemons, salvias, and paintbrushes.

For readers who may have no land or ambition to create a habitat garden, this book is still a pleasure to read. The photographs (taken by the author, her husband, and other hummingbird enthusiasts) are superb; the author's writing style is colorful, and the layout of the book is very pleasing. The book encourages the reader to become an armchair field biologist, vicariously observing the foraging hummingbirds defend their territories, construct their nests, and pass between their winter and summer homes.

Monarch Butterfly *continued from page 16*

Monarchs are opportunists and can be observed on native, naturalized non-native, and horticultural plants. Sometimes they embarrass native plant purists by utilizing non-native locally invasive plants like Siberian elm, salt cedar, naturalized rubber rabbitbrush, and horticultural plantings instead of native plants. Gardens planted for Monarchs can add to Monarch population levels and reduce the impacts of habitat loss from urbanization (Oberhauser et al. 2015).

Acknowledgements

SWMS: Gail Morris and Bob Morris; California spotters; Prescott Area volunteers: John Allerholt, Walt Anderson, Sue Arnold, Karen Austermiller, Mary Barnes, Helen Berg, Dan Black, Sheila Black, Darla Boggs, Linda Britt, Christina Brooks, Bart Brush, Randy Burns, Barb Butterfield, Gina Clark, Peggy Copen, Steve Copen, Kathleen Corum, Rich Cottine, Sue Cottine, Maggie Cox, Mary Curren-Perkins, Joan Duke, Nancy Ethridge, Mary Ellen Ewing, Diane Flannery, Leigh Ann Frankel, John Fromm, Thelma Fromm, Sandy Geiger, Denise Gibbs, Patty Harlan, Constance Hochstetier, Nancy Jensen, Dominique Jewett, Phyllis Jiacalone, Marion Johnston, Jane Kowalewski, Steven Lemie, Rich Lewis, Al Lodwick, Kris Lohay, Kay Lyons, Elizabeth Long, Cathy Michener, Lois Mail, Sharon Marmaduke, Pat McNiven, Garrett Mead, Heather Meade, Ruby Mead, Trace Meade, Caryl Merrit, Steve Miller, David Moll, Brian Morris, Dianne Murphy, Joanna Nellans, Cathy O'Connell, Rod Other, Susie Percy, Fiona Reid, Amparo Rifa, Linda Sanzo, Coya Steel Silverlake, Karen Stevens, Mara Trushell, Wayne Valerius, Steve Van Slyke, Wanda Lou Woodberry, Peter Yingling, Paul Yoder, Suzanne Yoder, and Lisa Zander.

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Left to right: Figure 1. Emory Oak (*Quercus emoryi*) detachable stem gall #128. *Collected and photographed by the Pinecrest Gall Research Station.* Figure 2. Cliff Rose (*Purshia*) monothalamic stem gall #142. *Collected and photographed by the Pinecrest Gall Research Station.* Figure 3. Stages of Gambel Oak (*Quercus gambelii*): stem hard, detachable, polythalamous Gall #104. *Photographed by Gary D. Alpert, Ph.D., Director of the Center for Bio-Cultural Diversity, Museum of Northern Arizona.*

Plant Galls of Prescott, Arizona

by Charlie DeMarco[1]

About four years ago, while hiking the trails at the Highland Center for Natural History in Prescott, Arizona, I noticed something that had been there all along but had escaped my attention on all my previous outings. It was a small, round, red ball on a scrub oak leaf about three-quarters of an inch in diameter. It looked like a tiny red apple. As I examined this curiosity, I noticed there were others just like it on the scrub oaks all around me. What was I looking at? At first it appeared to be a fruit, but it felt hollow and, most oddly, was attached to the leaf and not at the bud. In fact it appeared to have emerged right out of the middle of the leaf! That was strange indeed. I then thought it must be an insect's nest of some kind. Even more curious now, I went back to the Center's office and when I inquired, I was told it was a gall. What is a gall? Little did I know at that time I would be spending many hours over the next four years delving deeply into this question. It turns out there are thousands of types of galls. They are nests, yet they are not built by insects, but strangely, by the plant itself for the insect. Galls are thus said to be "induced."

Inducers

Galls can be induced in a number of ways by insects, fungi, bacteria, flies, midges, aphids, or moths. The common thread is that they all have a way of hijacking the plant's growth capabilities and diverting its food supply channels.

Distribution of Galls in the Prescott Area

The results of a casual inventory of galls in the Prescott area are presented in Table 1. These data were collected from March 18, 2014, until October 15, 2017, from an area within a 10-mile radius of Prescott, Arizona. I used a random sampling methodology by hiking through all the ecological zones (chaparral, piñon-juniper, pine-oak, and fir-aspen) within the sampling area. It is not well understood why, but worldwide, oaks are the most common gall-inducer targeted trees. In Table 1, I have grouped two of the local oaks under the heading "white oak" and these are *Quercus turbinella* and *Q. arizonica*. In the Prescott area these two trees have many more galls and types of galls than any other. Likewise in Table 1, all species of cottonwood, willow, rose, and

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[1]Pinecrest Gall Research Station, Prescott, Arizona, ultrawide4@gmail.com, prescottgalls.press.com, https://www.facebook.com/Prescottgalls

Table 1. Gall count by plant: Pinecrest Gall Research Station, Prescott gall survey

Plant	# Found
Quercus arizonica and *Q. turbinella* | White Oak	42
Q. emoryi | Emory Oak	12
Q. gambelii | Gamble Oak	11
Salix sp. | Willow	11
Celtis reticulata | Hackberry	4
Arctostaphylos sp. | Manzanita	4
Rhus trilobata | Three-leaf Sumac	3
Purshia sp. | Rose	3
Populus sp. | Cottonwood	3
Forestiera neomexicana | New Mexico Olive	2
Pinus monophylla | Pinyon Pine	1
Cercocarpus ledifolius | Mt. Mahogany	1
Juniperus deppeana | Alligator Juniper	1
Vitis arizonica | Arizona Grape	1
Juglans major | Arizona Walnut	1
P. ponderosa | Ponderosa Pine	1
Senegalia greggii | Cat's claw	1
Total	102

Plant Galls *continued*

manzanita are grouped. Please see the Pinecrest Gall Research Station's website (**prescottgalls.press.com**) for more specific information on gall species distribution in the Prescott area.

Life Cycle

In a typical scenario, a *Cynipid* wasp will insert its larva just below the leaf surface of a host plant. The insect has a special organ called an ovipositor for this purpose. Once deposited, the larva will then go to work hijacking the chemical components, processes, and perhaps the DNA present within the plant cells. The actual chemical and DNA hijacking process is not well understood, but it is how the plant is coerced to produce a construction totally alien to its normal growth: a gall. Make no mistake; the gall inducer is a parasite. In all but one known case the plant receives no benefit from this interaction, but on the other hand, the plant is very rarely killed or even substantially harmed by the interaction and most often takes the intrusion in stride. In fact, many galls can sometimes be seen on a single leaf and yet the leaf is still green and photosynthesizing normally. This is because at the point of growth the plant creates a nutrient sink. At this sink point a larger quantity of resources is provided by the plant for its normal growth. The gall insect hijacks the sink and encourages its continuation while directing the nutrient flow to itself rather than for plant growth.

The life cycle of various gall inducers can be quite complex. Some inducers spend a year stealing nutrients from the plant and developing in the gall. Later they drop to the ground, burrow in, pupate, and spend another year underground before emerging for only a week to mate and produce their own offspring before they die. Some galls produce a second generation of gall inducers in the same season. The earlier generation is one of males and females. These give birth to a generation of all females that then reproduce through parthenogenesis; that is, clone themselves asexually to produce next year's early generation of males and females. Strangely, the galls of these different generations may look very different and be induced on different host plants.

The inducer and the host plant have coexisted in nature for a very long time. Evidence in the fossil record shows that fungi-induced galls existed 200 to 300 million years ago during the Upper Paleozoic-Triassic Period in England. Suspected insect-induced galls existed about 225 million years ago, during the Triassic Period in France. The oldest confirmed insect-induced galls from North America are from the Late Cretaceous, about 115 million years ago in Maryland (Russo 1979). Interestingly, this way of life preceded the emergence of flowering plants which occurred about 130 million years ago.

Predators and Defenses

While in the gall, the inducer does not get a free ride. It may be subject to predation by numerous organisms, including birds, rodents, and a host of insects which have evolved along with the gall inducer in a close-knit interrelationship. The larva may have to put up with house-breakers (inquilines) that come uninvited to share the gall's protected space. In fact, the faunal environment can include many unexpected participants. For example, both the larvae and the inquilines may come under attack from parasitoid wasps. True parasites usually feed on the host without killing it, but the parasitoid wasps specialize in laying their eggs in the larva and/or the inquilines. As the gall develops, both the gall larva and inquilines may be eaten by the parasitoid wasp larva.

There are gall inducers which have evolved to induce their gall specifically within another gall. These are endogalls. There can be several other hyperparasites which parasitize

continued next page

Plant Galls *continued*

the parasites. In another case, some gall-inducer larva will produce a substance called honey dew. This substance attracts yellow jackets and ants. These insects have no interest in the larva but are fierce defenders of the honey dew food source and thereby provide a defense force for the gall. If half of the gall larva survive, it is a good season for the inducer, but more likely 80% to 90% will never reach maturity.

Left to right: Figure 4. *Disholcaspis pedunculoides*, the gall inducer of a White Oak (*Quercus arizonica*) stem spangle gall. The insect was identified by Dr James Nicholls Institute of Evolutionary Biology University of Edinburgh, United Kingdom. Figure 5. *Disholcaspis edura*, another gall inducer of a White Oak. *Specimens collected and photographed by the Pinecrest Gall Research Station.*

Gall Defenses

Gall inducers have evolved many defensive strategies against predation. Many galls have a very tough woody outer covering. Some gall exteriors are sticky and trap attackers or delay them and thereby aid the attacker's own predators. Some galls have very complex interiors with false chambers. Some gall inducers deposit larva deep within the gall thus frustrating attempts by other wasps to drill in and reach the embedded larva. Some gall inducers invest in sheer numbers in an attempt to have just some of their offspring reach maturity. Importantly, the actual number of host-plant species supported by the gall can easily exceed several dozen. The interrelationships are long-standing and complex.

Gall Evolution

I like to think about the application of one of the greatest scientific discoveries of all time, evolution, to the gall world. How did galls come to be? Did some insects at first just lay their eggs on the surface of leaves? Did some larva then discover some safety and shelter by burrowing into the leaf, twig or root surface? Did they "see" a potential to extract food there and evolve to exploit it?

Perhaps you will notice many kinds of galls as you explore our rich transition zone between the Sonoran Desert and the Colorado Plateau. Perhaps when you do, you will be awed, as I have been, at the rich texture and deep, long-term connections between all life forms in our natural world.

During this study I have developed the Pinecrest Gall Research Station facility to work with and record the specimens collected as well as house the collection. I have produced a graphical, easy-to-use webpage outlining my ongoing research results: **prescottgalls.wordpress.com**. Additionly, I post current photos and topic information on this Facebook page: **www.facebook.com/Prescottgalls/?ref=aymt_homepage_panel**

Please enjoy these resources and email me with any input or questions. Let me know of any errors I've made. If you see galls not shown on the website I would be grateful to hear about them. You can also arrange a visit to The Station or schedule a small-group gall walk.

Reference

Russo, R. 1979. Field guide to plant galls of California and other western states. California Natural History Guides, University of California Press, 379 pp.

Above: *Aquilegia chrysantha.* Inset: *A. triternata.*

SPOTLIGHT ON A NATIVE PLANT *by Douglas Ripley, Arizona Native Plant Society, Cochise Chapter, jdougripley@gmail.com. Photos courtesy the author.*

Golden Columbine (*Aquilegia chrysantha*) and Chiricahua Mountain Columbine (*A. triternata*)

Columbines are members of the Crowfoot Family (Ranunculaceae) and approximately 60–70 species of the genus occur throughout the Northern Hemisphere. The genus name was established by Linnaeus with a meaning that is uncertain; it may be derived from the Latin *aquila*, because the spurs resemble claws, or *aquileus*, also from the Latin, meaning "water-drawer" because many grow in moist habitats (Munz and Keck 1968). The common name "columbine" possibly comes from the Latin for "dove," due to the resemblance of the inverted flower to five doves clustered together. The most striking feature of the columbines is the series of nectar-bearing spurs, which project backward from the front of the flower and are a major attractant to birds (especially hummingbirds) and insects.

The seven species of columbines occurring in Arizona are always a special joy to encounter. Kearney and Peebles (1969) praised the golden columbine by saying, "With its large, long-spurred, canary yellow flowers, this is one of the handsomest plants in the state." It has a very wide distribution and can be found in Arizona, Colorado, New Mexico, Texas, Utah, and northwestern Mexico. Its preferred habitat is in damp places in mountainous canyons ranging in elevation from approximately 3,200 to 11,000 feet. Flowering occurs between April and September. The species was described by Asa Gray of Harvard University in 1873 based on a collection in 1852 by C. Wright in the Organ Mountains, Doña Ana County, New Mexico. The species name is derived from the Greek, "chrys," meaning gold (Gray 1873).

Another beautiful Arizona columbine is the Chiricahua Mountain columbine with a somewhat more restricted distribution, occurring most commonly in Southeastern Arizona and Southwestern New Mexico. It produces brilliant red flowers with triternate leaves (arranged in three parts). It also flowers between April and September. This species was described in 1918 by Edwin Blake Payson, a professor of botany at the University of Wyoming (Payson 1918). The species name refers to the leaf arrangement.

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SPOTLIGHT ON A NATIVE PLANT *continued*

It is well known that columbines form hybrids (Taylor 1967), and many attractive columbine hybrids have been developed for the nursery trade. But finding naturally occurring columbine hybrids in the wild is relatively easy as well. The photos used here, to illustrate the two columbine species, were taken in Rustler Park in the Chiricahua Mountains. The hybrid plant, pictured here, was observed between populations of *A. chrysantha* and *A. triternata*.

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Hybrid of *Aquilegia chrysantha* and *A. triternata*.

The University of Arizona Herbarium Announces Special Botanical Art Event

The U of A Herbarium is excited to celebrate the acquisition of an impressive piece of botanical artwork created and donated by artist Tilda Essig. We will present it to the community on Thursday, February 1, 2018, starting at noon, at the Herbarium.

The artwork has been framed, and will hang in the main room of the Herbarium. It will be an important addition to our collections on many levels, promoting the extensive grass collection and studies and emphasizing the valuable connection between the sciences and the arts.

This print is part of Essig's series of large-scale photographic prints of grasses using an extremely high resolution scanner and printed with an archival inkjet process on heavy watercolor paper.

This event will "unveil" the work, and Ms. Essig will be present and speaking about her aesthetic process and the technical challenges of the project.

Hope to see you there!

University of Arizona Herbarium, Herring Hall
1130 E. South Campus Drive (two doors south of Old Main)
herbarium@ag.arizona.edu (520) 621-7243

Left Sierra Juriquipa. *Photo courtesy Michael McNulty.* Right Tiger lily (*Tigridia pavona*). *Photo courtesy Robert A. Villa.*

170 Years of Natural History in Cuenca Los Ojos, Sonora, Mexico

by Thomas R. Van Devender and Ana L. Reina-Guerrero[1]

Boundary Surveys

The Treaty of Guadalupe Hidalgo in 1848 at the end of the United States-Mexico War established the boundary between the two nations, and expanded the United States to the Pacific Ocean. In 1853, the Gadsen Purchase added the area along the modern Arizona-New Mexico-Sonora border to the United States. The expeditions to survey the border between 1848 and 1855 were the first biological inventories of the borderlands. Many common Sky Islands plants were named for survey botanists Arthur Schott, Charles Wright, Christopher Parry, George Thurber, John Bigelow, and expedition director Major William H. Emory, U.S. Army.

Biologists on the Second U.S.-Mexico (1892-1894) boundary survey, led by U.S. Army Captain Edgar A. Mearns, inventoried the Sierra San Luis and Cajón Bonito. The area between Monument 73 at Arroyo Guadalupe (now Rancho Puerta Blanca) and Naco, Arizona/Sonora was visited in August 1893. In Mearn's 1907 report on the mammals of the boundary, Lieutenant David Dubose Gaillard described the Arizona-Sonora borderlands as "*bare, jagged mountains rising out of the plains like islands from the sea,*" the first time that this powerful "sky island in a desert sea" image was used. He wrote the general vegetation descriptions for sites visited on the expedition. Later he was the lead engineer on the Panama Canal construction project.

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[1]GreaterGood.org, 6262 N. Swan Rd., Tucson, AZ 85718, [2]Herbarium, University of Arizona, Tucson, AZ 85718.

Left Sierra San José. *Photo courtsey Dale Turner.* Center and Right Edgar A. Mearns and David D. Gaillard. *Public domain photos, courtesy Wikipedia.*

Cuenca Los Ojos *continued*

Rancho los Ojos Caliente on Cajón Bonito. *Photo courtesy Ana L. Reina-G.*

The Rivers

Cajón Bonito is the finest riparian habitat in northwestern Mexico and adjacent Arizona with dense cottonwood-willow riparian forest along a permanent stream in deep rocky canyons. It begins on Cerro Pan Duro, flows north to the foothills of the Sierra San Luis, west through the southern extension of the Peloncillo Mountains, and south into the Río Bavispe/Yaqui drainage. The Río Yaqui drainage extends into Cochise County, Arizona, in Arroyo Guadalupe; Blackwater Draw (Arroyo San Bernardino in Sonora); and Whitewater Draw (Río de Agua Prieta in Sonora). Cajón Bonito and the Río San Bernardino are northern tributaries of the Río Yaqui. The Río San Bernardino (as Blackwater Draw) originates in southeastern Arizona, where it flows through the San Bernardino/Leslie Canyon National Wildlife Refuge (NWR) just east of Douglas.

The Biotic Communities

The vegetation of northeastern Sonora is diverse. Chihuahuan desertscrub and desert grassland reach their western limits in southeastern Arizona and adjacent Sonora. Chihuahuan desertscrub is well developed on the limestone hills in the Agua Prieta area. At higher elevations, open, grassy oak woodlands are found in the Peloncillo and San Luis Mountains. After a severe fire on the west side of the Sierra San Luis in 1996, oak woodland converted to dense interior chaparral, dominated by shrub oaks. Lower slopes of the Sierra San Luis have extensive montane grassland. Pine-oak forest is present in the higher areas in the Sierras San Luis and Pan Duro. The riparian vegetation in the upper parts of Cajón Bonito, on Ranchos el Pinito and Pan Duro, is dominated by Arizona cypress (*Cupressus arizonica*) and Douglas fir (*Pseudotsuga menziesii*).

After the Mearns Expedition in 1894, the *la frontera* zone in northeastern Sonora was neglected biologically. Interest picked up again when Joe T. Marshall's 1954 studies of breeding birds, dominant trees, and vegetation in the Sierra San Luis were reported in his 1957 book, *Birds of Pine-Oak Woodland in Southern Arizona and Adjacent Sonora.* From 1975 to 1981, Stephen M. Russell and Gale Monson observed birds in Cajón Bonito for their 1998 book, *The Birds of Sonora.*

Charles T. Mason, Curator of the University of Arizona Herbarium, and his student Roger McManus made 29 plant collections in Cajón Bonito in May 1976. Richard S. Felger

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Interior chaparral and montane grasslands in the Sierra San Luis. *Photos courtesy the authors.*

Cuenca Los Ojos *continued*

and owner Rubén Ruíz collected 55 plant specimens from Rancho Pan Duro in July 1993.

In 1986, David G. Barker surveyed the reptiles and amphibians of the Sierra San Luis for a master's degree at the University of Texas at Arlington. The threatened Animas ridge-nosed rattlesnake (*Crotalus willardi* subsp. *obscurus*) was common in Cajón del Diablo (now part of Cuenca los Ojos, or CLO). In 2008, Matt Goode, University of Arizona, inventoried the reptiles and amphibians of Rancho Pan Duro in the upper Cajón Bonito.

View to the Sierra San Luis. *Photo courtesy Luis Gutierrez.*

Dean A. Hendrickson, Wendell L. Minckley, and Robert R. Miller began studying native fishes in the Río San Bernardino and Cajón Bonito in 1980. Eight species of Río Yaqui fishes occur in these streams. Seven species are protected as endangered, threatened, or rare in the United States and/or Mexico. The Yaqui catfish (*Ictalurus pricei*), which formerly occurred in San Bernardino Creek in Arizona, still survives in Cajón Bonito. Retired U.S. Fish and Wildlife fisheries biologist Charles Minckley (Wendell's brother) monitors the CLO fishes today. The San Bernardino springsnail (*Pyrgulopsis bernardina*) is a U.S. federally endangered species that only occurs in springs in CLO and the San Bernardino NWR.

In 1993, the Centro Ecológico de Sonora (CES) proposed the Sierra San Luis in the Sistema de Áreas Naturales Protegidas del Estado de Sonora (SANPES). The proposed area included the Sierra San Luis in both Chihuahua and Sonora as far south as Rancho Pan Duro and west to Rancho Nuevo. In 2011, the Comisión de Ecología y Desarrollo Sustenable del Estado de Sonora (CEDES, formerly CES) did another study for a proposed Sonoran state-protected natural area that included the western slopes of the Sierra San Luis, all of CLO, Rancho Pan Duro, and south along the Río San Bernardino. Neither proposed reserve was established.

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Clockwise from top left Mexican roundtail chub (*Gila minacae*). Ornate shiner (*Codoma ornata*). Cajón Bonito. *Photos courtesy James C. Rorabaugh.*



From left Fremont cottonwood (*Populus fremontii*) and desert grassland, Rancho Ojos Calientes. Valer Clark. *Photos courtesy the authors.*

Cuenca Los Ojos *continued*

Cuenca los Ojos Foundation

Valer Clark and her husband Josiah Austin bought five ranches in Sonora, from the Sierra San Luis west to Ranchos las Anitas and San Bernardino east of Agua Prieta. They established the Cuenca los Ojos Foundation (**cuencalosojos.org**) in the early 1990s to administer the land. This began an intense conservation effort. Cattle were removed from the ranches to allow recovery from severe overgrazing. Without grazing, the native bunch grasses are today very diverse and dense, surely one of the best desert grasslands in the Southwestern United States. Large gabions were built along the Río San Bernardino on Rancho San Bernardino to manage stream flow and floods, and to restore riparian vegetation and fish habitats. The riparian vegetation in Cajón Bonito dramatically recovered to its present glorious condition.

The establishment of CLO stimulated a variety of research. Robert Minckley (son of Wendell) of the University of Rochester studied bees and pollination in the San Bernardino valley from 2000–2007. Large collections of bees and plants were made. The job of one summer intern was to stretch out the tongues of bees as they were pinned! Minckley identified 383 species of bees and concluded that the bee fauna was one of the richest in the world.

In 2002, Robert Hunt and Walter Anderson of Prescott College publish their two-part study on the ecology and birds of Cajón Bonito in *Desert Plants*. Hunt's studies of the area have continued with a focus on the relationships between politics and ecology in the region.

In 2002–2004, Carlos A. López-G. and his students from the Universidad Autónoma de Querétaro studied beaver (*Castor canadensis*), black bear (*Ursus americanus*), bobcat (*Lynx rufus*), and mountain lion (*Puma concolor*) at Rancho el Pinito in the Sierra San Luis and in Cajón Bonito. Beaver were only found at Rancho el Diablo in Cajón Bonito. Their results were published in the 2005 proceedings of the second Madrean Archpelago symposium entitled "Connecting Mountain Islands and Desert Seas: Biodiversity and Management."

In April 2009, the authors and Nancy Zierenberg (Arizona Native Plant Society) led a field trip to CLO, and stayed in Rancho Puerta Blanca. The group observed plants in Arroyo Guadalupe, Cajón Bonito, and El Valle.

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From left Beaver. *Photo courtesy Wayne Van Devender.* Black bear. *Photo courtesy Rubén Ruiz.* Bobcat. *Photo courtesy Memo Galaz-G.*

From left Nancy Zierenberg on Rancho San Bernardino. *Photo courtesy Thomas R. Van Devender.*
AZNPS group at border monument on Rancho Puerta Blanca. *Photo courtesy Nancy Zierenberg.*

Cuenca Los Ojos *continued*

In 2009-2011, Jesús Sánchez-Escalante, Curator of the Universidad de Sonora Herbarium (USON), did extensive plant collections in northeastern Sonora under a grant from the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), the Mexican national biodiversity agency. In the summer of 2011, CLO sponsored student interns from the Universidad de Sonora to help with inventories of plants, birds, and mammals on the Sonoran ranches.

In May 2012, the third Madrean Archipelago symposium, "Merging Science and Management in a rapidly changing World: Biodiversity and Management," was held in Tucson, Arizona. In the 2013 conference proceedings, Van Devender and Sky Island Alliance colleagues provided an overview of the biogeography and conservation of the Sky Islands Region, a map and definitions of the Sky Islands, and the regional biogeography of the pines. About 25 additional oral presentations and published articles were on Sonoran Sky Island topics.

Arizona-Sonora Desert Museum (ASDM) Plant Inventories

The authors have had a long-term interest in the flora of *la frontera* within 100 km of the Arizona border in northeastern Sonora. In 2006-2007, we searched for the Cochise pincushion cactus (*Coryphantha robbinsorum*) in Sonora under a USFWS Section 6 grant. John Wiens at ASDM and Jesús Sánchez at USON helped with field surveys. The Cochise pincushion is a federally threatened species only known from the Magoffin Hills east of Douglas in Cochise County, Arizona. In 1984, Vincent Lopresti reported it in a publication in Spanish from limestone hills in Sonora (now on CLO). Limestone hills throughout the Agua Prieta area were searched without finding the cactus.

In 2007-2008, we searched for the false rainbow cactus (*Echinocereus pseudopectinatus*) and the Chihuahuan night-blooming cereus (*Peniocereus greggii* var. *greggii*) in the Agua Prieta area under a grant from the Tucson Cactus and Succulent Society. The false rainbow cactus is locally common from Cabullona east to Mesa las Víboras. The night-blooming cereus is scattered throughout the area, but is especially common on Mesa las Víboras. This is a large area of dwarf (a meter or less in height) velvet mesquite

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From left Cochise pincushion cactus. *Photo courtesy Erik F. Enderson*. Cerro Caloso limestone ridge east of Cabullona. *Photo courtesy Thomas R. Van Devender.*



From left False rainbow cactus. Dwarf mesquite on Mesa la Víboras. *Photos courtesy Thomas R. Van Devender.* Chihuahua night-blooming cereus. *Photo courtesy Erik F. Enderson.*

Cuenca Los Ojos *continued*

(*Prosopis velutina*) habitat on pure clay soils. The *Peniocereus* were taller than the mesquites!

Plant specimens collected on these projects were deposited with the University of Arizona and USON herbaria. The ASDM plant projects overlapped with Minckley's bee studies, and several times both groups worked out of CLO's Rancho Puerta Blanca.

MABA and MDE Expeditions

The Madrean Archipelago Biotic Assessment (MABA) Program was created at Sky Island Alliance in 2009 to document the biodiversity in the Sky Island mountain ranges of Sonora. The first MABA Expedition was to CLO, where biologists observed plants and animals of Rancho el Pinito in Cajón Bonito and Puerta Blanca in Arroyo Guadalupe. In 2015 the Madrean Discovery Expeditions program at **GreaterGood.org** was created to continue biotic inventories in Sonoran Sky Islands. To date, expeditions have gone to twelve Sky Islands, and mini-expeditions to eight others. An MDE Expedition of 57 biologists went to Cajón Bonito on Earth Day in April 2017.

After each Expedition, there were follow-up trips in other seasons or to nearby areas to make additional observations. El Valle, the cold, windy southern extension of the Animas Valley in CLO, was visited several times. About a dozen species of plants and the prairie rattlesnake (*Crotalus viridis*) found in El Valle were additions to the flora and fauna of Sonora. After MDE Cajón Bonito, herpetologist Jim Rorabaugh returned to take more data on the lowland leopard frogs (*Rana yavapaiensis*). Richard Bailowitz and Doug Danforth returned to Rancho San Bernardino twice, recording 60 species of damselflies and dragonflies — 13 of them in the damselfly genus *Argia***!** These observations supplement decades of their observations from San Bernardino NWR in Arizona.

Documenting the biodiversity of the Sonoran Sky Islands to support conservation efforts is a primary objective of the MABA/MDE programs. All of the plant and animal collections and observations from expeditions and many other sources, and many high-resolution images from the region, are publicly available in the Madrean Discovery Expedition database (**madreandiscovery.org**; linked to the MABA database). The MDE database serves as the primary repository of biological records for many protected areas in

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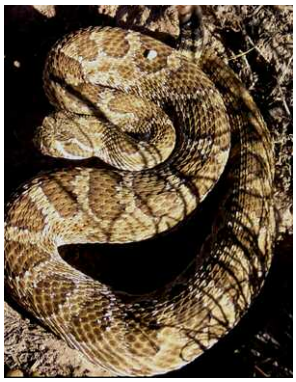

From left Wheel milkweed (*Asclepias uncialis*). *Photo courtesy Michael F. Wilson.* View of Sierra San Luis from plains grassland with Texas beargrass (*Nolina texana*) in el Valle. Spinystar (*Coryphantha vivipara*). Prairie rattlesnake. *Photos courtesy Thomas R. Van Devender.*

NEW! BOTANIST SPOTLIGHT *by Debbie Bird, Arizona Native Plant Society, Tucson Chapter*

Joan Tedford

Do you know anyone who loves plants as much as Joan Tedford? I first met Joan through some friends who were volunteering in Sabino Canyon. I'm a bit of a latecomer to this area and had the good fortune to meet Joan in 2012. We became fast friends and I learned so much from her. She was always ready to share her love and knowledge of plants. Over the years, it's amazing how many botanists and naturalists she has inspired along the way.

Joan graduated in 1951 with a degree in botany and microbiology from DePauw University in Indiana and subsequently worked for several years in the microbiology field. Joan and her husband Ted moved to Tucson in 1962 along with their two young children. Joan is a very talented musician, and participated in her church music program singing, and playing the flute and bells. Before her involvement with the Sabino Canyon Volunteer Naturalists (SCVN), Joan was a regular volunteer at a store called The West, where she taught needlecrafts. She also volunteered with the Tucson Audubon Society.

Joan became fascinated with the rich diversity of Arizona's flora and fauna and became an expert on the local flora, particularly in the Santa Catalina Mountains. Joan originally focused on birding and speaks of times when she would get up in the early morning and drive for hours with friends to see a rare or vagrant bird in another part of the state. She began to focus more on the plants "because they don't fly away and stay in the same position." Joan eventually became involved in many of the local nature and environmental education organizations. She began volunteering as a Sabino Canyon Volunteer Naturalist in 1987 under the tutelage of David Lazaroff. David thinks of Joan as "… a live wire and a forceful personality. She's also admirably tenacious. Once she took on the task of identifying Sabino Canyon's plants, she applied herself to it year after year. We've all benefited from her persistence and hard work. Her plant list is a significant legacy to the Sabino Canyon Volunteer Naturalists and to others who care about the canyon."

In 2014, Joan received the Emeritus Award from the Sabino Canyon Volunteer Naturalists (SCVN). During her time with the organization, she set up advanced training for speakers and helped many of the incoming volunteer naturalists learn about the plants of Sabino Canyon. She also advised on the SCVN Naturalist Guide, and led public

Joan accepting the Emeritus Award from the Sabino Canyon Volunteer Naturalists, 2015. *Photo courtesy Keene Turner.*

interpretation plant walks for over 25 years. During that same period, Joan created, vouchered, and maintained a comprehensive list of the plants of Sabino Canyon and Mount Lemmon. These lists have been posted on the Arizona Native Plant Society and Sabino Canyon webpages. Joan put together educational materials, such as a set of herbarium specimens in the Sabino Canyon Visitor Center, as well as a set of binders and sample cards of specimens at Palisades Visitor Center on Mount Lemmon.

Botanical author and naturalist Frank Rose knew of Joan from her list of plants on the Santa Catalina Mountains. As Franks says, "One of the best ways to come to know a new plant is to be introduced to it by someone who already knows it." Thus began a long friendship wherein Joan was able to help and advise Frank on plant identifications for his book *Mountain Wildflowers of Southern Arizona*.

Many may know Joan Tedford in recent years from her work at the UA Herbarium. She volunteered there from the mid 1980s until early 2017. On most Mondays and sometimes other days of the week, she could be found

continued next page

BOTANIST SPOTLIGHT *continued*

sorting, ordering, and filing the many specimens that are part of the Herbarium's specimen loan program. She has also spent a good part of her time at the Herbarium helping with plant identifications as well as joining in conversations about current taxonomy and what plants are being seen in the area. Joan is one of the most prolific botanical collectors in the Catalinas. She has collected over 1,000 specimens from the Catalinas that are deposited in the UA Herbarium and which represent an invaluable permanent record of the Mount Lemmon flora. Jim Verrier, who has collected extensively in the Santa Catalinas says, "One of the most impressive things about Joan is that she doesn't shy away from even the tiniest of plants. Most people walk away from them because they are difficult to identify. Joan is fearless about taking a specimen and putting it under the scope and researching until she can nail down the ID." Her enthusiasm inspires so many of us to be courageous about learning the terminology and keys for the flora.

I have had the good fortune to spend many delightful days with Joan botanizing in Sabino Canyon, Mount Lemmon, and the White Mountains of Arizona. Joan lives in Tucson where she and her husband, John, have a lovely new apartment overlooking the Catalina skyline, the mountains that she loves and knows so well. Although Joan has recently retired from her active field and herbarium work, she does get together for lunches and visits with friends. She is surely missed at the Herbarium and on the trails, but her contributions and friendship continue to educate and inspire so many of us who have had the good fortune to know her.

Cuenca Los Ojos

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Sonora, including the Cuenca los Ojos Foundation. MDE FLORA is part of the comprehensive SEINet network of 187 herbarium databases and more than 11.6 million plant records. Currently there are 6,277 plant and 4,629 animal records from the Municipio de Agua Prieta.

Some of the finest habitats in northwestern Mexico and a wonderfully diverse flora and fauna are on the Cuenca los Ojos Foundation lands in the borderlands of northeastern Sonora. Valer Clark and Josiah Austin's passion and love for the land and vision to protect it for the future created the finest private protected natural area in the Madrean Archipelago.

Clockwise from top left Cardinal meadowhawk (*Sympetrum illotum*). Bordered patch (*Chlosyne lacinia*). Tarascan dancer (*Argia tarascana*). *Photos courtesy Doug Danforth*.

Acknowledgements

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