



The Arizona
Native Plant
Society

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The mouth of Finger Rock Canyon (Mount Kimball is not visible in the photo).

Vegetation Changes in the Finger Rock Canyon Drainage, Santa Catalina Mountains, Arizona Since 1984

by C. David Bertelsen¹ Photos by the author.

The Finger Rock Canyon drainage is located in the front range of the Santa Catalina Mountains north of Tucson, Arizona. My study area, shown in Figure 1, is approximately 1,100 acres and constitutes about 0.06% of the mountain range. I have explored approximately 80 acres on foot, including the trail, three and one-half miles of the canyon bottom, and several side drainages. I first hiked to the top of Mt. Kimball in 1981 and fell in love with the canyon because of the changing vegetation over the elevation gradient of 4,158 feet. I was intrigued by how plant flowering varies with elevation and decided I wanted to learn more. I developed a protocol for what I initially thought would be a study of two or three years, and in January 1984, I began collecting data on each of the five miles. Essentially I have five one-mile-long transects (Figure 1).

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

As another year nears its end, I wish to thank all our members, Board members, chapter officers, and committee members for their support of, and participation in, the Arizona Native Plant Society. It is only through their conscientious contributions that we can hope to achieve our mission to promote knowledge, appreciation, conservation, and restoration of Arizona native plants and their habitats.

I'm obviously a little biased, but I think we can honestly say that we made a very good effort to achieve our mission's goals in 2019. Some of our specific accomplishments include:

Website Revision and Update: Developing and bringing online our new, revised, and updated website. If you have not done so already, please check it out give us any suggestions for its improvement.

Botany 2019 Conference: Held at the Eastern Arizona College on 31 August–1 September, the conference was attended by over 100 people representing every AZNPS chapter as well as participants from California, New Mexico, and Colorado. This

year's conference was jointly sponsored by the Gila Watershed Partnership of Arizona. Thirteen speakers made presentations covering a wide range of topics relative to the meeting theme "Exploring the Botanical Diversity, Ecology, and History of Arizona's Native Flora." The second day of the conference offered three interesting local field trips.

Conservation and Restoration Activities: Thanks to the efforts of the AZNPS Conservation Committee led by John Scheuring as well as by several individual chapters, the AZNPS has undertaken numerous important projects to enhance and restore native plant habitats in several parts of the state.

Education Opportunities: The Society continued to offer several botanical identification workshops throughout the year.

The Plant Press and Happenings: Through our two formal publications, we offer a forum for the discussion of current issues in Southwestern native plant conservation and other topics of interest to our readers.

Chapter Monthly Meetings and Field Trips: These ongoing activities continue to provide a great deal of enjoyment and education for our members. The annual extended field/workshop trip to the Chiricahua Mountains, sponsored by the Tucson and Cochise chapters, was held again this year on 21-23 September for a record of 48 participants.

Fiscal Soundness: We have continued to run the Society in a financially responsible way, maintaining a prudent reserve. Membership dues are by far our most important funding source. Our principal expenses are the cost of publishing *The Plant Press* and *Happenings*, our comprehensive insurance policy, website hosting and maintenance fees, and the salary for our part-time Society Administrator.

As I have said many times, we are continually seeking individuals to play an active part in managing and helping to run the Society. Such individuals can provide some new perspectives on our operations and ideas for new initiatives. Our Board of Directors is confirmed every three years. The next Board election will be held in March 2020. It would be wonderful if we could encourage new people to run for a Board position. Serving as a Chapter officer is also a great way to get involved. I hope you will consider one of these opportunities.

We hope you will enjoy this issue of *The Plant Press*, which, in addition to our regular features, offers seven different articles based on presentations at our Botany 2019 Conference.

We extend all our best wishes for an enjoyable holiday season and look forward to seeing you at future AZ Native Plant Society activities in the New Year.



Who's Who at AZNPS

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Vegetation Changes in the Finger Rock Canyon Drainage

continued

To date, 615 plant taxa, including ferns and spikemosses, have been identified. It is remarkable that about 45% of the known taxa of the Santa Catalina Mountains (Verrier 2018) are found in this small area. I monitor the 599 gymnosperms and angiosperms, plus 222 vertebrate taxa, recording species diversity by trail mile. Looking for vertebrates actually helps me see tiny flowers because as I keep changing my focus, I see more. A database record is a taxon (in “flower” for plants) on a mile and on a date. Each record may represent a single flower or vertebrate of a given species. Viable pollen (on anthers for angiosperms or airborne in the case of gymnosperms) is the primary determinant of “flowering.” Given the size of the study area and the time it takes to complete a survey, abundance cannot be measured, but it is assessed through continuous, long-term observation. The database currently includes 181,213 flowering records and 82,610 vertebrate records, collected during 1,713 surveys. A more detailed description of the study area, methodology, and flora may be found in Bertelsen (2018).

Area Climate

Absent weather stations in the canyon, Parameter-elevation Regression on Independent Slopes Model (PRISM) data is the best available source to characterize the climate of the study area. PRISM provides monthly climatic data interpolated from point station data for the continental United States (Daly *et al.* 2008). Among the many factors included in the interpolations is elevation. Although data is available from 1885 onward, data for the study area prior to 1930 has limited value because few weather stations existed in the vicinity of the canyon prior to that time (Michael A. Crimmins, personal communication, 2017). In late 2006, I installed three rain gauges near the bottom, middle, and top of the drainage and have collected monthly data since 2007 (except for 2013 when I was unable to check the gauges regularly). The gauges correlate well with the PRISM data ($r = 0.89, 0.89, 0.85$ respectively).

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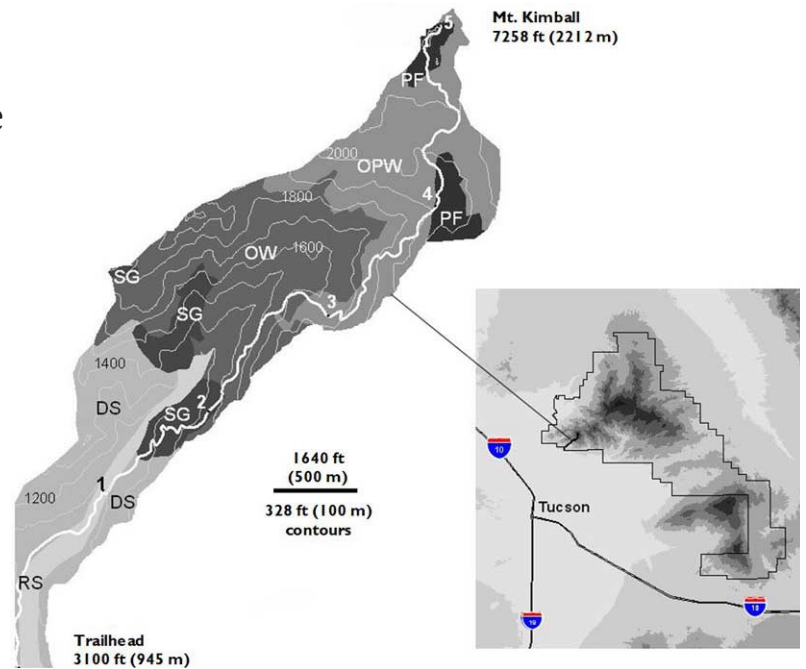


Figure 1. The Finger Rock Canyon drainage. The trail is the white line, with numbers indicating the end of each mile. The vegetative associations in the drainage are Desert Scrub (DS), Riparian Scrub (RS), Scrub Grassland (SG), Oak Woodland (OW), Oak-pine Woodland (OPW), and Pine Forest (PF). The inset shows the location of the area in the Santa Catalina Mountains, the solid line indicating the Santa Catalina Ranger District of the Coronado National Forest. *Source: Jeff Belmat and Theresa Crimmins based on data supplied by the author.*

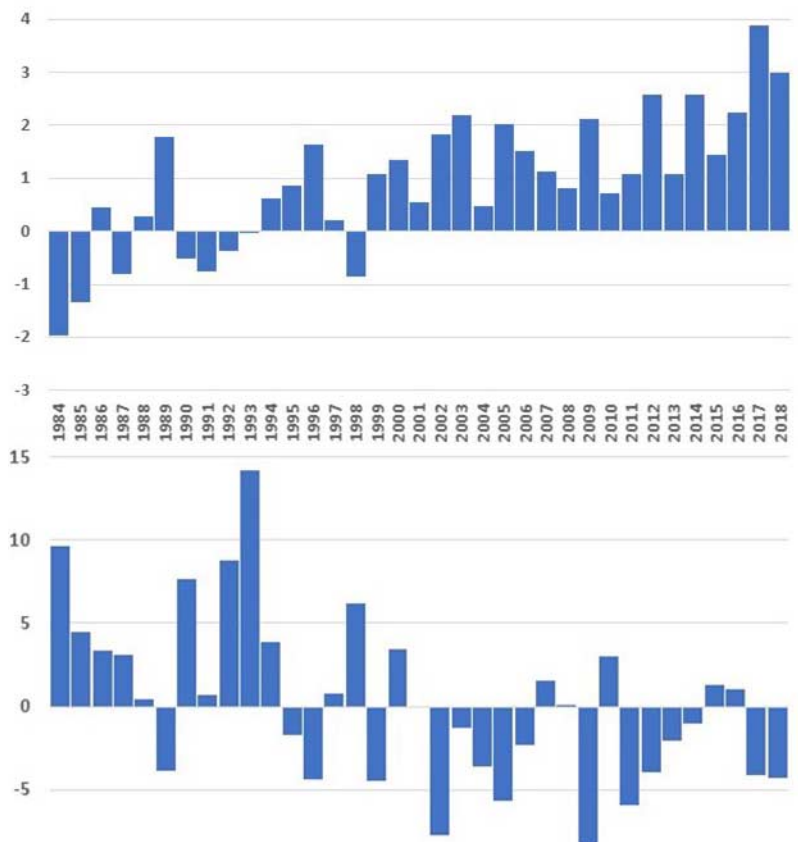


Figure 2. Anomalies in temperature in degrees Fahrenheit (upper) and precipitation in inches (lower) in the study area, 1984-2018. 0 = the 1930-2018 average for this area. *Source: Bertelsen (2018).*

Vegetation Changes in the Finger Rock Canyon Drainage *continued*

Figure 2 shows the average annual temperature and total precipitation anomalies for the study area from 1984–2018. Since 1994, average annual temperatures in the study area have been above the 1930–2018 average every year except in 1998. Moreover, annual precipitation in the last 25 years has been above the 89-year average in only 7 years. Taken together, this suggests that the current drought, at least in this area, began in the mid-1990s (see Arizona State Climate Office 2019; Woodhouse *et al.* 2010). In addition to higher temperatures which increase evapotranspiration, the intensity of monsoon storms has been increasing since 1970 (Demaria *et al.* 2019) and there has been an increase in precipitation variability (Dannenberg *et al.* 2019). Considerable rainfall in a short period of time results in greater runoff, more erosion, and less moisture available to plants. Prolonged drought, increasing temperatures, and increased storm intensity are all symptomatic of global climate change.

With both increasing temperatures and prolonged drought, based on a multitude of ecological studies too numerous to cite here, we can expect a number of things to occur in ecosystems:

- * Responses at the species level, not at the community level;
- * Phenology changes (e.g., earlier or later onset of flowering, changes in length of growing seasons);
- * Changes in abundance (e.g., increases, decreases, and disappearances of species);
- * Changes in composition (e.g., in growth forms and non-native species); and
- * Shifts, extensions, and contractions of species ranges to higher elevations or latitudes.

Assessing Environmental Changes

I have no doubt that all of these responses are occurring, but to demonstrate to a high degree of certainty (scientifically) that they are in fact occurring, and to determine the causes, we must have *long-term, high-resolution baseline data on both climate and vegetation*. Unfortunately we do not have enough high resolution data on either climate or vegetation for most (if any) ecosystems. Particularly problematic are apparent range changes since we have insufficient data on the actual ranges of most species. Consequently there are no definitive answers to questions like: Are the changes occurring in the study area representative of what is happening in the greater ecosystem? Are these changes short-term or long-term? Are they the effect of climate variability (i.e., drought) or global climate change? I do believe that, with nearly 36 years of

systematic observation, I can make some educated guesses, however.

In this paper I will refer to relatively few species, and sometimes to only a few individuals. Dirzo *et al.* (2018) concluded (emphasis added) that “Although species extinctions are of great evolutionary importance, *declines in the number of individuals in local populations and changes in the composition of species in a community* will generally cause greater impacts on ecosystem function.” Although they focused on fauna, I think the same can be said of vegetation. I am also describing changes in a relatively small area, but Deane and He (2018) concluded that “any mechanism of global change that selectively destroys small habitat patches will lead to imminent extinctions in most discrete metacommunities.” They looked at areas as small as ponds.

In the following sections, I will describe some of the cumulative changes that have occurred in less than 20 years in each of the vegetative associations. These changes involve both gradual and sudden change. Sudden change is hard to miss. Gradual change, however, is difficult to detect. It is hard to see what is no longer present—even if you have baseline data. Gradual change is usually unrecognized until cumulative effects result in crossing a threshold. Since 1996, I have seen the following changes to flora and fauna in the study area, changes I think are both fundamental and transforming. In the list below, “recognized” indicates a gradual change, and “saw” indicates a sudden change.

- * 1996—Recognized a sharp decline in reptile populations. At the time, I assumed this was simply due to the fact that populations had increased during the relatively wet 1980s and that numbers were simply returning to “normal.” Still, I began counting individuals.
- * 2002—Saw significant mortality in mature Saguaro (*Carnegiea gigantea*), Arizona White Oak (*Quercus arizonica*), Alligator Juniper (*Juniperus deppeana* var. *deppeana*), and Ponderosa Pine (*Pinus ponderosa* subsp. *brachyptera*), old individuals that certainly survived the droughts of the 1900s and 1950s. More of these species died in 2002 than in the previous eighteen years combined.
- * 2008—Recognized a sharp decline in bird populations and diversity. I now observe about 90% fewer individual birds and about 50% fewer species. I can sometimes hike for two or three hours without hearing or seeing a single bird.
- * 2009—Recognized a sharp decline in native arthropods, particularly spiders and native bees, but even flies and mosquitoes. There has been an increase in the number and

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Vegetation Changes in the Finger Rock Canyon Drainage

continued

distribution of non-native honey bees (*Apis mellifera*), however.

❖ 2011—Recognized a sharp decline in mammals and amphibians. Rock squirrels (*Spermophilus variegates grammurus*) and cliff chipmunks (*Eutamias dorsalis dorsalis*) used to be common on all miles, but now I am lucky to observe one in a day. This spring, canyon treefrogs (*Hyla arenicolor*) and red-spotted toads (*Bufo punctatus*) were so rare I could actually count the males calling in the bottom of the canyon.

❖ 2018—Saw significant mortality in Border Pinyon (*Pinus discolor*) in September when about 80 trees died. At the same time, pinyon die-off was recorded in the Rincon Mountains by the National Park Service.

During the first 11 years of my study the only significant change in vegetation I was aware of was the steady increase in the number of plant taxa I was seeing—likely because the 1970s were relatively dry and the 1980s, relatively wet. I may have been observing system recovery. Ninety percent of taxa in the current flora had been identified by 1994. Relatively little change in the flora was seen in the next seven years. When I first saw significant changes in vegetation in 2002, I began to *consciously* look for change, and the more I looked, the more I saw. Having an 18-year baseline certainly facilitated recognition of the impacts of on-going drought.

Nearly all annuals and 37% of perennials in the flora have shown significant change since 2002. Because annuals tend to *track climate fluctuations* while perennials are *adapted to long-term climate variability*, perennials are probably better indicators of climate-driven impacts to ecosystems. Since the onset of the drought, 50% or more of perennial grasses, succulents, and trees in the flora have undergone significant change. Species in all these life forms have declined in numbers and distribution, but there have been increases in non-native invasive grasses and in hybrid succulents. Of particular concern is that there has been little or no recruitment of perennial species in decline.



Figure 3. Mexican Passionflower (*Passiflora mexicana*).

Desert Scrub

Desert Scrub includes about 20.9% of the total drainage, but 41% of the flora of the study area (251 taxa) have been found here. At all elevations, annuals are most susceptible to decreasing precipitation, but in desert scrub, they make up 44% of the taxa. Since 2002, native spring annuals have not rebounded in years with good winter precipitation resulting in considerably more bare ground. I have to wonder if there has been a reduction in seed banks, particularly since non-native annuals such as London rocket (*Sisymbrium irio*), wild oats (*Avena fatua*), and Mediterranean grass (*Schismus barbatus*) continue to quickly respond to improved conditions. Among the changes I have seen in Desert Scrub are the following:

- ❖ One hundred eighty-five Saguaros have died, including 35 in 2002, 24 in 2011, and eight so far this year. Most mortality has been on the west side of the canyon and usually occurs late May and June.
- ❖ In 2009, 27 Staghorn Chollas (*Cylindropuntia versicolor*) died; 46 more died in the summers of 2013 and 2014.
- ❖ Typical Compass Barrel Cactus (*Ferocactus wislizeni*), once dominant, has been nearly replaced by a faster-growing hybrid barrel (*Ferocactus wislizeni* x *Ferocactus cylindraceus*). Nearly all mortality of barrel cacti has been of the typical Compass Barrel.
- ❖ There has been significant die-off of Foothill Paloverde (*Parkinsonia microphylla*) as well as many once-common shrubs, subshrubs, and herbaceous perennials.

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Vegetation Changes in the Finger Rock Canyon Drainage *continued*

- * Most native grasses—e.g., Bush Muhly (*Muhlenbergia porteri*), Fescues (*Festuca* species), Fluff Grass (*Munroa pulchella*), and the *ternipes* variety of Spidergrass (*Aristida ternipes*)—are nearly gone, but invasive, non-native Lehmann Lovegrass (*Eragrostis lehmanniana*), Natal Grass (*Melinis repens* subsp. *repens*), Buffelgrass (*Cenchrus ciliaris*), Mediterranean grass, and Soft Feather Pappusgrass (*Enneapogon cenchroides*)—hereafter called invasive Pappusgrass—have increased.
- * Engelmann Pricklypear (*Opuntia engelmannii* var. *engelmannii*) has declined sharply while Mohave Pricklypear (*Opuntia phaeacantha*) and an Engelmann x Tulip Pricklypear hybrid (*O. engelmannii* x *O. laevis*) have increased. Interestingly, Tulip Pricklypear is rare in the canyon. Vertebrates are losing a valuable food resource since Engelmann Pricklypear was clearly preferred over the other two species and the hybrid, all of which are rarely subject to herbivory.
- * Parry Penstemon (*Penstemon parryi*), once common in Desert Scrub, is now rare. Although it was always found in Oak Woodland, the center of the population has shifted more than 1,200 feet higher in elevation.

Riparian Scrub

Riparian Scrub includes 55.9% of the flora of the drainage (344 taxa) but comprises only about 6.4% of the total area. Xeroriparian systems, characterized by intermittent streams, merit a lot more attention because of their high biodiversity and the fact that they serve as refugia in times of drought. With climate change, such systems are likely to be the future state of the lush riparian areas we love so much like the San Pedro, Oak Creek Canyon, and Sabino Canyon. Changes here include the following:

- * Nearly half of the Netleaf Hackberry (*Celtis reticulata* var. *reticulata*) and Fremont Cottonwood (*Populus fremontii*) trees, both known Goodding Willows (*Salix gooddingii*), and two Desert Willows (*Chilopsis linearis* subsp. *arcuata*) have died.
- * Most native species typical of riparian areas such as Flatsedges (*Cyperus* species), Rushes (*Juncus* species), Cupgrasses (*Eriochloa* species), Hummingbird Trumpet (*Epilobium canum* subsp. *latifolium*), Yellow Monkey Flower (*Erythranthe guttata*), and Hooker's Evening Primrose (*Oenothera elata* subsp. *hookeri*) have sharply declined or disappeared.
- * Many once-common herbaceous perennials, subshrubs, and vines have become uncommon to rare.

- * The number of Engelmann x Tulip Pricklypear hybrids has increased.
- * Most non-native annual grasses such as Wild Oats, Wild Barley (*Hordeum murinum* subsp. *glaucum*), and Rabbitfoot Grass (*Polypogon monspeliensis*) have declined (except in years with good winter rains), but the non-native Buffelgrass, Annual Bluegrass (*Poa annua*), Fountain Grass (*Cenchrus setaceus*), and invasive Pappusgrass have increased greatly. These four species produce more biomass than all the native grass species in Riparian Scrub combined.
- * Several perennials, e.g., Staghorn Cholla, Bamboo Muhly (*Muhlenbergia dumosa*), and Berlandier Wolfberry (*Lycium berlandieri* var. *longistylum*) have died after being surrounded by dense patches of Buffelgrass or Fountain Grass. Since nearby plants of these native species outside the dense grass patches are not dying, I suspect Buffelgrass and Fountain Grass are allelopathic.
- * The highly invasive African Sumac tree (*Rhus lancea*) began to invade the canyon bottom in 2006. It is still being sold in Tucson and is well established along the Rillito in the River Park. The south-facing canyon drainages of the Catalinas provide a direct link between urban, suburban, and wildland areas, and it seems highly likely many more non-native species, such as Lantana (*Lantana camara*) and Oleander (*Nerium oleander*), will invade the mountains.

Scrub Grassland

There is not much Scrub Grassland in the study area—it makes up approximately 7.8% of the total area—but it includes 49.8% of the flora in the drainage (305 taxa). Until recently it was dominated by native grasses, but that changed quickly as the drought deepened. It is very likely this association is being transformed into an “Africanized” grassland dominated by non-natives, particularly Lehmann Lovegrass and invasive Pappusgrass. Fire would likely hasten this change. We talk of “fire-adapted ecosystems,” but I am concerned that climate change is re-writing that chapter of the book. There is high likelihood climate change will result in higher temperatures, less moisture available to plants (higher evapotranspiration, less rainfall, and greater run-off in increasingly frequent high-intensity storms), greater frequency of fire, and more invasive species. These systems may no longer be fire-adapted.

- * As many native grasses such as Longtongue Muhly (*Muhlenbergia longiligula*), Cotta grass (*Cotta pappophoroides*), Green Spangletop (*Disakisperma dubium*),

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Vegetation Changes in the Finger Rock Canyon Drainage

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and the *ternipes* variety of Spidergrass have declined, non-native Lehmann Lovegrass, invasive Pappusgrass, and Stink Grass (*Eragrostis cilianensis*) have increased exponentially.

- * Black Grama Grass (*Bouteloua eriopoda*), for example, declined sharply after 2002 and has not been seen at all since 2006 except for a single plant in 2016.
- * In 2015–2017, meter-high invasive Pappusgrass, an annual, was so dense on one slope that it crowded out nearly all native grasses, including most perennials, such as Bull Grass (*Muhlenbergia emersleyi*), Side-Oats Grama (*Bouteloua curtipendula* var. *caespitosa*), Hairy Grama (*Bouteloua hirsuta* subsp. *hirsuta*), Cane Beardgrass (*Bothriochloa barbinodis*), and Arizona Cottontop (*Digiteria californica* var. *californica*).
- * In the summers of 2013 and 2014, 58 Staghorn Chollas and many Engelmann Pricklypears died.
- * There has been a sharp decline or disappearance of many shrubs, subshrubs, and herbaceous perennials.
- * Scaly Cloak Fern (*Astrolepis cochisensis* subsp. *arizonica*), which I thought was the most dry-adapted of the ferns, has been replaced by Wavy Cloak Fern (*Astrolepis sinuata* subsp. *sinuata*).
- * The Englemann x Tulip Pricklypear and the Barrel Cactus hybrids have increased.
- * Two native grasses, Tanglehead (*Heteropogon contortus*) and the *gentilis* variety of Spidergrass, increased substantially in 2006–07. Although their abundance has decreased somewhat, they have persisted in new locations at higher elevations. The fact that the *ternipes* variety of Spidergrass has declined sharply while the *gentilis* variety has fared much better suggests that we should pay attention to intraspecific differences.

Oak Woodland

Oak Woodland comprises about 32.9% of the total drainage and includes 49.3% of the flora of the area (303 taxa). If current trends continue, Oak Woodland will become Scrub



Figure 4. Teddybear Cholla (*Cylindropuntia bigelovii*).

Grassland as trees and large shrubs such as Arizona Rosewood (*Vauquelinia californica* subsp. *californica*) continue to die. Although the area burned in the 2015 fire was not large—burning along a little over a half mile along the trail in Oak Woodland and Oak Pine Woodland—it was enough for me to see what the effect of increased fire will be in the area. In the entire burn area, more native species have reappeared in Oak Woodland than in Oak-pine Woodland, the opposite of what I expected. Native diversity has declined sharply in both areas, however. Lehmann Lovegrass remains the dominant grass species in the burn area and invasive Pappusgrass has a firm foothold. Fire would likely hasten the conversion to grassland.

- * The three highest saguaros on the southeast side of the canyon (the trail side) were dead by 2007. I have seen no evidence that saguaros are moving up-slope.
- * A large Alligator Juniper (rare in this association), six Mexican Blue Oaks (*Quercus oblongifolia*), and four Emory Oaks (*Quercus emoryi*) died between 2002 and 2014.
- * Many herbaceous perennial, subshrub, and shrub species have declined.
- * Mohave Penstemon (*Penstemon pseudospectabilis* subsp. *pseudospectabilis*) and Wild Cotton (*Gossypium thurberi*) are the only native species in Oak Woodland that clearly benefited from the fire, something that became obvious only this spring.
- * All reproductive Palmer Century Plants (*Agave palmeri*) were gone by 2006, largely due to herbivory by pocket gophers (*Thomomys bottae catalinae*) which could easily

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Vegetation Changes in the Finger Rock Canyon Drainage *continued*

move through the deeper soils it prefers. Relatively little mortality has been observed in Goldenflower Century Plant (*Agave chrysantha*) which seems to prefer rock outcrops and cliffs.

- * The native Spike Pappusgrass (*Enneapogon desvauxii*) is now rare. After the 2015 fire, the only known Arizona Muhly (*Muhlenbergia arizonica*) site was invaded by Lehmann Lovegrass; only 23 clumps remain. Fire was likely responsible for the reduction in number of plants, but Lehmann Lovegrass seems to be inhibiting recovery.
- * The *gentilis* variety of Spidergrass is the only native grass that has increased significantly in Oak Woodland since 2002 (but not in the burn area). Lehmann Lovegrass, Stink Grass, Red Brome (*Bromus rubens*), and invasive Pappusgrass, however, have increased much more, and each produces far more biomass than Spidergrass.
- * Two large clumps of Soap Aloe (*Aloe maculata*), an ornamental from South Africa, were seen in 2015 on the west side of the canyon. When flowering, they are visible from the trail.
- * Pancake Pricklypear (*Opuntia chlorotica*) is now rare, largely due to pocket gopher herbivory and fire, but the Engelmann x Tulip Pricklypear hybrid is moving into Oak Woodland.

Oak-Pine Woodland

Oak-pine Woodland constitutes approximately 27.5% of the total area of the drainage and 52.6% of the flora (324 taxa). Because of the greater density of trees and shrubs here, the considerable change occurring since the onset of the drought is harder to see. If changes continue and intensify, however, this area will likely evolve into a novel community dominated by shrubs and scattered trees.

- * More than 100 Arizona White Oaks and 27 Alligator Junipers have died. Sixty White Oaks and 15 Junipers died in 2002 alone.
- * A few scattered Emory Oaks and Silverleaf Oaks (*Quercus hypoleucoides*) died in 2010. Four Emory Oaks died in June this year.
- * Border Pinyon mortality was limited but on-going until last September. Unlike other species in which mortality affects primarily the older individuals, in pinyon it affects all age groups. Mortality now exceeds 200 trees including three that died in late October 2019. Evidence of bark beetles was first seen in the study area in February of this year and has also been detected in the Rincon Mountain pinyons.
- * Catclaw Mimosa (*Mimosa aculeaticarpa* var. *biuncifera*) has increased dramatically, now forming large stands between 5,600–6,000 feet and rapidly colonizing areas opened up by dead oaks. This portends a major structural change. I have yet to see a vertebrate in these stands.
- * One-third to one-half of the Pointleaf Manzanita (*Archostaphylos pungens*) has died.
- * Most Narrowleaf Hoptrees (*Ptelea trifoliata* subsp. *angustifolia*), including all large individuals, (the trees) have died.
- * Many subshrubs and herbaceous perennials have declined, but so far shrubs are holding their own.
- * Several once-common native perennial grasses—e.g., Red Spangletop (*Dinebra panicea* subsp. *brachiata*), Green Spangletop (*Disakisperma dubium*), Plains Lovegrass (*Eragrostis intermedia*), and Crinkleawn (*Trachypogon secundus*)—are now rare or uncommon.
- * Lehmann Lovegrass has increased greatly from 5,500–6,000 feet. I eradicated small patches of Natal Grass at 6,200 feet in both 2006 and 2016. Invasive Pappusgrass is now well established up to 6,250 feet.
- * All large clumps (more than 30 stems) of Claret-cup Hedgehog (*Echinocereus coccineus*) have died since 2002. Mortality occurs in spring, perhaps caused by the lack of snow cover which would protect them from desiccating winds.
- * Engelmann and Pancake Pricklypear have declined but likely Mohave x Englemann and Engelmann x Pancake hybrid pricklypears have increased. Although most hybrids have been present in the canyon since at least 1988, I became aware of the Englemann x Pancake hybrid only two years ago. Climatic conditions may be promoting hybridization or hybrid success. Perhaps there has been a change in pollinators, or perhaps honey bees forage further than native bees. It may, of course, simply be that hybrids are better adapted to changing conditions (hybrid vigor).
- * Soap Aloe was first found in Oak Pine Woodland in 2009 at 5,630 feet elevation. This clump survived the hard freeze in February 2011 when in Tucson the low was 18° two days in a row.
- * Only one Palmer spurge (*Euphorbia palmeri* var. *subpubens*) survived after 1996. Unlike most perennials which produce at least a few flower and fruits every year, it flowered only in 1998, 2001, and 2005 before dying.

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Vegetation Changes in the Finger Rock Canyon Drainage *continued*

- * In 2006, for the first and only time, most oaks above 5,400 feet were leafless from February until the onset of the monsoon, certainly due to the extremely dry October 2005–March 2006 cool season. During this time at least 75% of the Cory Mistletoe (*Phoradendron serotinum* subsp. *tomentosum*) died. I have seen little recovery since the die-off.
- * Sixweeks Threawn (*Aristida adscensionis*), a grass, is the only native annual that appears to be expanding its range in the canyon. Abundance is not increasing, but it is clearly moving up-slope. It is also the only annual that shifts its prime flowering season from spring to summer with increasing elevation. Unfortunately, it seems to be replacing five native annual Muhly and Lovegrass species (*Muhlenberbia fragilis*, *M. minuitissima*, *M. sinuosa*, *Eragrostis mexicana* subsp. *mexicana*, and *E. pectinacea* var. *pectinacea*)
- * As the drought deepened, Red Brome nearly disappeared in most of the canyon, but a large patch at 6,200 feet elevation persisted. Following the monsoon in 2015, a large patch appeared in the burn area in Oak Woodland where I had never seen it previously, and more scattered plants appeared nearly everywhere between Desert Scrub and Pine Forest. Reports of low seed viability in Red Brome (Jurand 2012) are not supported in the study area.
- * After the 2015 fire, the area burned in Oak-pine Woodland was densely covered by Lehmann Lovegrass and invasive Pappusgrass (unknown in the area prior to the fire). Plants were so dense, it looked as if the area had been aerially seeded with these two species (but that was not the case). Native species are *slowly* reappearing, except on ridgetops where Lehmann Lovegrass seems to have a firm foothold. I have seen no resprouting of Alligator Juniper or Sotol (*Dasyllirion wheeleri*), few of which survived the fire.
- * The fire was described by experts as “moderate” and “beneficial,” and I do not question those assessments given current standards and guidelines. But from what I have seen in the study area and elsewhere, I believe the desirability of prescribed fire should be reassessed in light of invasive species (which either increase or move into an area after fire), climate change (which will bring warmer temperatures, less moisture available to plants and more frequent fire), and the lack of resources (and, unfortunately, often the will) necessary to mitigate negative effects.

Pine Forest

- Pine Forest consists of about 4.5% of the total area of the drainage but has 22.1% of the flora (135 taxa). Until the appearance of the bark beetles in pinyons I thought Pine Forest would be the first vegetative association to disappear. I anticipated it becoming Oak-pine Woodland, but without pinyons, Oak Woodland with scattered Junipers and an occasional Ponderosa may be the result.
- * Eighty-three mature Ponderosa Pines have died, 31 in 2002 alone. Until last year, mortality occurred in late spring, early summer. The mortality rate has declined, but the die-off continues.
 - * Last year, three trees died in May, another in August, and three in November. None have died yet this year, likely because of the winter rains. I have seen no sign of bark beetles in Ponderosa and until last year no evidence of previous stress (e.g., yellowing or dropping needles). Yellow or brown needles are now common in both Ponderosa and Pinyon.
 - * At least 25 Arizona White Oaks on top of Mt. Kimball have died; six Silverleaf Oaks died in 2010.
 - * There has been a sharp decline in herbaceous perennials, subshrubs, and both Fendler Bluegrass (*Poa fendleriana*) and Bulb Panicgrass (*Zuloagaea bulbosa*). Lehmann Lovegrass has increased, and I keep pulling it up on top of Mt. Kimball.
 - * All large clumps of Claret-cup Hedgehog have died here also, although one clump of 25 stems has persisted on a northwest facing slope just below the peak, in an area usually covered with snow.
 - * The small population of Plains Pricklypear (*Opuntia macrorhiza*) on top of Mt. Kimball increased both in distribution and in numbers from 2006 to 2010. Two years ago pocket gophers began to eat them, and I can now find only three clumps, one of which is now half-eaten.
 - * At the same time, hybrids between Mohave Pricklypear and both Engelmann and Plains Pricklypears also increased. Last year, pocket gophers began to consume the Mohave-Plains hybrid, and it is now uncommon.
 - * New Mexico Groundsel (*Packera neomexicana* var. *neomexicana*) used to be common 2,000 feet lower in the canyon but is now common only on the peak. It was the first species to be obviously decimated by pocket gophers, in a little over two years, presumably because drought killed

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Vegetation Changes in the Finger Rock Canyon Drainage *continued*

more favored food plants. They then moved on to century plants and pricklypears. A single species, even a native species, can wreak havoc when an ecosystem becomes unstable.

Implications

Even if the drought ended tomorrow, cumulative changes that have occurred will probably not reverse themselves, particularly if temperatures continue to increase, precipitation decreases and becomes more variable, and storms become more intense. Tipping points have likely been passed. From what I have seen, the three greatest impacts of climate change in this area will be (1) a sharp reduction in moisture available to plants; (2) the exponential increase in invasive, non-native species; and (3) the increased frequency of fire. I do not think most native species will be able to adapt quickly enough.

If climate change is the underlying driver of the changes I am seeing, rather than cyclical drought—and this seems highly probable—significant changes will accelerate, and very different landscapes will emerge. This may sound like hyperbole, but consider: Tree mortality in California's Sierra Nevada Mountains since 2014 has reached 147 million trees; 18 million died last year alone (Alexander 2019). Drought, bark beetle, and fire are the direct cause of this mortality, and all will likely be exacerbated by climate change. The lead author of a study of tree recruitment and survival in Yellowstone National Park predicted the park will become a grassland by mid-century and commented on how rapidly change is occurring (Terrell 2019). Warmer soils, resulting from increasing temperatures and reduction of cover, are a serious problem. On nearly every hike in the canyon now, I feel an overwhelming sense of irreversible loss. There are “holes” everywhere where plants I walked by for twenty or twenty-five years used to be—and there is nothing in their place. Perhaps the saddest thing is that almost no one I meet on the trail has any sense of the changes that have occurred. They have no baseline. I am reminded of the poster Walt Kelly (creator of the Pogo comic strip) drew for the first Earth Day in 1970, showing Pogo the 'possum looking out over the swamp and saying, “We have met the enemy, and he is us.”



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Figure 1. Freshly cut *vaaka* (giant reed), Pótam. Fence, ramada roofing, and house roofing and wall also of *vaaka*; house cross is willow (*Salix gooddingii*). Photo by Peter Blystone, 1 Jun 2019.



Giant Reed in the Yoeme World of Sonora and Arizona

by Richard Stephen Felger¹ and Felipe Silvestre Molina²

Yoeme (Yoemem, plural) is the people's own name for themselves, while *Yaqui* is used by the general public and governments. *Yoem Bwiara* is the sacred, traditional Yoeme homeland centered along the lower Río Yaqui (Hiak Vatwe) in Sonora. There are also Yoeme communities in southern Arizona and elsewhere north of the border (Pascua Yaqui Tribe. <https://www.pascuayaqui-nsn.gov>). The first Yoeme communities in Arizona were founded in the late 19th and early 20th centuries due to persecution and genocidal violence in Sonora.

Our book, *Plants & Animals in the Yoeme world: Ethnoecology of the Yaquis of Sonora and Arizona*, will be available in spring 2020 as a Special Publication from the Desert Laboratory, University of Arizona. We include more than 400 plant species and 575 species of animal life.

Yoem Lutu'uria (Yoeme Truth) is a core belief that includes respect for all life, animals, plants, as well as rain, rocks, water, and wind. Yoem Lutu'uria includes the *Aniam*, the spiritual worlds or realms, such as *Huya Ania* (the natural or wilderness world). Let's look at one of the most magnificent plants of the Huya Ania: *vaaka* in Yoem noki (Yaqui language), *Arundo donax*, giant reed, or *carrizo* in Spanish.

This well-known giant grass has leafy stems three to more than five meters tall (Figure 1). New shoots emerge from thick, perennial rhizome-rootstocks throughout the warmer months, but especially in spring, and rapidly grow to full height. The

mature stalks are overtopped by a large, feathery inflorescence (panicle).

Vaaka is cultivated in towns and ranches in the Yoem Bwiara region and is often grown in household gardens in Arizona. In Sonora, the larger, mature stalks are often harvested in the fall, and the remaining *vaaka* is often burned in order to improve the vigor of the new growth, "so that it comes up better." In southern Arizona, *vaaka* has been harvested from wetlands, such as along the Santa Cruz River. In the Yoem Bwiara, it once grew all along the lower Río Yaqui. Felipe tells us, "My cousin and his wife Francisca, from Pótam, would visit my grandmother and talk about the *vaaka*. Francisca said when she was young, in the 1930s, the *vaaka* along the riverbanks arched over the river. That must have been a beautiful sight."

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Giant Reed in the Yoeme World *continued*

Edward Spicer (1980), the eminent scholar of Yoeme culture, shows a 1942 photo of people in a path through vaaka at the river, with this caption:

“Thick, high stands of carrizo once lined the banks of the Yaqui River. The cane was used for mats, house walls, bird cages, knives, spoons, and many other articles. Its exploitation by outsiders for commercial furniture was a political issue among Yaquis during the 1940s and 1950s. After the Obregón Dam was built to develop irrigated agriculture, the river ceased to flow in its lower course near the towns, and this important resource was much diminished.”

In an interview on May 31, 2019, in Pótam, Juana Lugo-Osuna told Felipe that her son was expecting visitors for the Holy Trinity Feast Days, but had a hard time looking for vaaka to cover his ramada roof. Felipe says, “He did bring in a truck load as we listened to Juana’s report. On our way out, Juana’s son came out to bid farewell and mentioned the hard times people are having looking for resources to build houses and ramadas. He said he had to go out again because he needed more vaaka to accommodate all the visitors from the other villages. He said the visitors will rest and sleep under the ramadas during the four days of Holy Trinity.”

Botanical publications report that *Arundo* is native to the Old World, although it has long been cultivated and naturalized in the warmer parts of the world. The earliest known specimen of *Arundo* in Sonora was collected by Edward Palmer at the Río Yaqui in 1869 (Figure 2). Presumably at some point during historical times, *Arundo* replaced the native and similar-appearing *Phragmites australis* (common reed) along the Río Yaqui. Their cultural uses would be interchangeable. Tomás Basilio ([1634] 1890) used *baca* as the term for *carrizo*, or *caña hueca* (hollow carrizo), which could have been *Arundo* or *Phragmites*. *Arundo* and *Phragmites* can be distinguished with certainty only by the spikelets:

Arundo donax: Lemmas with long hairs, the rachillas (spikelet stalks) glabrous.

Phragmites australis: Lemmas glabrous, the rachillas with long hairs.

Inset: Figure 2. Edward Palmer’s 1869 herbarium specimen of *Arundo donax* (<https://collections.nmnh.si.edu/search/botany/>).

Many authors have incorrectly used the name “bamboo” for vaaka. Actual bamboos in the vicinity of the Yoeme Bwiara in Sonora are the native *Otatea acuminata* and the non-native cultivated bamboos including *Phyllostachys aurea* (golden or Chinese bamboo). These bamboos have rigid, woody, and rather long-lived stems. *Otatea acuminata* in Yoem noki is *vakau* or *yo vakau* (enchanted vaaka), and in Spanish it is *otate* and in English it has been called weeping bamboo. This slender bamboo is native at springs in the Sierra Bacatete, or *Vakatetteve Kawim*, which translates as “tall cane/carrizo mountains,” the tall canes being *Otatea*.

Some Associations of Vaaka in Yoeme Culture

Larger vaaka stems were hollowed out for use as a container (like a canister or tube) to hold important papers. The open end is plugged with a clay or a wooden stopper—the other end being already sealed by the natural septum in the cane stalk. Felipe’s grandfather, Rosario Vakame’eri-Castillo in Marana made such cane containers for the family’s important papers. He used cottonwood root for the caps or stoppers. Ales Hrdlička (1904) reported, “On ranches each Yaqui employed keeps a personal account, which he carries in a tube made from the native bamboo [sic]. Each of these tubes is differently decorated on its surface with numerous incised figures, mostly of geometrical pattern.” Andres Pérez de Ribas ([1645] 1999) wrote, “When one nation invites another to forge an alliance for war they convey the invitation by sending a number of reed canes filled with tobacco.”

Ales Hrdlička (1904) reported, “baby-boards are constructed by fastening together native bamboo [sic] splints and adding at the head a properly bent hoop which supports a cloth to shade the head of the infant.” This description is based on a cradleboard he found in June 1902 at the Sierra Mazatán massacre site. Hrdlička collected this and other artifacts as well as skulls and bones as “specimens” he sent to the American Museum of Natural History in New York. In 2009, the remains were returned to Yoemem in Sonora for proper burial (Padilla & Moctezuma 2015).

Basketry

Vaaka stems have been used in making baskets (*waarim*) and mats (*hipetam*, or *petates* in Spanish). *Vaka chukte* (cane cutting) is the phrase for cutting vaaka to make mats, for house



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Figure 3. Don Nacho Amarillas making a waarim, Pótam. Photos by Bill Steen, 15 and 16 Dec 1988.

Giant Reed in the Yoeme World *continued*

construction, and for basketry. Baskets were sometimes also made from *wata*, the Goodding willow (*Salix gooddingii*). Men have been the traditional basket-makers, although Ales Hrdlička (1904) reported that women wove palm-fiber baskets.

In December 1988, Ignacio (Nacho) Amarillas-Sombra showed us how he makes baskets, and Bill Steen photographed the process (Figure 3). Don Nacho (deceased in 2005) had an artisanal business making *waarim* (*waari*, singular). Mixing Yoem noki and Spanish, he sometimes called them *warritos*.

Don Nacho selects and cuts *vaaka* stalks from the nearby Río Yaqui and brings them to the ramada at the family home in Pótam. He uses selected stems tips below the inflorescence, about a meter or less in length, and strips away the leaves. This leafless stem-tip is called *vaka moa* or *flor de carrizo*, the young growing tip, and is the part used for basket making.

Early the next morning the stalks of dry *vaaka moa* are cleaned and Don Nacho lightly mashes or taps the stalks with a *mano* on an *avaso* block (a cross-section of a cottonwood branch). Each *vaaka moa* is tapped in a series of light poundings all along the length of the stalk. Then holding down the pounded stalk he pulls it through, under the *mano*, splitting the stalk longitudinally. The *mano* is called *mata tutuha* (*mata* is a grinding stone or metate, and *tutuha* is the *mano* rock). Don Nacho now halves each of the stems with a knife and trims them longitudinally with the same knife to end up with two flat and even-sized splints from each stalk. The material is put away for the rest of the day, as there are other things to do.

At dawn of the next day, Don Nacho has separated the *vaaka* stalks into four piles. Several people are helping split more stalks into splints. Don Nacho continues working on the *vaaka* sticks and rattles them on the door of the room by the open kitchen to get one of the women out of bed to make coffee. It is rather cold,

and the women just aren't getting out of bed. So, Nacho finally is making the coffee himself and grouching about it. The blackened coffee pot hangs over burning logs and is boiling away. After a considerable pile of *vaaka* splints are prepared, he starts folding over splints to make a basket start and continues weaving the basket, finishing it by late morning.

Baskets of different sizes and shapes were ubiquitous in traditional Yoeme culture. Every kitchen had baskets. William Holden (1936) reported, "There was always a *tortilla* basket ... Then there was usually a larger basket in which the eating utensils were kept ... There might be other baskets, of varying sizes and shapes, for storage purposes." He saw "a large *carrizo* basket containing about a bushel of beans" in a house in Tórim.

Ralph Beals (1945) illustrated and described a "Carrying basket, or *wakal*, used in gathering *pitahaya* fruit (*organpipe* cactus, *Stenocereus thurberi*). Made of split canes twined with mesquite-bark strips.....Bailing wire is superseding bark."

Knives and spoons were made from *vaaka* stems, as well as stirring sticks for use in the kitchen.

Construction and Fencing:

Vaaka has been extensively employed in traditional Yoeme architecture. *Vaaka* is used for house walls and roofing (Figures 1, 4, & 5), as well as for the *pahko'ola* (ceremonial) ramada and fencing. Tall canes tied in bundles, often seen standing upright against a house or walls in the Yoem Bwiara, are considered a good omen, warding off evil thoughts called *eerim* (Figure 5).

When we visited the Jaimez family in Kompuertam (a village near Vicam), their house compound and garden were surrounded by *vaaka* fencing to protect it from animals (Figure 6). The house rooms were roofed with beams supporting

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Figure 4. Ramada for washing, Pótam. Vaaka poles, roofing, and fence; corner post is cottonwood (*Populus mexicana* subsp. *dimorpha*). Photo by Peter Blystone, 1 Jun 2019.

Giant Reed in the Yoeme World *continued*

hipetam (woven vaaka mats), which were covered with corrugated tarpaper and then covered with earth. Wildflowers and grasses grew on the roof. Vaaka walls of the sleeping rooms were adobe-plastered.

Hipetam (*petates*) are made from interwoven split vaaka stems. These all-purpose, strong mats form walls of traditional houses, and are used as sleeping mats, beds, and many other uses. Rosalio Moisés tells of appalling hard times in 1947 when he and his wife were making *hipetam* (Moisés *et al.* 1971):

“We could make three or four a day. Pancha took them to the Mexican storekeeper, who only paid forty centavos apiece. She took the 1.20 or 1.60 pesos of credit in food. Now we ate only twice a day. Making petates all the time is hard. You have to pound up the carrizo before you can weave the mats. Our hands were sore all the time.”

Music, Ritual, and Medicine

Vaaka features in numerous deer songs, integral parts of Yoeme celebrations and ceremonies (Evers & Molina 1987). Large diameter vaaka stalks are used to make the *kusia*, a two-piece flute played by the *tampaleo* (a musician who simultaneously plays a flute and drum at ceremonies). *Wiko’i Yau’ura* (Coyote Warrior or Bow Leaders’ Society) dancers include a split cane instrument, *vaka chamti* (cane split), in the coyote dance. The *vaka chamti* is made by cutting slender strips into a section of

cane about 30 centimeters long. The splits do not go through the septum at the stem node.

A special cane instrument, *vaka aapa*, is fashioned from a meter-long length of vaaka. It has a long peg on one end and a single, heavy string attached. It was used in the crow dance. The sound of the *vaka aapa* is not loud and this instrument was also used by men and boys for their own enjoyment.

Edward Spicer (1980) described “*Cohetes*, the small sky rockets consisting of cane cylinders about four inches long containing gunpowder and attached to a stick or weed stem....Held in the hand by the stem, the cohete is lighted with a firebrand and flung into the air. One usually goes up about twenty-five to thirty feet, hissing as it goes, and explodes with a loud pop. Dozens of such cohetes are necessary for ceremonies.” William Holden (1936) told of many small sky rockets being set off during a funeral in Tórim.

In 1934, Charles Wagner (1936) recorded a unique medicinal use of vaaka in Torim:

“Gunshot wounds are treated in a primitive but effective way. A section of bamboo [sic] having about the diameter of the wound is selected. Another piece with closed end is fitted into this, making a crude popgun. Brazil wood (*Haematoxylum brasiletto*, a legume tree) scrapings are placed in this ‘gun,’ which is then inserted and [the] wound

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From left: Figure 5. A portion of a house wall with vaaka stems. The horizontal canes are chinked with mud, and the vertical canes are not chinked, allowing ventilation. *Photo by Peter Blystone, 1 Jun 2019.* Figure 6. Kompuertam, Jaimez family home garden. *Photo by Bill Steen, 14 Mar 1989.*

Giant Reed in the Yoeme World *continued*

forced full of the scrapings. These, in contact with the tissue fluids, swell, stopping [the] hemorrhage. As the wound heals this plug is extruded....Fractures are placed in as good position as possible by manipulations and then splinted with split bamboo [sic].”

Muriel Painter (1986: 56) also tells of carrizo used as splints for healing fractures.

Toys

Spilt cane stalks are made into kite frames, and small baskets and miniature furniture for children’s play. A bow made of vaaka is called *vakawikoi’i*, and is the name of the children’s game that features this toy weapon. Children made “slingshots or blowguns....out of lengths of carrizo cane” (Moisés *et al.* 1971).

Weapons

Vaaka huiwam, arrow shafts, especially the foreshaft, were made from carefully selected cane stalks.

Vaaka takes its place as one of the most notable plants in the lives of traditional Sonoran Desert people.



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Left: Figure 1. Safford gridded fields at a landscape scale. *Google Earth 2017.*

Above: Figure 2. Ground view of grid alignments in field area adjacent to Gila River floodplain. *Photo by Paul Fish.*

Stone Grids and the Archaeology of Agave Cultivation in the Safford Valley, Arizona

by Suzanne Fish and Paul Fish¹

Alignments of cobbles and boulders form grids and terraces in the Safford Valley, Graham County, Arizona, creating huge checkerboards on the ground that are still strikingly visible today from the air (Figures 1 and 2). Native American farmers constructed these agricultural features to benefit crops planted in them during the distant past. The resulting archaeological patterns at a landscape scale have long been recognized by archaeologists, naturalists, and local residents, but have not been well understood. Geographer William E. Doolittle and archaeologist James A. Neely organized an interdisciplinary project in 1998 in order to better establish the role of the Safford grid systems in regional archaeology and ancient agriculture.

Study results were published in 2004 by the University of Arizona Press in a volume entitled *The Safford Valley Grids: Prehistoric Cultivation in the Southern Arizona Desert*, edited by Doolittle and Neely. Ten chapters by a variety of disciplinary experts explored the environmental and

archaeological setting and operation of the grids. Chapter topics included a history of previous study, paleoclimatic and archaeological contexts, the geological setting, a GIS analysis and mapping of gridded landscapes, topography and hydrology, soils, nature of crops grown, and integrative analysis and conclusions.

Our team of Chapter 9 authors (Suzanne K. Fish, Paul R. Fish, Arthur MacWilliams, Guadalupe Sánchez de Carpenter, and Karen Adams) were charged with investigating evidence for growing conditions and crops in the Safford grid fields. Addressing this topic reflected previous research and publications by Suzanne Fish, Paul Fish, and Charles Miksicek that had demonstrated large-scale Hohokam agave cultivation in “rockpile fields” and this crop’s economic importance for food, fiber, and probable alcoholic beverages. Hohokam agriculturalists to the west grew agave in extensive complexes consisting of “rockpiles,” simple terrace alignments, and check dams that crossed minor ephemeral drainages (Figures 3 and 4). These arrays of stone features intercepted, captured, and conserved both surface runoff and their suspended nutrients

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Figure 3. Hohokam rockpile with modern experimental planting of *Agave murpheyi*. Photo by Paul Fish.

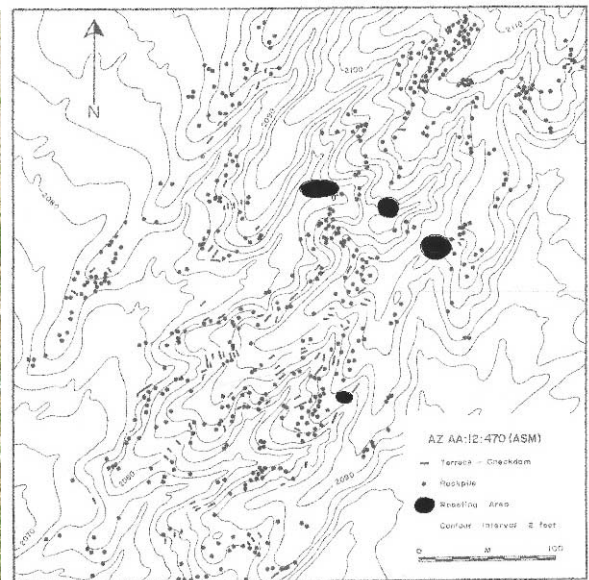


Figure 4. Mapped segment of a Hohokam rockpile field near Marana, Arizona.

Stone Grids and the Archaeology of Agave Cultivation *continued*

following rains. The resulting mulch and enrichment effects enhanced the growth environment of succulent crops planted at hotter and lower elevations and beyond their natural range. The archaeological complexes of stone features repeatedly co-occurred with roasting pits for prolonged baking of agave hearts. The pits yielded charred agave fragments and tissues confirming the crop, in addition to providing materials for radiocarbon dating. A third correlate of Hohokam rockpile complexes was a suite of distinctive chipped stone tools scattered on the field surfaces. Such tools are typical of ethnographic implements for harvesting and processing agave. The combined evidence for Hohokam rockpile fields suggested variables and conditions that might similarly apply to agave production in the Safford grids.

Extensive Safford-area grid systems are distributed on the north side of the Gila River overlooking the floodplain. A GIS analysis from aerial photographs of a 6 km² study area identified 82.2 ha of grid alignments within a well-defined cluster of fields (Figure 5). The collective length of alignments in the field cluster was 89,100 m, representing a greater construction effort per field area than the relatively more discontinuous and diffuse features in Hohokam rockpile fields.

Quadrangular units were predominately constructed on gentler slopes within grid systems, transitioning to parallel terraces on steeper terrain (Figure 6). Rockpiles represented a minor element within the Safford fields. The grids and terraces captured and conserved rainfall runoff to create a

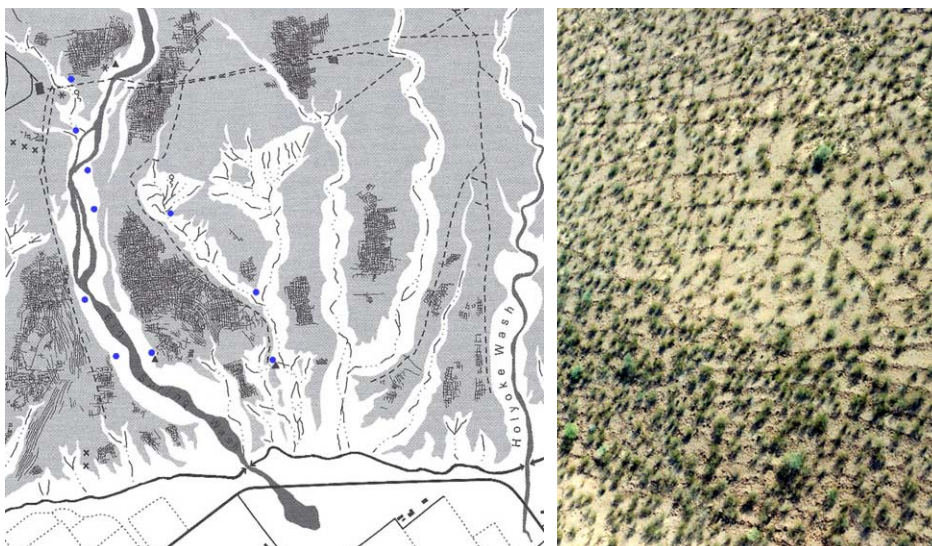
mulch effect along the stone alignments similar to mulch effects of the features in Hohokam rockpile fields. Relative measures of mean soil moisture content within grid

continued next page

From left:

Figure 5. Mapped segment of grids in Safford field cluster. Blue circles indicate roasting pits. From Dale Lightfoot in Doolittle and Neely (2004) Fig. 4b, p. 41.

Figure 6. Patterned variability in grid and terrace features in Safford fields. Google Earth 2017.



Stone Grids and the Archaeology of Agave Cultivation *continued*

systems produced values two times greater than outside of field areas. Nevertheless, soil scientists concluded the range of elevated moisture readings associated with grid systems was insufficient for annual crops such as corn, beans, and squash. Our pollen study of field sediments also failed to reveal traces of these or other such cultigens. Agave pollen was like-wise absent as expected for a crop that farmers customarily harvest prior to the full emergence of flowering stalks and pollen production. By harvesting in advance of reproductive maturity, cultivators also avoid the concurrent expenditure of stored carbohydrates available for human consumption.

The preferential growth of creosote bushes, the dominant perennials in the study area, clearly indicated the localization of a heightened moisture effect along the alignments themselves (Figure 7). Creosote densities growing in crown contact with grid borders and terrace alignments demonstrated the persistence of an enhanced microenvironment for the growth of desert perennials until today. Transect samples of these plants growing directly along stone alignments are from 1.6 to 5.0 times greater than in transects across the interiors of quadrangular grid units and the spaces between successive terraces.

As in the Hohokam case, the repetitive association of Safford gridded fields with roasting pits, carbonized pit contents commensurate with agave, and the distinctive suite of chipped stone tools for agave harvesting and processing on field

surfaces, together strengthen the case for agave's cultivated status as the primary crop. The roasting pits tend to be located in the alluvial soils of trans-bajada ephemeral drainages bounding field edges (Figure 5). Hohokam farmers similarly favored this placement, likely because alluvial sediments were easier to excavate with wood and stone tools. Furthermore, riparian trees offered an immediate fuel source. Flotation samples of three pits contents yielded monocot tissue morphologically compatible with agave and two of the pits contained fragmentary leaf bases that were more structurally distinctive. All three pits produced Precolumbian radiocarbon determinations, with calibrated midpoint dates before A.D. 1400. The Safford gridded fields are among a growing number of instances that confirm the importance of agave cultivation in the past across southern and central Arizona and more broadly in the Southwest.

Why might indigenous farmers have invested the time and effort to develop extensive fields dedicated to these succulent crops on dry slopes, especially as populations and demands for food grew? They always had the option of simply gathering from the region's wild agave populations. Why not invest the same effort into irrigated and floodwater farming that could better produce quantities of the well-known dietary staples of corn, beans, and squash? On the other hand, cultivated agave could extend production into zones marginal for more water-dependent crops and avert a degree of productive loss when rainfall was low. The versatility of agave crops also offered other economic incentives. Baked agave provided an abundant, sweet food (Figure 8) that was storable for months when dried. Agave could supply a fermentable base for alcoholic beverages like the drinks Apaches, Piman groups, and others served during gatherings and rituals in the period after European contact. A second realm of products was crafted with fibers extracted from agave leaves. All sorts of cordage from string to rope had widespread utility. Agave fibers provided the raw materials for nets, carrying baskets, sandals, bags, mats, and even was spun for textiles. Fiber items were comparatively lightweight for transport; they gained added value in trade from the labor and skills of crafters in finished products.

The authors led an Arizona Native Plant Society field trip to the 1998 study area in the Safford Valley just north of Pima, Arizona, following the annual meeting at

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Figure 7. Preferential growth of creosote bushes in contact with stone alignments. *Google Earth 2017.*



Figure 8. Baked agave hearts and individual slices sold as sweets by street vendors in Guaymas, Sonora. Photo by Charles Miksicek.



Figure 9. Summer annuals in Safford grid units in late July, 2019. Photo by Paul Fish.

Stone Grids and the Archaeology of Agave Cultivation *continued*

the Eastern Arizona College. It took place on September 1, 2019 when summer annuals were abundant in the gridded fields (Figure 9). Participants' observations of annuals, succulents other than agave, and additional perennial species (Table 1) offer preliminary data for evaluating: 1) which species are still responding to persisting field conditions; and 2) whether they indicate potential field resources in the past. Tom Van Devender compiled a list from his identifications, those of Ana Lilia Reina-G., Wendy Hodgson, Andrew Salywon, Richard Felger, Frank Reichenbacher, and comments by Deborah Sparrow. Additional field trip members, John Scheuring, Hanna Blood, Susanne Kraemer, Yanis Brankis, and Carl Tomoff, also participated in discussions of the field vegetation.



Table 1. Plants Observed During Safford Grids Field Trip, September 1, 2019

FAMILY	NAME
Amaranthaceae	<i>Tidestromia lanuginosa</i>
Anacardiaceae	<i>Rhus microphylla</i>
Asparagaceae	<i>Yucca elata</i>
Asteraceae	<i>Ambrosia dumosa</i>
	<i>Chaenactis</i> cf. <i>steviodes</i>
	<i>Logfia</i> cf. <i>depressa</i>
	<i>Hymenoclea monogyra</i>
	<i>Xanthisma spinulosum</i>
Boraginaceae	<i>Amsinckia tessellata</i>
	<i>Harpagonella palmeri</i>
	<i>Pectocarya recurvata</i>
Brassicaceae	<i>Caulanthus lasiophyllus</i>
	<i>Lepidium lasiocarpum</i>
Cactaceae	<i>Cylindropuntia leptocaulis</i>
	<i>Cylindropuntia spinosior</i>
	<i>Ferocactus wislizeni</i>
	<i>Grusonia emoryi</i>
	<i>Opuntia macrocentra</i>
Chenopodiaceae	<i>Atriplex confertifolia/obovate</i>
	<i>Atriplex polycarpa</i>
	<i>Salsola tragus</i> (invasive species)
Fabaceae	<i>Acacia greggii</i>
	<i>Parkinsonia florida</i>
	<i>Prosopis velutina</i>
	<i>Senna covesii</i>
Fouquieriaceae	<i>Fourquieria splendens</i>
Geraniaceae	<i>Erodium texanum</i>
Krameriaceae	<i>Krameria erecta</i>
Oleaceae	<i>Menodora scabra</i>
Plantaginaceae	<i>Plantago ovata</i>
Poaceae	<i>Aristida adscensionis</i>
	<i>Aristida purpurea</i> var. <i>nealleyi</i>
	<i>Bouteloua aristidoides</i>
	<i>Bouteloua barbata</i> var. <i>barbata</i>
	<i>Dasyochloa pulchella</i>
	<i>Hilaria rigida</i>
	<i>Muhlenbergia porter</i>
Polygonaceae	<i>Chorizanthe rigida</i>
Resedaceae	<i>Oligomeris linifolia</i>
Solanaceae	<i>Lycium andersonii</i>
Verbenaceae	<i>Aloysia wrightii</i>
Zygophyllaceae	<i>Larrea divaricata</i>

Effects of Fire and Reseeding on Sonoran Desert Plant Community Composition

by Kara Barron¹

If you look out over an undisturbed area of Sonoran Desert landscape in Arizona, you may notice that it is dominated by saguaro (*Carnegiea gigantea*) and foothills palo verde (*Parkinsonia microphylla*) in the uplands and triangle leaf bursage (*Ambrosia deltoidea*) and creosote (*Larrea tridentata*) in the valleys. It is also difficult not to notice prolific spring wildflower blooms after a rainy winter or magnificent cactus flowers in early summer.

Many of us value this beauty as plant enthusiasts, documenting it in social media posts or as framed photos that hang in living rooms and office lounges. There is also value in documenting these plants in a more detailed manner so that changes in plant communities can be monitored over time. This is especially important to land managers and others invested in conserving Sonoran Desert habitat and wildlife because they are increasingly at risk due to a changing fire regime.

Looking out over that same area of undisturbed Sonoran Desert a little longer you may begin to see the open space between plants. In fact, undisturbed Sonoran Desert habitat is made up of approximately 50% bare ground. This is important to maintaining Sonoran Desert plant communities as they are.

Fire is thought to be rare in the Sonoran Desert because that much bare ground keeps fires from igniting and spreading. In the past century it has been documented that fires are becoming more frequent. This is happening, in part, because of nitrogen deposition from burning fossil fuels and other urban activities. Heavy winter rains and extra nitrogen in the soil allows both native and introduced annual species (plants that germinate and die within one season) to fill in the bare ground and leave dense swaths of fuel during the dry summer months that can carry fires further and allow them to burn for longer periods of time.

This is a threat because most Sonoran Desert plants are not fire-adapted. Whether a species is fire-adapted depends on its ability to resprout or recolonize a burned area. Plants that are not fire-adapted are not adept at doing this. Increasing fire frequency could lead to permanent change in the plant

community if the fires occur so frequently the plant community cannot recover.

To better understand Sonoran Desert plant community composition and how it is affected by fire I conducted two studies: one that measured the changes in post-fire plant community composition with no intervention, and one that measured the changes in post-fire plant community composition at a completely different site that had been seeded with a mix of 28 plant species. The questions I asked for these studies included: (1) what species are present in my sites?; (2) how does fire and reseeded affect plant community attributes such as diversity and cover?; and (3) were there any significant differences in the distribution of cover between individual species or growth habits?

For the first study I monitored three fires that occurred within the McDowell Sonoran Preserve in Scottsdale, Arizona. In 1992, the Granite fire burned approximately 810 ha (2,000 acres) near the Brown's Ranch area. In 1993, the Ancala fire burned approximately 100 ha (250 acres) near Lost Dog Wash in the southern portion of the preserve and, in 1995, the Rio fire burned approximately 2,023 ha (5,000 acres) through the eastern midsection of the preserve (Figure 1). All three burned plant communities were left to recover without human intervention.

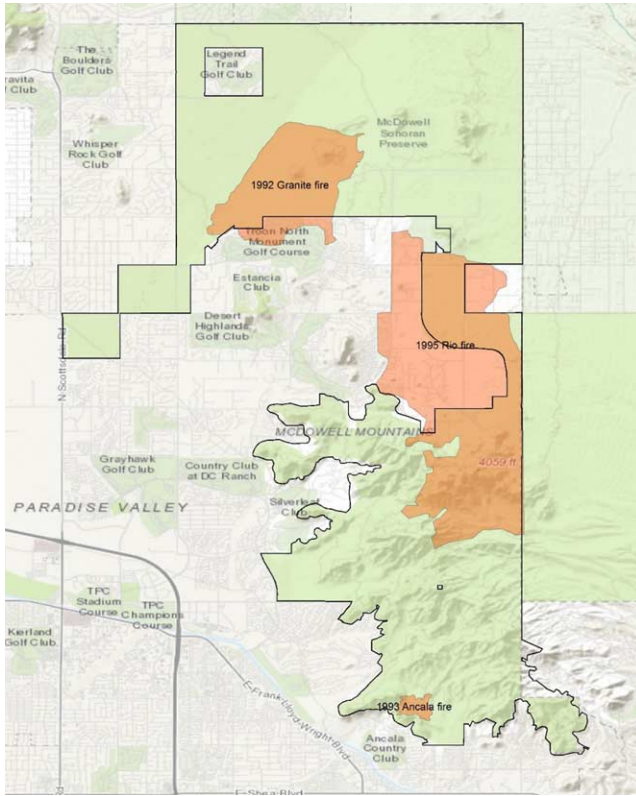
The second study was conducted at Cave Creek Regional Park in Cave Creek, Arizona, north of Phoenix. In June 2005, a fire started on private property immediately south of the park and spread into the park, burning approximately 1.5 ha (3.7 acres) (Figure 2). Researchers from Northern Arizona University (NAU) reseeded the portion of the burn located within the park using a diverse mix of 28 species and then covered the seeded area with a layer of straw mulch. They then monitored the germination of the seeded species for 32 months.

At all sites, I compared transects in burned areas with transects in adjacent unburned areas, measuring both the number of species (species richness) and the cover of each species. At Cave Creek Regional Park, a third transect was included within the reseeded area.

My findings show that for both the McDowell Sonoran Preserve and Cave Creek Regional Park sites, burned and

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Left: Figure 1. Map of the McDowell Sonoran Preserve with fire polygons. Park boundary is outlined in black and locations of the fires are shown as orange polygons. *Map sources: Esri, HERE, DeLorme, Intermap, inccretmet P Corp, GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community*

Above: Figure 2. Polygon of the Cave Creek Regional Park fire. The fire polygon is colored orange and the perimeter of the park is outlined in green. *Google Earth 2018.*

Effects of Fire and Reseeding on Sonoran Desert Plant Community Composition *continued*

unburned plant communities were similar in overall cover. This suggests that enough time has passed since the fire that the community has reestablished itself. Burned and unburned areas also had similar species richness, or number of species. However, significant differences between sites did arise when cover was broken down by growth habit and individual species.

For growth habits, succulents consistently showed a significant decline in cover post-fire across sites while subshrubs consistently showed a significant increase. A decline in succulent cover wasn't surprising since other research supports that Sonoran Desert cacti can take decades to mature. Brittlebush (*Encelia farinosa*) was the dominant subshrub in burned areas overall.

Differences were also found when looking at changes in cover for individual species. One surprising result was the decline in cover of nine annual species post-fire at the McDowell Sonoran Preserve. This difference did not show itself when overall difference in cover, pre- and post-fire, were measured. This is most likely because annuals make up more than 50% of the species diversity that exists in the Sonoran Desert so there would need to be significant changes for most of these

species to show a significant difference for the growth habit. Most of the research on fire effects in the Sonoran Desert focuses on dominant and/or perennial species, but this study indicates that more work needs to be done to understand what is happening with annuals and other nondominant species and how this may affect the plant community and the wildlife it supports.

Looking at the effects of reseeded at Cave Creek Regional Park, the reseeded area had a higher species richness than both the burned and unburned areas and this is likely due, in part, to the species used in the seed mix by NAU. Eleven of the 28 species seeded in the burned area had established populations at the time of this study (Table 1). Three of the 11 species found did not occur naturally in the park. These were fourwing saltbush (*Atriplex canescens*), cleftleaf wildheliotrope (*Phacelia crenulata*), and rose globemallow (*Sphaeralcea ambigua* var. *rosacea*). The results also showed that the reseeded area is more like the unburned area in both cover and species richness than the burned area is to the unburned area. This indicates that seeding may be facilitating recovery.

These studies support others suggesting that a changing fire regime in the Sonoran Desert will bring changes in plant

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BOOK REVIEW *Ries Lindley, University of Arizona Herbarium, Tucson; and Arizona Native Plant Society, Tucson Chapter*

Guide to the Plants of Arizona's White Mountains

by George C. West

With contributions by Julie Hammonds, and *Foreword* by Ellen L. West.

2019. University of New Mexico Press. Available at bookstores or directly from the University of New Mexico Press c/o Longleaf Services, Inc. To order, please call 800-848-6224 or visit www.unmpress.com. Also available at Amazon.com.

The sad news of George West's death in August 2016 has been tempered a little with the good news of the posthumous publication of his book, *Guide to the Plants of Arizona's White Mountains*. This guide will prove very useful to amateurs as well as the more serious naturalists botanizing the White Mountains. The White Mountains are in the east-central portion of the state. They harbor a lot of wonderful native plants but not many botanists.

It might be easier to appreciate the guide by knowing a bit more about the author. The name George West seems to crop up a lot in studies of the natural world. He is best known to bird watchers for *A Birder's Guide to Alaska*, a guide hundreds of pages long and filled with details on how to go birding in a state more than twice as big as Texas. He wrote other birding guides on specific areas of Alaska, e.g., the Kenai Peninsula; authored scores of academic papers; illustrated books; and created websites for public enlightenment. He worked in jobs from research scientist to academic administrator. His hunger for knowledge of the natural world was prodigious.

One of his book titles was *Do Hummingbirds Hum?* What we really wonder was, with all his energy, did George West hum?

Following George's retirement, he and his wife Ellen settled in Green Valley, Arizona. Among many other things, he undertook researching and taking photos for his White Mountains book. At the time of his unexpected passing, the book was largely completed; however, it still

required final editing. By a happy coincidence, three members of the Arizona Native Plant Society were able to provide assistance to the University of New Mexico Press editor to prepare the manuscript for publication.

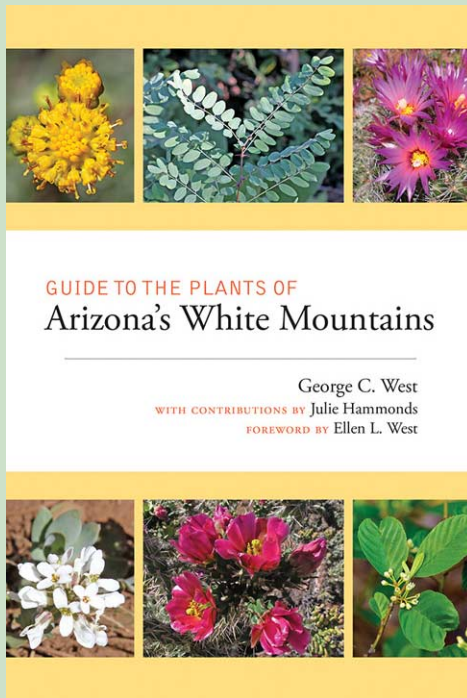
There are three basic sections in the guide: the trees at the beginning, the ferns at the end, and the flowering plants in between. Within the flowering plants, the entries are divided into flower colors, and within each flower color,

plants are organized by family, then species. A full page is devoted to each species, leaving room for several photos large enough to reveal appropriate detail and enough text to describe the plant. At the top of each page is a band of color denoting its place in the organizational scheme. When the book is closed, these color bands form color-coded groups that make it quick and easy to open the section of the book that includes the plant you are viewing. If you are looking at a yellow flower, you open the yellow section of the book, thus eliminating about 400 species with flowers that aren't yellow. If you know the family, you can go directly to that section.

If the family is Asteraceae (the Aster Family), then there are only about 50 pages to thumb through, even though this is the largest family in the guide!

At the top of each species page are a common name and the scientific name, each set apart with enough white space that the reader doesn't waste time wading through dense text for the plant ID. The plant's native/introduced

continued next page



BOOK REVIEW

Guide to the Plants of Arizona's White Mountains *continued*

status is listed prominently, as well as the common name and scientific name for the family. Flowering times are listed for each of the flowering plants, and each species has habitat information. The descriptions are right-sized, not too short, not too long. This is accomplished by using a minimum number of technical terms, and the technical terms used appear in the glossary. You will look first to the excellent photos, mostly by West himself, then at the description for confirmation of an ID. If you think you know the name of the plant and just want confirmation, there is a thorough index that includes both common and scientific names.

People who use field guides will recognize the crisp utility of this guide, in large part because of the common issues it has avoided. The photos are large and detailed, the species pages are not crowded, there are adequate descriptions, and the descriptions complement the photos. Habitat and occurrence are listed, adding yet another important aspect of plant ID.

It is easy to imagine a dog-eared copy of this manual lying on the dashboard as you drive through the natural wonders of the White Mountains. That's because it is easy to use and covers a small enough area to allow for the inclusion of all the commonly occurring species in the area. When the guide isn't on your dash, put it on a coffee table. No one will even notice it's a field guide, and it will spark a lot of interest and some interesting conversations.



Effects of Fire and Reseeding

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community composition. Over time this could mean the loss of plants that we value, such as the iconic saguaro cactus, but could also mean a loss in species that are rare but potentially crucial to supporting the Sonoran Desert ecosystem. If conservation of the Sonoran Desert as we currently know it is valuable to us, it is imperative that more monitoring and research be done to prepare for this changing fire regime. This can be done in part by using techniques such as floristic inventories to document the species that are present, along with more research and attention to the potential importance of nondominant species. When fires do occur, this kind of research will make land managers better prepared to act in ways that will facilitate recovery and preserve this ecosystem for decades to come.



Table 1. Species used to reseed at Cave Creek Regional Park. Those that that germinated and/or established are marked with an "X".

Seeded Species	Germinated during 2005-2008 monitoring period	Present during 2017 monitoring period
<i>Allionia incarnata</i>		
<i>Argemone hispida</i>	X	
<i>Aristida purpurea</i>	X	X
<i>Atriplex canescens</i>	X	X
<i>Baileya multiradiata</i>	X	
<i>Bothriochloa barbinodus</i>		
<i>Bouteloua curtipendula</i>		
<i>Bouteloua rockrothii (barbata)</i>		
<i>Calliandra eriophylla</i>		
<i>Castilleja exserta</i>	X	X
<i>Eragrostis intermedia</i>		
<i>Eschscholzia californica</i>	X	X
<i>Glandularia gooddingii</i>	X	
<i>Heteropogon contortus</i>	X	
<i>Hilaria belangeri</i>	X	
<i>Larrea tridentata</i>		X
<i>Lupinus sparsiflorus</i>	X	X
<i>Muhlenbergia porteri</i>		
<i>Olneya tesota</i>	X	X
<i>Panicum obtusum</i>		
<i>Penstemon eatonii</i>	X	
<i>Penstemon parryi</i>	X	
<i>Phacelia crenulata</i>	X	X
<i>Physaria gordonii</i>	X	X
<i>Senna covesii</i>	X	X
<i>Setaria vulpiseta</i>		
<i>Sphaeralcea ambigua</i> subsp. <i>rosacea</i>	X	X
<i>Sporobolus cryptandrus</i>		
TOTAL	18	11



Figure 1. Ron Coleman (1946-2019). Photo by Doug Ripley.

Hexalectris Rafinesque (Orchidaceae) — Crested Coral Root Orchids in Arizona

by Janet Fox¹

In honor of the late Ron Coleman, who played an instrumental role in the taxonomy of *Hexalectris* orchids in Arizona, and for whom two native orchids, *Hexalectris colemanii* and *Platanthera colemanii*, are named (Figure 1).

Hexalectris is a genus of terrestrial orchids in North America that occur from the northeastern to southwestern US and south into Mexico and Guatemala, and of which there are nine accepted species (Kennedy and Watson 2010). The species are distinguished from one another by flower size and color, labellum size and shape, and the number and height of raised longitudinal crests (lamellae) atop the midlobe of the labellum, which vary from five to seven (Kennedy and Watson 2010).

Orchids in the genus *Hexalectris* are primarily subterranean, perennial herbs with rhizomes that occasionally produce a 25 cm to 1-meter tall raceme of flowers above ground. It is one of only two genera of orchids in North America that are both achlorophyllous (lacks chlorophyll) and myco-heterotrophic (relies on a symbiotic relationship with fungi for nutrition and energy). The other genus is *Corallorhiza*, however, they are easily distinguished from *Hexalectris* by the multiple raised crests

down the center of the labellum in *Hexalectris* (Coleman 2002, Goldman *et al.* 2002).

Nothing conclusive is known about the pollinators of *Hexalectris*. In one study a bumblebee (*Bombus impatiens*) was observed visiting the flowers, but no pollinia were found on its body (Wallace and Embrey 2016). In that same study, and during field observations, tests determined that *Hexalectris* has no detectable scent, and so scent appears to be a minimal factor in attracting pollinators.

There are eight *Hexalectris* species known in the United States, with four occurring in Arizona: *H. arizonica*, *H. colemanii*, *H. parviflora*, and *H. warnockii* (SEINet 2019). Known habitats include mid-elevation scrub oak and oak-pine-juniper woodland in rocky canyons with partial to moderate shade and areas with duff and heavy leaf litter and thin humus layers (WestLand 2012).

The taxonomy of *Hexalectris* was revised as a result of a study in which samples of DNA were taken from the bracts of plants

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Crested Coral Root Orchids in Arizona *continued*

representing all the known species. The results erected three varieties to the status of species (see below). In addition, the study found that each *Hexalectris* species is associated with a different mycorrhizal fungus type (Kennedy & Watson 2010).

Arizona Coralroot — *Hexalectris arizonica* (S. Watson) A.H. Kennedy and L.E. Watson

Hexalectris arizonica (Figure 2) was first discovered in the Santa Rita Mountains by Pringle in 1881, but misidentified as *Corallorhiza arizonica* and then *H. spicata*. Recent genetic research (Kennedy and Watson 2010) elevated the two varieties Coleman identified as *H. spicata* var. *spicata* and *H. spicata* var. *arizonica* (Coleman 2002) to species level, and determined they were not conspecific with the *H. spicata* that grows in the eastern United States and is no longer considered part of our orchid flora. Our plants reverted to the specific epithet used for the original description as *Corallorhiza arizonica* and hence are now called *Hexalectris arizonica*.

H. arizonica emerges in July but flowers rarely open, as the species has evolved to self-pollinate (Coleman 2002). The stem, sepals, and petals are all pinkish-red in color. Individuals of *H. arizonica* have relatively small, self-pollinating, cleistogamous flowers that lack a rostellum and commonly grow up to one meter tall, (the tallest in the genus). However, *H. arizonica* is morphologically variable and some plants are shorter and have relatively large, open flowers in contrast to the typical tall, cleistogamous form (Coleman 2002). During fieldwork in Arizona, we have observed plants typical of both morphologies.

H. arizonica has been reported from the Dagoon, Chiricahua, Huachuca, Patagonia, Peloncillo, Rincon, Santa Rita, and Whetstone Mountains of southern Arizona (Baker 2012; SEINet 2019; USDA 2013; WestLand 2012). *H. arizonica* has also been reported in northeastern Arizona on Juniper Mesa and in Sycamore Basin, Yavapai County; in New Mexico in the Animas, Black Range, and Sacramento Mountains; and in Sonora, Mexico, in the Sierra Mazatan (SEINet 2019). This species is considered a sensitive plant by the U.S. Forest Service (USFS 2013).

Coleman's Coralroot — *Hexalectris colemanii* Catling A.H. Kennedy and L.E. Watson

Hexalectris colemanii (Figure 3) was first discovered in the Baboquivari Mountains by Toolin and Reichenbacher in 1981, but was misidentified as *H. spicata* (Coleman 2010). The orchid was detected in the Santa Rita Mountains, and misidentified again, by McLaughlin in 1986. Coleman and Catling determined that these orchids were in fact *H. revoluta*, the first documented



Figure 2. Arizona Coralroot (*Hexalectris arizonica*). Photo by Aaron Kennedy.

occurrence in Arizona, and a significant range expansion from the nearest known population in Texas (Coleman 2002). Upon further study, Catling recognized the Arizona plants to be distinct from the Texas variety, and published a formal description naming the Arizona variety *H. revoluta* var. *colemanii*, in honor of Ron Coleman who first recognized its distinct characteristics (Catling 2004). In 2010, *H. colemanii* was elevated to species level by Kennedy and Watson, based on genetic and morphological differences from *H. revoluta*, which is no longer considered part of our orchid flora.

H. colemanii emerges in May and flowers in June and July. The stem is pinkish-tan with showy striped purple to pink petals with maroon or purple stripes and the lower petal has distinct purple veining. The petals and sepals coil back more than 360 degrees, which is the defining characteristic of the species (Coleman 2002).

This species is considered a sensitive plant by the U.S. Forest Service (USFS 2013) and was petitioned for protection under the Endangered Species Act ; however, a 12-month review found that listing was not warranted (USFWS 2013). The finding was largely based on field surveys that identified previously unknown populations of this species in several mountain ranges of southeastern Arizona and southwestern New Mexico (Baker 2012, WestLand 2012).

H. colemanii has been reported from the Baboquivari, Dagoon, Chiricahua, Patagonia, Peloncillo, Santa Rita, and Whetstone

continued next page



From left: Figure 3. Coleman's Coralroot (*Hexalectris colemanii*). Photo by Ron Coleman. Figure 4. *Hexalectris parviflora*. Photo by Ron Coleman. Figure 5: Purple Spike Coralroot (*Hexalectris warnockii*). Photo by Aaron Kennedy.

Crested Coral Root Orchids in Arizona *continued*

Mountains (Baker 2012; SEINet 2019; USDA 2013; WestLand 2012).

***Hexalectris parviflora* L.O. Williams**

Hexalectris parviflora (Figure 4) was first discovered in 2015 in the Dragoon Mountains by Fox, and in the Peloncillo Mountains by Embrey. As it did not follow the key in the *Flora of North America* (Goldman *et al.* 2002), Fox consulted with Coleman and Kennedy who determined that it was *H. parviflora* (Coleman and Fox 2015).

Inflorescences are dull rose-lavender in color to a brown brick-red (Ames and Correll 1953). The terminal lobe of the lip is very prominent (Catling 2004) and solid magenta without the white or yellow lamellae as seen in other *Hexalectris* species (Kennedy and Watson 2010).

In Mexico, *H. parviflora* is known to occur between western Mexico and southwestern Guatemala (Williams 1940), with more recent descriptions extending along the Sierra Madre Occidental Mountains into northern Mexico (Kennedy and Watson 2010). The 2015 discovery in Arizona added a new orchid species to the U.S. and Arizona floras (Coleman and Fox 2015), and extended the known range of the species more than 200 miles north.

Purple Spike Coralroot — *Hexalectris warnockii* Ames and Correll

Hexalectris warnockii (Figure 5) was first discovered in 1939 in the Chiricahua Mountains by Fish. *H. warnockii* emerges in late July to early August with purple flowers, persisting until the first

week of September (Coleman 2002). Although *H. warnockii* occurs in portions of the known range of *H. colemanii*, it emerges and flowers later in the year and is darker in color, with petals and sepals that do not coil back 360 degrees or more. It differs from *H. arizonica* by a white lip striated with yellow (Coleman 2002).

H. warnockii has been reported from the Chiricahua and Huachuca mountains (SEINet 2019). This species is considered a sensitive plant by the U.S. Forest Service (USFS 2013).



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Figure 1. Watershed restoration structures (from left): Gabion, a wire enclosed rock structure in the channel; Check dam, a loose rock structure in the channel; and Media luna, a loose rock structure on the floodplain.

Vegetation Response to Landscape Conservation in the Sky Islands

by Natalie R. Wilson¹ and Laura M. Norman¹

All figures by: US Geological Survey, Western Geographic Science Center, Tucson, AZ

The Sky Island region is recognized globally as an area of rich biodiversity and productivity that has supported a long history of pre-European and post-European settlement and land use. This region is threatened in many ways, including climate change, increased wildfire interval and intensity, and increased use of ground and surface water resources by a growing human population. These threats, and others, have reduced the extent of unique habitats such as sacaton riparian grasslands, riparian gallery forests, and cienegas, as well as reducing grass cover needed for grazing. To combat these threats, watershed restoration practitioners have adopted a variety of techniques, including installing rock detention

structures in drainage channels and various other techniques to induce meander of the stream channel (Figure 1).

The USGS's Aridlands Water Harvesting Project (<http://usgs.gov/WGSC/Aridlands>) has been researching the effects of these structures for the past ten years. Our conceptual model for watershed restoration starts with an incised channel with ephemeral flow that is treated with the installation of a structure built to slow flow, increase sediment deposition, and increase infiltration. This model has been supported by the group's hydrological research (Norman et al. 2015; Norman et al. 2019; Norman et al. 2017). In our region, where vegetation dynamics are primarily driven by water availability, these hydrological changes should affect vegetation.

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Crested Coral Root Orchids in Arizona *continued*

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Vegetation Response to Landscape Conservation in the Sky Islands *continued*

We began to investigate changes in vegetation by using remote sensing. Remote sensing is the analysis of imagery captured by satellites, airplanes, or unmanned aerial systems and is a powerful tool for analysis of landscape-level changes. Satellite imagery was particularly useful in our research. Satellite imagery datasets span decades and cover the entire surface of the earth. Additionally, satellite sensors are designed to measure different sections of the electromagnetic (EM) spectrum, or bands, outside of the visible light spectrum. A commonplace digital photo will have information about the blue, green, and red bands of the EM spectrum, while satellite imagery will have information for blue, green, red, near infrared and shortwave infrared bands. The near infrared band of the EM spectrum is important in vegetation studies because live, healthy vegetation reflects more infrared waves than any other part of the EM spectrum. This means that if we could see infrared as a color, plants would be far more infrared than they are green. Remote sensing analysis often consists of combining these bands in different ways. One classic combination of bands is the Normalized Difference Vegetation Index (NDVI) which is a combination of the red and near infrared bands. NDVI in general terms is a measure of vegetation “greenness” but it has been correlated with plant biomass, canopy cover, and vegetation health which makes it invaluable in ecological studies such as ours (Figure 2). There are many sources of imagery for remote sensing analyses, but we have found that the Landsat satellite sensors provide the best data for our purposes. Landsat satellite sensors record the spectral bands needed for vegetation analysis and they have been recording data for decades, which is invaluable when studying long-term trends. Landsat also has a spatial resolution matches the scale of our analyses. Each satellite image is made of pixels, just like a digital photograph and each pixel corresponds with a certain amount of area on the surface of the Earth. Landsat pixels are roughly 30m by 30m, which isn't small enough to track individual trees but is small enough to separate vegetation communities like riparian corridors from upland areas.

Our remote sensing analyses were focused on restoration in the San Bernardino watershed. The San Bernardino watershed starts in Black Draw between the southeastern slopes of the Chiricahua Mountains in Cochise County and

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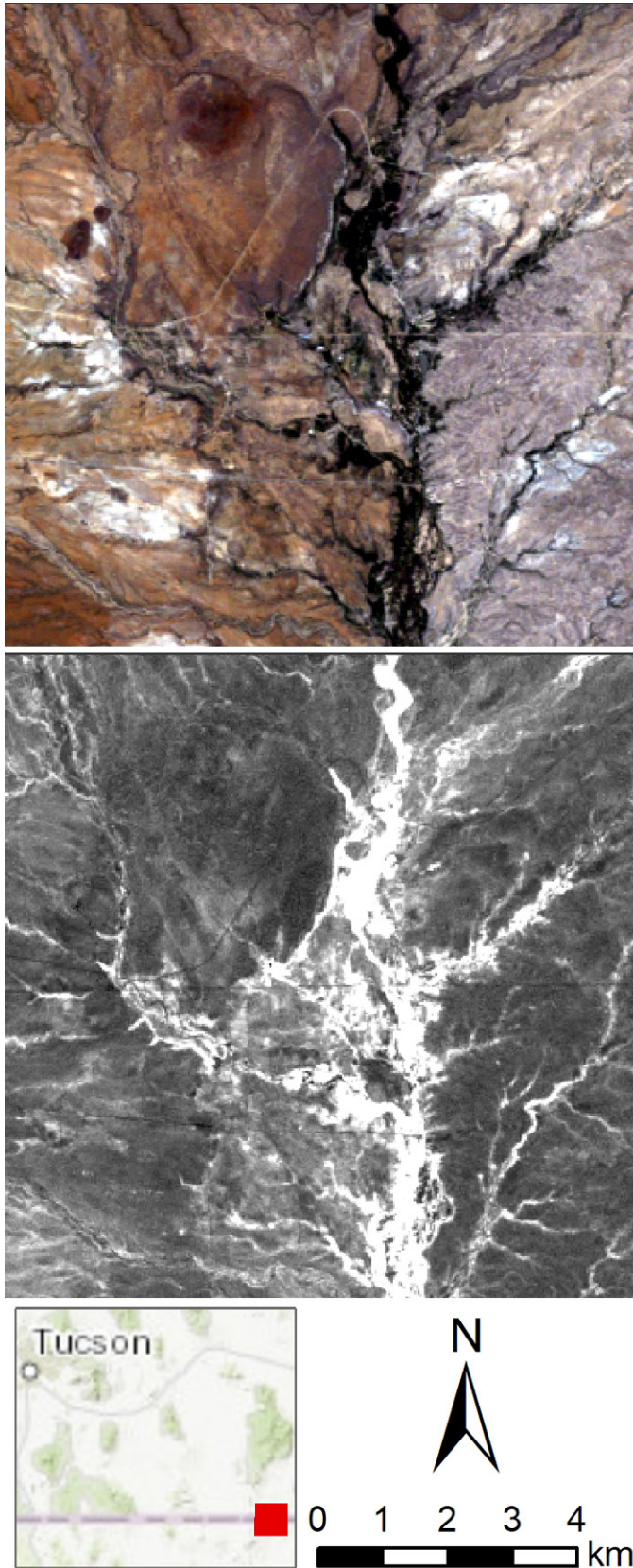


Figure 2. Satellite imagery of the San Bernardino Watershed (from top): Natural color image of the San Bernardino watershed from June 2010. NDVI derived for the same date, live vegetation is bright white while senescent vegetation and bare soil are gray. Location of the San Bernardino watershed in southeastern Arizona.

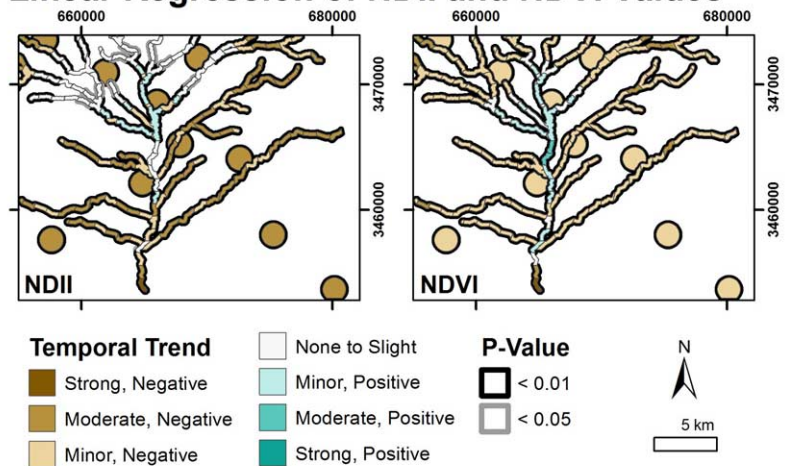
Vegetation Response to Landscape Conservation in the Sky Islands *continued*

the western slopes of the Guadalupe Mountains on the border with New Mexico (Figure 3). The San Bernardino River flows into Mexico at the San Bernardino National Wildlife Refuge (SBNWR), which was set aside for the restoration of native fish populations. South of the border are the holdings of the Cuenca Los Ojos Foundation (CLO), an organization dedicated to land conservation, habitat restoration, and research. Both SBNWR and CLO installed watershed restoration structures on their land. SBNWR installed 24 gabions from 1984 to 2012. CLO installed 49 gabions and large earthen berms from 2001 to 2016, nearly twice as many structures in half the time of the SBNWR.

Our first analysis focused on the area around these structures and used NDVI to measure changes in vegetation greenness from 1984 to 2013. They showed that close to restoration structures, the riparian vegetation was greener when compared to areas further from the structures. In addition, those areas were maintaining or increasing in greenness even in periods of decreasing precipitation, indicating the system's increasing resilience to drought (Norman *et al.* 2014). But this initial analysis focused only on the area within 300 m of structures. The next step for our group was to examine the effects on vegetation beyond the immediate area around a structure, to look at landscape-level effects.

In the same watershed, we examined areas upstream and downstream of a section of channel with restoration structures, dividing the riparian corridor into 1 km zones and comparing those to tributaries with no restoration structures and upland areas. Again, we used NDVI to assess vegetation greenness but we also used NDII, the Normalized Difference Infrared Index, which measures vegetation and soil moisture content. Previous work showed that NDII offers a different view of vegetation dynamics in the grasslands of southeastern Arizona (Wilson *et al.* 2016). We examined NDVI and NDII values over a 28-year period beginning in 1984. Restoration effects observed included increased vegetation greenness captured by higher trends in NDVI values over time as well as increased or stable vegetation and soil moisture content captured by positive or neutral trends in NDII values over time. This contrasted with negative trends in tributaries with no restoration structures where both NDVI and NDII decreased over time. We found that these effects extended at least 5 km downstream of the area with restoration structures.

Linear Regression of NDII and NDVI Values



Right: Figure 3 Results of linear regression of NDII and NDVI showing the strength of the temporal trend in vegetation water content and vegetation greenness.

Restoration effects also extended upstream of the area with restoration structures at least 1 km. An interesting finding was that the structures, particularly the intensive work on CLO lands, acted initially as a disturbance on the landscape, resulting in a short-term decrease in vegetation greenness and moisture content that was followed by full recovery. With this remote sensing work (Wilson *et al.* 2018), the USGS showed that watershed restoration structures have long-term positive effects on the vegetation in long sections of a riparian corridor.

Our next step was to investigate changes in more specific measures of vegetation abundance and species composition. We also wanted to examine how quickly changes occur, including changes that are not observable using satellite imagery. Five years ago, we developed a protocol to look at non-woody vegetation within the channel and implemented the protocol at several restoration sites throughout southeastern Arizona. The protocol was developed with the help of many folks from the Sky Island Restoration Cooperative, a loosely organized group of land managers, land owners, restoration practitioners, and researchers interested in restoration in our region. The design had to be flexible enough to be implemented at sites with different channel morphologies, robust to the variability in spatial distribution of plants in an area, and repeatable from year to year. Plots were randomly placed at restoration structures. Control plots were randomly placed in channels at least some distance from a structure, with the distance based on the size of the structure. Within the plots, nested quadrats were used to measure frequency which was the metric we used to quantify abundance. Basal and foliar cover classes were also

continued next page



Figure 4. Vegetation response at a gabion, 2015–2019; in 2018 and 2019, much of the tall herbaceous vegetation in the channel had been grazed to the ground.

Vegetation Response to Landscape Conservation in the Sky Islands *continued*

recorded for each quadrat. Data were collected during the monsoon growing season. Initial findings suggest that, overall, watershed restoration structures increase the abundance of perennial vegetation (Figure 4). However, we are continuing our analyses, examining changes in abundance by lifeform and family, changes in wetland species occurrence, and invasion of non-native species.

While collecting the field data, we made some observations of particular interest to botanists. First was a new occurrence of *Phemeranthus humilis* (Greene) Kiger, the Pinos Altos Flameflower (Figure 5). SEINet listed three occurrences of the species in Arizona with one being in the western Chiricahua Mountains. This new occurrence was found on the southeastern slopes of the Chiricahuas in 2015 when working alongside the folks participating in that year’s Botany Blitz. Botany Blitz is an event coordinated by the Sky Island Alliance where botanists work to record as many species as possible in an area over the course of a few days. Also, the first observations of *Cyperus hermaphroditus* (Jacq.) Standl. in the Chiricahuas were confirmed with the help of two experts in *Cyperaceae*, Max Licher of Northern Arizona University and Gordon Tucker of Eastern Illinois University.

In summary, watershed restoration structures have important, landscape-level impacts on the ecohydrology of southeastern Arizona. These impacts include increasing water availability to improve vegetation health along riparian corridors. However,

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Figure 5. *Phemeranthus humilis*, Pinos Altos Flameflower in flower.

Vegetation Response to Landscape Conservation in the Sky Islands

continued

questions remain about changes in vegetation composition due to these structures and research continues. With support from many stakeholders and collaborators, the USGS's Aridlands Water Harvesting Project will continue to strive to provide important information on the effects of watershed restoration structures to restoration practitioners, land managers, and land owners.

Acknowledgements

We would like to thank our collaborators at the US Forest Service, the National Park Service, the US Fish and Wildlife Service, the Bureau of Land Management, Sky Island Alliance, Borderlands Restoration, Cuenca Los Ojos, Deep Dirt Farm Institute, Stream Dynamics, and the University of Arizona. We would also like to thank the private landowners that allowed us access to restoration projects on their land. Special thanks to reviewers Steve Buckley and Andrew Bennett. This research was conducted with support from the Land Resources Mission Area of the US Geological Survey.



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Figure 1. View of the Sierra Chivato. Photo by Ana L. Reina-G.



Figure 2. Aerial view of oak woodland at Rancho Los Alisos base camp. Photo by Luis Gutiérrez, NortePhoto.

Preliminary Flora of the Sierra Chivato, Sonora, Mexico

by Thomas R. Van Devender¹, Stephen F. Hale², Ana Lilia Reina-Guerrero¹, John L. Anderson³, Chris Roll⁴, and Sky Jacobs⁵

Abstract

The Sierra Chivato is a relatively small Sky Island in the Madrean Archipelago in northern Sonora. This area was previously poorly known botanically until the Madrean Discovery Expedition in the spring of 2019. In this preliminary flora, we document 177 taxa in 59 families and 142 genera. Twelve species (6.8%) are non-native.

Introduction

The Madrean Archipelago is located between the Sierra Madre Occidental in eastern Sonora and western Chihuahua and the Mogollon Rim in central Arizona. In this area there are isolated 55 Sky Island mountain ranges or complexes of several ranges connected by oak woodland corridors (Van Devender *et al.* 2013). Thirty-two of them are in Sonora. Sky Islands are crowned with oak woodland or pine-oak forest. The lowland 'seas' include expanses of Sonoran and Chihuahuan desertscrub, desert grassland, foothills thornscrub, or tropical deciduous forest. In this paper, we present a preliminary flora of the Sierra Chivato, a Sky Island mountain range in north-central Sonora (Figure 1).

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Study Area and Methods

This preliminary flora is based on 2019 collections and observations from a March 4–7 scouting trip and the April 24–27 major Madrean Discovery Expedition (MDE) Sierra Chivato. The Río Santa Cruz localities were revisited on June 26. The only previous plant records for the Sierra Chivato were tree species recorded by Aaron D. Fleisch and Carlos González-S. on July 2010 breeding bird transects. Observations, collections, and images are available in the Madrean Discovery Expeditions database (madreandiscovery.org). Specimens were deposited into the University of Arizona (ARIZ), Universidad de Sonora (USON), and Arizona State University herbaria.

The Sierra Chivato (Figure 1) is located in the Municipio de Santa Cruz east of the towns of San Lázaro (Miguel Hidalgo) and Santa Cruz on the Río Santa Cruz. The higher part of the range is directly east of San Lázaro about 20 km south of the Arizona border. Our base camp at Rancho Los Alisos (31.15°N 110.55°W, 1,321 m elevation) was in a dense oak-juniper woodland on a hillside among granite outcrops and boulders (Figures 2 and 3). Foothills of the range extend northward almost to the U.S./Mexico border, where the sprawling San Rafael Valley dominates the landscape. The elevational range, from the Río Santa Cruz near San Lázaro at 1,297 meters to the highest peak (at 2,192 meters), is 895 meters.

The vegetation of the Sierra Chivato is desert grassland on its lower slopes and a relatively uniform and dense oak woodland

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Figure 3. A. Granite boulder hillside. Photo by Ana L. Reina-G. B. Mountain yucca (*Yucca madrensis*). Photo by Luis Gutiérrez. C. Border pinyon (*Pinus discolor*). Photo by Luis Gutiérrez, NortePhoto.

Preliminary Flora of the Sierra Chivato, Sonora, Mexico *continued*

above. Dominant trees include Mexican blue oak (*Quercus oblongifolia*), Emory oak/bellota (*Q. emoryi*), Arizona white oak (*Q. arizonica*), and alligator bark juniper/táscate (*Juniperus deppeana*), with scattered border pinyon (*Pinus discolor*; Figures 3 and 4). In some areas junipers are dominant. A few silverleaf oak (*Quercus hypoleucoides*) and Arizona madrone (*Arbutus arizonica*) are present on the highest ridges. A riparian forest of Arizona sycamore (*Platanus wrightii*) is in Arroyo La Piedra (Figure 5). Arizona walnut (*Juglans major*), Fremont cottonwood (*Populus fremontii*), and Goodding's willow (*Salix gooddingii*) occur occasionally in mountain canyons. A well-developed cottonwood-willow riparian forest occurs along the perennial reach of the Río Santa Cruz at El Paseo del Cajón (3.7 km [by air] NE of San Lázaro, 31.17°N 110.62°W; Figure 6). Dominant trees include Fremont cottonwood, Bonpland (*Salix bonplandiana*) willow, and Goodding's willow. Other trees include Arizona walnut, blue elderberry/tápiro (*Sambucus nigra* subsp. *cerulea*), and velvet ash/fresno (*Fraxinus velutina*). Notable shrubs include seep willow/batamote (*Baccharis salicifolia*) and willow ragwort/ruina (*Barkleyanthus salicifolius*).

Flora

The preliminary flora of the Sierra Chivato includes a total of 177 taxa in 59 families and 142 genera. Only 12 species (6.8%) are non-native. None of them are invasive. The most important families are Asteraceae (24 taxa), Poaceae (17 taxa), and Fabaceae (16 taxa), followed by Cactaceae (6 taxa), and Brassicaceae and Pteridaceae (5 taxa each). Additional families with four taxa are: Amaranthaceae, Apiaceae, Asparagaceae, Boraginaceae, Fagaceae, Plantaginaceae, Salicaceae, and Solanaceae. The genera with the most species were *Baccharis* and *Quercus* (4 taxa). *Aristida*, *Astragalus*, *Bouteloua*, *Mimosa*, *Myriopteris*, and *Salix* had three species each.

Discussion

The preliminary flora of the Sierra Chivato with only 177 taxa is limited. The trees, shrubs, and succulents are well represented. Herbaceous plants and grasses are poorly represented because sampling was only done in the spring.

The plants seen in desert grassland and oak woodland in the Sierra Chivato are typical of these habitats in southern Arizona

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Figure 4. A. Cane cholla (*Cylindropuntia spinosior*). Photo by Doug Danforth. B. Tufted milkweed (*Asclepias nummularia*). Photo by Thomas R. Van Devender. C. Weeping dalea (*Dalea versicolor*). Photo by Stephen F. Hale.



Figure 5. A. La Piedra. Photo by Mario Cirett-G. B. Arizona sycamore (*Platanus wrightii*). Photo by Ana L. Reina-G.

Preliminary Flora of the Sierra Chivato, Sonora, Mexico *continued*

and northern Sonora. The grasslands in the Río Santa Cruz Valley are a southward extension of the San Rafael Valley of Arizona (McLaughlin 2006). In Arizona, similar oak woodlands are present in the Huachuca Mountains (36 km NE; Bowers and McLaughlin 1996), the Canelo Hills (35 km NNE), and the Patagonia Mountains. The Patagonia Mountains extend into Sonora as the Sierra San Antonio as far south as Santa Cruz, ending just north of San Lázaro. In Sonora, similar oak woodlands are present in the Sierra Pinito (24 km SW), on Rancho El Aribabi in the Sierra Azul (34 km SSW; Sánchez-E. *et al.* 2013), and the Sierras Mariquita and Elenita (19 km ESE, 23 km SE; Carnahan *et al.* 2018). Species records of these floras are available in the MDE database and linked herbaria in the Southwestern Environmental Information Network (SEINet).

The Río Santa Cruz begins in the San Rafael Valley in Arizona, flows south to San Lázaro, loops west, and flows northward to reenter Arizona east of Nogales. It then flows north through Tucson to eventually reach the Gila River. Solis-G. and Jenkins (1998) and Solis *et al.* (2002a & b) studied the flora of the Río Santa Cruz in Sonora. Species that we encountered not in their reports include *Anisacanthus thurberi*, *Barkleyanthus salicifolius*, *Clematis ligusticifolia*, *Erythrostemon* (*Caesalpinia*) *gilliesii*, *Hydrocotyle ranunculoides*, *Lilaeopsis schaffneriana* subsp. *recurva*, *Mentzelia longiloba* var. *yavapaiensis*, *Nicotiana glauca*, *Oenothera rosea*, *Sapindus drummondii*, and *Tetramerium nervosum*. The Huachuca water umbel (*Lilaeopsis schaffneriana* subsp. *recurva*) was found in two localities

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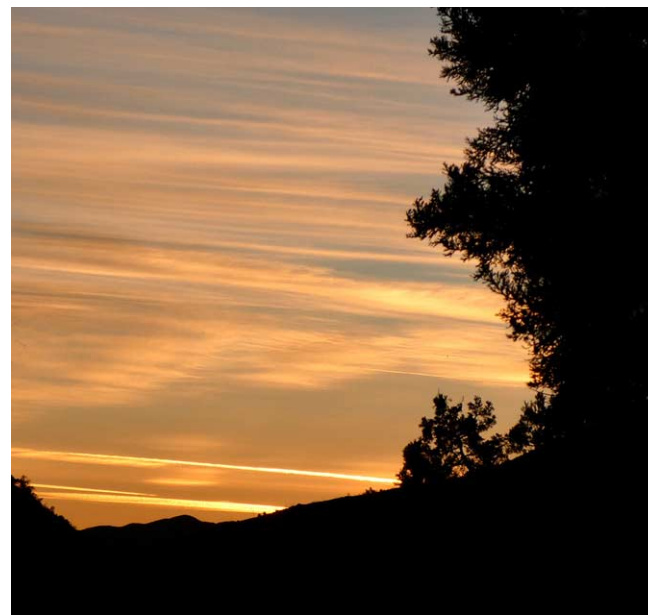


Figure 6. A. Aerial view of Río Santa Cruz. Photo by Luis Gutiérrez, NortePhoto. B. Sierra Chivato sunset. Photo by Ana L. Reina-G.



Figure 7. A. Huachuca water umbel (*Lilaeopsis schaffneriana* subsp. *recurva*) flowers. Photo by Ana L. Reina-G. B. Seep monkeyflower (*Erythranthe guttata*). Photo by Stephen F. Hale. C. Floating pennywort (*Hydrocotyle ranunculoides*). Photo by Ana L. Reina-G

Preliminary Flora of the Sierra Chivato, Sonora, Mexico *continued*

(Figure 7A). It is U.S. federally listed endangered species known from southern Arizona, Sonora, and Chihuahua. Floating pennywort (*Hydrocotyle ranunculoides*), which is native to North and South America and parts of Africa, was collected at two localities on the Río Santa Cruz (Figure 7C). These are the first records for the species in Sonora. One of us (TRV) subsequently collected it in the Río Bambuto south of Nogales (Municipio de Ímuris, Sierra Huacomea, Agua Caliente, 18.9 km [by air] N of Ímuris. 30.9583°N 110.86222°W, 1,095 m elev, T. R. Van Devender 2019-366, 13 August 2019. ARIZ). It is interesting that they did not see tree tobacco/*juan loco* (*Nicotiana glauca*) or yellow bird-of-paradise (*Erythrostemon gilliesii*), conspicuous shrubs native to South America.

Acknowledgments

We are grateful to **GreaterGood.org** for the financial and logistical support that enables such meaningful and important work in the field of conservation and biodiversity assessment in the Sky Islands Region of Sonora. We thank Luis Gutiérrez of NortePhoto, Doug Danforth, and Mario Cirett for use of their photos.



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CHECKLIST: Sierra Chivato page 1 of 3

An asterisk (*) denotes non-native status.

Pteridophytes

PTERIDACEAE

Astrolepis sinuata (Lag. ex Sw.) Benham & Windham

Bommeria hispida (Mett. ex Kuhn) Underw.

Myriopteris aurea (Poir.) Grusz & Windham

Myriopteris lindheimeri (Hook.) J. Sm.

Myriopteris tomentosa (Link) Fée

Gymnosperms

CUPRESSACEAE

Juniperus deppeana Steud.

PINACEAE

Pinus discolor D.K. Bailey & Hawksworth

Eudicots

ACANTHACEAE

Anisacanthus thurberi (Torr.) A. Gray

Elytraria imbricata (Vahl) Pers.

Tetramerium nervosum Nees

ADOXACEAE

Sambucus nigra L. subsp. *cerulea* (Raf.) Bolli

AMARANTHACEAE

Amaranthus palmeri S. Watson

Gomphrena caespitosa Torr.

Guilleminea densa (Humb. & Bonpl. ex Willd.) Moq.

**Salsola tragus* L.

ANACARDIACEAE

Rhus aromatica Aiton var. *trilobata* (Nutt.) Gray

Rhus virens Lindh. ex A. Gray var. *choriophylla* (Wooton & Standl.) L.D. Benson

Toxicodendron radicans (L.) Kuntze var. *divaricatum* (Greene) Barkley

APIACEAE

**Berula erecta* (Huds.) Coville

Eryngium heterophyllum Engelm.

Lilaeopsis schaffneriana (Schltdl.) J.M. Coult. & Rose subsp. *recurva* (A.W. Hill) Affolter

Spermolepis lateriflora G.L. Nesom

ARALIACEAE

Hydrocotyle ranunculoides L. f.

ARISTOLOCHIACEAE

Aristolochia watsonii Wooton & Standl.

APOCYNACEAE

Asclepias asperula (Decne.) Woodson

Asclepias nummularia Torr.

ASTERACEAE

Acourtia thurberi (A. Gray) Reveal & R. M. King

Ageratina paupercula (A. Gray) King & H.E. Robins.

Ambrosia confertiflora DC.

Ambrosia monogyra (Torr. & A. Gray) Strother & B.G. Baldwin

Artemisia ludoviciana Nutt.

Baccharis pteronioides DC.

Baccharis salicifolia (Ruiz & Pav.) Pers.

Baccharis sarothroides A. Gray

Baccharis thesioides Kunth

Barkleyanthus salicifolius (Kunth) H. Rob. & Brettell

Brickellia californica (Torr. & A. Gray) A. Gray

Chaetopappa ericoides (Torr.) G.L. Nesom

Cirsium neomexicanum A. Gray

Ericameria nauseosa (Pall. ex Pursh) G.L. Nesom & G.I. Baird

Erigeron tracyi Greene

Gamochoeta stagnalis (I.M. Johnst.) Anderb.

Guardiola platyphylla A. Gray

Helenium thurberi A. Gray

**Lactuca serriola* L.

Malacothrix fendleri A. Gray

Senecio flaccidus var. *flaccidus* Less.

Symphotrichum subulatum (Michx.) G.L. Nesom

Viguiera dentata (Cav.) Spreng.

Xanthisma gracile (Nutt.) D.R. Morgan & R.L. Hartm.

Xanthium strumarium L.

BORAGINACEAE

Cryptantha micrantha (Torr.) I.M. Johnston

Nama hispidum A. Gray

Phacelia arizonica A. Gray

Plagiobothrys arizonicus (A. Gray) Greene ex A. Gray

BRASSICACEAE

**Capsella bursa-pastoris* (L.) Medik.

Descurainia pinnata (Walter) Britton

Lepidium lasiocarpum Nutt.

**Nasturtium officinale* R. Br.

**Sisymbrium irio* L.

CACTACEAE

Coryphantha recurvata (Engelm.) Britton & Rose

Cylindropuntia spinosior (Engelm.) Knuth

Echinocereus rigidissimus (Engelm.) Hort. var. *rigidissimus*

Echinocereus santaritensis W. Blum & Rutow

Opuntia chlorotica Engelm. & Bigelow

Opuntia engelmannii Salm-Dyck

CAMPANULACEAE

Triodanis perfoliata (L.) Nieuwl. var. *biflora* (Ruiz & Pav.) Bradley

CANNABACEAE

Celtis pallida Torr.

Celtis reticulata Torr.

CARYOPHYLLACEAE

Cerastium texanum Britton

Drymaria effusa A. Gray

CHECKLIST: Sierra Chivato page 2 of 3

Silene antirrhina L.

CLEOMACEAE

Polanisia dodecandra (L.) DC.

CONVOLULACEAE

Evolvulus arizonicus A. Gray

Ipomoea longifolia Benth.

CUCURBITACEAE

Cucurbita digitata A. Gray

ERICACEAE

Arbutus arizonica (A. Gray) Sarg.

Arctostaphylos pungens Kunth

EUPHORBIACEAE

Croton texensis (Klotzsch) Muell.-Arg.

FABACEAE

Acmispon brachycarpus (Benth.) D.D. Sokoloff

Acmispon greenei (Wooton & Standl.) Brouillet

Amorpha fruticosa L.

Astragalus arizonicus A. Gray

Astragalus nothoxys A. Gray

Astragalus nuttallianus DC.

**Caesalpinia gilliesii* (Hook.) D. Dietr.

Calliandra humilis Benth. var. *reticulata* (A. Gray) L. Benson

Dalea pulchra Gentry

Dalea versicolor Zucc.

Erythrina flabelliformis Kearney

Eysenhardtia orthocarpa (A. Gray) S. Watson

Lupinus concinnus J. Agardh

Mimosa biuncifera Benth.

Mimosa dysocarpa Benth.

Mimosa grahamii A. Gray

Prosopis velutina Wooton

FAGACEAE

Quercus arizonica Sarg.

Quercus emoryi Torr.

Quercus emoryi Torr. x *Q. viminea* Trel.

Quercus hypoleucoides A. Camus

Quercus oblongifolia Torr.

FOUQUIERIACEAE

Fouquieria splendens Engelm.

GARRYACEAE

Garrya wrightii Torr.

JUGLANDACEAE

Juglans major (Torr.) Heller

LAMIACEAE

Salvia parryi A. Gray

Stachys coccinea Ortega

LOASCACEAE

Mentzelia albicaulis (Dougl.) Dougl. ex Torr. & A. Gray

Mentzelia longiloba J. Darl. var. *yavapaipenis* J.J. Schenk & L. Hufford

MALVACEAE

Sida abutifolia P. Mill.

MARTYNIACEAE

Proboscidea parviflora (Wooton) Wooton & Standl.

MONTIACEAE

Cistanthe monandra (Nutt.) Hershkovitz

NYCTAGINACEAE

Boerhavia coccinea P. Mill.

Mirabilis linearis (Pursh) Heimerl

OLEACEAE

Fraxinus velutina Torr.

ONAGRACEAE

Ludwigia peploides (Kunth) P.H. Raven

Oenothera primiveris A. Gray

Oenothera rosea L'Hér. ex Aiton

OROBANCHACEAE

Castilleja tenuiflora Benth.

PAPAVERACEAE

Argemone pleiakantha Greene

Corydalis aurea Willd.

PHRYMACEAE

Erythranthe guttata (Fisch. ex DC.) G.L. Nesom

PLANTAGINACEAE

Nuttallanthus texanus (Scheele) D. A. Sutton

Penstemon parryi (A. Gray) A. Gray

Plantago patagonica Jacq.

Veronica peregrina L. var. *xalapensis* (Kunth) Pennell

PLATANACEAE

Platanus wrightii S. Watson

POLEMONIACEAE

Eriastrum diffusum (A. Gray) Mason

Gilia mexicana A. & V. Grant

POLYGONACEAE

Eriogonum polycladon Benth.

Eriogonum wrightii Torr. ex Benth.

PORTULACEAE

Portulaca suffrutescens Engelman.

PRIMULACEAE

Androsace occidentalis Pursh

RANUNCULACEAE

Clematis ligusticifolia Nutt.

Myosurus cupulatus S. Watson

Thalictrum fendleri Engelm. ex A. Gray

RHAMNACEAE

Ceanothus buxifolius Willd. ex Schult. f.

RUBIACEAE

Bouvardia ternifolia (Cav.) Schldtl.

Galium proliferum A. Gray

Galium wrightii A. Gray

SALICACEAE

Populus fremontii S. Watson

Salix bonplandiana Kunth

Salix gooddingii Ball

Salix taxifolia Kunth

SANTALACEAE

Comandra umbellata (L.) Nutt.
Phoradendron serotinum (Raf.) M.C. Johnst. subsp. *tomentosum* (DC.) Kuijt

SAPINADACEAE

Dodonaea viscosa Jacq. var. *angustifolia* (L.f.) Benth.
Sapindus drummondii Hook. & Arn.

SAXIFRAGACEAE

Heuchera sanguinea Engelm.

SIMAROUBIACEAE

**Ailanthus altissima* (Mill.) Swingle

SOLANACEAE

Datura discolor Bernh.
Datura inoxia P. Mill.
 **Nicotiana glauca* Graham
Solanum rostratum Dunal

VITAEAE

Parthenocissus vitacea (Knerr) Hitchc.
Vitis arizonica Engelm.

ZYGOPHYLLACEAE

**Tribulus terrestris* L.

Monocots

ASPARAGACEAE

Agave palmeri Engelm.
Dasyliirion wheeleri S. Watson
Nolina microcarpa S. Watson
Yucca madrensis Gentry

COMMELINACEAE

Commelina dianthifolia Delile

JUNCACEAE

Juncus bufonius L.

POACEAE

Aristida adscensionis L.

Aristida purpurea Nutt.

Aristida ternipes Cav. var. *ternipes*

Bothriochloa barbinodis (Lag.) Herter

Bouteloua barbata Lag. var. *barbata*

Bouteloua curtipendula (Michx.) Torr.

Bouteloua hirsuta Lag.

**Cynodon dactylon* (L.) Pers. var. *dactylon*

Disakisperma dubium (Kunth) P.M. Peterson & N. Snow

**Eragrostis cilianensis* (All.) Vignolo ex Janch.

Eragrostis intermedia Hitchc.

Festuca octoflora Walt.

Muhlenbergia emersleyi Vasey

Muhlenbergia microsperma (DC.) Trin.

Piptochaetium fimbriatum (Kunth) Hitchc.

Poa bigelovii Vasey & Scribn.

**Polypogon monspeliensis* (L.) Desf.

Where A Game for Arizona Plant Nuts by Daryl Lafferty¹ and Leslie R. Landrum²

Daryl Lafferty has developed an online game for people who love Arizona plants. "Where?" you ask: <http://serv.biokic.asu.edu/dlafferty/Where/Where.php>

Go to the **Where** website and you will see a map of Arizona and a list of plants. The objective is to look at the names and images on the list on the right and guess where they were all found together. Mouse over the images to expand them. You get three guesses by clicking on points in Arizona that will be numbered 1, 2, and 3. Your error in kms will appear at the bottom after each guess. After the third guess, an X will appear on the correct spot. With a little experience you can often come pretty close to the right answer. There are three alternative maps to use and you can switch between them.

The program randomly searches through the SEINet database of AZ specimens, chooses one, and then finds everything collected nearby. So, all the species in the list will be found very near each other (discounting errors in ID and geo-referencing). The species with the highest number of collections (usually 2–6 specimens) are at the top. The less frequently collected species are alphabetical at the end.

We'd like to hear what you think of this program.

¹daryl@daryllafferty.com ²ASU Herbarium Curator, Arizona State University, Tempe, Arizona; les.landrum@asu.edu



Photos by the author.

SPOTLIGHT ON A NATIVE PLANT *Bob Herrmann Arizona Native Plant Society, Cochise Chapter*

Mexican Thistle (*Eryngium heterophyllum*)

At first sight of this plant one might think that it could possibly be a thistle in the Aster Family (Asteraceae). After all the plant has a silvery “thistle look” to it and the half egg-shaped flowers look like a composite. You might be hesitant to touch the plant thinking you may get poked. Taking a chance you will find it is soft and not at all prickly. You’ll begin to think this might not be a thistle after all. After examining the plant closely it’s the flowers that finally give it away as a member of the Parsley or Carrot Family (Apiaceae). What a surprisingly and interestingly disguised plant!

The Mexican Thistle can be found from southeastern Arizona, New Mexico, western Texas and throughout the Sierra Madre Mountains of Mexico as far south as Guadalajara. Following the start of the monsoons the Mexican Thistle begins to grow. In the Huachuca Mountains they start showing up in the 5,000 foot elevation range. You can find plants growing alone or many plants growing together in large colonies. Mexican Thistle reaches a height of about two feet. It produces

clusters of flowers in July that can last well into October. I have observed bees, butterflies, and winged beetles visiting this plant.

What a wonderful native plant to photograph! The different changes the plant goes through in its cycle from a weedy look to a thistle look-alike makes every visit to this plant exciting. It changes in flower color from white and green in a young plant to a beautiful sky blue in a mature plant. Even after the plant dies it presents interesting photo opportunities. You can come back and enjoy photographing this plant throughout its life cycle.

Described and named by Linnaeus, the genus name *Eryngium* is derived from the Greek word *erungos* for thistle, alluding to the spiny leaves that characterize the genus. The species was described and named by the eminent German-American physician/botanist George Engelmann. The name *heterophyllum* refers to the fact that the leaves on the same plant are different.





THE ARIZONA NATIVE PLANT SOCIETY

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For more information, please drop us a line, visit www.aznativeplantsociety.org, or get in touch with one of the chapter contacts below:

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