The Vegetation and Flora of the Lower Verde River, Arizona

by

Cole Larson-Whittaker

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved July 2020 by the
Graduate Supervisory Committee:

Kathleen B. Pigg, Chair
Andrew Salywon
Wendy Hodgson

ARIZONA STATE UNIVERSITY

August 2020

ABSTRACT

For this study, the flora of the northern section of the Lower Verde River, within the Tonto National Forest in Yavapai and Gila Counties, Arizona was documented and analyzed. The study site, part of the northern leading edge of the Sonoran Desert, encompasses about 16,000 hectares and is located approximately 45 miles north-northeast of Phoenix. The area, extends roughly 28 river miles from the East Verde River in the north to Chalk Mountain in the south and is largely only accessible by foot, or by boat, and as a result was previously extremely under-collected. Over a three-year study period, from August, 2017 to May, 2020, 835 plant specimens were collected and identified, representing 360 species which, combined with earlier herbarium specimens collected by others, resulted in 427 plant species found in the study area. The plant diversity of this remote region reflects three distinct vegetation communities: upland Sonoran Desert, perennial riparian corridor, and semi-desert grasslands. Together, these communities act as an important transition zone between the Sonoran Desert and higher elevation habitats. Perennial streams are biodiversity hotspots within the study area. For example, the 400 hectares of Red Creek that falls within the study boundaries contain 28% of the total species. The study site contains several plants of conservation importance including 12 species endemic to Arizona, 22 vulnerable or imperiled species, five US Forest Service sensitive species, and one Federally Endangered species. In order to compare the diversity of the Lower Verde River Flora to nine other similar/related floras in Arizona, a species-area curve using five different models was generated. The resulting models showed the Lower Verde River flora to be very close to, although slightly below, the species-accumulation curve which may indicate that roughly 50-100 species may yet be added to the flora. This prediction seems realistic, as there were several locations that could not be collected due to remoteness and excessive heat.

DEDICATION

To Samantha, thank you for always believing in me, without your infinite love and support this would not have been possible; and to my family who fostered my curiosity, always encouraged my joy, and taught me to think outside of the box.

ACKNOWLEDGMENTS

Over the past three years I have been fortunate to have been surrounded by such a supportive and nurturing community and this flora would not have been possible without the help of faculty, researchers, mentors, volunteers and grad students that made up that community.

I would like to thank my graduate committee for all the hard work and long hours they put in to helping me with not only this thesis, but with teaching me to be a botanist. Thank you, Wendy Hodgson and Andrew Salywon for taking me on as a graduate student, and helping turn my love for *Agave* into a life-long passion for the plants of Arizona, the Sonoran Desert and the Southwest. Thank you, Kathleen Pigg for listening to my ideas and helping me synthesize them into articulate thoughts and observations.

Liz Makings without your passion for teaching your seemingly endless knowledge of the flora of Arizona, this flora would have never been possible. You helped me build a framework of taxonomic knowledge that I will continue to use for the rest of my life.

Thank you to the researchers at the Desert Botanical Garden, Shannon Fehlberg, Steve Blackwell, Joni Ward and Sarah Hunkins, the time you took out of your busy schedules to answer my questions and teach me was truly invaluable. Thank you also to Dawn Goldman and Cass Blodgett for, among other things, teaching basics about how to collect plants. Thank you also to all the DBG herbarium volunteers for mounting my specimens and teaching me what to look for to get a beautiful collection.

Thank you JP Solves, Alison Willis, and Zach Berry for your help collecting and for letting me bounce countless ideas off of you guys. You guys taught me so much.

This flora was conducted on land stolen from the Northeastern Yavapai and Western Apache, whose ancestors stewarded the flora of this region for millennia.

TABLE OF CONTENTS

CHAPTER Page

APPENDIX

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The work presented here is a floristic survey of a southern section of the Verde River in the Tonto National Forest, central Arizona, USA. Floras, such as this one, have been and continue to be the standard method for collecting and analyzing information about plants within a certain geographic area. Floras provide foundational information not only about plant taxonomy but also ecology, biogeography, biodiversity, and land use within the study area (Palmer et al., 1995). These data are vital to long-term conservation of natural areas, particularly within the southwestern U.S. The flora of the Southwest, until recent decades, has been understudied in many of the rugged and roadless areas, due in large part to lack of accessibility. The Verde River is no exception. The main material products of floristic studies are herbarium specimens, which are then deposited in herbaria to make them accessible to other scientists, land managers, non-governmental organizations, students and more. Today specimens themselves and their associated label data are usually further digitized and databased to be made available to the broader audience through online natural history portals such as the Southwestern Environmental Information Network (SEINet; http://swbiodiversity.org/seinet/).

This flora was conducted in the Tonto National Forest, along the Lower Verde River, in Yavapai and Gila counties, Arizona. The study site extends from its northern boundary at the confluence of the East Verde River, south to Horseshoe Reservoir and Chalk Mountain (Figure 1), a stretch of approximately 28 river miles that includes roughly one mile to each side of the river. In areas where tributary streams or large washes connected to the river, the study included two miles up each major tributary. The study area encompasses approximately 16,000 hectares. The fieldwork for this study was conducted from August, 2017 to May, 2020.

The northern and southern boundaries of the study were chosen in relation to earlier and ongoing floristic studies in order to create a contiguous stretch of documented river. The southern boundary of the study site abuts the study area of Joni Ward and Dawn Goldman who published the *Flora of Lime Creek* that lies to the south and west of Horseshoe Reservoir (Goldman and

Ward, 2010). Thus the area south of Chalk Mountain and the northeast shore of Horseshoe Reservoir made for a natural southern terminus. The canyon of the East Verde, a tributary to the Verde River, was chosen as the northern limit, as its steep cliffs act as a natural boundary between the Sonoran Desert to the south and the Central Highlands to the north (Fig. 2). Additionally, just north of the East Verde, Joni Ward, and other Desert Botanical Garden Herbarium (DES) staff and volunteers are working on a flora project of Fossil Creek (Joni Ward, personal communication, 2020). The Verde Valley, approximately 15 river miles upstream of this study's northern terminus, has been extensively studied over the years by scores of botanists and as a result is very well represented in the regional herbaria collections. Recently, Frankie Coburn found 729 taxa while conducting his *Flora of the Upper Verde*, thoroughly documenting the upstream reaches of the river (Coburn, 2015).

The area was also chosen because compared to the rest of the Verde River (based on available data in SEINet), relatively few collections had been made within it. Specifically, prior to this study, only about 200 collections have been made in the study area, with most of those specimens coming from the southernmost region. Relatively few plants have been collected in the northern part of the study area because of the inaccessibility of this section of the Verde River, as much of it is located within the roadless area of the Mazatzal Wilderness Area. The terrain of the study area is extremely rugged, with steep canyons, tall mesas and high mountains. Combined with previous and current studies of the Verde River Watershed, the current study will fill the last large blank spot on the botanical map of the Verde River.

CHAPTER 2

BACKGROUND

The Verde River runs in a southerly direction from where it originates in the southern part of the Colorado Plateau, through the central highlands, and into the Sonoran Desert. The Central Highlands of Arizona are the physiographic transition zone between the Colorado Plateau to the north and the Sonoran Desert to the south (Elston and Young, 1991). The Colorado Plateau is mostly higher elevation (>4000ft), with hot summers and cool winters, receiving the majority of precipitation in the winter months (Davey et al., 2006). The Sonoran Desert in the southern part of the state is primarily arid and low-lying (<2500ft) Basin and Range with hot summers and warm winters, which receives both winter rains and late summer monsoons. Although the Central Highlands are a physiographic transition zone, floristically they are part of the Central Arizona District of the Madrean Floristic Province that is influenced by the Chihuahuan Desert, the Sierra Madre Occidental, and the Sonoran Desert (McLaughlin, 1992). This flora is in an area that is basically an ecotone between the Central Arizona District and the Arizona Upland Sonoran Desert (McLaughlin, 1992).

The myriad of habitats that are mostly defined by the plant communities along the Lower Verde River are home to many species of wildlife. There is very little apparent direct human impact on the wildlife of the Lower Verde River because of the large, inaccessible tracts of federal land. The study area is the last stretch of the undammed portion of the Verde River. There are 16 federally listed species along the Lower Verde: eight species of fish including the Loach Minnow (*Tiaroga cobitis*), the Razorback Sucker (*Xyrauchen texanus*), the Spikedace (*Meda fulgida*), and the Headwater Chub (*Gila nigra*), five species of birds including the California Least Tern (*Sterna antillarum browni*), the Mexican Spotted Owl (*Strix occidentali lucida*), the Yellow-billed Cuckoo (*Coccyzus americanus*), the Southwestern Willow fFycatcher (*Empidonax traillii extimus*), and the Yuma Ridgways Rail (*Rallus obsoletus yumanensis*), and the Northern Mexican Gartersnake (*Thamnophis eques megalops*), the Chiricahua Leopard Frog (*Rana chiricahuensis*), and the

Grey Wolf (*Canis latrans;* https://ecos.fws.gov/ipac/). The Lower Verde is a stopover point for 24 federally listed species of migratory birds (https://ecos.fws.gov/ipac/).

Wildlife species observed during collection trips include Javalina (*Tayassu tajacu*), Desert Bighorn Sheep (*Ovis canadensis nelsoni),* the Southwest River Otter (*Lontra canadensis sonora*), Spotted Skunk (*Spilogale gracilis*), Hooded Skunk (*Mephitis macroura*), and Kit Fox (*Vulpes macrotis*). Tracks and scat from two individual Mountain Lions (*Felis concolor*) were found. Denning behavior from at least two family groups of Coyote (*Canis latrans*) was observed during the spring of 2019. Five individual Gila Monsters (*Heloderma suspectum*) were observed at different locations throughout the study area, and Western Diamondback Rattlesnake (*Crotalus atrox*) was common. A nesting pair of Bald Eagles (*Haliaeetus leucocephalus*) was observed during the spring of 2019 around the Mule Shoe Bend area of the study area.

The Verde River Watershed

The Verde River watershed drains approximately 1.7 million hectares and spans over 170 miles from the headwaters near Paulden, AZ to the confluence with the Salt River east of Phoenix. The river flows undammed for approximately 125 miles, nearly its entire length, until Horseshoe Reservoir - the first of two consecutive impoundments along the channel (Neary, 2012). The Verde River can be divided into three sections based on topographic, biotic and hydrologic features: Upper, Middle, and Lower (from north to south) (Coburn, 2015) (Fig. 1).

Gently sloping hills and a wide canyon/river corridor characterize the Upper Verde River from the headwaters near Paulden to Sycamore Canyon (Fig. 1). The Upper Verde River, including the headwater and its tributaries, drains roughly 900,000 hectares of the total 1.7 million of the entire watershed. The Upper Verde is likely the most biodiverse area within the watershed, as the habitats within this area range from the alpine tundra of the San Francisco Peaks to desert scrub of the Mogollon Rim (Coburn, 2015).

The Middle Verde extends from Sycamore Canyon to just north of Fossil Creek and drains an area of roughly 390,000 hectares, approximately half that of the Upper Verde (Fig. 1). The Middle Verde largely encompasses the broad Verde Valley, which was once an ancient lakebed, and supports a flora that is a distinct mix of cold tolerant Sonoran Desert species and Mogollon Rim species.

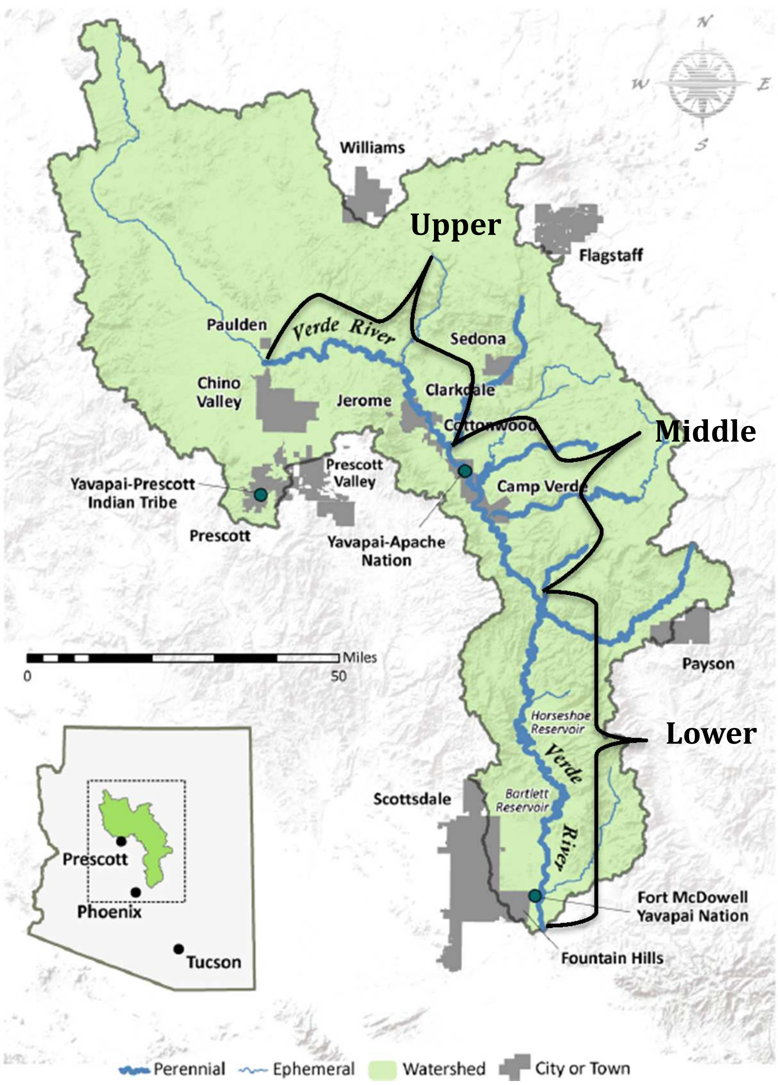


Figure 1. A map of the of the Verde River watershed, showing the Upper, Middle and Lower sections. Redrawn from Friends of the Verde River (verderiver.org).

The Lower Verde River begins below the Verde Valley, just southwest of Camp Verde, and continues south until it reaches the Salt River, extending for approximately 100 miles. Despite being the longest of the three sections, the Lower Verde River, like the Middle Verde, also drains an area of roughly 415,000 hectares, nearly half of the area of the Upper Verde. The water in the Lower Verde is fast moving and flows through a much narrower channel compared with the other two sections upstream. The Lower Verde River is largely fed by upstream input rather than by the local watershed, except during rain events, when its many side canyons and perennial streams drain the basin it cuts through.

Geography

The Central Highlands of Arizona, which run in a northwest-to-southeasterly direction into central-western New Mexico, is categorized by high mountains, such as the Mazatzal and Bradshaw Mountain ranges that are separated by deeply incised canyons, as well as large broad valleys, such as the Verde Valley and Tonto Basin (Nations and Stump, 1983). The Verde River cuts to the west of the Mazatzal Mountains and runs east of Bloody Basin and the New River Mountains (Chronic, 1994).

To the east of the Lower Verde River lie the foothills of the Mazatzal Mountains, which are comprised of a tableland of buttes roughly 2800-5500 feet above sea level that are separated by deep V-shaped canyons about 700-1200 feet deep. There are five perennially flowing streams that cut through these canyons, spaced at fairly regular intervals: East Verde, Canyon Creek, Wet Bottom Creek, Sycamore Creek and Deadman Creek (Fig. 2).

On the western side of, and parallel to, the Lower Verde River there is a steep granitic ridge that runs almost the full length of the study area - from 4700 feet near Squaw Peak at the north to 3000 ft at Tangle Creek in the south (Fig. 2). This ridge is the steepest topographical relief occurring in the study area. To the west of the granitic ridge is Bloody Basin, an area of approximately 40,000 acres. Due to the height and erosion resistance of this ridge, Bloody Basin is drained entirely by Red Creek and Tangle Creek, which are the sole perennially flowing waterways on the western side of the river in the study area. The low point in the study area is around 2200 feet above sea level and the high point is 4700 feet, though the majority of the study site sits below 3800 feet.

Geology

The Lower Verde River cuts through the Central Highlands and exposes the geologic transition zone between the Colorado Plateau and the Basin and Range of southern Arizona. Four geological horizons are exposed along this stretch of river, from oldest to youngest: Precambrian granite, Paleozoic limestone, Miocene/Pliocene basalt, and Pleistocene sedimentary rocks (Pearthree, 1993). The Paleozoic limestone outcrops are edaphic soils that harbor several Forest Service sensitive species (Anderson, 1996).

Precambrian granite, formed 1.5 billion years ago, is the oldest and most common rock type in the study area, having formed during a massive, Himalayan-scale orogeny event. To the west of the river, many of the hills, as well as the gravel and desert pavement are also largely composed of this pink feldspar-rich Precambrian granite (Pearthree, 1993).

The next oldest deposits in the study area are Paleozoic limestones that were deposited in a shallow marine environment between 400 and 240 MYA. They are found at Chalk Mountain, Lime Creek and other limestone outcrops around Horseshoe Reservoir (Pearthree, 1993).

During the middle Miocene to early Pliocene, 15 to 10 MYA, the region experienced a period of increased volcanic activity. Basalt flows covered large areas of the Central Highlands, including much of the study area, to the east of the river (Nations and Stump, 1983). The resulting basaltic bedrock has become deeply incised by subsequent erosion, which is evidenced by the tablelands found east of the river, including Mule Shoe Bend, Wet Bottom Mesa, and Racetrack Mesa (Pearthree, 1983).

Throughout the study site and adjacent to the river are a series of late Pliocene to late Pleistocene terraces and alluvial fans deposited over the past 4 million years. Within the study site, these terraces are no more than 200 meters wide, largely due to the steep, basalt canyon walls. Wider terraces occur south of Dry Wash, in the southern quarter of the study area, as the canyon widens. The lowest of these terraces are the most recent, having been deposited sometime in the last 10,000 years (Pearthree, 1983).

The Lower Verde River contains two distinct geomorphological sections. The study area is located in the first section, characterized by its steep, V-shaped canyon walls, stretches from Fossil Creek to the start of Bartlett Reservoir, while the second extends from Bartlett Reservoir to the confluence with the Salt River. Situated within a broad valley, the flora here is characterized by primarily Sonoran Desert species, with strong influences from the higher elevation habitats that surround the valley. As the Verde River reaches Bartlett Reservoir, the terrain gives way to low, undulating hills, and the river meanders until the confluence with the Salt River. Here the flora is primarily Sonoran Desert scrub.

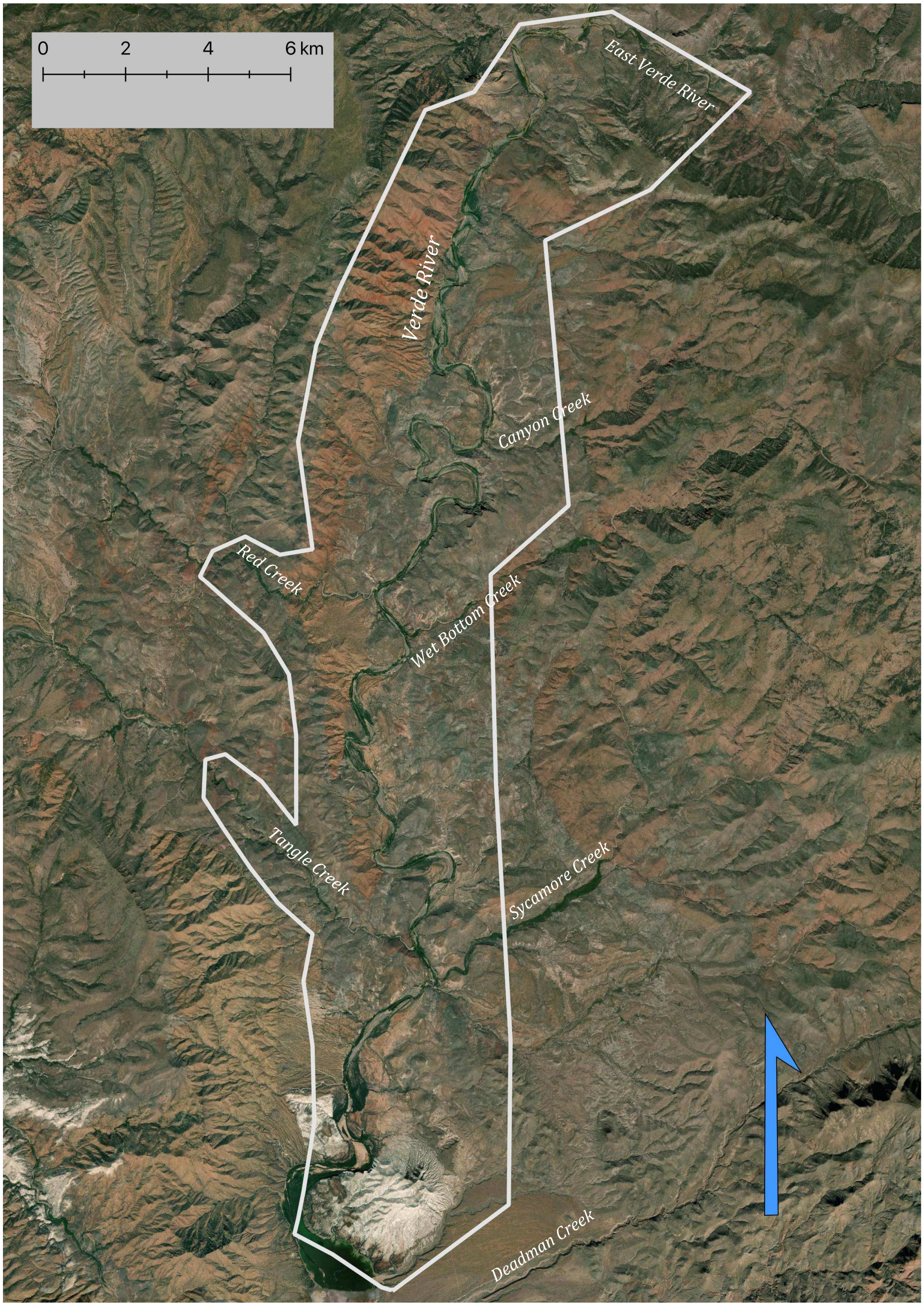


Figure 2. The study area along the Lower Verde River, showing the seven perennial tributaries. The study area extends from Chalk Mountain, north to the East Verde River.

Hydrology

The Lower Verde River has a yearly average flow rate of 397 cubic feet per second (cfs), with peak and low flows that can fluctuate greatly (National Water Information System, 2020). During the summer monsoon season the base flow varies between 100 and 300 cfs, while storm events can contribute to flows of up to 4,000 cfs depending on the severity, duration and distance from the river channel (USGS, 2020). Winter and spring flows fed by thawing snow at higher elevations of the watershed, coupled with winter rains (at lower elevation), contribute to higher base flow, between 700 and 1400 cfs. Winter and spring storms or sudden thaws can swell the flow to over 30,000 cfs. The lowest water level during the study period was 40 cfs and the highest water level was 27,000 cfs (Fig. 3).

Within the study area, six perennially flowing tributaries feed into the Verde River: the East Verde River, Red Creek, Wet Bottom Creek, Sycamore Creek, Tangle Creek, and Deadman Creek (Fig. 2). The East Verde River enters the Verde River on the northeastern boundary of the study site and is the largest of the tributaries within the study area, draining an estimated ~330 mi^2 area. The study area drains roughly 350 mi^2 between the East Verde and Horseshoe Reservoir. Red Creek and Tangle Creek drain the majority of Bloody Basin to the west of the river. Canyon Creek, Wet Bottom Creek, Sycamore Creek and Deadman Creek are perennially flowing streams that drain the area to the east of the river. Of these perennially flowing tributaries, Wet Bottom Creek is the only one in the study site, besides the East Verde River, to have a USGS stream gauge. Nevertheless all of these streams are both in close proximity and similar to one another in size, climate, and topography, and follow very similar trends and patterns, draining areas with very similar topographically. The highest flow rate for Wet Bottom Creek during the study period was ca. 1500 cfs. Average flow in these streams is typically less than 5cfs, and flood events occur during both winter and summer rains, and vary from year to year (Fig. 3).

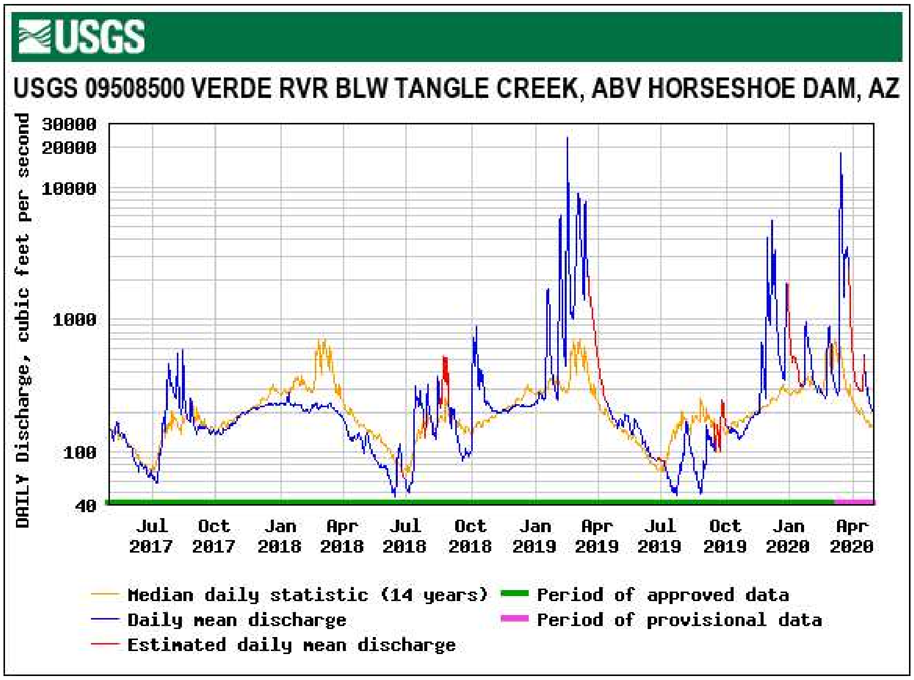


Figure 3. Flow rate of the Verde River below Tangle Creek and above Horseshoe Dam during the study period (National Water Information System, 2020a).

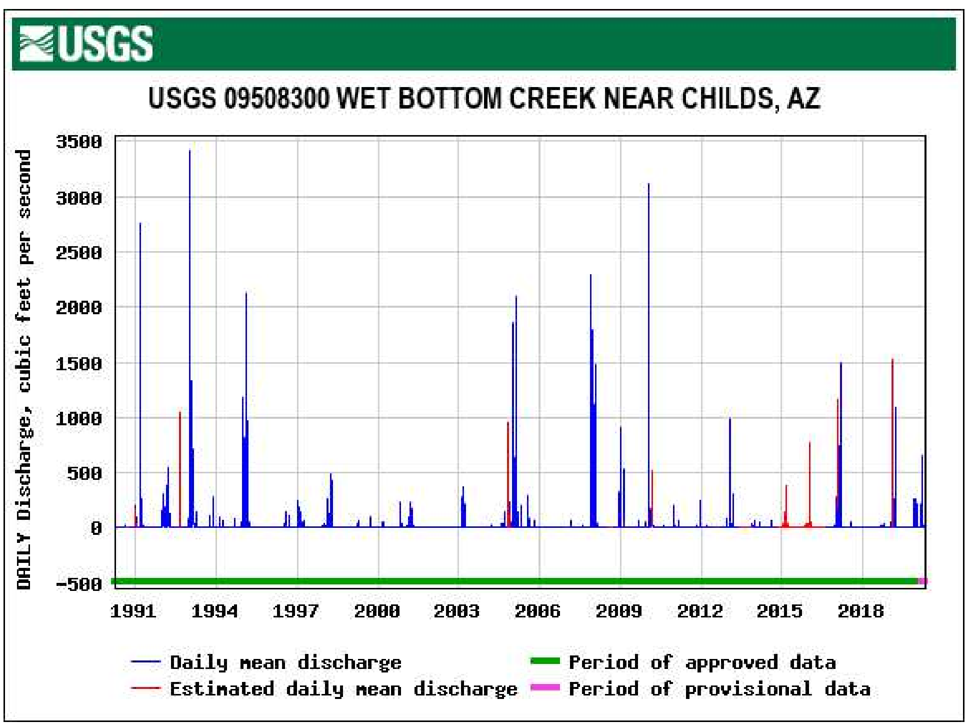


Figure 4. Flow rate of Wet Bottom Creek from 1991-2018. As the only perennial stream whose flow is monitored, Wet Bottom can be used to understand the flow of the other perennial streams in the Lower Verde River Watershed, as they drain similar areas (National Water Information System, 2020b).

Climate

The study area, located at the northern end of the Lower Verde, has a climate very similar to the rest of the semi-arid Upland Sonoran Desertscrub with bimodal winter/summer rainfall regime and hot summer temperatures. However, compared to typical Sonoran Desert, the region is unique in its higher elevations which results in colder winter temperatures, where nights regularly fall below freezing for several weeks in the winter.

The hottest months are June, July and August, when average maximum temperatures reach 101.2^0F, 105^0F, and 102.6^0F, respectively (Table 1). The coolest months are December and January with average minimum temperatures of 41.8^0 F and 40.3^0F, respectively.

Table 1. Average maximum and minimum temperatures at Bartlett Dam from 1939-2016. Though not in the study site, Bartlett Dam has the closest weather station, and can be used as a benchmark for the study area. (Western Regional Climate Center, 2020)

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Avg. Max. Temp. (^{0} F)	65.1	69.3	73.2	82.0	91.2	101.2	105.0	102.6	98.3	87.8	74.8	66.5
Avg. Min. Temp. (^{0} F)	40.3	42.6	45.6	51.8	59.3	67.7	75.5	74.5	69.6	59.3	47.7	41.8

Precipitation along the Lower Verde River typically occurs mostly during the late winter and spring from November to March and summer months from July-September, with an average of 14.23 inches of rainfall per year. Winter rains are typically derived from widespread storm systems originating in the Pacific Ocean. While winter rains can start as early as November, and continue into March and April, most rainfall occurs primarily in December through February.

Summer rains are typically violent, localized monsoons driven by moisture-laden winds sweeping northwest from the Gulf of Mexico (NOAA, 2020). The study period followed this trend with the majority of the rainfall occurring during the winter months, and July/August (Fig. 5). The driest months were April, May, and June.

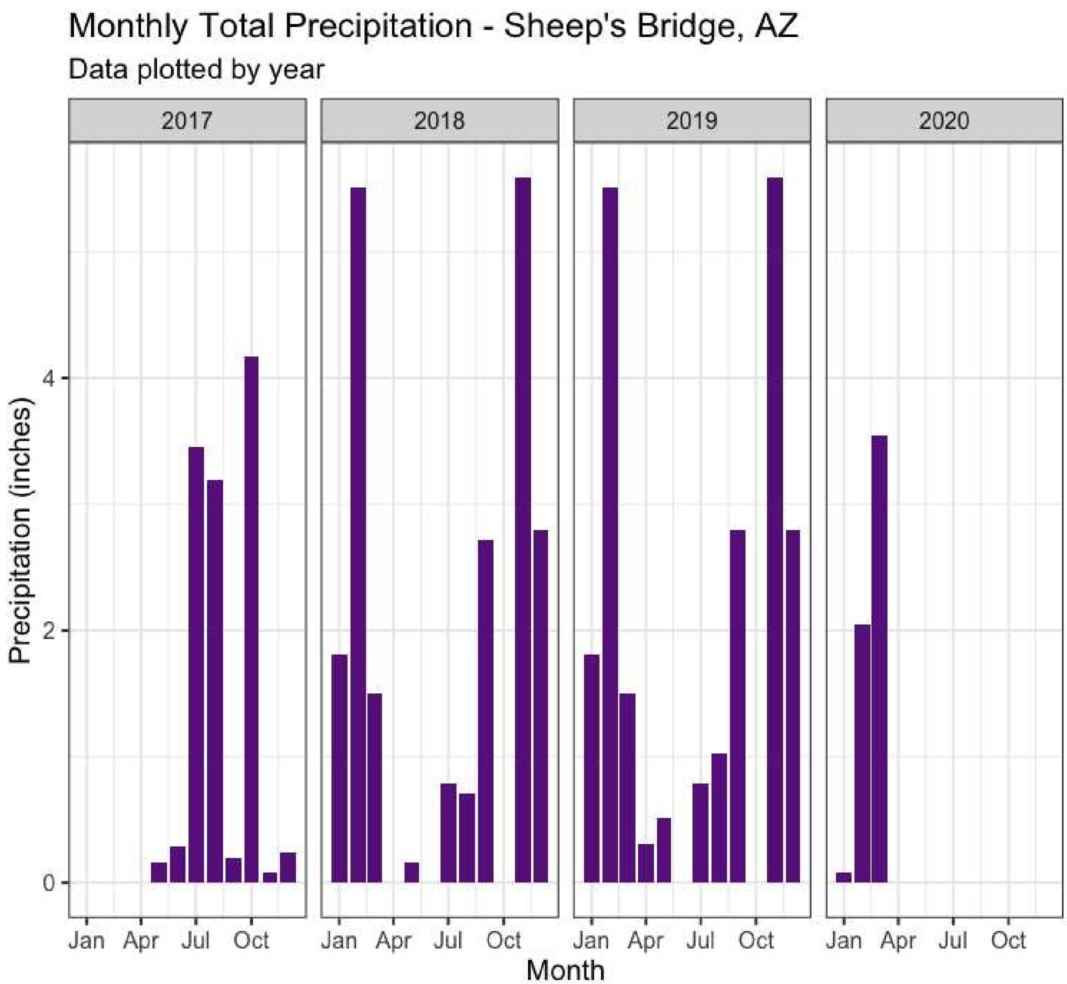


Figure 5. Monthly precipitation totals at Sheep's Bridge, Arizona from April 2017 to March 2020. (Redrawn from Abatzoglou, in press)

The rugged and varying topography of the study area creates numerous microclimates, with slope and aspect important factors driving the diversity of the many biotic communities. The higher elevations of the tablelands east of the river provide cooler nighttime temperatures, while the deeply incised canyons provide cooler daytime temperatures. The rainshadow effect creates relatively uniform precipitation regimes within the Lower Verde basin, but actual rainfall amounts can vary significantly, particularly with monsoons (Rivera et al., 2014).

Four USGS River Gaging stations, two along the Verde, one on the East Verde and one on Wet Bottom Creek, provide the only climatic data within the actual study area. Approximate temperatures and rainfall were obtained for the study area (Fig. 6) using data from Oregon State University's PRISM (Parameter-elevation Regression on Independent Slopes Model (Abatzoglou, in press).

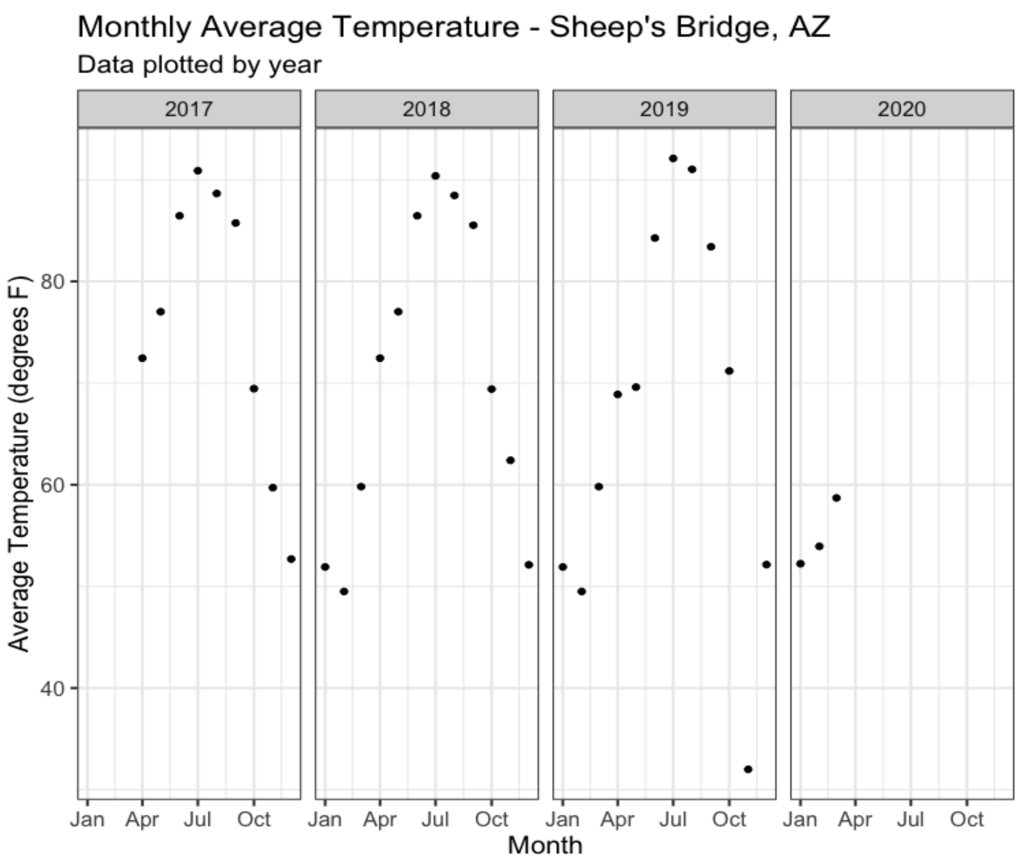


Figure 6. Monthly average temperature at Sheep's Bridge, Arizona from March 2017- April 2020 estimated from PRISM data (Abatzoglou, in press).

Pre-contact history

The Lower Verde River, like many other watercourses in the Southwest, has supported humans for thousands of years. The limited evidence of human presence along the Lower Verde River earlier than 3000 years BP consists of a single projectile point in the vicinity of Horseshoe Reservoir and many lithic scatters throughout the study area (Ciolek-Torrello, 1997). The low frequency of these Late Archaic sites, dating from approximately 5000 YBP to 3000 YBP, seem to indicate that the Lower Verde River was used intermittently for resource-procurement and plant-processing (Ciolek-Torrello, 1997). From 3000 to 1350 YBP habitation patterns along the Lower Verde were either temporary or bi-seasonal, with villages dispersing for the summer months to smaller farms in the outlying areas (Ciolek-Torrello, 1997).

Along the Lower Verde River the Hohokam were the first group with permanent human settlements. The earliest evidence of Hohokam settlements is pottery and dwellings dating from 1350-1300 YBP (Ciolek-Torrello, 1997). The Hohokam were an agricultural society that ranged from the Phoenix Basin and Verde River east to Tonto Basin, south to the Tucson Basin and along the San Pedro River and to what is now Sonora, Mexico (Ciolek-Torrello, 1997). The Hohokam were master engineers and were known for their intricate canal systems. There are examples of three Hohokam canals around the Horseshoe Reservoir area, as well as one of only two known prehistoric aqueducts in the state of Arizona (Van West and Altschul, 1997). Around 900 YBP, the Central Arizona Tradition developed in the Verde Valley to the north and was a society with influences from the Hohokam in the south and the Hopi and Kayenta Anasazi in the north (Wilcox, 2014).

Over the next 200 years the Central Arizona Tradition spread southward to the Verde River, the Agua Fria River, Bloody Basin and Perry Mesa and developed into the Sinagua Culture (Wilcox, 2014). The settlement patterns of the Central Highlands seems to indicate increased conflict, as settlements began to concentrate at the tops of easily defendable hills and mesas, with agricultural land on the floodplains below (Wilcox, 2014). Evidence indicated that both the Sinagua and the Hohokam societies likely began to rapidly depopulate these long established communities around 600 YBP.

From 1350-600 YBP the primary crops grown along the Lower Verde were maize, beans, squash, cotton and likely agave. *Hordeum pusillum, Cylindropuntia* sp., *Amaranthus sp., Chenopodium sp.,* and *Yucca* grew wild, cultivated, or semi-domesticated and were used as important food plants (Van West and Altschul, 1997). Farming practices of the Hohokam consisted of at least two strategies. Along the floodplains, canal systems and groundwater channeling were used to irrigate the more water-intensive crops such as maize, squash and beans, while terraces and various rock features were built on surrounding bajadas, in order to retain ground moisture for more drought-tolerant plants such as *Agave*, *Prosopis, Celtis* and various species of *Opuntia* and *Cylindropuntia* (Van West and Altschul, 1997).

From 600 YBP to 100 YBP, it is believed that primarily the Northeastern Yavapai and to a lesser extent the Western Apache, both semi-nomadic peoples, used the study area intermittently for seasonal food gathering (Whittlesey, et al., 1997). The Yavapai and Western Apache are culturally and linguistically distinct, and although archeologists are unable to differentiate between artifacts produced by them, early oral accounts have been used to determine land use within the study area (Ferg and Tessman, 1997). Unlike the Northeastern Yavapai, there is little known about Western Apache land use within the study area, aside from the occasional reference. The Northeastern Yavapai primarily relied on the use of wild foods for their diet, including cactus fruits, cholla joints and buds, acorns, pinon seeds, mesquite pods, and most importantly *Agave.* Roasted *Agave* seems to have been a staple food, and was communally pit-roasted and then pounded to a pulp before being dried for long term preservation (Gifford, 1936; Whittlesey and Benaron, 1997; Hodgson, 2001). The Northeastern Yavapai also cultivated maize, pumpkins and tobacco, and would plant the maize along a stream or spring and return only when it was ready to harvest. Prior to European settlement in the area for cattle and sheep ranching, there were several reported massacres of both Yavapai and Western Apache by white settlers that occurred in the areas surrounding the study site (Ferg and Tessman, 1997).

Historical land uses

Historically, the study area has been used for both sheep and cattle grazing. While cattle are currently the only livestock currently grazing in parts of the study area, sheep grazing has predominated in the past (Doyle, 1987). Starting in the 1870s and continuing into the early 1980s, sheepherders brought their flocks down from their summer pastures in the San Francisco Mountains and the Mogollon Rim to overwinter in this river valley. In what was considered a conservation measure during the establishment of the National Forests in 1905, President Theodore Roosevelt created permitted grazing allotments within the newly created public lands (Doyle, 1987). While these grazing allotments were practical for ranchers, as cattle can be left to graze year round, allotments posed issues for the sheep men, who needed to move their herds from summer to winter pastures. This resulted in the formation of sheep driveways - lanes that allowed herders to move their sheep though cattle country from their summer to winter ranges without encroaching on the cattlemen's allotment (Doyle, 1987). In 1926 Tonto National Forest redrew their allotment boundaries, largely due to overgrazing, resulting in the three allotments along the Lower Verde River that are still currently in use: Chalk Mountain, Red Hill and Pete's Cabin Mesa. In order to access the Chalk Mountain and Pete's Cabin Mesa allotments, sheepherders had to bring their flocks east across the river in the fall and back west across the river in the spring (Doyle, 1987). The crossing, especially in the spring, resulted in sheep being swept away by the strong river currents. In order to mitigate loss and increase the safety for the herders, a large suspension bridge was built in the 1940s approximately four miles north of Chalk Mountain. The bridge was rebuilt in the 1980s and remains in use to this day.

The Chalk Mountain and Pete's Cabin Mesa allotments, though still technically active, do not appear to be currently used for grazing cattle. Cattle were observed by the author grazing within the Red Hill allotment, specifically along Red Creek during all three years of the study. The allotment appeared to be overgrazed, likely due to the presence of a perennial water source for the cattle. Algal blooms were observed downstream of these areas, a sign of eutrophication, likely due to elevated levels of nitrogen and phosphorus from an abundance of cow excrement urine. Cattle were also observed illegally grazing along the Verde River outside of the Pete's Cabin Mesa allotment, but within the designated Wild and Scenic Verde River boundaries. This illegal grazing was observed in the Spring of 2018 and Spring of 2019 and was reported to land managers at Tonto National Forest.

An example of the effects of this historical grazing that can still be seen is on the alluvial bajadas north of Chalk Mountain. Signs of cattle grazing that occurred into the early 2000s can be seen here in the form of disturbed soils that still bear the deep imprints of cow hooves These bajadas are dominated by densely growing non-native grasses such as red brome (*Brumus rubens*) and *Schismus* spp. amongst widely spaced creosote, and little else.

Conservation Efforts

A large portion of the Lower Verde, extending from south of Camp Verde to Horseshoe Reservoir, is a designated a "Wild and Scenic River" for its outstanding natural, cultural, and recreational values in a free-flowing condition, with dams constructed only in its lower section (National Wild and Scenic Rivers System, Accessed 2020). The study area also contains large tracts of the Mazatzal Wilderness Area, which is federally protected. The Verde River is also of conservation concern to the Tonto National Forest, as it has several Forest Service sensitive plant species.

The three main conservation threats to the study area are climate change, fire and cattle grazing. Climate change is predicted to accelerate in the Southwest, with warmer, wetter winters and hotter, drier summers (Huxman, 2013). These climatic changes may influence plant (and animal) species distributions, whether negatively or positively in this transitional area, although exactly how is unknown (Raferty et al, 2016). The collections made for this flora could be of use now as references for predictive models of how habitats are affected by climate change, and could also act as future references to gauge how habitats have changed. For example, *Canotia holacantha*, a species associated with higher elevations of the Sonoran Desert, could see an increase in its range as higher elevation areas supporting grasslands and chaparral become hotter and drier. Conversely, *Agave chrysantha,* a primarily Semi-Arid Grassland species, could see its range decrease for the same reasons. By studying the northern leading edge of the Sonoran Desert scientists can start to gain an understanding of how species and habitats will react and shift in the face of climate change. Arizona Upland Sonoran Desert, the primary habitat type within the study area, is not a fire-adapted ecosystem, although the two other habitat types that surround the study area (Interior Chaparral and Semi-Desert Grassland) are fire-adapted. Sonoran Desert Scrub does not have the fuel density needed to promote and carry naturally occurring fires, and as a result most are small (less than 10 acres) and of a low enough intensity that perennial species are able to survive (Lata, 2019). The lack of fuel is due to both ample space between trees and shrubs, as well as the lower density of annual wildflowers that fill that intershrub space (Horn et al, 2015; McDonald and McPherson, 2010).

CHAPTER 3

METHODS

The present study had two primary goals. The first goal was to collect and identify specimen of vascular plants within the Lower Verde River Watershed. The second goal was to compare the diversity of the Lower Verde River Flora to nin other similar/related floras in Arizona with a species-area curve using five different models.

The first primary goal of this study was to collect specimens of all vascular plant species within the study area to produce an annotated and vouchered checklist for the Lower Verde River (Table 2). The field portion of this study was conducted from August 2017 to March 2019. During this time, I spent approximately 36 days working at the study site, with 8 visits occurring during and after the summer monsoons and months from August through October, and 6 visits occurring during the spring rains and subsequent months from February-June. Because the area is remote and mostly a wilderness area, there are only two main vehicle access points into the area. Therefore, collecting trips lasted an average of 3 days and had to be planned ahead of time to maximize distance traveled on foot, as well as to ensure that there was always access to water at least once per day.

I endeavored to make collections within each significant different plant community or geological substrate within an area. In order to plan trips I used satellite imagery, geologic and topographic maps, as well as on-ground visual scanning. Each area was then searched on foot, for up to 2 hours, for any flowering or fruiting plants. At each collection site the location, GPS coordinates, elevation, habitat type, geomorphic landform, slope, amount of shade, associated taxa, and soil type were recorded in my field notebook and assigned to the taxa collected in that area. The following features were recorded for each individual plant collected: abundance, growth form, size, flower color, and any other distinctive characteristics. Collected plants were immediately pressed in a field press and transferred to a standard drying press upon return to the Desert Botanical Garden. Whenever possible, at least two specimens of each taxon at a collection site were collected and the vouchers were deposited in the Desert Botanical Garden Herbarium (DES) and the Arizona State University Vascular Plant Herbarium (ASU). Duplicates will be sent to the U.S. National Arboretum Herbarium (US).

Table 2. Date and duration of collecting trips to the Lower Verde River for this study.

Date	**Duration (days)**	**Collections made**	**Sites collected**
2017			
August 20	1	4	1
September 9	2	47	9
September 16	2	123	11
2018			
February 18	2	10	2
March 2	8	104	22
July 30	4	73	14
August 13	2	30	8
August 28	2	51	11
September 18	2	61	6
October 4*	1	5	1
2019			
March 3	3	88	8
March 17	3	109	6
April 21	2	74	6
April 26	2	46	7
TOTALS			
14 trips	**36 collecting days**	**825 collections**	**112 sites**

The primary sources I used to identify plant specimens were volumes of *Flora of North America* (www.fna.org) and *Arizona Flora* (Kearney and Peebles, 1960), along with available treatments from the *Vascular Plants of Arizona* Project (http://www.canotia.org/vpa_project.html).

Herbarium specimens at both DES and ASU were used as references when confirming identification and identifying unknown taxa. When available, the species descriptions in SEINet (http://swbiodiversity.org/portal/index.php) were also used as an identification reference.
Flora of North America and Tropicos (tropicos.org) were the primary sources used for updated taxonomic nomenclature. The Angiosperm Phylogeny Group IV system of classification (Stevens, 2001 onwards, accessed June 2020) was used for the most up-to-date family classification.
In order to supplement my collections I examined and verified identifications of all collections made by other individuals within the study site deposited at DES and ASU. I also queried the SEINet to find other collections in the study area that have been databased and uploaded by other institutions.

Taxa were compiled into a checklist ranked alphabetically, by family, genus, species, subspecies/variety(if present) and author, and annotated with: frequency (widespread, frequent, local, rare), abundance when present (abundant, common, rare). Duration (perennial, annual, biennial), and life form (tree, shrub, succulent, forb, ephemeral) were assigned using data from USDA Plants Database (plants.usda.gov). Taxa were assigned Native/Non-Native Status using USDA Plants, and wetland status using the US Army Corps of Engineers Wetland Indicator List (U.S. Army Corps of Engineers, 2018) Taxa endemic to Arizona were noted using data from the Arizona Natural Heritage Programs Heritage Data Management System and our Endemic Plant report? (Hodgson et al,. 2013).

Conservation status was given using the list of Threatened and Endangered species from the U.S. Fish and Wildlife Service (https://www.fws.gov/endangered/, Accessed June 2020), the Tonto National Forest Sensitive Species List (https://www.fs.usda.gov/detail/tonto/landmanagement/resourcemanagement/?cid=fsbdev3_018778, Accessed June 2020), and the Arizona Natural Heritage Program Heritage Data Management System (https://www.azgfd.com/wildlife/heritagefund/, Accessed June 2020). Vegetation community types were determined by comparing Brown and Lowe's Biotic Communities of the Southwest (1982) to associated taxa lists, habitat notes and observations in the field.

The Oregon State University's Parameter-elevation Regressions on Independent Slopes (PRISM) model was used for average temperature and rainfall figures within the study site. Data for the average monthly maximum and minimum temperature from 1939 to 2012 at Bartlett Dam were compiled by the National Oceonographic and Atmospheric Administrations National Climatic Data Center. Stream flow and water level data were taken from the U.S. Geological Survey National Water Information System.

In order to test the hypothesis that the Lower Verde River flora would be comparable in diversity to other similar floras of but of different total areas, a species-area curve was generated. Species-area curves are used to examine the diversity of ecological regions, given varying area sizes. Several floras of the northern Sonoran Desert were chosen for comparison with the Lower Verde Flora on the basis of their similar elevations and latitude. *The Flora of Seven Springs* (Doan, 2002) was chosen as a perennial riparian area in central Arizona, with a mix of Sonoran Desert and higher elevation ecosystem influences. *The Flora of the San Pedro River* (Makings, 2005) and the *Flora of the Eagletail Mountains* (Newton, 2013) were chosen to represent a southern Arizona riparian zone and an area with no riparian area, respectively. Three floras, *The Vascular Flora of the Spur Cross Ranch Conservation Area* (Hunskins and Smith, 2013), *The Vegetation and Flora of the McDowell Sonoran Preserve* (Jones and Hull, 2014), and *The Flora of Lime Creek* (Goldman and Ward, 2010) were chosen to represent primarily Upland Sonoran Desert habitats. *The Flora of the Upper Verde River* (Coburn, 2015) was chosen, as it is upstream of this study site. *The Flora of the Sierra Estrella Mountains Regional Park* (Sundell, 1974) and *The Flora of the South Mountains* (Daniel et al., 1992) were chosen to represent lower Sonoran Desert mountain ranges to the south of the study area. In order to construct a Species-Area Curve the number of species for each flora was obtained from SEINet. Analysis was conducted in R with the vegan package using a modified version of open source code created by Jari Oksanen (Oksanen, 2019; See Appendix B).

CHAPTER 4

RESULTS

Field collections in the Lower Verde study area produced a total of 835 collections representing 347 species (360 taxa). An herbarium search revealed an additional 103 species with nine infraspecific taxa and two infraspecific hybrid species. The total number of species, including prior collections, was 427, with 21 infraspecific taxa, and 2 hybrids, bringing the total number of taxa to 450 (Appendix A).

The most species-rich families in the flora are Asteraceae (68 spp., 15% of the flora), Poaceae (47 spp., 10%), and Fabaceae (40 spp., 9%) (Fig. 7). Other important families, in order of number of taxa collected, include Boraginaceae, Brassicaceae, Cactaceae, Euphorbiaceae and Solanaceae. Together these 8 families comprise 52% of the flora. Of the 258 genera found within the flora, the five most frequently represented are *Euphorbia* (11 spp.), *Eriogonum* (8 spp.), *Aristida* (7 spp.), *Phacelia* (7 spp.), and *Astragalus* (6 spp.).

Perennials comprise 58% of the flora's taxa with 261 species and annuals comprise 39% with 175 spp. (Fig. 8). The predominant growth forms are forbs (225 spp., 50% of the flora), shrubs (67 spp.,15%) and graminoids (57 spp., 13%). Notably 21 taxa (5%) are succulent, including 15 taxa in the family Cactaceae, five taxa (Agavaceae), and *Dudleya saxosa* ssp. *collomiae* (Crassulaceae).

One hundred and fifteen taxa associated with wetland habitats occur within the study area. Of these, 17 are obligate wetland (15 native, two non-native), 21 facultative wetland (18 native, three non-native), 22 are facultative (19 native, 3 non-native), and 55 facultative upland taxa (44 native, 11 non-native) (Fig. 9). These taxa, found in the riparian areas along the Verde and the perennial streams and annual dry washes, comprise 26% of the total flora. Of the 414 native taxa (Table 3), 96 (23%) are associated with wetland habitats (Fig. 10).

The 36 non-native taxa account for 8% of the flora. Of these, annuals account a little over half (20 of 36, or 55%) of non-native taxa (Fig. 11). Non-native species in the flora are primarily forbs (20 spp.) and graminoids (14 spp.) (Fig. 12). All of the non-native graminoids are in the family Poaceae and make up 29% of the family within the flora. Nineteen of the 36 non-native species (53%) are associated with wetland habitats (Fig. 10).

Four of the five species-area curve models, Arrhenius, Gleason, Gitay and Michaelis-Menten, showed that this flora had been slightly under collected. The log-log linear model showed the flora had the expected number of species given the area (Figure 13).

Table 3. Taxonomic examination of the Flora of the Lower Verde River, the left two columns giving a breakdown of the taxa, and the right three giving a breakdown of native/non-native status, endemism, and conservation status.

Taxonomic Rank	#		Special Status Plants	# Taxa	% Total Flora
Families	78		Native	414	92
Genera	258		Non-Native	36	8
Species	427		Arizona Endemics	12	3
Infraspecific Taxa	21		Forest Service Sensitive	5	1
Hybrids	2		Arizona Natural Heritage Program List	52	12
Total Taxa	450		Federally Threatened or Endangered	1	<1

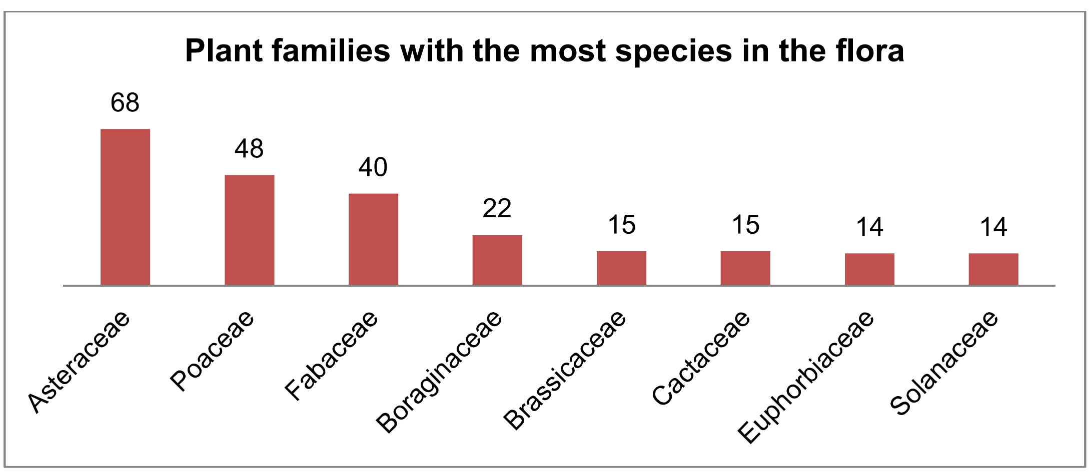
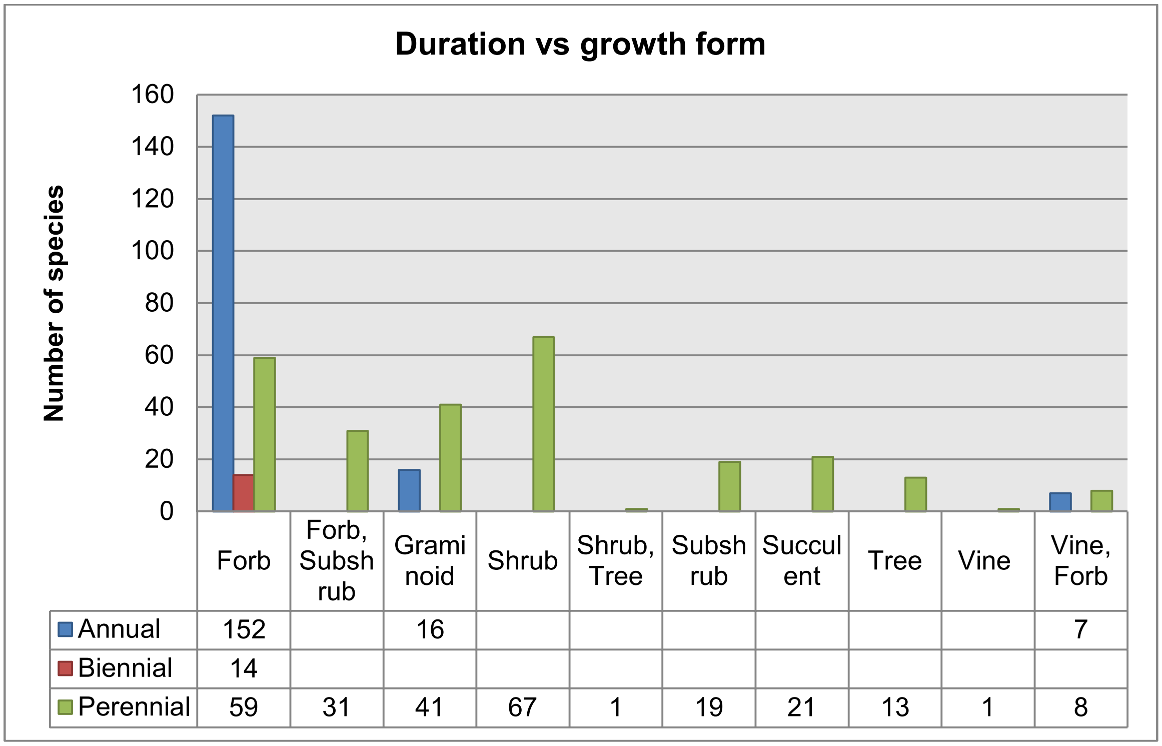


Figure 7. Most species rich families in the Flora of the Lower Verde River. These eight families contain 52% of the flora's total species.



	Forb	Forb, Subshrub	Graminoid	Shrub	Shrub, Tree	Subshrub	Succulent	Tree	Vine	Vine, Forb
Annual	152		16							7
Biennial	14									
Perennial	59	31	41	67	1	19	21	13	1	8

Figure 8. Comparison of duration and growth form of plants within the Flora of the Lower Verde River. Both annuals and forbs are the most common life-forms and together contain the highest biodiversity of any group.

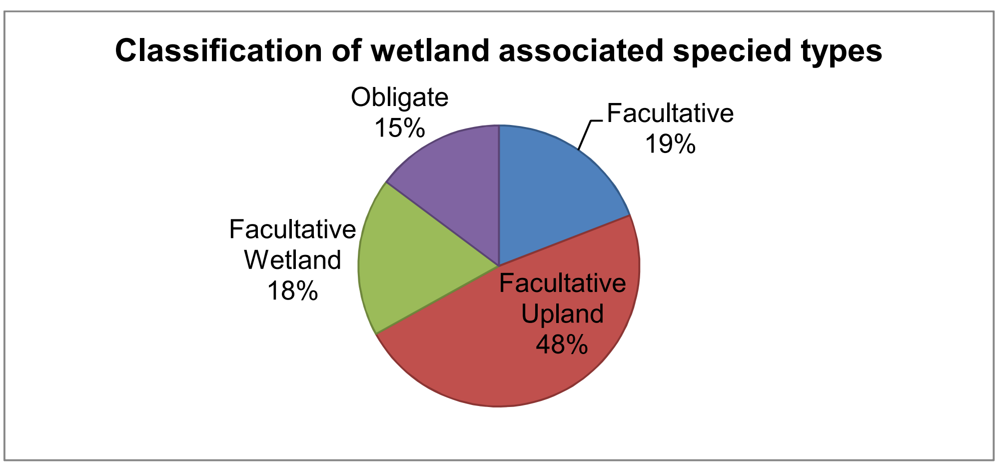
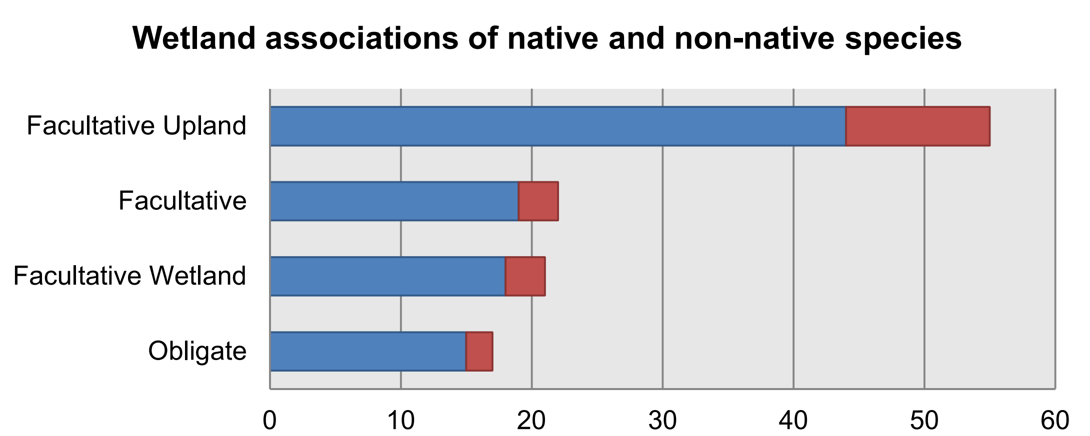


Figure 9. The Flora of the Lower Verde River contains 115 Wetland Associated species. The majority of these species (48%) are facultative upland.



	Obligate	Facultative Wetland	Facultative	Facultative Upland
Native	15	18	19	44
Non-Native	2	3	3	11

Figure 10. A comparison of the percentage of native versus non-native and wetland or uplant status. 53% of non-native species in this flora are associated with wetland habitats compared to 23% of native species.

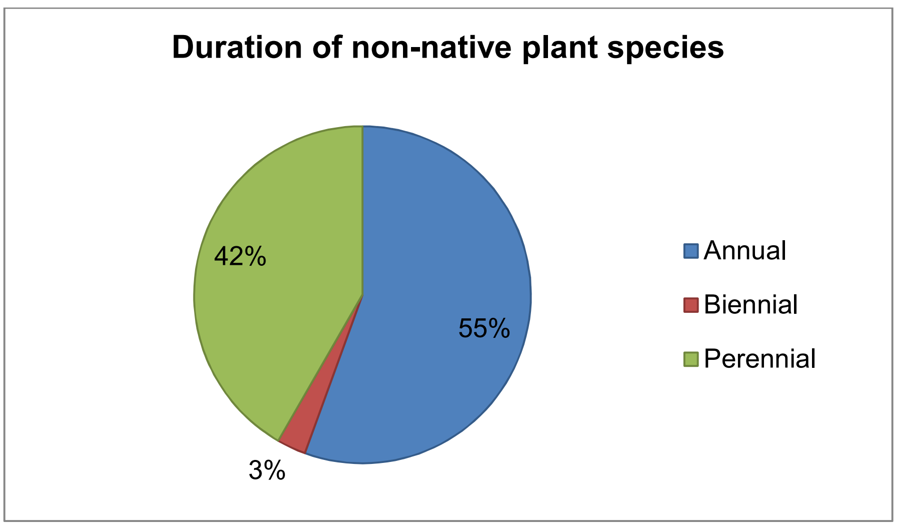


Figure 11. The percent of annual, biennial and perennial species in the flora. Annual species make up the majority of the non-native species in the flora of the Lower Verde River.

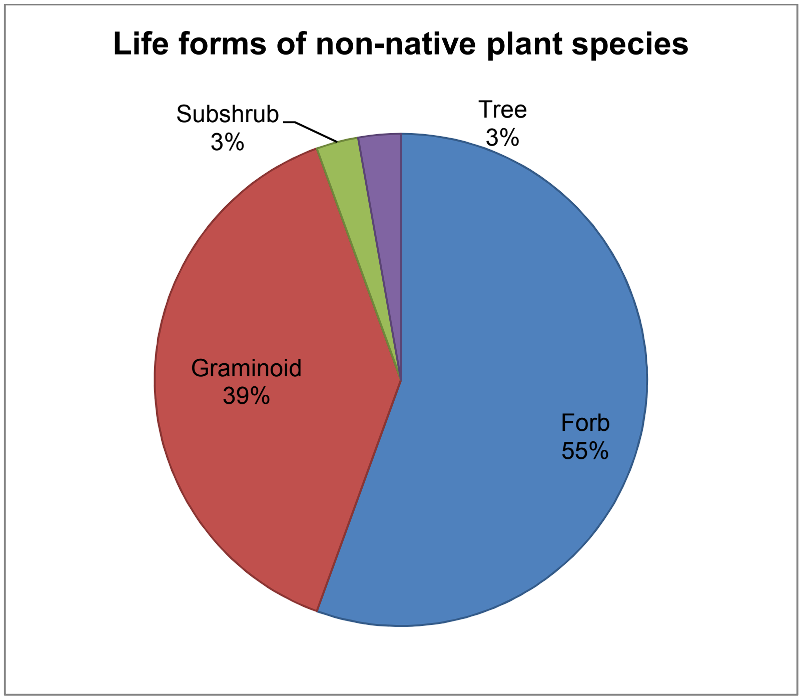


Figure 12. The percent of non-native life forms in the Flora of the Lower Verde River.

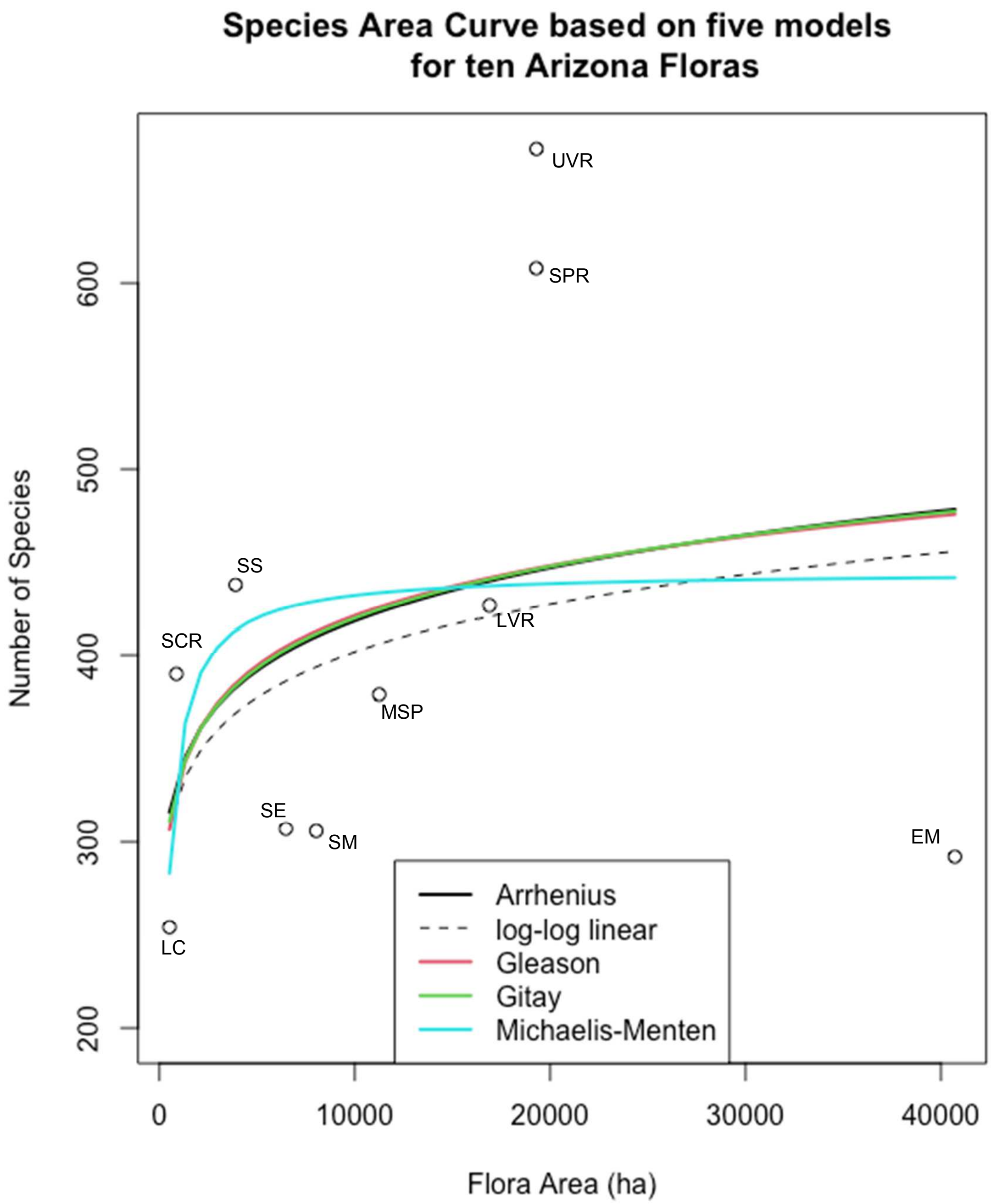


Figure 13. Five species-area curve models comparing nine Arizona floras to the Flora of the Lower Verde River (LVR). The floras of the Upper Verde River (UVR) and the San Pedro River (SPR) are riparian floras of a comparable size to this study. The floras of the McDowell Sonoran Preserve (MSP), Spur Cross Ranch Conservation Area (SCR) and the Seven Springs Region (SS) are of comparable elevations to the study area. The Flora of Lime Creek (LC) is the closest geographically to the study area. The floras of the Sierra Estrela Mountains Regional Park (SE), South Mountain Park and Preserve (SM) and Eagletail Mountains (EM), are exemplary of lower elevation Sonoran Desert mountains.

Notable Taxa

The following are descriptions of the 22 notable taxa found within the study area. Any conservation status is noted at the end of the description. This list includes 12 species endemic to Arizona, as well as 10 species that constitute a range extension, unique distribution, are of conservation concern, or were interesting to the author.

Endemic taxa

Agave chrysantha (Agavaceae) – Occurs throughout central and southern Arizona, primarily in middle elevations (3,000-5,000 ft.). This species likely contains cryptic taxa (Andrew Salywon and Wendy Hodgson, pers. comm. 2019). Four known populations are found in the northern half of the study area; two on grassland-topped mesas (3200-3600 ft.), and two at the crests of north-facing slopes (2600-3000 ft.). Individuals are frequent in canyons and perennial washes.

Agave cf. chrysantha. (Agavaceae) – This agave may have been cultivated or represent another pre-contact domesticate that is associated with archeological features found with materials associated with prehistoric peoples in the study site. Several individuals were found by Wendy Hodgson prior to the study (Hodgson, pers. comm. 2020); however, populations could not be found during the study period, but are likely still there, as the area is very hard to navigate.

Acmispon mearnsii var. equisolensis (Fabaceae) – Var. *equisolensis* is a limestone obligate species known only from the limestone soils around Horseshoe Reservoir. This species was observed at Chalk Mountain but a specimen was not taken, as collections had been made in the past and this species is locally endemic, and likely part of a very small population. This is a U.S. Forest Service Sensitive species. (Hodgson et al, unpublished data)

Astragalus recurvus (Fabaceae) – Found primarily along the Mogollon Rim and throughout the Central Highlands at higher elevations (5000-7000 ft.) but occasionally in lower areas.

Found in two locations; just north of Chalk Mountain on Ister Flat, and just north of Sheep's Bridge. This species is found along several of the tributaries north of the study site including West Clear Creek and Fossil Creek. (Hodgson et al, unpublished data)

Cylindropuntia acanthocarpa var. *thornberi* (Cactaceae) – Occurring at low to middle elevations from 2000 to 5000 feet, this variety of *C. acanthocarpa* is found on rocky slopes and ridges in Sonoran desertscrub, semi-arid grasslands, and chaparral transition areas. Known primarily from the Central Arizona Highlands and a population in the Grand Canyon. (Hodgson et al, unpublished data)

Dudleya saxosa subsp. *collomiae* (Crassulaceae) – Grows on rocky outcrops between 1500 and 6000 feet. Found in Arizona's Central Highlands. (Hodgson et al, unpublished data)

Eriogonum arizonicum (Polygonaceae) – Occurring below 3600 feet in grasslands, desertscrub, and gravelly washes throughout the Central Arizona Highlands. Found in several locations in the study area. (Hodgson et al, unpublished data)

Eriogonum ripleyi (Polygonaceae) – Populations on Chalk Mountain and the limestone outcrops around Horseshoe Reservoir are disjunct from the primary population in the Verde Valley. Grows on well-drained, powdery soil below 6000 feet. This is a U.S. Forest Service Sensitive species. (Hodgson et al, unpublished data)

Purshia subintegra (Rosaceae) Limestone soils around Horseshoe Reservoir provide habitat for one of only four populations of *P. subintegra.* This species is a limestone obligate, and is the only Federally Listed endangered plant species in the study site. (Hodgson et al, unpublished data)

Polygala rusbyi (Polygalaceae) Endemic to the area around Horseshoe Reservoir, Verde Valley, Chino Valley, Fraziers Well, and between Peach Springs to Kingman. In the vicinity of Horseshoe Reservoir, this species occurs with *P. subintegra, Lotus mearnsii* var. *equisolensis* and *Eriogonum ripleyi* on limestone soils. This species was observed at Chalk Mountain but a specimen was not taken, as collections had been made in the past and this species is locally endemic, and likely part of a very small population. This is a U.S. Forest Service Sensitive species. (Hodgson et al, unpublished data)

Mentzelia longiloba var. *yavapaiensis* (Loasaceae) – Endemic to central and northern Arizona at elevations between 1400 and 5400 ft. (Hodgson et al, unpublished data)

Perityle ciliata (Asteraceae) – Grows on crevices and rock faces throughout central Arizona as well as the Grand Canyon. Typically occurs at mid to upper elevations (3600-8000 ft), but was found in a canyon seep at approximately 2400 feet. (Hodgson et al, unpublished data)

<u>Other notable taxa:</u>

Pectis rusbyi (Asteraceae) – Herbaceous annual found at middle elevations along gravelly hillsides, from central Arizona to southern Sonora, Mexico and into southern Baja California. Typically found along smaller mountain ranges within its distribution.

Senecio lemmonii (Asteraceae) – A northern Sonoran Desert species found throughout the southern half of Arizona, with disjunct populations in Baja California.

Drymaria pachyphylla (Caryophyllaceae) – Uncommon herbaceous annual, found in the study site along the bottom of the East Verde River. Found in New Mexico, west Texas, northern Mexico, and southeastern Arizona, these collections constitute a possible range extension of over 200 miles.

Carex ultra (Cyperaceae) – Occurs in moist, well-drained sand or gravel soils usually between 5000 and 6000 feet in elevation. Two collections were made within the study site; one by Glenn Rink along the Verde River, and one by Marc Baker (determined by Glenn Rink) at a seep in a side canyon. This is a U.S. Forest Service Sensitive species.

Lotus alamosanus (Fabaceae) – Found primarily in northern Mexico, on the gravel slopes of washes and canyons, the collection within the study site is a northern range extension of almost 50 miles. This is a U.S. Forest Service Sensitive species.

Phaseolus acutifolius var*. acutifolius* (Fabaceae) – Annual vine found only at the mouth of Red Creek, where it was observed growing (without flowers) in August of 2018 and collected April of 2019. A food plant traditionally used by current and pre-historic cultures in the Southwest.

Sphinctospermum constricta (Fabaceae) – Rare, only found in one location in study site in a sandy wash. This collection constitutes a range extension of approx. 120 miles.

Geranium lentum (Geraniaceae) – Rare in the study site, and found only at one location, in Red Creek, this collection constitutes a western range extension of approximately 100 miles. Limited collections on SEINet indicate that *G. lentum* occurs primarily at higher elevations in woody, mountainous areas as well as in the canyons of the Navajo Reservation.

Stemodia durantifolia (Plantaginaceae) – Found at mid-elevations near perennial water sources. Range extends from central Arizona, south into Mexico along the Sierra Madre Occidental, also in the Grand Canyon.

Andropogon glomeratus var*. glaucopsis* (Poaceae) – Perennial clumping grass species found primarily in the coastal plains of the Southeast. Populations in Arizona are always associated with perennial water availability in the form of seeps, springs, canyons and washes. In the southwest, this species does not appear to occur north of Arizona. Population found in the study area was growing in the talus of a canyon wall, where a seep emerged.

<u>Vegetation types</u>

The Lower Verde Flora site contains three biotic communities as defined by Brown (1994): Sonoran Riparian Deciduous forest and woodlands, Sonoran desertscrub – Arizona upland subdivision, and Semidesert Grassland. These are used as the framework for the vegetative communities, and are further broken down into sub-types, or series within these three communities: 1) Sonoran Riparian Deciduous forest and woodlands: River series, Floodplain series, and Perennial stream series, 2) Sonoran desertscrub – Arizona Upland subdivision: Cactus-Palo Verde series, annually flooded dry wash series, Calcareous outcrop series, Creosote flat series, and 3) Semidesert Grassland.

Sonoran Riparian Deciduous forest and woodlands

The perennial riparian corridor is by far the most biodiverse habitat found within the study area. One hundred and fifteen taxa found in the study area are associated with wetlands habitats. However, this vegetation is not limited to wetland species, but also contains a variety of upland species growing in the area.

River series:

The river series is dominated by four species: *Populus fremontii, Salix gooddingii, Fraxinus velutina,* and *Arundo donax.* Other frequently occurring species found directly adjacent to the river, in areas not dominated by *Arundo,* include *Tamarix chinensis, Platanus wrightii, Vitis arizonicus, Pluchea sericea, Typha latifolia, Paspalum dilatatum, Persicaria lapathifolia,* and *Lythrum californicum.* From observations made during the flora, approximately half of the Verde River in this area has been channelized by huge stands of *Arundo donax* so dense nothing else is able to grow, and in areas where *Arundo* has not channelized the river, it still dominates the leading edge of the river.

Frequent flooding is the primary driver for biodiversity along riparian corridors (Naiman et al.,1993). Flooding is extremely variable year-to-year creating microhabitats with different species assemblages depending on successional stage, soil type, and other factors.

Floodplain series:

The floodplain, which sits one to two meters above the height of the active river channel during its non-monsoon or spring flooding level of approximately 100 cubic feet per second (USGS, 2020). These floodplains are inundated and reshaped during years of high winter precipitation, as well as during the flash floods in the monsoon months.

The shrub species that dominate these floodplains are *Prosopis velutina* and *Baccharis sarothroides,* but other common species include *Mimosa aculeaticarpa, Baccharis salicifolia, Ambrosia ambrosioides, Cephalanthus occidentalis, Chilopsis linearis, Baccharis salicifolia, Dodonea viscosa,* and *Anisacanthus thurberi.* The most common herbaceous perennials found on the floodplains include *Datura wrightii, Helianthus annuus, Proboscidea parviflora, and Maurandya antirrhiniflora.* The most common are *Echinochloa crus-galli, Aristida purpurea, Eragrostis intermedia and Hordeum murinum.*

Terraces formed by 5-10 year flood events occur occasionally along this stretch of the Verde River (Fig. 14). These terraces are unique because they are typically dominated by stands of *Prosopis velutina* and are commonly referred to as '*bosques'*, after the Spanish word for forest or wooded area. *Prosopis velutina* is able to thrive due to its deep roots that tap into the water table of the river below (Minckley, 1984). Because of the dense shade that the mesquite *bosques* provide, few species occur in its understory except for several grass species, *Solanum elaeagnifolium,* and *Marah gilensis.* Mesquite *bosques* along the Lower Verde River are heavily used by cattle, both feral and tended.

Figure 14. An example of an eroded floodplain streambank along the East Verde. A mesquite bosque is growing on the bajada. Note the depth of the mesquite roots reach to roughly the level of the river, ca. 5 m below (Photo taken by author, March 2018).

Perennial stream series:

The perennially flowing streams have a high level of plant diversity as well as a wide variety of microhabitats. The streams in the study area contain a high species diversity from the surrounding vegetative communities and microhabitats into a relatively small area (Fig. 15). One example is Red Creek where, in the only 400 hectares of area collected, 124 species (28% of the total species) were found (Fig. 16). It was observed that, because of the presence of water, these perennially flowing streams enable species found in higher elevations, as well as Sonoran Desert species that are sensitive to high summer temperatures or low winter temperatures to survive. Perennial streams series can largely be split into two habitat types, and apart from the largest trees found in both (*Populus fremontii, Fraxinus velutina,* and *Platanus wrightii*), they are very distinct.

Figure 15. The thin, riparian strip of Red Creek quickly transitions into upland Sonoran Desert. The transition area is where many higher elevation species grow, due to increased water availability (Photo taken by the author, April 2019).

Figure 16. Red Creek, as one of the largest perennially flowing waterways, is a very diverse are within the flora, containing 124 of the species found (Photo taken by author, April 2019).

The higher elevation (upstream) reaches of the perennial streams, though surrounded by Sonoran desertscrub, are more likely to contain shrub species associated with Interior Chaparral such as *Juniperus* spp*., Berberis haematocarpa, Rhus ovata, Cupressus arizonica,* and *Ceanothus greggii* above the floodplain or channel (Fig. 17). In the lower (downstream) reaches the plant community changes to species associated with lower elevations and more heat and drought tolerant species like *Celtis pallida, Prosopis velutina, Simmondsia chinensis,* and *Lycium* spp (Fig 18).

Figure 17. A view looking west along the East Verde, an important stream in the study area, as its slopes support two distinct habitat types. Pinion/juniper forest can be seen on the slopes on the southern side of the canyon (left) and Sonoran Desert Scrub can be seen on the northern slopes of the canyon (right) (Photo taken by the author, March, 2018).

Figure 18. The East Verde River looking due east, March, 2018. Sonoran desert riparian corridor in the foreground including *Phragmites*, *Salix gooddingii,* and *Populus fremontii,* with Upland Sonoran desertscrub on the slopes in the background and interior chaparral/ pinion juniper woodland on the top of the plateau (Photo taken by the author, March, 2018).

Arizona Upland Subdivision – Sonoran desertscrub

Brown (1994) described three series within the Arizona Upland Subdivision - Sonoran desertscrub that transition as the elevation increases: Paloverde-Cacti-Mixed Scrub, Jojoba-Mixed Scrub, and Creosotebush- Crucifixion thorn. As this study area is at the northern-most reaches of the Sonoran Desert, these three series are hard to distinguish from one another because of the elevation gradient and various microclimates that compress these subdivisions together. Therefore, Arizona Upland Sonoran desertscrub will be used to classify this habitat type.

Cactus-Palo Verde series:

The most common series of the Arizona Upland Subdivision – Sonoran desertscrub is the Cactus-Palo Verde series dominated by dense to moderate mixed trees and shrubs, as well as diverse cactus species. *Parkinsonia microphyllum, Carnegeia gigantea,* and *Simmondsia chinensis* are the dominant species that help identify this habitat (Fig. 19). Other tree species include *Olneya tesota, Prosopis velutina,* and *Parkinsonia florida,* of which the latter two can often also be found in shrub form. *Fouquieria splendens* occurs at slightly higher elevations, as well as on slopes with a northern aspect. Shrub species include *Acacia greggii, Larrea tridentata, Hyptis emoryi, Dodonea viscosa, Ericameria laricifolia, Canotia holacantha,* and *Lycium* spp., with smaller shrubs commonly including *Eriogonum fasciculatum, Encelia farinosa, Ambrosia deltoidea, Calliandra eriophylla, Stephanomeria pauciflora, Brickellia californica, Bebbia juncea,* and *Zinnia acerosa*. *Gutierrezia microcephala* can be very common in areas where grazing has occurred.

Apart from the nearly ubiquitous *Carnegiea gigantea*, cactus species from several genera occur in this community. In more exposed, arid areas, *Echinocereus bonkerae* and several species of *Cylindropuntia* occur, including *C. acanthocarpa, C. bigelovii, and C. fulgida.* With increasing elevation, these species are joined by *Opuntia engelmannii* and *O. phaeacantha* (Fig. 20). In extremely arid and exposed areas such as canyon walls, rock faces, and slopes with a southern aspect, *Ferocactus cylindraceus* can be found and is usually associated with *Calliandra eriophylla* (Fig. 21). At higher elevations along steep canyon walls are communities of *Agave chrysantha* and *Fouquieria splendens.* During the monsoon season, sparse annuals occur, seemingly regardless of the amount of rainfall, including *Boerhavia intermedia, Eriogonum* spp., and *Euphorbia polycarpa. Eriogonum arizonicum* is a notable Arizona endemic occurring within the site. *Boerhavia coccinea, Euphorbia arizonica, Stephanomeria thurberi, Allionia incarnata,* and *Senna covesii,* are all common fall-flowering herbaceous or suffrutescent perennials. In the spring, a dense annual community can occur with enough moisture and include *Rafinesquia californica, Daucus pusillus, Logfia* spp., *Amsinckia* spp., *Cryptantha* spp., *Phacelia* spp., *Draba cuneifolia, Eschscholzia californica, Lepidium* spp., *Silene antirrhina, Lupinus* spp., *Erodium* spp., *Oenothera albicaulis, Castilleja exserta, Gilia* spp., and *Plantago* spp.

Figure 19. Typical Cactus-Palo Verde series with *Parkinsonia microphylla, Encelia farinosa, Carnegiea gigantea* and *Simmondsia chinensis* in the foreground. Notice the red brome that composes the majority of the ground cover (Photo taken by author, above Red Creek looking south, April, 2019).

Figure 20. Cactus-Palo Verde series that has been impacted by fire in the past. Notice the burns and discoloration on the *Opuntia phaeacantha* and *Carnegiea gigantea* in the middle-left and middle of the photo, respectively (Photo taken by the author, September, 2018).

Annually flooded dry wash series:

These washes are all ephemeral and usually only carry water from spring and summer rains. During this study, I observed that the dry washes usually only have flowing water after the summer monsoons. Perennial plants in these washes respond to spring rains by flowering slightly sooner than their upland counterparts in a similar area, probably as a result of the shallower ground water. The sometimes strong monsoonal rains also create intermittent scouring of the wash bottom, which creates a disturbed habitat. The level of disturbance experienced radiates out from the main channel, and creates a disturbance gradient with the greatest disturbance in the center of the channel and the least disturbed near the sides. Few species grow in the very bottom of these washes, except *Euphorbia arizonica* and *Boerhavia intermedia.*

Moving outward from the center, small terraces or ledges are often present around 20-100 cm above the canyon bottom. The near vertical banks of these terraces are good habitat for many spring ephemerals such as *Parietaria pensylvanica*, *Eucrypta micrantha, Phacelia distans, Gallium aparine*, and C-3 grasses such as *Vulpia octoflora, and Hordeum pusillu*m.

The slopes and walls of the washes and canyons have many Sonoran Desert upland associated species including *Parkinsonia microphylla, Canotia holacantha, Celtis pallida, Lycium* spp*., Cottsia gracilis, Atriplex canescens, Lotus rigida*, *Brickellia californica,* and *Bebbia juncea,* as well as interior chaparral influences such as *Berberis haematocarpa, Celtis reticulata* and, in the northern most washes of the study area, *Ceanothus greggii and Arctostaphylos* sp. Notably absent from this plant community in this study area is *Justicia californica*, a common member of dry wash communities in the Sonoran Desert, which is found in all of the parks and preserves around Cave Creek and Phoenix. Common summer annuals include *Polanisia dodecandra, Phaseolus acutifolius, Boerhavia* spp*., Marina parryi,* and *Ipomoea costellata.* Common summer perennial forbs and vines include *Aristolochia watsonii, Hibiscus coulteri, and Funastrum cynanchoides*

Calcareous outcrop series:

It is the lack of any dense scrub that distinguishes calcareous soil scrubland from the other Arizona Upland Subdivision series. The desert scrub occurring on the limestone outcrops around Horseshoe Reservoir, including Chalk Mountain and Lime Creek, is dominated by sparse to moderate shrubs and subshrubs, with trees occurring very rarely. Dominant shrub species include *Dodonea viscosa, Simmondsia chinensis,* and *Fouquieria splendens. Juniperus arizonica*, though typically a tree, grows smaller and more shrub-like on these soils. The most common shrubs and subshrubs include *Parthenium incanum, Canotia holacantha, Acacia constricta, Krameria bicolor, Polygala macradenia, Aloysia wrightii, Psilostrophe cooperi,* and *Zinnia acerosa. Allionia incarnata* and *Eriogonum inflatum* are the most common forbs and can be found growing and flowering throughout the year given enough precipitation. *Cuscuta* sp. was only observed once, when a 'super bloom' covered many of the shrubs within the 'caldera' of Chalk Mountain in August of 2018.

The ephemeral calcareous washes on the slopes and within the basin of Chalk Mountain have greater water availability and less sun exposure sustaining perennial species such as *Nicotiana obtusifolia, Maurandya antirrhiniflora,* and *Stephanomeria pauciflora.* The limestone soils have comparatively low levels of nitrogen and phosphorus, restricting the growth of the dominant Sonoran Desert species such as *Parkinsonia microphylla* and *Larrea tridentata* (Anderson). Several primarily Chihuahuan Desert and Colorado Plateau Province disjunct species are found on these deposits. Four Forest Service Sensitive rare limestone obligate species occur on the calcareous soils around Horseshoe Reservoir: *Lotus mearnsii* var. *equisolensis,* (which is endemic to this immediate area and listed as Critically Imperiled by the AZGFD Heritage Data Management System), *Polygala rusbyi* (an Arizona endemic listed as a Forest Service Sensitive species), *Purshia subintegra* (an Arizona endemic listed as Endangered by the USFWS), and *Eriogonum ripleyi* (listed as Imperiled by the AZGFD Heritage Data Management System).

Creosote flat series:

The creosote flat series is found only at two locations in the southern reaches of the study area: Ister Flat just north of Chalk Mountain and the uplands just south of Dry Wash. Historically, these areas have been the site of heavy disturbances from cattle grazing and fire, respectively. The primary species found within this habitat type are *Larrea tridentata, Calliandra eriophylla, Opuntia* spp.*, Schismus arabicus, and Eriogonum inflatum.*

Figure 21. An example of blending biotic communities in the higher elevations of the study areas *Juniperus, Mimosa aculeaticarpa and Berberis haematocarpa,* chaparral and grass-land species grow with *Calliandra eriophylla, Crossosoma bigelovii,* and *Ferocactus cylindraceus.* Photo taken by author, March, 2018.

Semi-Desert grassland

The Semi-Desert grasslands within the study site occupy a small total area and are only found at higher elevations along the buttes to the east of the Verde River and on northern aspect slopes towards the northern end of the study site. This habitat type is the least common within the study area and is dominated by primarily annual grasses such as *Bromus rubens, Aristida purpurea, Bouteloua curtipendula, Hordeum pusillum,* and *Schismus arabicus,* but also includes perennial grasses such as *Eragrostis lehmanniana, Avena fatua, and Sporobolus wrightii*. Shrubs are sparse in the habitat type, but common species include *Krameria bicolor, Simmondsia chinensis, Dodonea viscosa, Acacia greggii, Mimosa aculeaticarpa* var*. biuncifera, Ericameria laricifolia*, *Juniperus osteosperma and Agave chrysantha that* are also abundant (Fig. 22).

Figure 22. Semi-Desert grassland found on top of Wet Bottom Mesa and the other table-lands to the east of the Verde River.

CHAPTER 5

DISCUSSION

This flora, comprises 427 species (450 taxa) in 258 genera and 78 families, furthers our understanding of the plant diversity along the Verde River, as well as within its watershed (Table 3). The flora is mostly composed of Sonoran Desert Arizona Upland species and to a lesser extent Semi-Arid Desert Grassland species. Within these two biotic communities eight different vegetative communities, each with distinct species assemblages are represented.

The description of the Lower Verde River flora provides the baseline data necessary for current and future comparative studies of this region with others. In comparison to other northern Sonoran Desert sites of similar elevation, the Lower Verde River flora has more taxa, than the floras of Spur Cross (Hunskins and Smith, 2013; 396 taxa), Seven Springs (Doan, 2002; 342), and McDowell Sonoran Preserve (Jones and Hull, 2014; 379 taxa). The Lower Verde flora has fewer taxa than both the San Pedro (Makings, 2005; 620 taxa) and the Upper Verde (Coburn, 2015; 729 taxa), two other riparian floras of comparable size.

The Lower Verde River flora is primarily composed of Sonoran Desert species, but also supports elements of Interior Chaparral and Semi-Desert Grasslands in areas of higher elevation. The most species-rich plant families, Asteraceae, Poaceae, and Fabaceae (Fig. 7), are reflected in the archetypal species assemblage in the study area; *Carnegeia gigantea, Parkinsonia microphylla, Cylindropuntia acanthocarpa, Ericameria laricifolia, Ambrosia spp.,* and *Larrea tridentata* with other secondary species varying from site to site. Plants characteristic of chaparral and grassland vegetation found in the higher elevations of the flora include elements of the Central Arizona District of the Madrean Floristic Province (McLaughlin, 1992; Brown, 1994). In the study site these species are often found interspersed in primarily Sonoran Desert communities. These include *Berberis haematocarpa, Rhus ovata, Mimosa aculeaticarpa,* and *Agave chrysantha*.

Wetland Plants and Riparian Communities

The riparian communities within the study site, whose wetland associate species constitute 115 of the 450 taxa (Fig. 10), within the study site are constantly changing due to flood disturbances which create a patchwork of microhabitats in different stages of ecological succession (Naiman et al.,1993). Plants in riparian communities in the study area commonly grow no larger than small trees or shrubs, as the frequency of flooding prevents long term survivorship of individuals. Though disturbance is common, there are species that remain relatively unaffected, and may become well-established trees such as *Fraxinus velutina, Populus fremontii,* and *Salix gooddingii* as well as thin-leafed, flexible shrubs such as *Baccharis salicifolia* and *Chilopsis linearis* are typically unaffected. Perennially flowing streams in particular have a high species density, as narrower strips of riparian vegetation quickly transition into distinct upland microhabitats, where many plants to grow together in a small area. For example, along Red Creek 124 of the taxa (28%) found in the study area are found either in or directly adjacent to the riparian zone on the upland slopes of Red Creek. This 400-hectare area comprises just two percent of the total study area yet contains over a quarter of the total species. The riparian corridors are where the influences of higher elevation plant communities are seen within the study area. Perennial streams in particular, act as refugia for upland species typical of the Central Arizona Floristic district, likely due to increased water availability and reduced temperatures extremes. These species include *Solanum douglasii, Stemodia durantifolia, Pectis rusbyi, Lotus alamosanus, Perityle ciliata,* and *Eriogonum arizonica.* The high diversity found in Red Creek is potentially vulnerable to habitat destruction from both heavy livestock grazing and an illegal “social road” that runs straight through the streambed (personal observation).

Life/growth form

Annual forbs account for the study sites highest species diversity, as they constitute 34% (152 species) of the total flora (Fig. 8). The growth of these annuals depends primarily on the broadly bi-modal precipitation regime of the Sonoran Desert. From personal observations during this study, summer annuals appear to respond to precipitation within two to three weeks of a rainfall event. Winter annual germination does not appear to rely solely on rainfall, but a host of other factors including temperature, both soil and air, and timing of rainfall (Huxman, 2008). Currently, winter rains and summer monsoons are becoming less regular and predictable while fall rains, in the form of dissipated Pacific cyclones, are becoming more frequent (Weiss and Overpeck, 2005). Changes in rainfall could cause shifts in the species assemblages of annual forbs, potentially reducing the overall plant diversity in the study area. Rainfall also has a large impact on perennials, which comprise 58% of the total taxa in the study area. Sustained soil moisture is required for many perennial species to germinate (Notaro et al., 2016). Summer monsoons trigger flowering and fruiting of many perennials, and winter rains then enable seeds to germinate and seedlings to establish. Shifting temporal rain patterns and multi-year droughts could hinder perennial recruitment, altering the biodiversity of the study area (Bowers et al., 2004).

Non-native plants are also impacted as a result of changing rainfall patterns. Red brome (*Bromus rubens*), a non-native species pervasive on the landscape, has been found to germinate best when moisture is available and temperatures are below 90 degrees F (Horne et al. 2015), a germination syndrome that benefits from increased rainfall Pacific storms during October and November in the Sonoran Desert.

Fire

Non-native taxa account for 8% of the flora (Table 3). Annuals account for 20 of the 36 non-native taxa (Fig. 11). Non-native species in the flora are primarily forbs (20 spp.) and graminoids (14 spp.) (Fig. 12). All of the non-native graminoids are in the family Poaceae, and make up 29% of the family within the flora. Nineteen of the 36 non-native species are associated with wetland habitats (Fig. 10).

Non-native grasses, particularly Red Brome, have been cited as a significant contributor to the fuel load for wildfires in the Sonoran Desert (Horn et al., 2015). Fires pose a significant threat to the conservation of the study area, as the Sonoran Desert is not evolutionarily adapted to a fire regime. Fires are common along the edges of the Sonoran Desert, as it is surrounded by the fire-adapted habitats (e.g., chaparral and semi-desert grassland, Brenner and Kanda, 2013). Introduced species, particularly grasses, seem to be accelerating the frequency and severity of fires in the Sonoran Desert (McDonald and McPherson, 2010). Exotic grasses, such as *Bromus rubens, Pennisetum ciliare*, and *Schismus* spp., respond to above average precipitation by growing more densely than native species in intershrub space, creating a readily available fuel source that was previously uncommon in the Sonoran Desert (Lata, 2019). This creates a positive feedback loop, as many of these non-native grass species are highly opportunistic, favoring consistent disturbance events such as fire.

Large-scale fires have been notably absent from the study area in recent decades, despite large fires affecting other areas that are similar to the study area in topography, elevation, climate and plant composition. The effects of wildfires on Sonoran Desert plant communities can last for decades after a fire. Species of Cactaceae are notably absent from post fire plant communities in the Sonoran Desert, as succulent species are more susceptible to permanent fire damage, and are less likely to return following a fire (Barron, 2018). In June 2019 the Mountain Fire burned 7,470 acres just south of Horseshoe Reservoir and the study area (Fig. 23). The fire came close to burning the vegetation of the limestone outcrop areas that support several endemic species including *Lotus mearnsii var. equisolensis, Purshia subintegra, Polygala rusbyi,* and *Eriogonum ripleyi*.

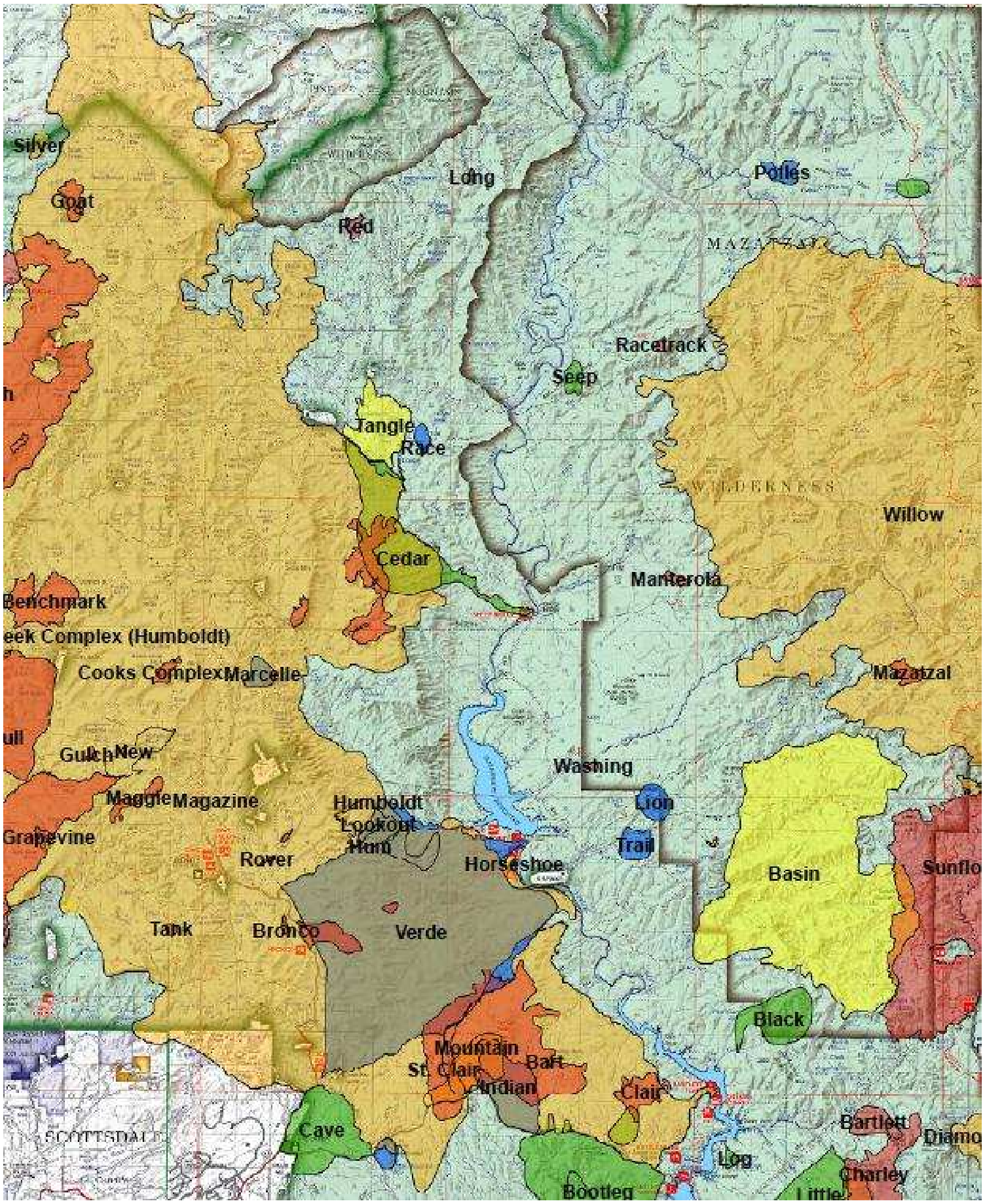


Figure 23. Fires near the study site in the Tonto National Forest from 1970-2019. While many of these fires occur in habitats adapted to fire, many have occurred in Sonoran Desert habitats. In 2004 and 2005 the Willow Fire burned 120,000 acres of the Mazatzal Wilderness Area and the Cave Creek Complex Fire burned 250,000 Woodbury Fire in the Superstitions that burned 123,875 during June and July of 2019. These fires all burned fire adapted and non-fire adapted habitats.

Species-area relationships

Floras are important datasets for the understanding of the biodiversity in Arizona (e.g. Makings, 2005; Coburn, 2015). Using a species area curve to compare this flora to others in Arizona can offer some insight into the larger ecological factors at play by examining the relationship between the size of an area and the number of species found in that area. One of the biggest factors influencing the species-area relationship is habitat heterogeneity, as area increases so does the number of available habitats (Scheiner et al., 2000). The number of species in this flora falls under, but close, to the predicted value given by four models and above the curve for the log-log linear model (Fig. 13). Given the data, the species area curve models may indicate that the expected total number of species is more than what was collected. All of the models were roughly similar for the cursory purposes of this analysis. The high probability of finding new species to add to the flora makes sense given the several areas I was unable to access during the monsoon months of the study period, including the perennial Sycamore Creek and several areas north of Mule Shoe Bend. As this is a riparian area that cuts through the transition between higher elevation habitats and the Sonoran Desert, I expect at least an additional 100-150 species are found within the study site.

The floras of Seven Springs and the Lower Verde have roughly the same number of species, 438 and 427 respectively (Doan, 2002) yet the Seven Springs Flora has much higher species per area (Fig. 13). It is difficult to compare the two floras, as they have different elevations and areas, the 3900 hectares of Seven Springs occur between 3600 and 5200 feet, and the 16000 hectares of the Lower Verde River occur primarily between 2200 and 3800 feet. The higher elevation of the Seven Springs region likely accounts for the similar species counts, as it contains more biotic communities, including interior chaparral and great basin conifer woodland, along with semidesert grassland and riparian woodland. The flora of the Upper Verde River with 729 taxa was significantly more diverse than the Lower Verde, despite having similarly sized areas, 19,300 and 16,000 respectively (Coburn, 2015) (Fig. 13). This higher diversity is most likely a result of an increased number of vegetation types, 13, occurring along the Upper Verde. Though the closest geographically, the flora of Lime Creek was the smallest of those compared, both in terms of area (517 hectares) and number of taxa (254; Goldman and Ward, 2010). There the primary soil type is limestone, a nutrient poor substrate that limits the growth of many species not adapted to the soil (Anderson, 1996).

Conclusion

One hundred and twelve sites were visited over 36 collecting days, and herbarium specimens were examined, resulting in 427 species across 78 families (Table 3.). The Lower Verde River is an important floristic area as it lies on the transition between the northern Sonoran Desert and higher elevation ecosystems of central Arizona. The Sonoran Desert is primary floristic driver in this area, but higher elevation species found along perennial streams highlight the floristic influence the Madrean Floristic Province. These perennial streams hold much of the biodiversity in the study area, and as such deserve increased conservation measures, to avoid any habitat degradation due to cattle. Fires pose a significant threat to the conservation of the Sonoran Desert habitats in the study area, due largely to the transitional nature of this area and the high density of non-native grass species. The species diversity is not particularly high when compared to other riparian corridors, but it does contain many rare, endemic and disjunct taxa. This flora provides a baseline of floristic knowledge that can be used in the future to examine how different natural and anthropogenic phenomenon impact this area.

REFERENCES

ABATZOGLOU, J.T., D.J. MCEVOY, and K.T. REDMOND. in press. The West Wide Drought Tracker: Drought Monitoring at Fine Spatial Scales, *Bulletin of the American Meteorological Society.*

ANDERSON, J. L. 1996. Floristic patterns on Late Tertiary Lacustrine deposits in the Arizona Sonoran Desert. *Madrono 43 (2): 255-272.*

BARRON, K. L. 2018. *Fire and Reseeding Effects on Arizona Upland Plant Community Composition and a Preliminary Floristic Inventory of Cave Creek Regional Park.* Masters Thesis, Arizona State University, Tempe.

BOWERS, J. E., R. M. TURNER and T. L. BURGESS. 2004. Temporal and spatial patterns in emergence and early survival of perennial plants in the Sonoran Desert. *Plant Ecology 172: 107-119.*

BRENNER, J. C. and L. L. KANDA. 2013. Buffelgrass (*Pennisetum ciliare*) Invades Lands Surrounding Cultivated Pastures in Sonora, Mexico. *Invasive Plant Science and Management 6 (1): 187-195.*

BROWN, D. E. 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. 1st edn. University of Utah Press. Salt Lake City.

CHRONIC, H. 1983. *Roadside Geology of Arizona*.12th printing. Mountain Press Publishing Company. Missoula.

CIOLEK-TORRELLO, R. 1997. Prehistoric Settlement and Demography in the Lower Verde Region. Pp. 531-588. In: S. M. Whittlesey, R. Ciolek-Torrello and J. H. Altschul [eds.]. *Vanishing River: Landscapes and Lives of the Lower Verde Valle*y. SRI Press, Tucson.

COBURN, F. S. 2015. *Flora of the Upper Verde River, Arizona.* Masters Thesis, Arizona State University, Tempe.

DAVEY, C. A., K. T. REDMOND and D. B. SIMERAL. 2006. Weather and Climate Inventory, National Park Service, Southern Colorado Plateau Network. Natural Resource Technical Report NPS/SCPN/NRTR— 2006/007. National Park Service, Fort Collins.

DOAN, S. 2002. Flora of the Seven Springs Region, Tonto National Forest, Maricopa County, Arizona. Masters Thesis, Arizona State University, Tempe.

DOYLE, G. A. 1987. Verde River Sheep Bridge (Red Point Sheep Bridge). Historic American Engineering Record, HAER AZ-10, Tonto National Forest, Western Regional Office, National Park Service.

ELSTON, D. P. and R. A. YOUNG. 1991. Cretaceous-Eocene (Laramide) Landscape Development and Oligocene-Pliocene Drainage Reorganization of Transition Zone and Colorado Plateau, Arizona. *Journal of Geophysical Research 96 (B7); 12,389-12,406.*

FERG, A. and N. TESSMAN. 1997. Two Archival Case Studies in Western Apache and Yavapai. Pp. 215-279. In: S. M. Whittlesey, R. Ciolek-Torrello and J.H. Altschul [eds.]. *Vanishing River: Landscapes and Lives of the Lower Verde Valle*y. SRI Press, Tucson.

FLORA OF NORTH AMERICA EDITORIAL COMMITTEE, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford. Vol. 1, 1993; vol. 2, 1993; vol. 3, 1997; vol. 4, 2003; vol. 5, 2005; vol. 7, 2010; vol. 8, 2009; vol. 19, 2006; vol. 20, 2006; vol. 21, 2006; vol. 22, 2000; vol. 23, 2002; vol. 24, 2007; vol. 25, 2003; vol. 26, 2002; vol. 27, 2007; vol 28, 2014; vol. 9, 2014; vol. 6, 2015.

GIFFORD, E. W. 1936. Northeastern and Western Yavapai. *University of California Publications in American Archaeology and Ethnology* 34: 247-345.

GOLDMAN, D., and J. WARD. 2010. A survey of the vascular plants in the area of Lime Creek, Maricopa County, Arizona. Taxon 59 (6): 1783-1800.

HODGSON, W. C. 2001. Food plants of the Sonoran Desert. University of Arizona Press, Tucson.

HORN, K. J., R. NETTLES and S. B. St. CLAIR. 2015. Germination response to temperature and moisture to predict distributions of the invasive grass red brome and wildfire. *Biological Invasions 17: 1849-1857.*

JONES, S. and C. HULL. 2014. Vegetation and Flora of the McDowell Sonoran Preserve, Maricopa County, Arizona. *CANOTIA 10: 1-34.*

HUNKINS, S and K. SMITH. 2013. A Vascular Plant Inventory of the Spur Cross Ranch Conservation Area, Maricopa County, Arizona. *CANOTIA 9: 21-49.*

HUXMAN, T. E., G. BARRON-GAFFORD, K. L. GERST, A. L. ANGERT, A. P. TYLER and D. L. VENABLE. 2008. Photosynthetic resource-use efficiency and demographic variability in desert winter annual plants. *Ecology 89 (6): 1554-1563.*

HUXMAN, T. E., S. KIMBALL, A. L. ANGERT, J. R. GREMER, G. A. BARRON-GAFFORD and D. L. VENABLE. 2013. Understanding past, contemporary, and future dynamics of plants, populations and communities using Sonoran Desert winter annuals. *American Journal of Botany 100 (7); 1369-1380.*

KEARNEY, T,, and R. H. PEEBLES. 1960. Arizona Flora. University of California Press, Berkeley.

LATA, M. 2019. Fire ecology report, Woodbury Fire, June 8th-July 15th, 2019. Tonto National Forest, U.S. Forest Service.

MAKINGS, E. 2005. Flora of the San Pedro Riparian National Conservation Area, Cochise County, Arizona. *USDA Forest Service Proceedings RMRS-P-36: 92-99.*

MCDONALD, C. J. and G. R. MCPHERSON. 2011. Fire behavior characteristics of buffelgrass-fueled fires and native plant community composition in invaded patches. *Journal of Arid Environments 75 (11): 1147-1154*

MCLAUGHLIN, S. P. 1992. Are Floristic Areas Hierarchically Arranged? *Journal of Biogeography 19: 21-32.*

MINCKLEY, W.L. and T. O. CLARK. 1984. Formation and Destruction of a Gila River Mesquite Bosque Community. *Desert Plants 6: 23-30.*

NAIMAN, R. T, H. DECAMPS and M. POLLOCK. 1993. The Role of Riparian Corridors in Maintaining Regional Biodiversity. *Ecology Applications 3 (2): 209-212*

NATIONAL WATER INFORMATION SYSTEM 2020a. Verde River below Tangle Creek. United States Geological Survey. https://waterdata.usgs.gov/az/nwis/inventory/?site_no=09508500 . Accessed June 2020.

NATIONAL WATER INFORMATION SYSTEM, 2020b. Wet Bottom. United States Geological Survey. https://waterdata.usgs.gov/nwis/nwisman/?site_no=09508300 . Accessed June 2020.

NATIONAL WILD AND SCENIC RIVERS SYSTEM. Verde River, Arizona. https://www.rivers.gov/rivers/verde.php. Accessed June 2020.

NATIONS, D. and E. STUMP. 1983. *Geology of Arizona.* Revised Printing. Kendall/Hunt Publishing Company, Dubuque.

NEARY, D. G., A. L. MEDINA and J. N. RINNE. 2012. Synthesis of Upper Verde River research and monitoring 1993-2008. Gen. Tech. Rep. RMRSGTR-291. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station. Fort Collins.

NEWTON, D. R. 2012. *The Vascular Flora of the Eagletail Mountain Region.* Masters Thesis, Arizona State University, Tempe.

NOAA. 2020. Climate of Arizona. National Climatic Data Center, Asheville, North Carolina.

NOTARO, M., A. MAUSS and J. W. WILLIAMS. 2012. Projected vegetation changes for the American Southwest: combined dynamic modeling and bioclimatic-envelope approach. *Ecological Application 22 (4): 1365-1388.*

OKSANEN, J. 2019. SSarrhenius: Self-Starting nls Species-Area Models, In vegan: Community Ecology Package. https://rdrr.io/rforge/vegan/man/SSarrhenius.html . Accessed May, 2020.

PALMER, M. W., G. L. WADE, and P. NEAL. 1995. Standards for the Writing of Floras. *BioScience 45 (5): 339-345.*

PEARTHREE, P. A. 1993. Geologic and geomorphic setting of the Verde River from Sullivan Lake to Horseshoe Reservoir. *Arizona Geological Survey, Open-File Report 93-4.*

RAFFERTY, N. E., C. D. BERTELSEN and J. L. BRONSTEIN. 2016. Later flowering is associated with a compressed flowering season and reduced reproductive output in an early season floral resource. *Oikos 125: 841-828.*

RIVERA, E., F. DOMINGUEZ and C. CASTRO. 2014. Atmospheric Rivers and Cool Season Extreme Precipitation Events in the Verde River Basin of Arizona. *Journal of Hydrometeorology, 15* (2), 813-829.

SCHEINER, S. M., S. B. COX, M. WILLIG, G. G. MITTELBACH, C. OSENBERG and M. KASPARI. 2000. Species richness, species–area curves and Simpson’s paradox. *Evolutionary Ecology Research 2: 791-802.*

SOUTHWEST ENVIRONMENTAL INFORMATION NETWORK. 2020. SEINet. http://swbiodiversity.org/seinet/index.php. Accessed June 2020.

STEVENS, P. F. (2001 onwards). Angiosperm Phylogeny Website. Version 14, July 2017 [and more or less continuously updated since]. http://www.mobot.org/MOBOT/research/APweb/. Accessed June 2020.

U.S. ARMY CORPS OF ENGINEERS. 2018. National Wetland Plant List, version 3.4. http://wetland-plants.usace.army.mil/. U.S. Army Corps of Engineers, Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH

VAN WEST, C. R. and J. H. ALTSCHUL. 1997. Environmental Variability and Agricultural Economics along the Lower Verde River A.D. 750-1450. Pp. 337-389. In: S. M. Whittlesey, R. Ciolek-Torrello and J. H. Altschul [eds.]. *Vanishing River: Landscapes and Lives of the Lower Verde Valle*y. SRI Press, Tucson.

WEISS, J. L. and J. T. OVERPECK. 2005. Is the Sonoran Desert losing its cool? *Global Change Biology 11: 2065-2077.*

WESTERN REGIONAL CLIMATE CENTER. Bartlett Dam, Arizona. 2020. DRI. Accessed June 2020. https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?az0632

WESTERN REGIONAL CLIMATE CENTER. Horseshoe Dam, Arizona. 2020. DRI. Accessed June 2020.https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?az4182

WHITTLESEY, S. M. and S. BENARON. 1997. *Yavapai and Western Apache Ethnohistory and Material Culture*. Pp. 143-178. In: S. M. Whittlesey, R. Ciolek-Torrello and J. H. Altschul [eds.]. *Vanishing River: Landscapes and Lives of the Lower Verde Valle*y. SRI Press, Tucson.

WHITTLESEY, S. M., W. L. DEAVER and J. J. REID. 1997. *Yavapai and Western Archeology of Central Arizona.* Pp. 185-214. In: S. M. Whittlesey, R. Ciolek-Torrello and J. H. Altschul [eds.]. *Vanishing River: Landscapes and Lives of the Lower Verde Valle*y. SRI Press, Tucson.

WILCOX, D. R. 2014. Verde Valley Archaeology in Macroregional Context. *Archaeology Southwest Magazine 28: 18-20.*

APPENDIX A

ANNOTATED CHECKLIST FOR THE LOWER VERDE RIVER

Family	Scientific Name	Author	Duration	Life Form	Native Status	Wetland Status	Endemic Status	Collections
Selaginellaceae	Selaginella arizonica	Maxon	Perennial	Forb	Native			CLW, 158
Equisetaceae	Equisetum laevigatum	A. Braun	Perennial	Forb	Native	FACW		CLW, 297
Pteridaceae	Adiantum capillus-veneris	L.	Perennial	Forb	Native	FACW		MB, 8814
Pteridaceae	Cheilanthes covillei	Maxon	Perennial	Forb	Native			WH, 20044
Pteridaceae	Cheilanthes X parishii	Davenport (pro sp.)	Perennial	Forb	Native			MW
Pteridaceae	Pellaea longimucronata	auct. non Hook.	Perennial	Forb	Native			WH, 19916
Pteridaceae	Pellaea truncata	Goodding	Perennial	Forb	Native			JN, B-51
Ephedraceae	Ephedra fasciculata	A. Nels.	Perennial	Shrub	Native			CLW, 767
Ephedraceae	Ephedra viridis	Coville	Perennial	Shrub	Native			WH, 19934
Cupressaceae	Juniperus arizonica	(R. P. Adams) R. P. Adams	Perennial	Tree	Native			CLW, 251, 254, 466
Cupressaceae	Juniperus monosperma	(Engelm.) Sarg.	Perennial	Tree	Native			WH, 4862
Cupressaceae	Juniperus osteosperma	(Torr.) Little	Perennial	Tree	Native			CLW, 152
Acanthaceae	Anisacanthus thurberi	(Torr.) A. Gray	Perennial	Shrub	Native			CLW, 779, WH, 6223, 30713

Adoxaceae	Sambucus nigra subsp. canadensis	(L.) R. Bolli	Perennial	Shrub	Native	FACU		MW
Adoxaceae	Sambucus nigra subsp. cerulea	Raf.	Perennial	Shrub	Native			CLW, 832
Agavaceae	Agave	L.	Perennial	Succule nt	Native			WH, 30719, 30723, 30717
Agavaceae	Agave chrysantha	Peebles	Perennial	Succule nt	Native		Endemic	CLW, 299, 363, WH, 30762, 30716, 30720, 30760
Agavaceae	Agave cf. chrysantha		Perennial	Succule nt	Native		Endemic	WH, 19966
Agavaceae	Yucca baccata	Torr.	Perennial	Succule nt	Native			WH, 30770, 30728, 19952
Agavaceae	Yucca baccata var. brevifolia	(Schott ex Torr.) L. Benson & Darrow	Perennial	Succule nt	Native			CLW, 758
Amaranthaceae	Amaranthus fimbriatus	(Torr.) Benth. ex S. Wats.	Annual	Forb	Native			CLW, 427
Amaranthaceae	Amaranthus hybridus	L.	Annual	Forb	Native			CLW, 56
Amaranthaceae	Amaranthus palmeri	S. Watson	Annual	Forb	Native	FACU		CLW, 389
Amaranthaceae	Amaranthus x palmeri		Annual	Forb	Native	FACU		CLW, 487
Amaranthaceae	Atriplex canescens	(Pursh) Nutt.	Perennial	Shrub	Native			CLW, 312, 446, 483

Amaranthaceae	Chenopodium fremontii	S. Watson	Annual	Forb	Native	FACU	CLW, 130, 146
Amaranthaceae	Tidestromia lanuginosa	(Nutt.) Standl.	Annual	Forb	Native		CLW, 457
Amaryllidaceae	Nothoscordum texanum	M.E. Jones	Perennial	Forb	Native		WH, 6203
Anacardiaceae	Rhus ovata	S. Watson	Perennial	Shrub	Native		CLW, 220, 247
Apiaceae	Bowlesia incana	Ruiz & Pav.	Annual	Forb	Native	FACU	CLW, 662
Apiaceae	Daucus pusillus	Michx.	Annual	Forb	Native		CLW, 536, 569, 606, 688, 735, 776, 785, 794, 811, 819, WH, 20043
Apiaceae	Spermolepis echinata	(Nutt. ex DC.) A. Heller	Annual	Forb	Native	FACU	WH, 6245
Apocynaceae	Funastrum	R. Br.	Perennial	Vine, Forb	Native		CLW, 197
Apocynaceae	Funastrum crispum	(Benth.) Schlechter	Perennial	Vine, Forb	Native		MW
Apocynaceae	Funastrum cynanchoides	(Decne.) Schltr.	Perennial	Vine, Forb	Native	FACU	CLW, 316, 479, 816
Aristolochiaceae	Aristolochia watsonii	Woot. & Standl.	Perennial	Vine, Forb	Native		CLW, 73,

Asparagaceae	Dichelostemma capitatum	(Benth.) Alph. Wood	Perennial	Forb	Native	FACU	CLW, 229, 288, 289, 515, 527, 567, 630, 680, 703, 792
Asteraceae	Acamptopappus sphaerocephalus	(Harv. & A. Gray) A. Gray	Perennial	Shrub	Native		WH, 19957
Asteraceae	Ambrosia ambrosioides	(Cav.) W.W. Payne	Perennial	Shrub	Native		CLW, 182, 193, 257
Asteraceae	Ambrosia artemisiifolia	L.	Annual	Forb	Native	FACU	CLW, 147
Asteraceae	Ambrosia confertiflora	DC.	Perennial	Forb	Native		CLW, 454
Asteraceae	Ambrosia eriocentra	(A. Gray) W.W. Payne	Perennial	Shrub	Native		CLW, 417, 440, WH, 19958, 30711
Asteraceae	Artemisia ludoviciana	Nutt.	Perennial	Forb, Subshrub	Native	FACU	CLW, 481
Asteraceae	Asteraceae	Bercht. & J. Presl		Forb, Subshrub	Native		CLW, 327
Asteraceae	Baccharis brachyphylla	A. Gray	Perennial	Shrub	Native		CLW, 19, 179, 186,
Asteraceae	Baccharis salicifolia	(Ruiz & Pav.) Pers.	Perennial	Shrub	Native	FAC	CLW, 134, 259, 290, 356
Asteraceae	Baccharis salicina	Torr. & A. Gray	Perennial	Shrub	Native	FACW	CLW, 424, 513,

Asteraceae	Baccharis sarothroides	A. Gray	Perennial	Shrub	Native	FACU	CLW, 465, 475
Asteraceae	Bahiopsis parishii	(Greene) E.E. Schilling & Panero	Perennial	Shrub	Native		CLW, 478, 495, 745, WH, 6236, 19947
Asteraceae	Baileya multiradiata	Harv. & A. Gray	Biennial	Forb	Native		CLW, 42, 456, 702, 732
Asteraceae	Bebbia juncea	(Benth.) Greene	Perennial	Shrub	Native		CLW, 133, 198, 499,
Asteraceae	Brickellia californica	(Torr. & A. Gray) A. Gray	Perennial	Shrub	Native	FACU	
Asteraceae	Brickellia coulteri	A. Gray	Perennial	Shrub	Native		CLW, 84, 192
Asteraceae	Calycoseris parryi	A. Gray	Annual	Forb	Native		CLW, 733, 736, 768
Asteraceae	Chaenactis stevioides	Hook. & Arn.	Annual	Forb	Native		WH, 19929
Asteraceae	Cirsium neomexicanum	A. Gray	Biennial	Forb	Native		CLW, 753, WH, 19917
Asteraceae	Conyza canadensis	(L.) Cronquist	Biennial	Forb	Native		CLW, 114, 262, 386
Asteraceae	Dyssodia	Cav.	Annual	Forb	Native		BGP & AW
Asteraceae	Dyssodia papposa	(Vent.) Hitchc.	Annual	Forb	Native		CLW, 431
Asteraceae	Eclipta prostrata	(L.) L.	Biennial	Forb	Native	FAC	CLW, 115
Asteraceae	Encelia farinosa	A. Gray ex Torr.	Perennial	Shrub	Native		CLW, 209, 553, 622, 821, WH, 19923
Asteraceae	Encelia virginensis	A. Nels.	Perennial	Shrub	Native		WH, 19949, 30715A

Asteraceae	Ericameria laricifolia	(A. Gray) Shinners	Perennial	Shrub	Native		CLW, 227, 494, 560,
Asteraceae	Ericameria linearifolia	(DC.) Urbatsch & Wussow	Perennial	Shrub	Native		CLW, 370, 637,
Asteraceae	Erigeron concinnus	(Hook. & Arn.) Torr. & A. Gray	Perennial	Forb	Native		CLW, 746
Asteraceae	Erigeron divergens	Torr. & A. Gray	Annual/Perennial	Forb	Native		CLW, 721, 798
Asteraceae	Eriophyllum lanosum	(A. Gray) A. Gray	Annual	Forb	Native		CLW, 704, WH, 19927
Asteraceae	Gutierrezia microcephala	(DC.) A. Gray	Perennial	Subshrub	Native		CLW, 464, 509,
Asteraceae	Helianthus annuus	L.	Annual	Forb	Native	FACU	CLW, 3, 18, 88, 125, 149
Asteraceae	Heterotheca subaxillaris	(Lam.) Britton & Rusby	Annual	Forb	Native		CLW, 122
Asteraceae	Hymenoclea monogyra	Torr. & A. Gray ex A. Gray	Perennial	Shrub	Native		KA
Asteraceae	Isocoma pluriflora	(Torr. & A. Gray) Greene	Perennial	Forb, Subshrub	Native		CLW, 76
Asteraceae	Lactuca tatarica var. pulchella	(Pursh) Breitung	Biennial	Forb	Native	FAC	CLW, 144

Asteraceae	Lasthenia californica	DC. ex Lindl.	Annual	Forb	Native			CLW, 589, 695, 830, Wendy C. Hodgson, 19951
Asteraceae	Logfia depressa	(A.Gray) J.Holub	Annual	Forb	Native			CLW, 708
Asteraceae	Logfia filaginoides	(Hook. & Arn.) Morefield	Annual	Forb	Native			CLW, 672
Asteraceae	Machaeranthera	Nees	Biennial	Forb	Native			CLW, 325
Asteraceae	Machaeranthera asteroides var. asteroides	Torr.	Perennial	Forb	Native			WH, 19960
Asteraceae	Melampodium leucanthum	Torr. & A. Gray	Perennial	Subshrub	Native			CLW 372, 701, 780, WH, 6227, 19961, 30715B
Asteraceae	Monoptilon bellioides	(A. Gray) Hall	Annual	Forb	Native			CLW, 636
Asteraceae	Oncosiphon piluliferum	(L. f.) Kallersjo	Annual	Forb	Non-Native	FACU		CLW, 823
Asteraceae	Packera quercetorum	(Greene) C. Jeffrey	Perennial	Forb	Native			MB, 8820
Asteraceae	Parthenium incanum	Kunth	Perennial	Shrub	Native			CLW, 407
Asteraceae	Pectis rusbyi	Greene ex A. Gray	Annual	Forb	Native			CLW, 449, 459
Asteraceae	Perityle ciliata	(L.H. Dewey) Rydb.	Perennial	Subshrub	Native		Endemic	CLW, 213

Asteraceae	Porophyllum gracile	Benth.	Perennial	Shrub	Native		CLW 196, 341, 420, 554, WH, 19963
Asteraceae	Pseudognaphalium luteoalbum	(L.) Hilliard & B. L. Burtt	Annual	Forb	Non-Native	FAC	CLW, 377
Asteraceae	Psilostrophe cooperi	(A. Gray) Greene	Perennial	Subshrub	Native		CLW, 415, 563, 568, WH, 19926
Asteraceae	Rafinesquia californica	Nutt.	Annual	Forb	Native		CLW, 669, WH, 20037
Asteraceae	Rafinesquia neomexicana	A. Gray	Annual	Forb	Native		CLW, 634, 664, 725, 800
Asteraceae	Senecio flaccidus var. monoensis	(Greene) B.L. Turner & T.M. Barkl.	Perennial	Subshrub	Native		CLW, 818, WH, 6220
Asteraceae	Senecio lemmonii	A. Gray	Perennial	Forb, Subshrub	Native		CLW, 770
Asteraceae	Sonchus oleraceus	L.	Annual	Forb	Non-Native	UPL	CLW, 385, 628, 683, WH, 20036
Asteraceae	Stephanomeria pauciflora	(Torr.) A. Nels.	Perennial	Forb, Subshrub	Native		CLW, 101, 323, 339, 463, 492

Asteraceae	Stephanomeria tenuifolia	(Raf.) Hall	Perennial	Forb, Subshrub	Native		CLW, 175, 321
Asteraceae	Stephanomeria thurberi	A. Gray	Perennial	Forb	Native		CLW, 49
Asteraceae	Thymophylla acerosa	(DC.) Strother	Perennial	Forb, Subshrub	Native		CLW, 428, WH, 19959
Asteraceae	Trixis californica	Kellogg	Perennial	Shrub	Native		WH, 6211
Asteraceae	Uropappus lindleyi	(DC.) Nutt.	Annual	Forb	Native		CLW, 587, 670, WH, 6221, 19920
Asteraceae	Xanthisma gracile	(Nutt.) D.R.Morgan & R.L.Hartm.	Annual	Forb	Native		CLW, 23, 248, 728
Asteraceae	Xanthisma spinulosum	(Pursh) D.R. Morgan & R.L. Hartman	Perennial	Forb	Native	UPL	CLW, 1, 174, 501, 771, 782
Asteraceae	Xanthium strumarium	L.	Annual	Forb	Native	FAC	CLW, 36, 90, 91, 128
Asteraceae	Zinnia	L.	Perennial	Forb	Native		BGP & AW
Asteraceae	Zinnia acerosa	(DC.) A. Gray	Perennial	Subshrub	Native		CLW, 391, 411, 414, 488, 493

Berberidaceae	Berberis haematocarpa	Wooton	Perennial	Shrub	Native		CLW, 537, 578, WH, 19914
Bignoniaceae	Chilopsis linearis	(Cav.) Sweet	Perennial	Shrub	Native	FAC	CLW, 11, 28, 181
Boraginaceae	Amsinckia intermedia	Fisch. & C.A. Mey.	Annual	Forb	Native		CLW, 226
Boraginaceae	Amsinckia menziesii	(Lehm.) A. Nels. & J.F. Macbr.	Annual	Forb	Native		CLW, 546, 558, 588, 642, 667, 687, 720
Boraginaceae	Cryptantha barbigera	(A. Gray) Greene	Annual	Forb	Native		CLW, 678
Boraginaceae	Cryptantha maritima	(Greene) Greene	Annual	Forb	Native		CLW, 583, 650, 692
Boraginaceae	Cryptantha muricata	(Hook. & Arn.) A. Nelson & J. F. Macbr.	Annual	Forb	Native		CLW, 551, 570, 610, 656, 691, 723, 772
Boraginaceae	Cryptantha pterocarya	(Torr.) Greene	Annual	Forb	Native		CLW, 225
Boraginaceae	Emmenanthe penduliflora	Benth.	Annual	Forb	Native		CLW, 635, WH, 6239, 19962
Boraginaceae	Eriodictyon angustifolium	Nutt.	Perennial	Shrub	Native		WH, 20042
Boraginaceae	Eucrypta micrantha	(Torr.) Heller	Annual	Forb	Native		CLW, 542, 576, 604, 658, 666, 674, 696
Boraginaceae	Lappula occidentalis	(S. Wats.) Greene	Biennial	Forb	Native		CLW, 594
Boraginaceae	Nama hispida	A.Gray	Annual	Forb	Native		MW

Boraginaceae	Pectocarya platycarpa	(Munz & I. M. Johnst.) Munz & I. M. Johnst.	Annual	Forb	Native		CLW, 648
Boraginaceae	Pectocarya recurvata	I.M. Johnston	Annual	Forb	Native		CLW, 556, 611, 693, Wendy Hodgson, 19922
Boraginaceae	Phacelia affinis	A. Gray	Annual	Forb	Native		WH, 19909
Boraginaceae	Phacelia crenulata	Torr. ex S. Watson	Annual	Forb	Native		CLW, 246, 655, Wendy Hodgson, 19912
Boraginaceae	Phacelia crenulata var. corrugata	(A. Nelson) Brand	Annual	Forb	Native		CLW, 822
Boraginaceae	Phacelia cryptantha	Greene	Annual	Forb	Native		CLW, 739
Boraginaceae	Phacelia distans	Benth.	Annual	Forb	Native		CLW, 596, 620, 649, 677, 730, 766, 803, Wendy Hodgson 6231
Boraginaceae	Phacelia ramosissima	Douglas ex Lehm.	Annual	Forb	Native	FACU	CLW, 802
Boraginaceae	Phacelia tanacetifolia	Benth.	Annual	Forb	Native		WH, 19930
Boraginaceae	Pholistoma auritum	(Lindl.) Lilja	Annual	Vine, Forb	Native		CLW, 682

Boraginaceae	Plagiobothrys arizonicus	(A. Gray) Greene ex A. Gray	Annual	Forb	Native		CLW, 571
Brassicaceae	Boechera perennans	(S. Watson) W. A. Weber	Perennial	Forb, Subshrub	Native		CLW, 236
Brassicaceae	Brassica tournefortii	Gouan	Annual	Forb	Non-Native		CLW, 726
Brassicaceae	Capsella bursa-pastoris	(L.) Medik.	Annual	Forb	Non-Native	FACU	CLW, 277
Brassicaceae	Caulanthus lasiophylla	(Hook. & Arn.) Greene	Annual	Forb	Native		
Brassicaceae	Chorispora tenella	(Pall.) DC.	Annual	Forb	Non-Native		CLW, 205, 713
Brassicaceae	Descurainia pinnata	(Walter) Britton	Annual	Forb	Native		CLW, 203, 270, 530, 586, 654
Brassicaceae	Draba cuneifolia	Nutt. ex Torr. & A. Gray	Annual	Forb	Native		CLW, 201, 268, 284, 520, 526, 660
Brassicaceae	Lepidium densiflorum	Schrad.	Annual	Forb	Native	UPL	CLW, 212, 585, 621
Brassicaceae	Lepidium fremontii	S. Watson	Perennial	Shrub	Native		CLW, 651, 686
Brassicaceae	Lepidium lasiocarpum	Nutt.	Annual	Forb	Native		CLW, 700
Brassicaceae	Lepidium virginicum	L.	Annual/Biennial	Forb	Native	FACU	CLW, 547
Brassicaceae	Lepidium virginicum var. medium	(Greene) C.L. Hitchc.	Annual/Biennial	Forb	Native	FACU	WH, 6223

Brassicaceae	Physaria gordonii	(A. Gray) O'Kane & Al-Shehbaz	Annual	Forb	Native		CLW, 253, 600, 639
Brassicaceae	Sisymbrium irio	L.	Annual	Forb	Non-Native		CLW, 232, 241, 283, 525, 573, 619, 711, WH, 19906
Brassicaceae	Thysanocarpus curvipes	Hook.	Annual	Forb	Native		CLW, 204, 562, 653, 685
Cactaceae	Cylindropuntia acanthocarpa	(Engelm. & Bigelow) F.M. Knuth	Perennial	Succulent	Native		CLW, 59, 162, WH, 30727 (var. acanthocarpa)
Cactaceae	Cylindropuntia acanthocarpa var. thornberi	(Thornber & Bonker) Backeb.	Perennial	Succulent	Native	Endemic	Lucas C. Majure, 6932
Cactaceae	Cylindropuntia bigelovii	(Engelm.) Knuth	Perennial	Succulent	Native		CLW, 163, WH, 30729, 30731
Cactaceae	Cylindropuntia fulgida var. fulgida	Engelm.	Perennial	Succulent	Native		JA, 94-2
Cactaceae	Cylindropuntia leptocaulis	(DC.) Knuth	Perennial	Succulent	Native		CLW, 24, 48, 313, 366, 448, WH, 6250, 19913
Cactaceae	Echinocereus engelmannii	(Parry ex Engelm.) Lem.	Perennial	Succulent	Native		CLW, 168, WH, 30726

Cactaceae	Echinocereus engelmannii var. engelmannii		Perennial	Succulent	Native		WH, 30721
Cactaceae	Echinocereus fendleri ssp. fasciculatus	(Engelm. ex B.D. Jackson) L. Benson	Perennial	Succulent	Native		WH, 6251, 6252
Cactaceae	Ferocactus cylindraceus	(Engelm.) Orcutt	Perennial	Succulent	Native		CLW, 301, 334, 368, WH, 30768
Cactaceae	Mammillaria grahamii	Engelm.	Perennial	Succulent	Native		CLW, 17, 164
Cactaceae	Opuntia chlorotica	Engelm. & Bigelow	Perennial	Succulent	Native		WH, 30763
Cactaceae	Opuntia engelmannii	Salm-Dyck	Perennial	Succulent	Native		CLW, 22, 69, 161
Cactaceae	Cylindropuntia leptocaulis x C. whipplei	Dc.	Perennial	Succulent	Native		LM, LAM-1466
Cactaceae	Opuntia macrorhiza	Engelm.	Perennial	Succulent	Native		MW
Cactaceae	Opuntia phaeacantha	Engelm.	Perennial	Succulent	Native		CLW, 820
Campanulaceae	Lobelia cardinalis	L.	Perennial	Forb	Native	OBL	JO, B-29

Campanulaceae	Nemacladus glanduliferus var. orientalis	McVaugh	Annual	Forb	Native		WH, 6243, 19964
Campanulaceae	Nemacladus orientalis	(McVaugh) Morin	Annual	Forb	Native		MH, 6243
Cannabaceae	Celtis pallida	Torr.	Perennial	Tree	Native		CLW, 60, 70, 358, 359, 396, 405, 468, WH, 19940
Cannabaceae	Celtis reticulata	Torr.	Perennial	Tree	Native	FAC	WH, 6200
Caryophyllaceae	Drymaria glandulosa	Bartl.	Annual	Forb	Native		CLW, 657
Caryophyllaceae	Drymaria pachyphylla	Woot. & Standl.	Annual	Forb	Native	FACU	CLW, 263, 278
Caryophyllaceae	Eremogone ferrisiae	(Abrams) R.L.Hartm. & Rabeler	Perennial	Forb, Subshrub	Native		CLW, 271
Caryophyllaceae	Herniaria hirsuta	L.	Annual	Forb	Native		CLW, 532
Caryophyllaceae	Silene antirrhina	L.	Annual	Forb	Native		CLW, 597, 617, 697, 729, 747, 761, 788
Cleomaceae	Peritoma lutea	(Hook.) Raf.	Annual	Forb	Native	FACU	LM, LAM-1450
Cleomaceae	Polanisia dodecandra	(L.) DC.	Annual	Forb	Native	FACU	CLW, 10, 79, 328, 345, 383
Cleomaceae	Polanisia dodecandra var. trachysperma	(Torr. & Gray) Iltis	Annual	Forb	Native	FACU	WMS, 6
Convolvulaceae	Evolvulus arizonicus	A. Gray	Perennial	Forb	Native		CLW, 98

Convolvulaceae	Ipomoea barbatisepala	A. Gray	Annual	Vine, Forb	Native		CLW, 13
Convolvulaceae	Ipomoea costellata	Torr.	Annual	Vine, Forb	Native		CLW, 99, 460,
Convolvulaceae	Ipomoea cristulata	Hallier f.	Annual	Vine, Forb	Native		JO, B-49
Crassulaceae	Dudleya saxosa subsp. collomiae	(Rose) Moran	Perennial	Succulent	Native		WH, 6228, 30712
Crossosomataceae	Crossosoma bigelovii	S. Watson	Perennial	Shrub	Native		CLW, 217, 218, 258, 544
Cucurbitaceae	Echinopepon wrightii	(A. Gray) S. Wats.	Annual	Vine, Forb	Native	FAC	CLW, 472
Cucurbitaceae	Marah gilensis	Greene	Perennial	Vine, Forb	Native		CLW, 252, 591, 777
Cyperaceae	Carex spissa	L. H. Bailey	Perennial	Graminoid	Native	FAC	MB, 8813
Cyperaceae	Carex ultra	Bailey	Perennial	Graminoid	Native	FAC	GR, 13032
Cyperaceae	Cyperus odoratus	L.	Perennial	Graminoid	Native	FACW	GR, 16381
Cyperaceae	Schoenoplectus pungens	(Vahl) Palla	Perennial	Graminoid	Native	OBL	CP, 2306

Cyperaceae	Schoenoplectus tabernaemontani	(C. C. Gmel.) Palla	Perennial	Graminoid	Native	OBL		GR, 16382
Cyperaceae	Scirpus atrovirens	Willd.	Perennial	Graminoid	Native	OBL		CLW, 12, 510
Euphorbiaceae	Croton texensis	(Klotzsch) Muell.-Arg.	Annual	Forb	Native			CLW, 331
Euphorbiaceae	Ditaxis lanceolata	(Benth.) Pax & K. Hoffmann	Perennial	Forb, Subshrub	Native			CLW, 343
Euphorbiaceae	Ditaxis neomexicana	(MŽll.Arg.) A. Heller	Perennial	Forb	Native			CLW, 187
Euphorbiaceae	Euphorbia arizonica	Engelm.	Perennial	Forb	Native			CLW, 9, 31, 40, 53, 54, 55, 96, 107, 154, 200, 429
Euphorbiaceae	Euphorbia capitellata	Engelm.	Perennial	Forb	Native			CLW, 16, 47, 306, 314, 361, 394
Euphorbiaceae	Euphorbia eriantha	Benth.	Annual	Forb	Native			CLW, 443, WH 6209
Euphorbiaceae	Euphorbia florida	Engelm.	Annual	Forb	Native		Endemic	CLW, 72, 305
Euphorbiaceae	Euphorbia heterophylla	L.	Perennial	Forb	Native	UPL		CLW, 106
Euphorbiaceae	Euphorbia hyssopifolia	L.	Annual	Forb	Native			CLW, 342, 397

Euphorbiaceae	Euphorbia melanadenia	Torr.	Perennial	Forb	Native		CLW, 250
Euphorbiaceae	Euphorbia micromera	Boiss. ex Engelm.	Annual	Forb	Native		CLW, 102
Euphorbiaceae	Euphorbia parryi	Engelm.	Annual	Forb	Native		CLW, 97, 109,
Euphorbiaceae	Euphorbia polycarpa	Benth.	Annual	Forb	Native		CLW, 103, 104, 105, 176, 360
Euphorbiaceae	Euphorbia setiloba	Engelm. ex Torr.	Annual	Forb	Native		CLW, 30
Fabaceae	Acacia constricta	Benth.	Perennial	Shrub	Native		GR, 16370
Fabaceae	Acacia greggii	A. Gray	Perennial	Shrub	Native		CLW, 68, 165
Fabaceae	Acacia wrightii	Benth. ex A.Gray	Perennial	Shrub	Native		CLW, 365
Fabaceae	Acmispon brachycarpus	(Benth.) D.D.Sokoloff	Annual	Forb	Native		CLW, 574
Fabaceae	Amorpha fruticosa	L.	Perennial	Shrub	Native	FACW	ERB, B-657
Fabaceae	Astragalus	L.	Perennial	Forb	Native		CLW, 274, AMP, 86-49
Fabaceae	Astragalus calycosus var. scaposus	(A. Gray) M.E. Jones	Perennial	Forb	Native		JA
Fabaceae	Astragalus lentiginosus	Douglas	Perennial	Forb, Subshrub	Native	UPL	AMP, 86-48

Fabaceae	Astragalus lentiginosus var. maricopae	Barneby	Perennial	Forb, Subshrub	Native	UPL		WH, 19954
Fabaceae	Astragalus recurvus	Greene	Perennial	Forb	Native		Endemic	CLW, 618, 712,
Fabaceae	Astragalus wootonii	E. Sheld.	Biennial	Forb	Native			WH, 19932
Fabaceae	Calliandra eriophylla	Benth.	Perennial	Shrub	Native			CLW, 167, 194, 221, 287, 748, WH, 6215, 19911
Fabaceae	Dalea formosa	Torr.	Perennial	Forb, Subshrub	Native			CLW, 534, 787
Fabaceae	Fabaceae	Lindl.	Annual	Forb	Native			CLW, 461
Fabaceae	Galactia wrightii	A. Gray	Perennial	Vine, Forb	Native			CLW, 294, 310
Fabaceae	Lotus alamosanus	(Rose) Gentry	Perennial	Forb	Native			CLW, 624
Fabaceae	Lotus mearnsii var. equisolensis	J.L. Anderson	Perennial	Subshrub	Native			CLW, obs
Fabaceae	Acmispon rigidus	(Benth.) Greene	Perennial	Forb, Subshrub	Native			CLW, 184, 191, 243, 249, 266, 592, WH, 6225
Fabaceae	Lotus salsuginosus var. brevivexillus	Ottley	Annual	Forb	Native			WH, 6240

Fabaceae	Lupinus arizonicus	(S. Wats.) S. Wats.	Annual	Forb	Native		CLW, 557, 601, 783
Fabaceae	Lupinus bicolor	Lindl.	Annual	Forb	Native		CLW, 584, 719,
Fabaceae	Lupinus concinnus	J.G. Agardh	Annual	Forb	Native		CLW, 629
Fabaceae	Lupinus sparsiflorus	Benth.	Annual	Forb	Native		CLW, 219, 647, 694, 749, 760
Fabaceae	Lupinus sparsiflorus subsp. mohavensis	Dziekanowski & D. B. Dunn	Annual	Forb	Native		WH, 6204, 6230
Fabaceae	Marina parryi	(Torr. & A. Gray) Barneby	Perennial	Forb, Subshrub	Native		CLW, 29, 75, 180, 473, 497, 781, WH, 19937
Fabaceae	Medicago polymorpha	L.	Annual	Forb	Non-Native	FACU	WH, 19921
Fabaceae	Melilotus indica	(L.) All.	Perennial	Forb	Non-Native	FACU	CLW, 791
Fabaceae	Melilotus officinalis	(L.) Lam.	Perennial	Forb	Non-Native	FACU	CLW, 92, 178, 188, 275, 329, 387
Fabaceae	Mimosa aculeaticarpa	Ortega	Perennial	Shrub	Native		CLW, 319
Fabaceae	Mimosa dysocarpa	Benth.	Perennial	Shrub	Native		PF, 4200-1
Fabaceae	Parkinsonia florida	(Benth. ex A. Gray) S. Watson	Perennial	Tree	Native		CLW, 27, 190
Fabaceae	Parkinsonia microphylla	Torr.	Perennial	Tree	Native		CLW, 813

Fabaceae	Phaseolus	L.	Annual	Vine, Forb	Native		CLW, 507
Fabaceae	Phaseolus acutifolius	A. Gray	Annual	Vine, Forb	Native		CLW, 812
Fabaceae	Prosopis glandulosa var. torreyana	(L. Benson) M.C. Johnston	Perennial	Tree	Native	FACU	EA, 146
Fabaceae	Prosopis velutina	Wooton	Perennial	Tree	Native	FACU	CLW, 354, 825
Fabaceae	Senna covesii	(A. Gray) Irwin & Barneby	Perennial	Forb, Subshrub	Native		CLW, 33, 45, 388, 393, 439, 491
Fabaceae	Sphinctospermum constrictum	(S. Wats.) Rose	Annual	Forb	Native		CLW, 126
Fabaceae	Trifolium albopurpureum	Torr. & A. Gray	Annual	Forb	Native	FACU	WH, 19942
Fabaceae	Trifolium mucronatum subsp. lacerum	(Greene) J. Gillett	Annual	Forb	Native		WH, 19942A
Fouquieriaceae	Fouquieria splendens	Engelm.	Perennial	Shrub	Native		CLW, 233, 255, WH, 6214, 6235
Gentianaceae	Eustoma exaltatum	(L.) Salisb. ex G. Don	Annual	Forb	Native	OBL	CLW, 346, 350
Geraniaceae	Erodium cicutarium	(L.) L'H_r. ex Aiton	Annual	Forb	Non-Native		CLW, 579, 608, 826

Geraniaceae	Erodium texanum	A. Gray	Annual	Forb	Native		CLW, 605, 710, WH, 6246
Geraniaceae	Geranium lentum	Woot. & Standl.	Perennial	Forb	Native		CLW, 805
Juncaceae	Juncus articulatus	L.	Perennial	Graminoid	Native	OBL	LM, LAM-1459
Juncaceae	Juncus macrophyllus	Coville	Perennial	Graminoid	Native	FACW	CLW, 347
Juncaceae	Juncus torreyi	Coville	Perennial	Graminoid	Native	FACW	LM
Krameriaceae	Krameria bicolor	S.Watson	Perennial	Shrub	Native		CLW, 291, 300
Krameriaceae	Krameria erecta	Willd. ex J.A. Schultes	Perennial	Shrub	Native		CLW, 756, WH, 6242
Lamiaceae	Hedeoma drummondii	Benth.	Perennial	Forb, Subshrub	Native		CLW, 118, 467, 833
Lamiaceae	Hedeoma nana	(Torr.) Briq.	Perennial	Forb	Native		CLW, 315
Lamiaceae	Hyptis emoryi	Torr.	Perennial	Shrub	Native		CLW, 65, 66, 216, 224, 245, 267, 502, WH, 62222, 6237, 6210
Lamiaceae	Lamium amplexicaule	L.	Annual	Forb	Non-Native		CLW, 264, 279, 593, 801

Lamiaceae	Salvia columbariae	Benth.	Annual	Forb	Native			CLW, 632, WH, 6248
Liliaceae	Calochortus kennedyi	Porter	Annual	Forb	Native			CLW, 740, 741, WH, 6202
Liliaceae	Calochortus kennedyi var. kennedyi		Annual	Forb	Native			WH, 6202, 19953
Loasaceae	Mentzelia longiloba var. yavapaiensis	J. J. Schenk & L. Hufford	Perennial	Forb	Native		Endemic	GR, 16384
Loasaceae	Mentzelia longiloba	(Nutt.) A. Gray	Perennial	Forb	Native			CLW, 117, 477
Loasaceae	Mentzelia pumila	Torr. & A. Gray	Biennial	Forb	Native			CLW, 322, 337
Lythraceae	Lythrum californicum	Torr. & A. Gray	Perennial	Forb, Subshrub	Native	OBL		CLW, 37, 113, 326, 349, 378
Malpighiaceae	Cottsia gracilis	(A. Gray) W.R. Anderson	Perennial	Vine, Forb	Native			CLW, 67, 169, 332, 444, 480, 498, 742, WH, 6217
Malvaceae	Abutilon incanum	(Link) Sweet	Perennial	Subshrub	Native			CLW, 506
Malvaceae	Abutilon parvulum	A. Gray	Perennial	Subshrub	Native			CLW, 401
Malvaceae	Ayenia filiformis	S. Watson	Perennial	Subshrub	Native			CLW, 505
Malvaceae	Ayenia insulicola	Cristobal	Perennial	Subshrub	Non-Native			CLW, 462

Malvaceae	Ayenia microphylla	A. Gray	Perennial	Subshrub	Native		CLW, 317
Malvaceae	Gossypium thurberi	Todaro	Perennial	Shrub	Native		CLW, 124
Malvaceae	Herissantia crispa	(L.) Briz.	Perennial	Forb, Subshrub	Native		CLW, 58, 85
Malvaceae	Hibiscus coulteri	Harvey ex A. Gray	Perennial	Subshrub	Native		CLW, 330
Malvaceae	Sida abutifolia	P. Mill.	Perennial	Forb	Non-Native		CLW, 71
Malvaceae	Sphaeralcea ambigua	A. Gray	Perennial	Subshrub	Native		CLW, 689, 825
Malvaceae	Sphaeralcea emoryi	Torr. ex A. Gray	Perennial	Subshrub	Native		CLW, 572, 722, 754,
Martyniaceae	Proboscidea parviflora	(Wooton) Wooton & Standl.	Annual	Forb	Native		CLW, 119
Montiaceae	Calandrinia ciliata var. menziesii	(Hook.) J.F. Macbr.	Annual	Forb	Native	FACU	WH, 19928
Montiaceae	Claytonia parviflora	Douglas ex Hook.	Annual	Forb	Native	FACU	CLW, 260, 282, 641
Montiaceae	Claytonia perfoliata	Donn ex Willd.	Annual	Forb	Native	FAC	CLW, 237, 543,
Nemacladaceae	Nemacladus longiflorus	A. Gray	Annual	Forb	Native		CLW, 215, 614

Nyctaginaceae	Allionia incarnata	L.	Perennial	Forb	Native		CLW, 34, 120, 173, 320, 369, 412, 441, 453, 482, 489, 718
Nyctaginaceae	Boerhavia	L.	Perennial	Forb	Native		CLW, 490
Nyctaginaceae	Boerhavia coccinea	P. Mill.	Perennial	Forb	Native		CLW, 8, 62, 93, 121, 148, 151, 338
Nyctaginaceae	Boerhavia erecta	L.	Perennial	Forb	Native	FACU	CLW, 172, 303, 442
Nyctaginaceae	Boerhavia intermedia	M.E. Jones	Annual	Forb	Native		CLW, 7, 390, 455
Nyctaginaceae	Boerhavia spicata	Choisy	Annual	Forb	Native		CLW, 5, 83
Nyctaginaceae	Commicarpus scandens	(L.) Standl.	Perennial	Shrub	Native		CLW, 496
Nyctaginaceae	Mirabilis	L.			Native		CLW, 504
Nyctaginaceae	Mirabilis laevis var. villosa	(Benth.) Curran	Perennial	Subshrub	Native		CLW, 430, 595, 659, WH, 6208, 6218, 19950
Nyctaginaceae	Mirabilis multiflora	(Torr.) A. Gray	Perennial	Subshrub	Native		CLW, 234
Nyctaginaceae	Mirabilis oxybaphoides	(A. Gray) A. Gray	Perennial	Forb	Native		CLW, 575
Oleaceae	Fraxinus velutina	Torr.	Perennial	Tree	Native	FAC	CLW, 50, 74, 222, 308, 335, 352, 470, 807, WH, 19939, 30767

Oleaceae	Menodora scabra	A. Gray	Perennial	Subshrub	Native		CLW, 145, 304, 406, 447, 612, 752, WH, 6249
Onagraceae	Eulobus californica	Nutt. ex Torr. & A. Gray	Annual	Forb	Native		WH, 6238
Onagraceae	Camissonia micrantha	(Hornem. ex Spreng.) Raven	Annual	Forb	Native		WH, 20040
Onagraceae	Epilobium canum subsp. latifolium	(Hook.) P. H. Raven	Perennial	Forb	Native		CLW, 157
Onagraceae	Eremothera chamaenerioides	(A. Gray) W.L. Wagner & Hoch	Annual	Forb	Native		CLW, 623, WH, 19948
Onagraceae	Gaura hexandra subsp. gracilis	(Woot. & Standl.) Raven & Gregory	Annual	Forb	Native		LM, LAM-1452
Onagraceae	Gaura mollis	James	Annual	Forb	Native		LM, LAM-1452
Onagraceae	Ludwigia peploides	(Kunth) P. H. Raven	Perennial	Forb	Non-Native	OBL	CLW, 375
Onagraceae	Ludwigia peploides subsp. peploides	(Kunth) Raven	Perennial	Forb	Non-Native	OBL	LM, LAM-1456
Onagraceae	Oenothera albicaulis	Pursh	Annual	Forb	Native		CLW, 714, WH, 19933, 30714

Onagraceae	Oenothera cespitosa	Nutt.	Perennial	Forb, Subshrub	Native		CLW, 522, 549, 631, WH, 19915
Onagraceae	Oenothera curtiflora	W. L. Wagner & Hoch	Annual	Forb	Native	FACU	LM., 1452
Onagraceae	Oenothera deltoides	Torr. & Fr_m.	Annual	Forb	Native		WH, 6207
Onagraceae	Oenothera primiveris	A. Gray	Annual	Forb	Native		CLW, 679
Orobanchaceae	Castilleja angustifolia	(Nutt.) G. Don	Perennial	Forb, Subshrub	Native		CLW, 208
Orobanchaceae	Castilleja applegatei	Fern.	Perennial	Forb, Subshrub	Native		CLW, 538, 727
Orobanchaceae	Castilleja exserta	(Heller) Chuang & Heckard	Annual	Forb	Native		CLW, 516, 521, 555, 580, 616, 644, 709, 731, 763, 784
Orobanchaceae	Castilleja minor	(A. Gray) A. Gray	Annual	Forb	Native	OBL	WH, 19956
Oxalidaceae	Oxalis stricta	L.	Perennial	Forb	Native	FACU	CLW, 108
Papaveraceae	Corydalis aurea	Willd.	Annual	Forb	Native		CLW, 539, 598
Papaveraceae	Eschscholzia californica	Cham.	Annual	Forb	Native		CLW, 535, 545, 581, 602, 640, 737, 773

Phrymaceae	Mimulus cardinalis	Douglas ex Benth.	Perennial	Forb	Native	FACW	WH, 6206
Phrymaceae	Mimulus glabratus	Kunth	Perennial	Forb	Native	OBL	WH, 19943
Phrymaceae	Mimulus guttatus	DC	Annual	Forb	Native	OBL	CLW, 273, 793
Phrymaceae	Mimulus rubellus	A. Gray	Annual	Forb	Native	FAC	WH, 19944
Plantaginaceae	Collinsia parviflora	Lindl.	Annual	Forb	Native		CLW, 280, 533
Plantaginaceae	Keckiella antirrhinoides	(Benth.) Straw	Perennial	Shrub	Native		CLW, 769
Plantaginaceae	Keckiella antirrhinoides subsp. microphylla	(A. Gray) Straw	Perennial	Shrub	Native		WH, 6201
Plantaginaceae	Maurandya antirrhiniflora	Humb. & Bonpl. ex Willd.	Perennial	Vine, Forb	Native		CLW, 64, 132, 351, 421, 458
Plantaginaceae	Mecardonia procumbens	(P. Mill.) Small	Annual	Forb	Native	FACW	CLW, 261
Plantaginaceae	Penstemon eatonii	A. Gray	Perennial	Forb	Native		CLW, 817
Plantaginaceae	Plantago ovata	Forssk.	Annual	Forb	Native	FACU	CLW, 615, 684
Plantaginaceae	Plantago patagonica	Jacq.	Annual	Forb	Native		CLW, 559, 565, 690, 724, 751, 757, 786, 828, 835, WH, 6213
Plantaginaceae	Plantago rhodosperma	Decne.	Annual	Forb	Native	FAC	CLW, 808

Plantaginaceae	Stemodia durantifolia	(L.) Sw.	Annual	Forb	Native	OBL	CLW, 185, 286, 348, 376
Plantaginaceae	Veronica arvensis	L.	Annual	Forb	Non-Native	FACU	CLW, 199
Plantaginaceae	Veronica peregrina	L.	Annual	Forb	Native	FAC	CLW, 795, WH, 19945
Platanaceae	Platanus wrightii	S. Watson	Perennial	Tree	Native	FACW	CLW, 39, 357, 469
Poaceae	Andropogon glomeratus var. glaucopsis	(Elliot) C. Mohr	Perennial	Graminoid	Native	FACW	CLW, 485
Poaceae	Aristida	L.	Perennial	Graminoid	Native		BP, 86-57
Poaceae	Aristida adscensionis	L.	Annual	Graminoid	Native		CLW, 336
Poaceae	Aristida purpurea	Nutt.	Perennial	Graminoid	Native		CLW, 2, 155, 371, 373, 433, 552
Poaceae	Aristida purpurea var. fendleriana	(Steud.) Vasey	Perennial	Graminoid	Native		MW
Poaceae	Aristida purpurea var. parishii	(A.S. Hitchc.) Allred	Perennial	Graminoid	Native		WH, 19935
Poaceae	Aristida purpurea var. wrightii	(Nash) Allred	Perennial	Graminoid	Native		MW

Poaceae	Aristida ternipes	Cav.	Perennial	Graminoid	Native		CLW, 235
Poaceae	Avena fatua	L.	Annual	Graminoid	Non-Native		CLW, 764, 797, WH, 19919
Poaceae	Bothriochloa barbinodis	(Lag.) Herter	Perennial	Graminoid	Native	UPL	CLW, 139, 156, 296, 434
Poaceae	Bothriochloa laguroides	(DC.) Herter	Perennial	Graminoid	Non-Native		CLW, 231
Poaceae	Bouteloua aristidoides	(Kunth) Griseb.	Annual	Graminoid	Native		CLW, 137
Poaceae	Bouteloua barbata	Lag.	Annual	Graminoid	Native		CLW, 138
Poaceae	Bouteloua barbata var. rothrockii	(Vasey) Gould	Perennial	Graminoid	Native		CLW, 450
Poaceae	Bouteloua curtipendula	(Michx.) Torr.	Perennial	Graminoid	Native		CLW, 77, 302, 419, 435, 484
Poaceae	Bouteloua repens	(Kunth) Scribn. & Merr.	Perennial	Graminoid	Native		CLW, 78
Poaceae	Bromus arizonicus	(Shear) Stebbins	Annual	Graminoid	Native		CLW, 717
Poaceae	Bromus rubens	L.	Annual	Graminoid	Non-Native		CLW, 242, 523, 627, 645, 675, 705, 716, 743, 774, 806

Poaceae	Cynodon dactylon	(L.) Pers.	Perennial	Graminoid	Non-Native	FACU	CLW, 426, 452
Poaceae	Dasyochloa pulchella	(Kunth) Willd. ex Rydb.	Perennial	Graminoid	Native		CLW, 524
Poaceae	Echinochloa crus-galli	(L.) P. Beauv.	Perennial	Graminoid	Non-Native	FACW	CLW, 141, 384
Poaceae	Elymus elymoides	(Raf.) Swezey	Annual	Graminoid	Native	FACU	WH, 19941
Poaceae	Elymus glaucus	Buckley	Perennial	Graminoid	Native	FACU	WH, 30734
Poaceae	Elymus glaucus subsp. Glaucus		Perennial	Graminoid	Native	FACU	CLW, 790
Poaceae	Eragrostis cilianensis	(All.) Vignolo ex Janch.	Perennial	Graminoid	Non-Native	FACU	CLW, 136
Poaceae	Eragrostis intermedia	A.S. Hitchc.	Annual	Graminoid	Native		CLW, 362
Poaceae	Eragrostis lehmanniana	Nees	Perennial	Graminoid	Non-Native		CLW, 15, 82
Poaceae	Heteropogon contortus	(L.) Beauv. ex Roemer & J.A. Schultes	Perennial	Graminoid	Native	FACU	CLW, 35, 43, 81, 432, 503
Poaceae	Hilaria belangeri	(Steud.) Nash	Perennial	Graminoid	Native		WH, 19918

Poaceae	Hilaria mutica	(Buckley) Benth.	Perennial	Graminoid	Native		CLW, 404, WH, 19936, 30733
Poaceae	Hordeum murinum	L.	Perennial	Graminoid	Non-Native	FACU	CLW, 715
Poaceae	Hordeum pusillum	Nutt.	Annual	Graminoid	Native	FACU	CLW, 755
Poaceae	Leptochloa panicea subsp. Brachiata	(Steudl.) N. Snow	Annual	Graminoid	Native		CLW, 402
Poaceae	Muhlenbergia rigens	(Benth.) A.S. Hitchc.	Perennial	Graminoid	Native	FAC	WH, 19955
Poaceae	Panicum capillare	L.	Perennial	Graminoid	Native	FACU	CLW, 95
Poaceae	Paspalum dilatatum	Poir.	Annual	Graminoid	Non-Native	FAC	CLW, 38
Poaceae	Paspalum distichum	L.	Perennial	Graminoid	Native	FACW	JJ, 92
Poaceae	Pennisetum setaceum	(Forssk.) Chiov.	Perennial	Graminoid	Non-Native		CLW, 87, 344
Poaceae	Phragmites australis	(Cav.) Trin. ex Steud.	Perennial	Graminoid	Native	FACW	WH, 4865
Poaceae	Poa bigelovii	Vasey & Scribn.	Perennial	Graminoid	Native		CLW, 269, 676

Poaceae	Polypogon monspeliensis	(L.) Desf.	Annual	Graminoid	Non-Native	FACW	CLW, 80, 810, 809
Poaceae	Schismus arabicus	Nees	Annual	Graminoid	Non-Native		CLW, 626, 706, 829
Poaceae	Schismus barbatus	(Loefl. ex L.) Thellung	Annual	Graminoid	Non-Native		CLW, 206
Poaceae	Scleropogon brevifolius	Phil.	Perennial	Graminoid	Native		LG, 65-46
Poaceae	Sorghum halepense	(L.) Pers.	Perennial	Graminoid	Non-Native	FACU	CLW, 51, 140, 295, 311, 425
Poaceae	Sporobolus contractus	A.S. Hitchc.	Perennial	Graminoid	Native		MW
Poaceae	Vulpia octoflora	(Walter) Rydb.	Annual	Graminoid	Native	UPL	CLW, 211, 625, 681, 698
Poaceae	Dinebra panicea subsp. brachiata	(Steud.) P. M. Peterson & N. Snow	Annual	Graminoid	Native	FACW	CLW, 135, 395, 451
Polemoniaceae	Eriastrum diffusum	(A. Gray) Mason	Annual	Forb	Native		CLW, 750
Polemoniaceae	Eriastrum eremicum	(Jepson) Mason	Annual	Forb	Native		MW
Polemoniaceae	Gilia clokeyi	Mason	Annual	Forb	Native		CLW, 603, 634
Polemoniaceae	Gilia flavocincta	A. Nels.	Annual	Forb	Native		CLW, 239, 281, 561, 564, 633, 671
Polemoniaceae	Gilia flavocincta subsp. Flavocincta		Annual	Forb	Native		CLW, 699, 775

Polemoniaceae	Gilia minor	A.& V. Grant	Annual	Forb	Native		CLW, 528
Polemoniaceae	Linanthus bigelovii	(A. Gray) Greene	Annual	Forb	Native		CLW, 665
Polemoniaceae	Phlox tenuifolia	E. Nels.	Perennial	Forb, Subshrub	Native		WH, 20039
Polygalaceae	Polygala macradenia	A. Gray	Perennial	Shrub	Native		CLW, 408, 410
Polygalaceae	Polygala rusbyi	Greene	Perennial	Subshrub	Native	Endemic	CLW, obs
Polygalaceae	Polygala scoparioides	Chod.	Perennial	Forb	Native		GR, 16386
Polygonaceae	Eriogonum	Michx.	Biennial	Forb	Native		BP, 86-58
Polygonaceae	Eriogonum arizonicum	S. Stokes ex M.E. Jones	Perennial	Forb	Native	Endemic	WH, 19910, 30765
Polygonaceae	Eriogonum capillare	Small	Annual	Forb	Native		CLW, 41, 153, 340
Polygonaceae	Eriogonum fasciculatum	Benth.	Perennial	Shrub	Native		CLW, 476, 548, 566, 582, 638, 738,
Polygonaceae	Eriogonum fasciculatum var. polifolium	(Benth.) Torr. & A. Gray	Perennial	Shrub	Native		WH, 6216, 6219, 19924
Polygonaceae	Eriogonum inflatum	Torr. & Fr_m.	Perennial	Forb	Native		CLW, 44, 100, 171, 293, 413, 418, 486, 827
Polygonaceae	Eriogonum polycladon	Benth.	Annual	Forb	Native		CLW, 123

Polygonaceae	Eriogonum ripleyi	J.T. Howell	Perennial	Forb, Subshrub	Native		Endemic	GR, 16383
Polygonaceae	Persicaria lapathifolia	(L.) Delarbre	Annual	Forb	Native	FACW		CLW, 131
Polygonaceae	Persicaria pensylvanica	(L.) M. GÊmez	Annual	Forb	Native	FACW		CLW, 298, 380
Polygonaceae	Rumex hymenosepalus	Torr.	Perennial	Forb	Native	FGOO		WH, 6226
Portulacaceae	Portulaca suffrutescens	Engelm.	Perennial	Forb, Subshrub	Native			JO, B-45
Primulaceae	Anagallis arvensis	L.	Annual	Forb	Non-Native			CLW, 834
Ranunculaceae	Anemone tuberosa	Rydb.	Perennial	Forb	Native			CLW, 517, 541, 673
Ranunculaceae	Aquilegia chrysantha	A. Gray	Perennial	Forb	Native	FAC		CLW, 789
Ranunculaceae	Delphinium parishii	A. Gray	Perennial	Forb	Native			CLW, 734, 744, 765
Rhamnaceae	Ziziphus obtusifolia	(Hook. ex Torr. & A. Gray) A. Gray	Perennial	Shrub	Native			CLW, 374, 436
Rhamnaceae	Sarcomphalus obtusifolius var. canescens	(A. Gray) M.C. Johnston	Perennial	Shrub	Native			CLW, 392
Rosaceae	Purshia stansburiana	(Torr.) Henrickson	Perennial	Shrub	Native			GR, 16369

Rosaceae	Purshia x subintegra	(Kearney) Henrickson	Perennial	Shrub	Native		Endemic	GR
Rubiaceae	Cephalanthus occidentalis	L.	Perennial	Shrub	Native	OBL		CLW, 150, 292
Rubiaceae	Cephalanthus occidentalis var. californicus	Benth.	Perennial	Shrub	Native	OBL		EB
Rubiaceae	Galium aparine	L.	Annual	Forb	Native	FACU		CLW, 244, 613, 762, 804
Rubiaceae	Galium microphyllum	A. Gray	Perennial	Forb	Native	FACU		CLW, 129, 238
Rubiaceae	Galium stellatum	Kellogg	Perennial	Forb, Subshrub	Native			CLW, 609
Salicaceae	Salix exigua	Nutt.	Perennial	Shrub, Tree	Native	FACW		CLW, 652
Salicaceae	Salix gooddingii	Ball	Perennial	Tree	Native	FACW		CLW, 195, 353, 382, 814, WH, 6234
Santalaceae	Phoradendron californicum	Nutt.	Perennial	Shrub	Native			CLW, 518
Santalaceae	Phoradendron serotinum subsp. macrophyllum	(Engelmann) Kuijt	Perennial	Forb, Subshrub	Native			WH, 30766

Sapindaceae	Dodonaea viscosa	(L.) Jacq.	Perennial	Shrub	Native	FACU	CLW, 177, 189, 423, 815, WH, 19931
Sapindaceae	Dodonaea viscosa var. angustifolia	(L. f.) Benth.	Perennial	Shrub	Native	FACU	RE, 472
Saururaceae	Anemopsis californica	(Nutt.) Hook. & Arn.	Perennial	Forb	Native	OBL	JO, B-28
Scrophulariaceae	Penstemon pseudospectabilis subsp. connatifolius	(A. Nels.) Keck	Perennial	Forb, Subshrub	Native		WH, 6232
Scrophulariaceae	Verbascum thapsus	L.	Biennial	Forb	Non-Native	FACU	EB, B-655
Simmondsiaceae	Simmondsia chinensis	(Link) Schneid.	Perennial	Shrub	Native		CLW, 25, 46, 52, 223, 398, 399, 550, WH, 6212, 19925
Solanaceae	Calibrachoa parviflora	(Juss.) D'Arcy	Annual	Forb	Non-Native	FACW	CLW, 116
Solanaceae	Datura	L.	Biennial	Forb	Native		CLW, 89
Solanaceae	Datura wrightii	Regel	Perennial	Forb	Native	UPL	CLW, 20, 110
Solanaceae	Lycium	L.	Perennial	Shrub	Native		
Solanaceae	Lycium berlandieri	Dunal	Perennial	Shrub	Native		CLW, 183
Solanaceae	Lycium californicum	Nutt. ex A. Gray	Perennial	Shrub	Native		CLW, 832
Solanaceae	Lycium exsertum	A. Gray	Perennial	Shrub	Native		CLW, 26, WH, 19925B

Solanaceae	Lycium fremontii	A. Gray	Perennial	Shrub	Native		MW
Solanaceae	Nicotiana glauca	Graham	Perennial	Shrub	Native	FAC	EA
Solanaceae	Nicotiana obtusifolia	M. Martens & Galeotti	Perennial	Forb, Subshrub	Native	FACU	CLW, 14, 32, 207, 379, 422, 474
Solanaceae	Solanum americanum	P. Mill.	Annual/short lived perennial	Forb	Native	FACU	EB
Solanaceae	Solanum douglasii	Dunal	Annual/Short-lived perennial	Forb, Subshrub	Native	FAC	CLW, 508
Solanaceae	Solanum elaeagnifolium	Cav.	Perennial	Forb	Native		CLW, 4, 309
Solanaceae	Solanum physalifolium	Rusby	Annual	Forb	Non-Native		CLW, 230
Tamaricaceae	Tamarix chinensis	Lour.	Perennial	Tree	Non-Native	FAC	CLW, 318, 381, WH, 6224
Typhaceae	Typha domingensis	Pers.	Perennial	Forb	Native	OBL	CLW, 142
Urticaceae	Parietaria hespera	Hinton	Annual	Forb	Native	FACU	CLW, 646
Urticaceae	Parietaria pensylvanica	Muhl. ex Willd.	Annual	Forb	Native	FACU	CLW, 529, 668, 707, 796
Verbenaceae	Aloysia wrightii	Heller ex Abrams	Perennial	Shrub	Native		CLW, 416, 438
Verbenaceae	Verbena bracteata	Cav. ex Lag. & Rodr.	Biennial	Forb	Native		LM, LAM-1453

Verbenaceae	Verbena gracilis	Desf.	Perennial	Forb	Native		WH, 20041
Verbenaceae	Verbena neomexicana	(A. Gray) Small	Perennial	Forb	Native		CLW, 86
Vitaceae	Vitis arizonica	Engelm.	Perennial	Vine	Native	FACU	CLW, 778
Zygophyllaceae	Kallstroemia grandiflora	Torr. ex A. Gray	Annual	Forb	Native		CLW, 6, 94, 112
Zygophyllaceae	Kallstroemia hirsutissima	Vail ex Small	Annual	Forb	Native		CLW, 307
Zygophyllaceae	Kallstroemia parviflora	J.B.S. Norton	Annual	Forb	Native		CLW, 111
Zygophyllaceae	Larrea tridentata	(Sess_ & Moc. ex DC.) Coville	Perennial	Shrub	Native		CLW, 367, 500

APPENDIX B

R SCRIPT FOR SPECIES AREA CURVE MODEL

```
S <- flora$Species
area<-flora$Area
plot(S ~ area, xlab = "Flora Area (ha)", ylab = "Number of Species",
    ylim = c(200, max(S)))
## The Arrhenius model
marr <- nls(S~SSarrhenius(area, k, z))
marr
## confidence limits from profile likelihood
confint(marr)
## draw a line
xtmp <- seq(min(area), max(area), len=51)
lines(xtmp, predict(marr, newdata=data.frame(area = xtmp)), lwd=2)
## The normal way is to use linear regression on log-log data,
## but this will be different from the previous:
mloglog <- lm(log(S) ~ log(area))
mloglog
lines(xtmp, exp(predict(mloglog, newdata=data.frame(area=xtmp))),
    lty=2)
## Gleason: log-linear
mgle <- nls(S ~ SSgleason(area, k, slope))
lines(xtmp, predict(mgle, newdata=data.frame(area=xtmp)),
    lwd=2, col=2)
## Gitay: quadratic of log-linear
mgit <- nls(S ~ SSgitay(area, k, slope))
lines(xtmp, predict(mgit, newdata=data.frame(area=xtmp)),
    lwd=2, col = 3)

## One canned model of standard R:
mmic <- nls(S ~ SSmicmen(area, slope, Asym))
lines(xtmp, predict(mmic, newdata = data.frame(area=xtmp)),
    lwd =2, col = 5)
legend("bottom", c("Arrhenius", "log-log linear", "Gleason", "Gitay", "Michaelis-Menten"),
col=c(1,1,2,3,5), lwd=c(2,1,2,2,2),
             lty=c(1,2,1,1,1))
```